ENERGY 2030

The Greens 100% Renewable Electricity Plan for WA

February 2017

THE GREENS

Acknowledgements

We acknowledge the following people and organisations for their contributions to this report:

Chantal Caruso: Lead author

James Eggleston: Lead research assistant

Steve Gates, Angus King, Len Bunn, Ben Rose, Sustainable Energy Now (SEN): Development of SIREN Toolkit and PowerBalance modelling software

Adam Bandt MP and Jay Tilley: Authors of the Australian Greens RenewAustralia plan for 90% stationary electricity by 2030

Shahan Jereiian: Lead analysis and consultant, Energy 2030 modelling reports

Nina Jurak and the Office of Robin Chapple MLC

Betty Joy Richards: Report design

GREENS.ORG.AU/WA

Contents

Foreword

There's good news and bad news in this report.

The good news is this study outlines a costed, practical roadmap for reaching 100% renewable energy on the Western Australian south-west grid in a little over a decade. A surge of investment and employment in the technical, trades and services industries, a robust safety net for those employed in the faltering coal industry, and a powerful example that can inspire others to ramp up the clean energy transition in their own backyards.

"We're not bluffing: it's all in here – using technology on the market today we can get out of the fossil business for good by the year 2030 while improving reliability, energy independence and driving down costs."

It turns out there isn't a way to get to 100% clean energy by 2030, there are a multitude of ways. Go heavily with the cheapest – solar or wind. Prioritise residential and industrial battery storage and let a million power stations bloom. Stick with large, proven solar thermal plants in the Sunbelt. Leave room for promising emerging technologies like wave energy. Accordingly, this document presents alternative scenarios rather than one fixed path, balancing cost, practicality, deployment time and local employment potential.

That's the good news. We're not bluffing: it's all in here – using technology on the market today we can get out of the fossil business for good by the year 2030 while improving reliability, energy independence and driving down costs.

The bad news is, this document was not prepared by clean energy experts within the Western Australian State Government, because Premier Colin Barnett had most of them sacked. It is not Government policy to adopt anything close to these ambitious targets; instead, the Liberal National coalition chose to burn hundreds of millions of dollars restarting obsolete coal units that turned out not to be needed after all.

The other bad news is that our precious state is flying blind into the storms of climate change, because our Premier also purged most of the climate expertise from State Government bureaucracy, meaning that the state has no plan for adapting to the increasingly hostile conditions we are already experiencing.

So, while this plan is largely a technical document dealing with costs, technology scenarios and an uplifting reminder of global best practice, it is principally a political call to action. Now is the time for determined campaigning, alliance building, advocacy and physical resistance to the deadening and increasingly unforgiving status quo. The engineer who squeezes a fraction greater efficiency out of a silicon wafer, whether she knows it or not, has linked arms with the student locked on to a coal loader and the legislator who brokers a deal to mandate clean energy targets.

Energy2030 is dedicated to those too young yet to vote, whose future we hold in trust. Let's get to work.

Scott Ludlam
Australian Greens Senator for Western Australia

Image: Senator Scott Ludlam visiting the SolarReserve's Ivanpah concentrated solar thermal plant, Nevada USA

Executive Summary

Western Australia is blessed with some of the world's best renewable energy resources and available land on which to build the infrastructure, yet we have one of the lowest mixes of renewable energy in the developed world. Just 9% of WA's power comes from renewable sources[1], much lower than the global average, which is now 19%.

Meanwhile, WA's total annual greenhouse gas emissions have increased by 8% since 2010 to 86 million tonnes of Co2e per year. This includes 49.3 MtCo2e from the stationary energy sector (up by 2% since 2010[2]). The commencement of the Pluto and Gorgon LNG hubs add a further 10MtCo2e[3].

In contravention to the Paris Agreement which sets out a global action plan limit global warming to well below 2C, we are heading towards a climate catastrophe.

As one of the sunniest and windiest places in the world, WA can lead the transition to a clean energy powered future. **This is why the Greens are the only party providing a genuine solution by showing a credible pathway to 100% renewable power on the WA South West grid.**

Energy 2030 proves WA could be powered by 100% renewable energy within 13 years.

This Plan focuses on Western Australia's stationary energy use[4] and builds on our two previous 'Energy 2029' studies released in 2013 and updated in 2014, as well as a number of proven, credible studies that have shown 100% renewable energy is technically achievable, including one by the Australian Energy Market Operator[5].

The Greens' Energy 2030 Plan:

1. Provides a roadmap to reach 100% renewable electricity on the South West Grid by 2030 and illustrates two costed scenarios to get there.
2. Establishes a new government authority called Renew Western Australia to drive the transition, responsible for planning and leveraging $500 million of investment into construction of new energy generation over the next four years in WA;
3. Supports workers as we transition away from fossil fuels through a $100m Clean Energy Transition Fund to ensure coal workers and communities are not left behind, with $6.6m each year for direct training and re-skilling programs and investment for new businesses;
4. Introduces a staged Phase out Plan based on new state based emissions and pollution intensity standards, to enable the orderly and stable closure of our dirtiest coal and gas-fired power stations, and a fair transition for all.

10 Key Principles of Energy 2030

1. Harness WA's vast and abundant renewable resources that are already proven at the commercial scale
2. Harness the opportunities and unstoppable global investment surge in renewables
3. Increase our efficiency and cut our energy demand by at least one third
4. Flatten our peak demand profile
5. Make energy cheaper
6. End the Waste: stop paying for capacity that was never needed, and stop gold-plating an antiquated network
7. Establish a new state government authority – Renew Western Australia – to drive the transition
8. Support workers as we transition away from fossil fuels through a $100m Clean Energy Transition Fund
9. Introduce an orderly Phase Out plan, guided by emissions intensity and pollution standards of WA's coal and gas-fired power stations
10. Address the Climate Emergency

3 Credible Scenarios

Energy 2030 modelled two different scenarios for the South West Interconnected System (SWIS).

Both plans included 20% oversupply, and modelling was undertaken using WA expert body Sustainable Energy Now's (SEN) Integrated Renewable Energy Network (SIREN) Toolkit and PowerBalance simulation software.

Scenario 1: Emphasises large scale solar thermal and found WA could achieve 100% renewably powered electricity from:

- 12 solar thermal (CST) stations
- 29 wind farms
- 4 existing Biomass plants
- 6 utility scale Solar PV farms
- Up to 700,000 households and businesses installing solar PV and battery storage

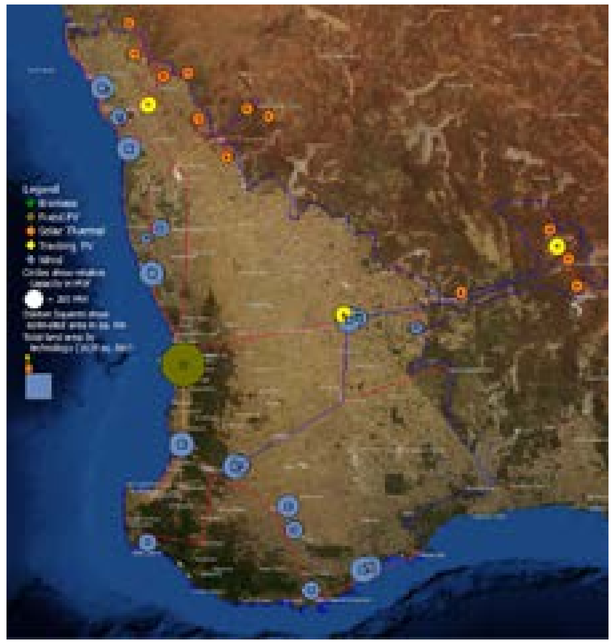
Scenario 2: Focused on lowest-cost technologies (Wind & PV) and found WA could achieve 100% renewable electricity from:

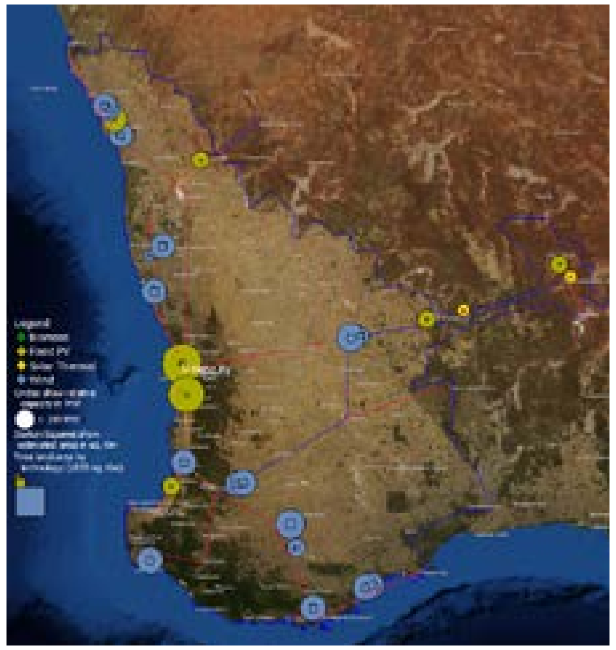
- 27 wind farms
- 2 solar thermal (CST) stations
- 8 Solar PV farms and
- 4 existing biomass plants
- Up to 700,000 households and businesses installing solar PV and battery storage

The good news is that while both Scenarios will need 41-51 renewable power stations by 2030, 17 already exist. We're already well on our way.

Dragging us Backwards: Barnett's Total Fail on Climate and Energy

- **Completely overestimated WA's energy demand – costing us $200 million a year in extra capacity**
- **Refurbished instead of retiring ageing coal-fired power station Muja AB, costing taxpayers $330 million**
- **Caught totally off-guard by the massive demand for rooftop PV**
- **Paid outmoded power stations to stay on in case they're needed**
- **Forced households to sign contracts saying they wouldn't install battery storage systems or large rooftop solar PV in their own house Locked in WA's ongoing oversupply of dirty electricity for 20 or 30 years via secret contracts and the Collie Coal debacle**
- **Actively prevented entry into the market by clean energy companies or community-owned renewable organisations**
- **No emissions reduction target**
- **No Climate Change Unit – he abolished this in 2013**
- **No commitment to renewables beyond the existing federal target of 20% by 2020**
- **No feed-in tariff for renewable energy since 2011**
- **Hardly any funding or policies for stimulating the renewable energy industry, with ground-breaking pilot projects being funded mainly by ARENA, and recent cuts to the Low Emissions Energy Development Fund of $3.5million**
- **A 20-year energy plan proposing both increases in energy demand and reliance on fossil fuels**





Scenarios 1 &2: Location and type of technology

Clean Energy Jobs

Energy 2030 is a jobs rich plan.

The move to 100% renewable power creates 151,000 – 156,000 jobs to 2030 or about 12,000 new jobs each year (Table 1). This is higher than the number of people employed in WA's entire mining industry at the height of the mining boom.[6]

This includes:

- 79,000-87,000 jobs in construction and installation;
- 6000-8000 jobs in operations and maintenance; and
- 49,000-55,000 jobs in manufacturing.

(*Calculations are in job years which means one year of one job)

Image credit: Elena Elisseeva

Scenario 1 creates a total of 156,497 jobs to 2030, or over 12,000 new jobs each year:

RENEWABLE ENERGY JOBS - SCENARIO 1	CAPACITY (MW)	C & I JOBS	O & M JOBS	MANUF. JOBS	TOTAL JOBS
Roof-top PV	1,210	15,730	847	8,107	25,894
Solar Thermal Farm (CST)	1,200	1,560	720	1,116	4,596
Tracking Solar PV Farm	800	10,400	560	5,360	17,120
Wind Farm	5,482	17,542	1,645	25,765	50,434
Biomass Facility	3,013	42,182	4,520	8,738	58,452
TOTAL JOBS	-	87,414	8,291	49,086	156,497

Scenario 2 creates a total of 151,257 new jobs to 2030, or about 11,600 new jobs each year:

RENEWABLE ENERGY JOBS - SCENARIO 2	CAPACITY (MW)	C & I JOBS	O & M JOBS	MANUF. JOBS	TOTAL
Roof-top PV	2,000	26,000	1,400	13,400	42,800
Solar thermal Farm (CST)	200	260	120	186	766
Fixed Solar PV Farm	1,010	13,130	707	6,767	21,614
Wind Farm	6,482	20,742	1,945	30,465	59,634
Biomass Facility	1,363	19,082	2,045	3,953	26,442
TOTAL JOBS	11,055	79,214	6,216	54,771	151,257

Many of these jobs will be located in regional areas and would provide a massive boost to local economies, as well as new opportunities for training and trades.[7]

Findings

The modelling of the two 100% Renewable electricity scenarios demonstrates that the 2030 projected load demand on the South West Interconnected System (SWIS) electricity grid can be supplied from 100% renewable energy sources.

Many studies have found 100% renewable energy would produce electricity prices at an amount similar to business as usual if there is at least some global action on climate change[8,9].

Our study found it would in fact be cheaper than business as usual, when a carbon price of $30/tCO2 was added and surplus generation is sold at $30/MWh:

- Scenario 1 (CST focus) Levelised Cost of Energy (LCoE) $125.80/MWh
- Scenario 2 (Wind and PV focus) LCOE $121.45/MWh
- Scenario 3 – Business as usual LCOE $129/MWh

No Change to Your Power Bills

A national study called the Homegrown Power Plan also found the cost of transitioning Australia's energy system to 100% renewables by 2050 would pay for itself in lower prices by 2025, and save $90 billion by 2050, and fuel cost savings would cover 110% of the capital investment needed[10,11].

Our modelling also shows that going to 100% renewable electricity will have no impact on people's power bills, with all scenarios predicted to cost consumers 27c/kWhr by 2030.

Over the longer term however the average household power bill would be significantly less given there will be no fuel costs. Recent studies have shown that billions could actually be saved from the transition to renewables over the long term.

Staged, Orderly Fossil Fuel Phase Out Plan

Energy 2030 includes a timetable for a staged, stable closure of fossil-fueled power stations.

Like US President Obama's *Clean Power Plan* the Greens propose to use state-based pollution intensity standards that become tighter over time to phase out fossil fuels from the worst polluters down.[12]

Introducing emissions standards for power stations provides a mechanism by which our dirtiest power stations may be removed from the electricity market. As large fossil-fueled power stations are decommissioned, a concurrent a phase-in of large scale renewables will occur. (Model 1)

The Greens propose the Australian Energy Market Operator (AEMO), in consultation with Renew Western Australia would have a new authority to direct generators that exceed the pollution standard to close down their units or decommission entirely.

ENERGY GENERATION SCENARIOS	SCENARIO 1	SCENARIO 2	SCENARIO 3: (BAU)
Total Generation Capacity (MW)	11,705	11,055	7,381
Demand-side Management modelled (MW)	550	550	0
Storage Moten Salt (CST) (MWh)	13,000	0	0
Storage Behind Meter Battery (MWh)	8000	8000	0
Projected Load at 2030 (GWh)	23,584	23,584	26,142
Modelled Total Generation at 2030 (GWh)	29,783	30,103	26,142
% surplus RE generation	21%	22%	0%
Carbon Price ($/tCO2e)	$30	$30	$30
Total Annual Energy Cost (including carbon price) ($ million)	$3,177	$3,258	$2,917
Total Emissions (KtCO2e)	1,157	1,939	15,116
CO2e Emissions as % of BAU	8%	13%	100%
Cost of Emissions Reduction from BAU ($/tCO2e)	$14	$8	$0
Weighted Average LCoE ($/MWh)	$132	$128	$112
Weighted Average LCoE ($/MWh) with $30/tCO2e carbon price	-	-	$129
Weighted Average LCoE ($/MWh) if surplus energy sold at $30/MWh	$125.80	121.45	-

Table 2. Comparison of 3 scenarios

Approximately 500MW a year in new renewable capacity is added to the grid as we power down our most polluting and inefficient fossil power generators, based on new emissions intensity and air pollution standards the Greens will introduce.

By 2030 all coal generation has been phased out, and some gas-turbines have been retained and modified to run on bio-fuels during potential shortfall periods of low solar and wind supply.

The transition from our existing primarily fossil-fueled electricity generation system to 100% renewable sources will ensure a reliable and economically affordable supply as all the existing coal plants are retired and the gas plants are reduced and modified to run on biomass fuel supply.

The transition can be achieved in an orderly fashion and is appropriate to retire the majority of the coal generators as they are reaching the end of their useful lives.

Supporting Transition in Collie

The global energy market is undergoing massive structural shifts, and fossil fuel industries face uncertainty as the inevitable shift to renewables gathers pace. Here in WA as the mining construction also phases down, thousands of workers face the prospect of unemployment with no transition plan in place.

WA's two black coal mines are located in Collie, employing almost 900 people. In addition hundreds more are employed at Collie's Muja, Bluewaters, and Collie 1 power stations.

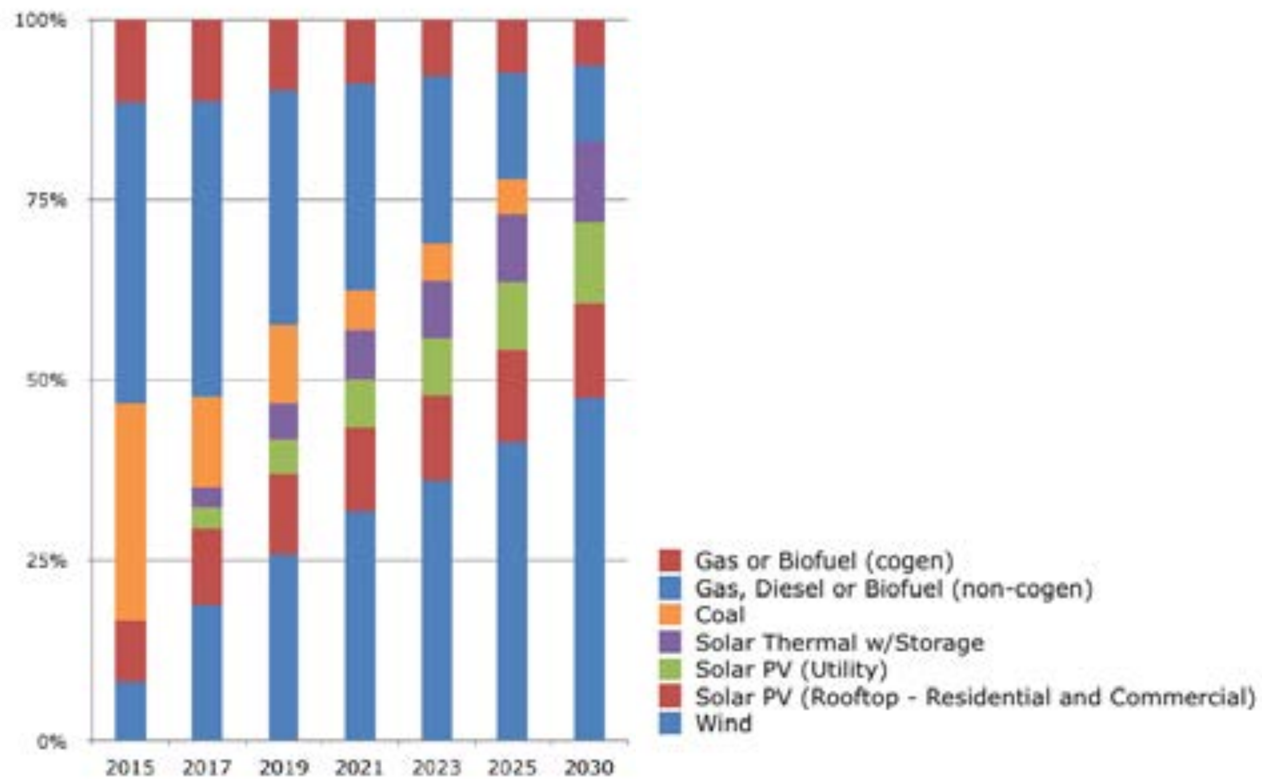
This is why we have proposed a $100m Clean Energy Transition Fund over 15 years to ensure coal workers and communities are not left behind, with $6.65m each year for direct training and re-skilling programs, investment for new businesses, and to assist new industries move to affected areas.

The Greens are also committed to working with the Collie community to help develop a transition plan, and build on our work and outreach in 2013 which identified Collie as a future renewable energy zone in WA.

Collie is an ideal future renewable hub because it has high quality renewable energy resources including solar, biomass and wind; it's ideally located to supply renewable energy to the South-West Interconnected System (SWIS), there are already billions of dollars invested in power generation and transmission infrastructure, and it has a local workforce skilled in electricity generation and maintenance with transferable skills relevant to utility scale renewable energy generation.

There are now many countries and cities with 100% renewable energy plans, as well as credible and costed roadmaps showing not only is it possible, but cheaper, safer, and will create more jobs than the fossil-dependent business as usual. Energy 2030 adds to this list, and puts forward another case to show that there are no technical, engineering, or economic constraints holding us back, merely political will.

Model 1: Energy 2030 Phase Out Plan



Part 1: The Opportunity

A Focus on WA's Electricity

Energy 2030 proves WA can be powered by 100% renewable energy by the year 2030.

This Plan focuses on Western Australia's stationary energy use[13] and builds on our two previous 'Energy 2029' studies released in 2013 and updated in 2014.

Energy 2030 asks the questions that the state government has avoided answering:

Is it possible to shift towards a future energy scenario that is energy-efficient and based entirely on renewable energy sources, how soon could we get there, what it would cost, and how many jobs could this create?

To this end, this plan analyses Western Australia's current electricity use and projected energy demand to 2030 and through industry engagement puts forward credible, proven commercial-scale options for meeting this demand entirely through energy efficiency and a range of renewable technology.

The Western Australian population is forecast to grow from around 2.2 million people in 2009 to around 2.8 million in 2031, with 93 per cent in the area served by the South West Interconnected System (the 'SWIS'), and accounts for half of the total electricity generated in WA. Energy 2030 proposes our most urgent challenge lies in transforming the SWIS to a distributed, renewable system as rapidly as possible.

Unlike our two previous studies, this Plan has modeled a rapid and widespread adoption of proven, existing commercial scale renewable energy technologies and only includes concentrated solar thermal, solar photovoltaics (PV), wind, battery storage and biomass.

While WA has an abundance of wave, geothermal, and pumped hydro storage potential, these have not been included in this plan because of an absence of reliable economic data.

Energy 2030 builds on the Australian Greens RenewAustralia Plan released in 2015, which put forward a roadmap to achieve 90% renewable power on the National Electricity Market (NEM), and provided a suite of policy and funding proposals to drive the transition.

There are now many countries, regions and cities which have 100% renewable energy plans, as well as a number of credible and costed roadmaps showing it is not only possible to achieve 100% renewable power, but cheaper and safer than business as usual. These include:

- The ground-breaking Zero Carbon Australia Stationary Energy Plan (2010) by Beyond Zero Emissions and the University of Melbourne Energy Research Institute, which provided the first costed, technologically credible path to achieving 100% renewable electricity for the entire nation's stationary energy needs by 2020[14]. The Plan:
    - Showed there are no technical or economic barriers to a complete decarbonisation of Australia's energy sector
    - Debunked the myth that renewable energy cannot provide baseload power, and
    - Could be delivered for little to no extra cost to households than the business-as-usual scenario based on fossil fuels.
- The Home-grown Power Plan: 100% Renewable Australia (2016), a joint project between Solar Citizens and Getup! which helped inform how Germany would implement its 80% renewable target for 2050, and found:
    - Transitioning Australia to 100% renewable energy by 2050 would cost less than continuing on the current path
    - The cost of moving all electricity, industry and transport onto renewables would save $90 billion by 2050
    - Fuel cost savings would cover 110% of the capital investment needed [15,16]
- As a condition of the passage of the Clean Energy Act in 2011, the Australian Greens commissioned the Australian Energy Market Operator (AEMO) to inquire into the potential for the national electricity grid to transition to 100% renewable energy. It found a future 100% renewable power system was manageable and there were no operational issues to prevent secure and reliable operability of a 100 per cent renewable future NEM power system.[17]

The Unstoppable Global Shift to Clean Power

In addition to the number of credible roadmaps showing 100% renewable energy is possible in Australia, there are a growing number of countries have also adopted ambitious targets, including:

- Germany (currently 28%, aiming for 80-100% by 2050)
- New Zealand (currently 80% aiming for 90% by 2025)
- Scotland (currently 80% aiming for 100% by 2020)

A further 38 countries now have renewable energy targets of between 50-100%.

Uganda, Costa Rica, Ethiopia, and Mozambique have all reached 90-99% renewable power generation, and many more are well on their way to kicking the fossil habit completely with renewable energy now accounting for 80% in New Zealand, 68% in Austria, 62% in Sweden, 49% in Latvia, 43% in Denmark, 38% in Spain, 27% in Argentina, 25% in Germany, and even 21% in China[18].

While the dates and targets vary, these studies and real life examples show the hurdles to switching to renewables are social and political, rather than technical or economic.

Good News Story: Germany

In 2009, the German Government set an aspirational target and Plan for sourcing 100% of Germany's electricity from renewable energy by 2050.

It has created 300,000 direct jobs in renewable energy and has a renewable energy industry with an annual turnover of AU$50 billion.

Key Principles of Energy 2030

The switch to 100% renewable power requires a redesign of our current, antiquated electricity system, which requires a rebooted set of principles with a clean economy and clean politics at its heart.

PRINCIPLE 1: HARNESS WA'S VAST RENEWABLE RESOURCES

WA is home to some of the best solar and wind resources in the world. We have one of the highest solar radiation levels in Australia, we are the third windiest region in the world, with average wind speeds along the coast of 27km/hr, and a vast coastline of 12,900km making wind energy viable.

We're in one of the best positions of any state or country to generate energy from solar, wind, wave, geothermal, and sustainable biomass resources.

Despite being blessed with some of the world's best renewable energy resources and available land on which to build the infrastructure, we have one of the lowest mixes of renewable energy in the developed world.

Just 9% of all electricity consumed on the WA SWIS came from renewable sources[19], much lower than the global average, which is now 19%[20].

PRINCIPLE 2: HARNESS THE UNSTOPPABLE GLOBAL INVESTMENT SURGE IN RENEWABLES

Global investment in renewables has increased exponentially over the last decade from USD$40 billion in 2004 to $270 Billion (USD) in 2015. (Figure 1)

Global investment in renewable energy has also outstripped that of fossil fuels, with investment in new renewable capacity outpacing that of fossil fuels for the fifth year running[21], jumping to a massive 50% of all new capacity built in 2013.

By the end of 2015, renewables accounted for almost 28% of the world's power generating capacity, enough to supply an estimated 23% of global electricity[22]. (Figure 2)

The Intergovernmental Panel on Climate Change Special Report on Renewable Energy Sources examined likely future scenarios for renewable energy globally and found up to 77% of the world's energy was likely to be supplied by renewable energy by 2050[23]. The longer we wait, the higher we risk missing this once in a lifetime opportunity to harness the clean energy boom.

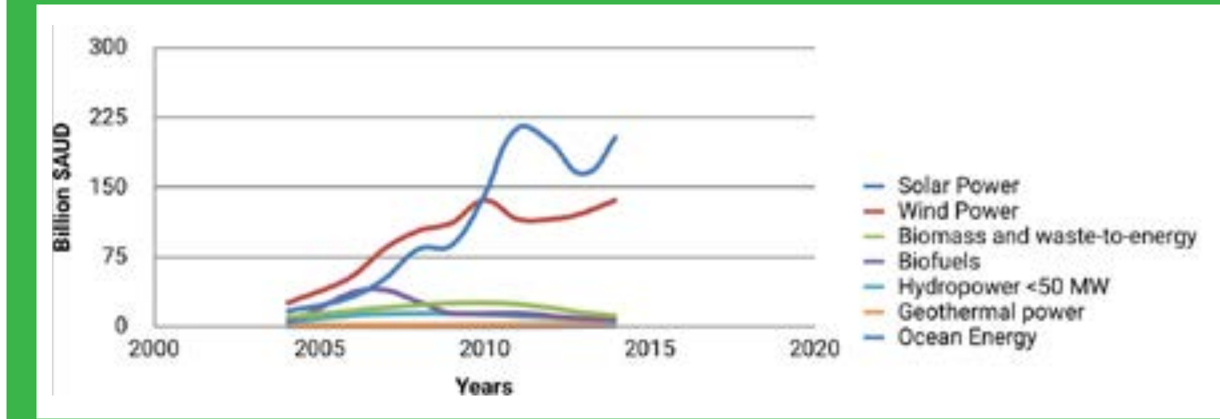


Figure 1: Global Trends in Renewable Energy Investment, 2004 - 2014, Source: Ren21 Global Status Report

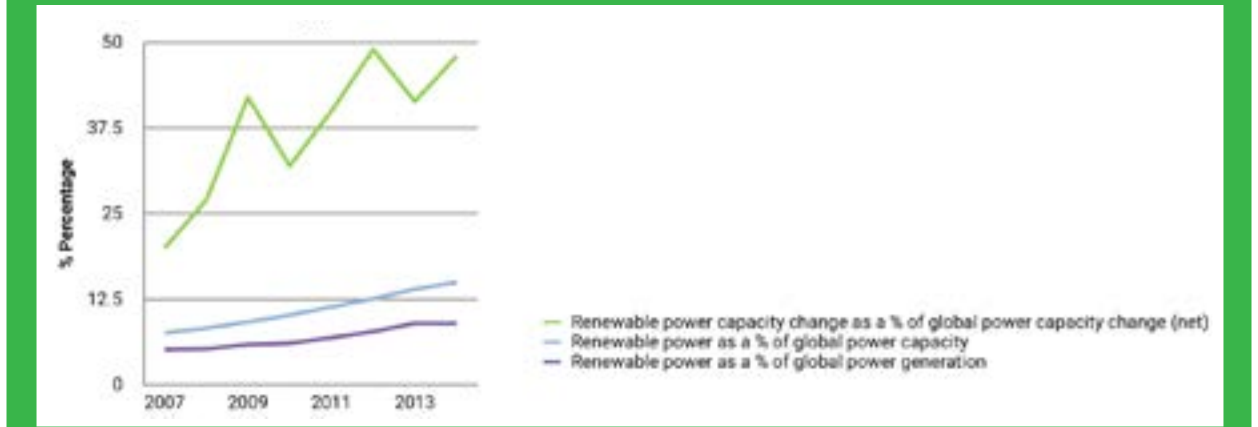


Figure 2: Renewable power generation and capacity as a proportion of global power, 2007 - 2014, Source: Ren21 Global Status Report

PRINCIPLE 3: INCREASE OUR EFFICIENCY AND CUT OUR ENERGY DEMAND BY AT LEAST ONE THIRD

The Greens' commitment to clean up our energy system and our economy also means investing in technologies to use energy smarter and more efficiently. Energy conservation and energy efficiency are the cheapest and most important parts of any renewable energy plan. Our target is to increase energy efficiency by at least one third by 2030.

Making our homes and workplaces more efficient will create a whole host of new jobs in construction, consulting, local government, software development, data analytics and engineering.

Currently the state government has no energy efficiency target, and its projections for energy demand into the future are for wildly unrealistic exponential growth.

WA is one of the most energy-intensive states in the world and our technologies consume more energy per person each year than most other developed nations and all other Australian States and Territories[24]. We have failed to adopt any energy efficiency targets to try and make our economy more productive.

Unlike other countries which are making efforts to reduce their energy demand, WA's total demand for energy is expected to increase by 59% by 2029[25], with some estimating future growth in demand even higher – largely due to the demands of the mining industry[26]. Our energy demand has already tripled over the past 22 years.

PRINCIPLE 4: FLATTEN OUR PEAK DEMAND PROFILE

WA's SWIS has a particularly problematic electricity demand profile with extreme peaks in demand on hot days and cold evenings and lower overnight baseload demand. (Figure 3)

There are many proven (and cheaper) ways to reduce peak demand profiles, including increasing installation of rooftop solar PV, building new housing with higher energy efficiency standards which don't need energy intensive heating and cooling during peak times, retrofitting existing buildings, and introducing smart meters which allow us to shift when we use electricity.

The record level of rooftop PV installation in WA has already reduced the peak demand profile significantly. In 2012 for example, during a Senate inquiry into electricity prices, the Greens confirmed that WA's rooftop solar panels were saving WA taxpayers at least $7.7 million each year by avoiding 'peaking power', the most expensive electricity to produce[27].

Yet, instead of harnessing the cheapest and most effective ways to reduce our peak demand profile, the Barnett government did the complete opposite - and invested over $400 million into additional fossil fuel powered capacity that was barely used.

PRINCIPLE 5: MAKE ENERGY CHEAPER

One of the biggest myths is that renewable energy drives up prices for everyone else, when the opposite is true. Recent analysis of the Renewable Energy Target showed power prices will be cheaper with the RET, and in the long run it will save every Australian household up to $140 on their electricity bill each year[29].

When the Liberal Government attacked the Renewable Energy Target, they commissioned a study in the hope to prove how expensive clean energy was compared to coal. The facts disappointed them. The report showed that clean energy pushes down power prices by being the cheapest to operate, which drives competition, further bringing power prices down. The analysis showed that the more the renewable energy supply was increased, the more households saved on their power bills[30].

Measures to roll out solar panels for lower income households means that many Australians will be in a better position to escape the traps of energy poverty.

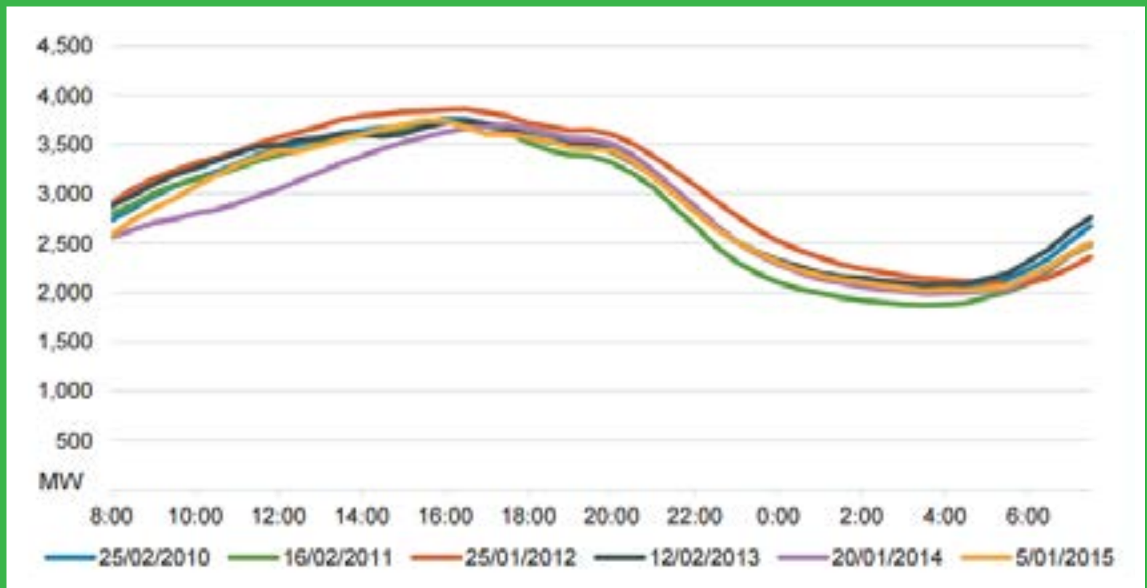


Figure 3: Peak Day Load Profiles, 2010 to 2015[28]

PRINCIPLE 6: END THE WASTE

Western Australians have been completely swindled by the Barnett government's mismanagement of our energy network. It has thrown billions of taxpayer dollars at propping up an antiquated power network, and passed this on in the form of higher and higher bills. In April this year it was reported the annual cost of electricity delivery is now over $500 million more than the state-owned utilities can recoup from users[31].

The two main areas of waste have been paying for capacity that was never needed; and gold plating an antiquated network.

Paying for Capacity that was Never Needed

One of the drivers of WA's runaway power bills has been the state government's over-investment in extra capacity that was never needed.

Barnett's Botches

- **Completely overestimated WA's energy demand – costing us $200 million a year in extra capacity**
- **Caught totally off-guard by the massive demand for rooftop PV, with 30% of WA households now sporting solar panels (in turn significantly reducing peak demand)**
- **Refurbished instead of retiring ageing coal-fired power station Muja AB costing taxpayers $330 million**
- **Paid outmoded power stations to stay on in case they're needed**
- **Forced households to sign contracts saying they wouldn't install battery storage systems or large rooftop solar PV in their own house**
- **Locked in WA's ongoing oversupply of dirty electricity for 20 or 30 years via secret contracts and the Collie Coal debacle**
- **Actively prevented entry into the market by clean energy companies or community-owned renewable organisations**

The 2015-6 Electricity Market Review revealed the extent of the problem - largely as a result of demand growth being considerably below forecasts. The graph below highlights how badly WA's Independent Market Operator got it wrong. (Figure 4) The green blocks show how much capacity was added to the SWIS, the yellow line shows how much capacity was forecast to be needed, and the red line how much was in fact required at the peak.

This included the Barnett government wasting $330million on the refurbishment of Muja A&B coal fired power stations[33], and the $95 million investment into a new 82MW diesel-powered peaking plant in Merredin, for which taxpayers will pay $15 million a year even if it's never switched on under WA's bizarre capacity payments system[34].

It found in 2016-17 there will be an excess of capacity of a massive 1061 MW (or 23%). This translates to a cost of $112 -$200 million per year - and is passed on through higher power bills and taxes[35].

Instead of paying for extra capacity, our modelling shows even using 100% renewable power, we can generate 20-30% above estimated demand, and sell this on to high intensity industries such as mining and manufacturing.

Gold Plating an Antiquated Power Network

The cost of maintaining and expanding WA's electricity network (operated by Western Power) is one of the single biggest expenses of state government spending.

Over 2010- 2013 the state government spent $3.8 billion on maintaining and upgrading our existing fossil-powered electricity assets[36]. In 2015-16 it spent another $3.5 billion on the grid and $200 million on fossil fuel plant capital expenditure. Not one dollar was allocated to renewables in the 2013/14 and 2014/15 budgets.

In the last 10 years the state has spent a total of $1.4 billion on new fossil fuel plants and just $92 million on renewables[37].

For the same $1 billion we spend every year on outdated energy infrastructure, we could instead use it to build up a smart, renewably powered grid.

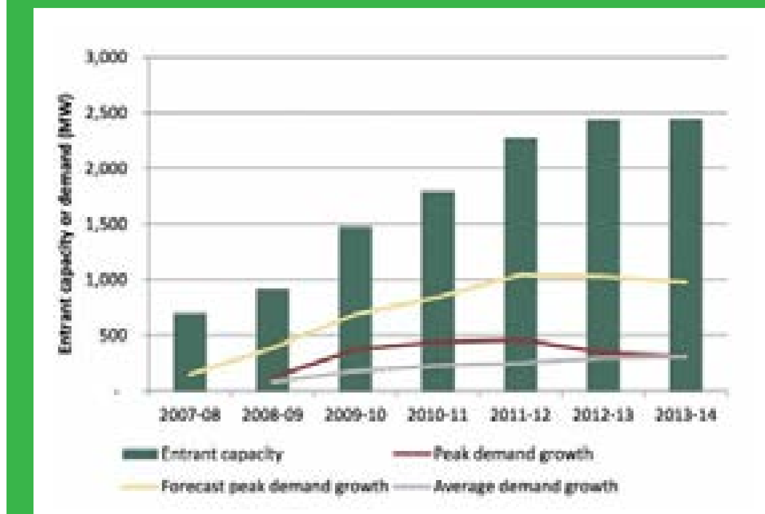


Figure 4: Forecast versus actual peak demand growth and capacity added in WA[32]

PRINCIPLE 7: ESTABLISH A NEW STATE GOVERNMENT AUTHORITY – RENEW WESTERN AUSTRALIA – TO DRIVE THE TRANSITION

In 2015 the Australian Greens proposed establishing a new government authority called RenewAustralia – tasked with planning and driving the transition to 90% renewable energy in Australia by 2030, and responsible for leveraging $5 billion into planning, construction and operating new energy generation over the next four years.

Given WA's electricity network is independent of the National Electricity Market (NEM), and our more ambitious target of 100% renewable electricity by 2030, this report proposes the establishment of Renew Western Australia, a new unit within the WA government responsible for planning and overseeing the transition, and reporting directly to RenewAustralia.

Specifically, Renew Western Australia would be established by an Act as a statutory authority to:

- Oversee the transformation of WA's electricity system
- Ensure affected communities are supported
- Ensure closures of coal fired power stations proceed in a planned manner.

Its functions would include:

- Law reform and advice functions, including reviewing existing laws and proposing necessary changes; and
- Renewable energy project functions, including building, financing, owning or operating, and running reverse actions for private sector renewable energy projects.

Renew Western Australia would work together with the CEFC and ARENA, and help plan and direct the massive annual installation of new renewable energy capacity that would be required to meet the target by 2030.

The Greens have proposed funding of up to $500m for Renew Western Australia over four years.

PRINCIPLE 8: SUPPORT WORKERS AS WE TRANSITION AWAY FROM FOSSIL FUELS THROUGH A $100M CLEAN ENERGY TRANSITION FUND

The global energy market is undergoing massive structural shifts, and fossil fuel industries face uncertainty as the inevitable shift to renewables gathers pace. New coal, gas and uranium projects are no longer economically viable as large scale renewables have become competitive. Here in WA as the construction boom phases down thousands of workers face the prospect of unemployment, with no transition plan in place.

This is why the Greens are strongly advocating for a just and stable transition. We are committed to ensuring no workers are left behind, and that communities are supported during the inevitable closure of coal mines and power stations.

During the 2016 federal election the Greens announced a Clean Energy Transition Fund which would invest $1bn over the next 15 years - including $100 million into WA. This translates to $6.6 million per year for direct training and re-skilling programs, investment support for new businesses and enterprises, and to assist new industries move to affected areas.

This would be funded through ending the federal subsidy on miners' fuel and making them pay fuel excise tax, which would save $6 billion a year. Imposing a thermal coal export levy would raise an additional $700 million a year.

We propose Renew Western Australia would be tasked with administering the Clean Energy Transition Fund in WA.

Transition planning must start now. It's also why Energy 2030 includes a staged plan for the closure of coal (and eventually gas)-fired power stations, and measures to attract new 21st century industries to those areas that need it.

Supporting WA's Coal Workers Through the Transition

WA's two black coal mines are located in Collie, employing 896 people, with 658 employed at the Muja Open Cut coal mine and 238 at Premier Coal. Hundreds more are employed at Collie's Muja, Bluewaters, and Collie 1 Power stations.

The value of coal to the state was $301 million2014-15. Coal mining represents less than 1% of WA's total mining employment.

The Greens are committed to working with the Collie community to help develop a transition plan, and build on our work and outreach in 2013 which identified Collie as one of five future renewable energy zones in WA.

Collie is an ideal future renewable hub because:

- **Preliminary analysis indicates Collie has high quality renewable energy resources including solar, biomass and wind.**
- **It's ideally located to supply renewable energy to the South-West Interconnected System (SWIS) now and in the future**
- **There are already billions of dollars invested in power generation and transmission infrastructure**
- **It has a local workforce skilled in electricity generation and maintenance, with transferable skills relevant to large scale / utility size renewable energy generation**

We have a responsibility to ensure WA workers are looked after and that no coal power worker has to suffer the anxiety and financial insecurity that comes from abruptly losing their job. An orderly transition like this offers workers the security to plan their future – rather than being at the mercy of secret government handshakes and inevitable market shocks for which there is no Plan B.

Just transition assistance for workers is crucial, because the clean energy transformation must also be an equitable one.

PRINCIPLE 9: AN ORDERLY PHASE OUT PLAN GUIDED BY EMISSIONS INTENSITY AND POLLUTION STANDARDS OF WA'S COAL AND GAS-FIRED POWER STATIONS.

Building up clean energy infrastructure is only one side of the coin. The other is the staged closure of coal-fired and other fossil fuel power stations.

That is why a planned closure, starting with WA's oldest and worst polluting power plants is the responsible thing to do.

In a surprise move in April 2016 Minster Nahan instructed Synergy to shut down 380MW of fossil fuel capacity in the next two years. Analysts expect this to include the 240MW Muja A and B unit at Collie. This was announced as part of an effort to save costs of up to $130 million per year by eliminating excess capacity on the grid, with the Minister saying:

"The retirement of excess capacity is aligned to the business's long term corporate strategy. Synergy is in the process of reviewing the cost efficiency of each of its generation assets to determine the best commercial outcomes for the business and the state and will announce plant retirement plans in due course."[38]

Many of WA's coal fired power stations we rely on for our power are half a century old and well past their use-by date.

Staged and predictable closures are necessary to create the investment environment for building significant clean energy infrastructure.

Like former US President Obama's Clean Power Plan the Greens propose to use state-based pollution intensity standards that become tighter over time to phase out fossil fuels from the worst polluters down[39].

Introducing emissions standards for power stations provides a mechanism by which our dirtiest power stations may be removed from the electricity market. As large fossil-fueled power stations are decommissioned, a concurrent a phase-in of large scale renewables will occur.

The Greens propose the Australian Energy Market Operator (AEMO), in consultation with Renew Western Australia would have a new authority to direct generators that exceed the pollution standard to close down their units or decommission entirely.

The timing of these closures would be determined by consideration of supply-demand conditions and managing load profiles through storage technologies. The overarching goal of closures is to ensure renewable energy generation is increased at the same rate that fossil-fueled power stations are closed, to ensure projected demand for electricity is adequately served and blackouts will not occur.

Until recently this approach has been impossible due to the secrecy around the emissions of WA's power stations.

The carbon emissions profile of WA's power stations on the SWIS has not been publicly available, despite repeated efforts of Greens in the WA parliament[40]. The recent Electricity Market Review in WA recommended changing this by making the IMO reportable to the AEMO, which if adopted, will mean the emissions intensity figures for all WA power stations will now be publicly available, and the orderly phase out process can begin[41].

Emissions data used in this report is based on a volunteer international body CAMA (that calculates the emissions profile of every power station on the planet, Table 10).

Emissions and air pollution data is the most responsible and orderly way to plan our fossil-fuel phase out, and the Greens will continue to advocate for this data to be made publicly available as soon as possible.

"We know that climate change, if it is not addressed, will have grievous impacts on Western Australia. Many have spoken, justifiably, about the Great Barrier Reef. I speak up now for its Western Australia equivalent, the Ningaloo Reef on the north-west coast, which rivals the GBR in beauty and biodiversity. It also supports a multimillion-dollar tourism industry. It is under threat from warming and acidifying oceans. If current trends in the climate continue, the south-west of Western Australia will potentially experience 80 per cent more drought months by 2070, and that will wipe out one of the world's most biodiverse botanic regions, at enormous cost to us all. In Western Australia up to $30 billion in assets—that is, more than 20,000 residences, 2,000 commercial buildings and 9,000 kilometers of roads—are at risk from sea-level rise. Along the west coast and southern coast, the sea level is actually rising faster than most of the world average or the average around Australian coasts".

- Senator Scott Ludlam, Senate speech during debate on the Clean Energy package, 2011

PRINCIPLE 10: ADDRESS THE CLIMATE EMERGENCY

The window to take action to prevent catastrophic climate change is closing. 2016 was the hottest year ever recorded[42], and we are already seeing the impacts of climate change here in WA and globally.

We are already experiencing hotter summers, more unpredictable seasons and storms, and record heatwaves. The South West of WA has been identified by the IPCC as one of the global areas to be most affected by climate change, with reduced rainfall and increased drought predicted.

In 2012 the International Energy Agency (IEA) and the World Bank give their most urgent warnings yet that a safe climate is slipping out of our reach.

Yet Western Australia is ideally placed to lead the world in meeting this challenge. We have enormous opportunity and responsibility to take on this generation-defining challenge.

It is time to urgently develop new models of technologies and governance needed to make large scale emissions reductions in the timeframe required to preserve a safe climate.

The Australian government's current 2030 climate target is to cut emissions by 26 per cent on 2005 levels by 2030. In real terms this puts us at the back of the pack. It is woefully inadequate and will not achieve Paris-Agreement commitments to keep global warming within 1.5 degrees. It is also now clear that present policies have no hope of meeting even these weak targets.

The Greens targets are for a 40-50 per cent GHG emissions reduction on 2000 levels by 2025; a 60-80 per cent reduction by 2030; and net-zero pollution by 2040[43].

Barnett's Climate Fail
There has been a reckless abandonment of climate change mitigation and adaptation efforts by the State Government. On several key indicators WA is the worst performing in the world.

Western Australia currently has:

- No emissions reduction target (our so called Climate Change strategy states "an emissions reduction target is not considered appropriate for Western Australia"[45])
- No Climate Change Unit (this was abolished in 2013)
- No commitment to renewables beyond the existing federal target of 20% by 2020
- No feed-in tariff for renewable energy since August 2011[46]
- Hardly any funding or policies for stimulating the renewable energy industry, with groundbreaking pilot projects being funded mainly by ARENA and other Commonwealth funds
- A 20 year energy plan – the Strategic Energy Initiative - Energy 2031 – which proposes increases in both energy demand and reliance on fossil fuels, including coal and conventional and unconventional gas

Based on figures provided by the WA Government to NGERs WA's total annual greenhouse gas emissions are 86.1 million tonnes of carbon dioxide equivalent per annum (MtCo2e), up from 79.5 MtCo2e in 2010 – an 8% increase[47]. This figure includes including 49.3 MtCo2e from the stationary energy sector (up by 2% since 2010)[48].

It's worth noting that the emissions have already increased by a further ten million tonnes of carbon pollution from the commencement of Pluto, and Gorgon LNG hubs, with a further 3 LNG hubs due to come online (Browse Basin, Prelude and Wheatstone) adding another 24.5 mtpa, representing almost a doubling of our entire state emissions[49].

Under Premier Barnett, our state government action on climate and energy policy has gone backwards by decades.

Many Western Australians would be unaware of the amount of taxpayer support provided to fossil fuel companies directly via state government departments.

The Office of State Development has an annual budget worth $453 million per year and 142 full time employees[50]. It is almost entirely devoted to progressing fossil fuel discovery, extraction and export activities. In 2010 for example it allocated $105.5 million to develop two LNG infrastructure sites: $101m on the Browse Basin LNG precinct and $4.5m for the Ashburton North and Anketell strategic industrial areas in 2010[51].

The Mines and Petroleum Department has an annual budget of about $88 million per year, with 641 employees[52]. Between 2010-2014 $94 million was allocated to assisting the petroleum and uranium industries (mostly through regulation)[53], and another $80m over five years was allocated to the Exploration Incentive Scheme (EIS) in which taxpayers contribute to the drilling costs of fossil fuel exploration companies by up to $200,000 each drilling hole[54].

Figure 5: Historical rainfall patterns in WA 1911-2013[44]

Part 2: The Good News: The Energy Revolution

WA has an abundance of renewable energy resources, including solar, wind, wave, geothermal and biomass. This section summaries each technology and its potential application in WA.

Technologies assessed are:

1. Demand reduction, through energy efficiency and load management programs
2. Solar Energy, including
   - Concentrating Solar Thermal (CST)
   - Solar PV
3. Battery Storage
4. Wind Energy
5. Bioenergy, and
6. Wave, Geothermal and Hydropower energy

1. DEMAND REDUCTION

Reducing electricity demand is one of the most effective – and cheapest – ways to delay or eliminate altogether the need for our utilities to build further capacity.

The two main ways are through:

- **Energy Efficiency Programs**
  Using less power to perform the same tasks. This involves a permanent reduction of demand through more efficient processes, buildings or equipment; and
- **Load Management (or demand side management) Programs**
  Any reactive or preventative method to reduce, flatten or shift demand. In simple terms the goal is to change the load pattern and encourage less demand at peak times and peak rates.

Energy Efficiency

"Energy efficiency is Australia's untapped energy resource—a means to improve the productivity of the economy as well as an important element in moving towards a prosperous low-carbon future…To date, Australia has not consciously or explicitly targeted world best practice in energy efficiency policy and, by comparison with other countries, has significant gaps in its energy efficiency policy armoury".[55]

– Australian Government Report of the Prime Minister's Task Group on Energy Efficiency, 2010

Energy efficiency is the most important and cost-effective option to reduce energy demand and achieve a renewably powered future.

The foundation of the new energy economy rests equally on renewable energy technologies and a major investment in energy efficiency through every sector of society.

This energy efficiency target will give innovative businesses and researchers a financial incentive to find smarter ways to do things. Making our homes and workplaces more efficient will create a whole host of new jobs in construction, consulting, manufacturing, engineering, and design.

Much of our energy is lost to inefficiencies in our aging infrastructure, built environment and appliances/devices. By addressing this it is possible to cut the electrical energy we require by as much as half.

Under business as usual our demand for electricity will grow by 57% over 20 years, and there is no energy efficiency target, according to the WA government's Strategic Energy Initiative 2031 Directions Paper (2011).

Instead, Energy 2030 proposes an energy efficiency target of 30%, which would save about 470 petajoules by 2030 – enough to power 1.5 million present day households for a year.

"The worst energy efficiency program you can come up with will still be a cheaper way to abate emissions than the best renewable energy program."

- Dr George Wilkenfeld, Australian energy and planning policy consultant

The Global Movement
The IEA estimated investment in energy efficiency markets worldwide was between USD $310 - $360 billion in 2014, which was larger than investment in renewable energy, or in coal, oil and gas electricity generation, confirming energy efficiency's place as the 'first fuel' [56].

The IEA also reported energy efficiency investments over the last 25 years as the primary reason for the uncoupling of energy consumption from economic growth, and combined, energy efficiency measures in IEA countries has saved consumers USD $5.7 trillion on energy[57].

Many other developed economies already use only half to two-thirds of our per capita energy consumption.

Yet here in WA we have no energy efficiency target, despite being one of the most energy intensive states in the whole world.

Beyond Zero Emissions' Zero Carbon Australia 2020 Stationary Energy Plan showed easy energy efficiency improvements such as insulation, upgraded appliances, and improved industrial processes can reduce total end-use energy by 30%[58].

Cape Town
The City of Cape Town's initiative to improve energy efficiency in government buildings resulted in 20% savings in electricity per month, achieved through an energy audit to determine potential energy saving opportunities, and installing simple measures including timers so that water is only heated when needed, replacing inefficient urns with insulated electric water heating systems, and installing energy efficient lighting and solar water heaters[59].

Germany
Germany and Australia have a similar per capita gross domestic product, and have a comparable economy with metal refining industries, including five aluminum smelters and car manufacturing. Yet Germans currently use about 36% less electricity than Australians[60].

The German Parliament's Commission on Protecting the Earth's Atmosphere found energy savings of 35-40% were feasible[61] and over five years committed to reducing its annual energy use by 933 Petajoules (PJ)/year through energy efficiency alone – almost as much as Western Australia uses in an entire year (945 PJ/year).

During the rollout of the program the German economy continued to grow by 1.6%, whilst energy demand decreased by 1.2%, proving it's possible and imperative - to decouple energy demand from economic growth[62].

Germany plans to improve its use of energy still further, through the implementation of a National Energy Efficiency Action Plan which includes rapid rollout of smart metering, increased investment in energy efficiency for public buildings, new targets in government procurement processes, long-term, low-interest loans for retrofitting of old residential buildings, subsidies for new low energy houses, employing specialised energy managers within municipal governments, demand management projects to foster energy-saving actions by consumers, and improved energy consumption labelling on motor vehicles, equipment and other products.

Load Management and Demand Side Management

Load management programs are any reactive or preventative method to reduce, flatten or shift demand. A simple example is the use of energy storage units to store energy during off-peak hours and discharge them during peak hours. Demand Side Management (DSM) offers financial incentives or returns to users who agree to turn down demand when supply is short.

Case Study: California
California was among the first regions anywhere to introduce large-scale energy-efficiency and reduction programs, and demonstrated for every $1 billion spent on efficiency measures, from upgrading lighting to improving building insulation, $2 billion is saved. (Figure 6)

By moderating consumer behaviour on peak-load days, California also avoided building expensive gas-fired peaking power stations that would have been used for fewer than 50 hours a year.

Instead of installing smart meters, households and businesses could voluntarily sign up to have air-conditioners fitted with chips that allowed utilities to remotely idle the units for short periods. Those who signed up for the chips receive discounts on their power[63].

California's successful bipartisan implementation of energy efficiency policy saved taxpayers more than $65 billion, helped lower their residential electricity bills to 25 percent below the national average, and contributed to the state's continuing leadership in creating green jobs[64].

Case Study: DSM in WA
The way DSM has been operating in WA meant that $430 million has been handed out to providers, even though their services have been used for just 106 hours on eight occasions – including testing – in the past decade.[66]

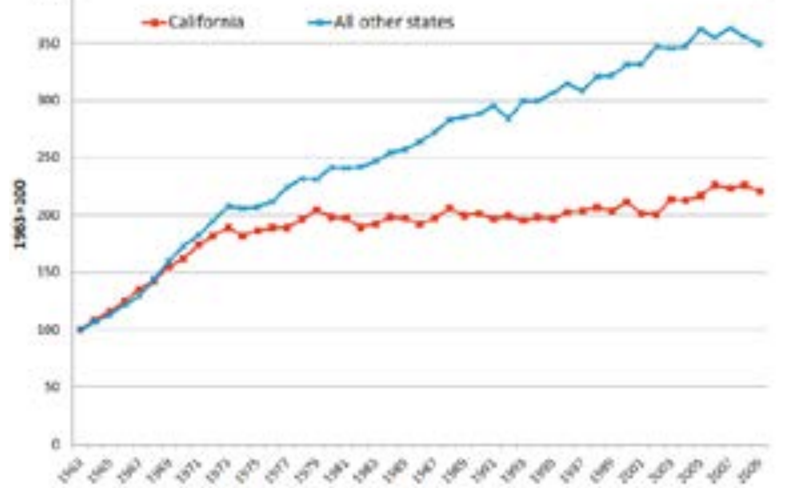


Figure 6: California stabilises energy demand whilst national average increases[65]

Energy Efficiency in our Plan

Energy 2030 adopts a realistic target of reducing electricity demand by 30% by 2030 through energy efficiency and energy conservation measures.

- **Our target is to cutting our electricity demand by at least 30% through energy efficiency and load management programs by 2030**
- **A 30% reduction would save about 470 petajoules by 2030 – enough to power 1.5 million present-day households for a year[67]**
- **Under Business as usual there is no energy efficiency target and a forecast electricity growth of 57% over 20 years (or 2.3% per year) reaching a total 26,000 GWh in 2030.**
- **A 30% reduction in the growth of electricity demand growth reduces the total amount of electricity required by 2030 to 23,000 GWh**
- **550MW of demand-side management (DSM) is also included in the modelling.**

(See the Full Roadmap in Part 3)

2. SOLAR ENERGY

There are two main types of solar energy technology that can be used on a large scale in WA to achieve 100% renewable energy in our plan:

- **Concentrating Solar Thermal (CST) Energy Systems**
  Which concentrate the sun's energy to produce heat, used to produce steam to drive a turbine and generate electricity , often with thermal storage on site; and
- **Solar Photovoltaic (PV) Energy Systems**
  Which convert solar energy directly into electricity by producing an electric current when exposed to sunlight. These can be deployed at the household scale (residential solar panels), commercial scale (warehouse rooftops) or in utility scale 'solar farms'.

Concentrating Solar Thermal (CST)

CST is now a proven and reliable, utility scale technology.

Globally, installed capacity has steadily grown over the last 10 years, and by the end of 2014 was just over 4GW, which is double the peak demand of WA's entire electricity network. CST was first developed at a commercial scale at the Andasol and Torresol plants in Spain and is now being deployed around the world.

Developed in the 1970s, CST technology uses mirrors or lenses to concentrate sunlight onto a single point, and uses a heat transfer fluid (usually water, molten salt or oil) to transfer the energy to a central power system to make steam to power an electrical generator. Typical CST plants use standard steam turbines and often integrate thermal energy storage which can be used to run a turbine and generate electricity after the sun has gone down or during extended cloudy periods.

Better than Baseload
One key characteristic of CST plants with thermal storage are their 'better than baseload' characteristics. The addition of storage makes the plants highly responsive, able to ramp output up or down rapidly in response to fluctuating output from wind installation or PV arrays.

CST Plants in Action at 2016:

- There are 61 CST plants already in operation around the world, generating a total of 4650MW, with the majority in Spain (2,300 MW) and the USA (1,777 MW)[68]
- There are another 22 commercial scale CST plants under construction, of between 14MW-370MW, which combined will generate a total of another 1332 MW globally[69]
- A further 16 CST plants are under development[70]

What is Possible?
Beyond Zero Emissions' proposed up to 60% of Australia's electricity needs could be met using solar thermal technology by 2020[71].

A more modest report commissioned by the Australian Solar Institute in 2012 found CST could provide about 30 per cent of Australia's total current electricity generation capacity by 2020 with only modest extensions to the national electricity grid and would create jobs for around 4,000 people in construction and ongoing operations, with the majority of these jobs in regional areas[72].

In 2006 a report by Next Energy found that with an average solar thermal radiation level of about 7.3 GJ per square metre per year, an area of under 300sq km with 20% efficiency could supply all of WA's projected 2030 electricity needs[73].

Where Would we Build it?
A comprehensive, peer reviewed study of potential locations for CST in WA was completed in 2012[74] and provided the most detailed guidance on prospective areas for large-scale solar thermal installations, while giving order-of-magnitude estimates of technical production potential.

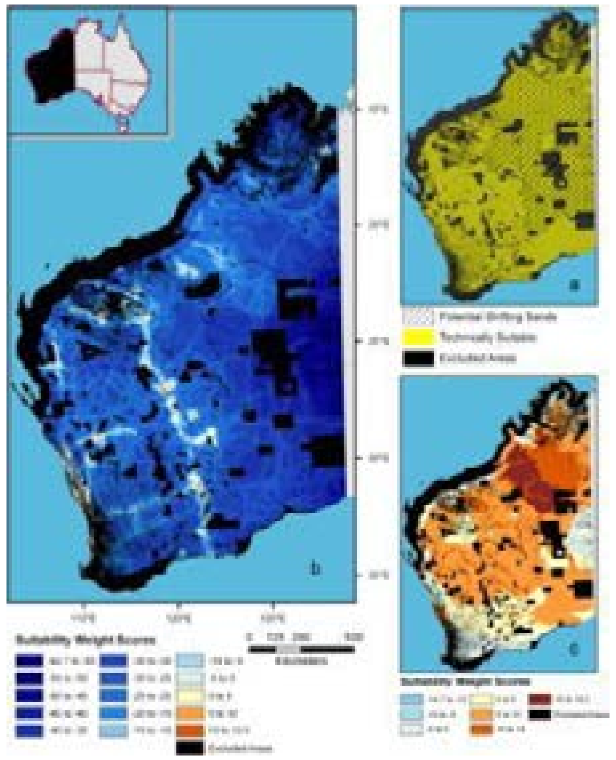
The study identified that a full 70% of WA's land mass is technically suitable for CST – and if put into production under utility-scale parabolic trough CST plants, the theoretical output would be fifty times greater than the demand of the entire industrialised world.

The study overlaid existing grid infrastructure and a number of other variables to arrive at a more modest estimate of actual site suitability, of 11,200 km2, or around 0.6% of the area identified as technically suitable. This greatly reduced land area if dedicated to CST electricity production would be capable of powering one third of the planet's electricity demand. (Map 1)

The locations it found most suitable are the Wheatbelt, Mid-West, Kalgoorlie and the Pilbara.

Jobs-Rich Technology

It's estimated every 100MW system creates about 500 jobs during construction, 38 permanent jobs during its operation and a further 56 indirect permanent jobs.



Map 1: Strategic Site Suitability in WA[74]

The Wheatbelt
With its abundant sunshine, grid connections and availability of freehold land, the Wheatbelt is an obvious place to build solar farms. The Wheatbelt's weather patterns are ideally suited to co-located wind and solar generation plants, as winds in the Wheatbelt tend to be strong in the later afternoon and evening as sunshine declines. Wheatbelt areas are also highly prospective for backup fuel sources, with biomass co-firing to carry CST plants through rare simultaneous solar and wind droughts.

The Mid-West
With strong support from local government and the iron ore industry, Mid-West Energy proposed to build two 100MW CST plants at Perenjori south of Geraldton and put in a competitive bid for funding under the Federal Government's Solar Flagships program which was unfortunately unsuccessful, with no Flagships money allocated to WA. The area remains under study.

In 2012 Solastor, in consortium with Carbon Reduction Ventures, announced the proposal for a 1.5MW grid-connected concentrated thermal power station near Morawa, east of Geraldton. The project, if developed, will be a valuable test bed despite its small scale, as the developers propose to use solid graphite as the energy storage medium rather than molten salt or hot oil, giving it 18 hours of energy storage.

Kalgoorlie
Kalgoorlie is connected to the SWIS and receives abundant sunshine, and is an obvious priority location for major concentrated solar power generation hub[75]. In Kalgoorlie, there is strong local industry, business and local government support to work hard towards this outcome.

Current Costs
The evidence leans toward the capital costs of CST falling by 50% within a decade if present annual growth rates of 40% are maintained.

As CST systems become the cheapest way of generating bulk dispatchable electricity and financial markets become more comfortable with the risk profile of CST projects, it is difficult to imagine – politics notwithstanding – why anyone would build a large fossil-fired power station again.

Solar Thermal in our Plan

Energy 2030 adopts an ambitious but realistic target of energy generated from CST technology.

Under Scenario 1:

- **12 new 100MW CST stations are constructed with molten storage**
- **1200MW of capacity is added**
- **14% of the electricity mix will be generated by CST by 2030**

Under Scenario 2:

- **2 new 100MW CST stations are constructed**
- **200MW of capacity is added**
- **2% of the electricity mix will be generated by CST by 2030**

With our world-class solar resource identified and a large investment pool through the CEFC, it's time Australia takes its place as a global leader in solar energy.

The Greens (WA) want WA to be the home to the first CST plant in Australia. We have nothing against Port Augusta, we just want to be first.

Solar PV

The world's largest existing solar energy farms now have the same or larger capacity as a typical Western Australian coal-fired power station, and they provide electricity to hundreds of thousands of homes.

Solar Photovoltaic (PV) cells convert solar radiation directly into electrical current. PV panels can be used both for small-scale household and large-scale commercial plants. One of its major benefits is that it corresponds well with higher daytime and peak electricity demands and is embedded directly into the area where the energy is needed, needing little or no additional transmission infrastructure.

Solar PV has Become an Unstoppable Force:

- At least 70 solar PV plants larger than 50 MW operating globally, with a combined capacity of 7.1 GW and accounting for about 4% of global capacity[76]
- Global PV capacity grew from 2.6 GW to 177 GW between 2004 to 2014[77]; in Australia it grew from 2.7MW to 3294.2 MW – a massive increase of almost 122,000%
- Germany leads the world in total installed solar PV capacity, with 39.5 GW in November 2015, equivalent to Australia's entire Solar PV capacity twelve times over, and enough to cover WA's entire peak electricity needs almost four times over[78]. This is despite receiving just half the amount of sunshine than WA

Household PV in WA
Western Australia is the third highest user of solar PV in the country, with almost 24% of homes with a rooftop PV system, equal to 546 megawatts of capacity at November 2016 - up from 100MW in 2013. This is the equivalent capacity to two coal-fired power stations[79].

The average capacity of new rooftop PV systems has also increased from 1.5kw to 5 kW. This means for every 46,000 new rooftop solar PV systems installed, 230 MW will be generated during times of peak generation. This is comparable to the amount produced by a typical WA coal-fired power station.

At current rates of growth Perth's rooftops could soon have renewable power capacity equivalent to 1GW by 2020.

The cost of solar PV has decreased dramatically as installation and economies of scale have increased worldwide.

The massive global growth in cumulative installed capacity relative to decreases in costs is striking (Figure 7). It shows at the end of the year 2000 the cumulative global installed Solar PV capacity was less than 1 GW, by the end of 2014 it had exceeded 180 GW.

Since 2012 the cost per Watt ($AUD/W) has fallen by half for large household systems of 3kW to 20kW systems. This leaves the vast rooftop expanses of WA's commercial buildings likely to take up rooftop solar in a massive way, and provide an even greater proportion of WA's electricity.

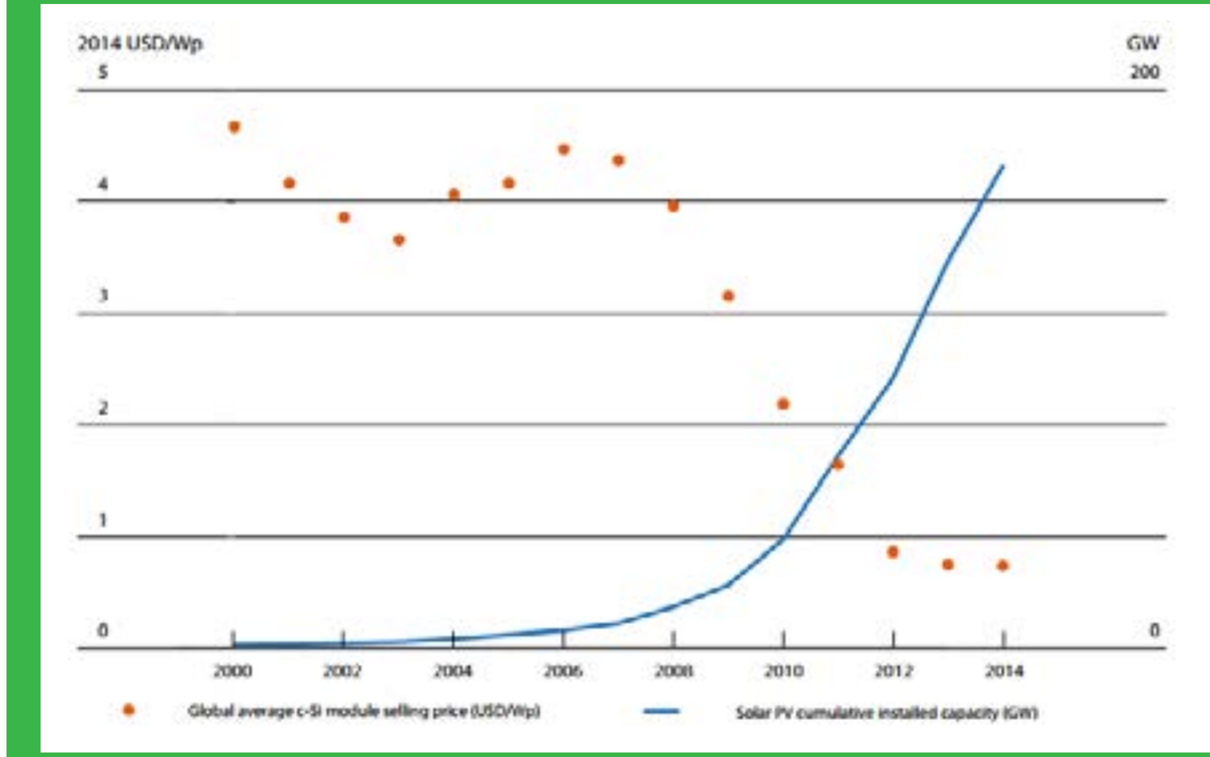


Figure 7 – Cumulative Global Solar PV Deployment and Solar PV Module Prices ($USD/W) 2000 - 2014[80]

Figure 8 – The world's largest solar farm, California's 579 MW Solar Star was switched on in June 2015[81]

Commercial Scale Solar Farms
Given the rapidly falling price and increased capacity of solar PV technology, large utility-scale solar PV plants are now also being widely installed across the globe. Greater efficiencies and sun tracking capabilities are always advancing in order to achieve greater energy outputs from the sun.

The world's largest operating solar plant is the 579 MW Solar Star located in the United States. Connected to the Californian grid on June 2015, the plant comprises of 1.7 million solar panels spread over 13 square kilometers. (Figure 8)

The largest proposed Solar PV power station is Project Helios, potentially to be located in Greece, with a nominal output of 10 GW (roughly twenty times greater than the world's largest existing Solar plant the Solar Star).

Utility scale PV plants are at medium maturity across Australia, and Australia's largest Solar PV Plant is NSW's Nyngan Solar Plant has a capacity of 102MW.

Case Study: Geraldton's Solar Farm was the First Utility Scale Plant in Australia
In WA the 10MW Greenough River Solar Farm, 50km south-east of Geraldton was completed and switched on in 2012, with potential to expand to 40MW[82]. The Western Australian Government provided $20 million to Verve Energy to develop the 10 megawatt Greenough River Solar Farm just south of Geraldton. It opened in October 2012, making it one of Australia's largest PV generation projects and Australia's first utility-scale solar PV farm[83].

Smaller solar PV farms in Carnarvon (15kW) and Kalbarri (20kW) already exist.

Australia's first utility scale solar farm opened in Greenough, WA in 2012.
Source: RenewEconomy http://reneweconomy.com.au/australias-first-utility-scale-solar-farm-officially-opened-in-wa-70785/

The Future is Bright for Solar PV
In a shock admission given the lack of support for renewables in WA, Treasurer Mike Nahan recently said solar and batteries will be the main source of power in 20 years in WA, saying "solar makes perfect sense, given that Perth is Australia's sunniest major city with around 300 days of sunshine a year." He noted that despite a record heat wave and four days of 40°C plus temperatures in February 2016, and record demand of 4,047 MW, demand-side management was not needed. When the WA grid hit that level around 5pm local time on Feb 9, solar was providing more than 200MW, after contributing more than 300MW for much of the day[84].

Global forecasts are incredibly positive;

- The International Energy Agency said solar could form the backbone of the world's electricity market, and solar PV could account for 20 per cent of global capacity by 2050 – or about 12,000 GW[85]. That compares to around 177 GW now[86].
- Industry forecasts suggest that solar PV could provide 20 per cent more of the country's electricity in a zero carbon scenario (the rest would come from an equal amount of solar thermal – with storage, with about half coming from wind and the rest in the form of gas-fired generation)[87].
- More recently, Bloomberg New Energy Finance predicted that even within the current 'do nothing case', by 2040 over 50% of Australia's installed capacity will be located behind the meter. They estimate 49% of all Australian residential buildings will have Solar PV with a capacity of 36,800MW. This translates into 18% of all generation coming from behind-the-meter[88].

Even the conservative federal Bureau of Resource Economics and Energy believes solar PV would be unequivocally the cheapest form of new-build generation by 2030, and the best sites might be cheaper than coal or gas[89]. This is likely to be a substantial underestimate, with solar PV already achieving grid parity in a number of markets.

Solar PV in our Plan

Energy 2030 adopts an ambitious target of energy generated from Solar PV technology.

Scenario 1 Includes:

- **6 utility scale Solar PV farms with 2010 MW capacity**
- **1200MW capacity of Rooftop Solar PV**
- **17% of the total energy mix generated by Solar PV**

Scenario 2 Includes:

- **8 smaller Solar PV farms with 1010 MW capacity**
- **2000MW capacity of Rooftop Solar PV**
- **Over 22% of the total energy mix generated by Solar PV**

3. BATTERY STORAGE

Battery storage is the game changer for our renewable energy future.

Until recently batteries have been the missing link, but now provide the ability to reliably store excess electricity during times of peak generation to be discharged as needed.

Energy storage is the 21st century's silver bullet to facilitate zero carbon emission energy generation by overcoming the technical challenge of supply volatility characteristic of renewable technologies (IEA, 2014)

What is Battery Storage?
Batteries have always had the potential to revolutionise our electricity system, and until recently the challenge has been to scale up batteries into the market in a way that is economically viable[90].

Recent breakthroughs show developments in manufacturing have accelerated this technology into a mass deployment stage across a wide range of applications at varying scales, including residential homes, commercial buildings, industrial operations, utility grid-scale systems, and electric vehicles.

Batteries provide the ability to reliably store excess electricity during times of peak generation to be discharged as needed - matching demand. Scalable energy storage systems have long been the missing link for small and large-scale renewable electricity generation[91].

The Global Mega Shift
Rapidly increasing efficiency and plunging manufacturing costs over the last ten years has seen battery storage emerge as a force to radically reshape our energy system[92].

A global mega shift towards battery storage uptake is underway, driven by the fact that almost any kind of renewable energy source (solar, wind, wave etc.) can be combined with a battery storage unit and will become a cheaper option than relying entirely on electricity from the grid[93].

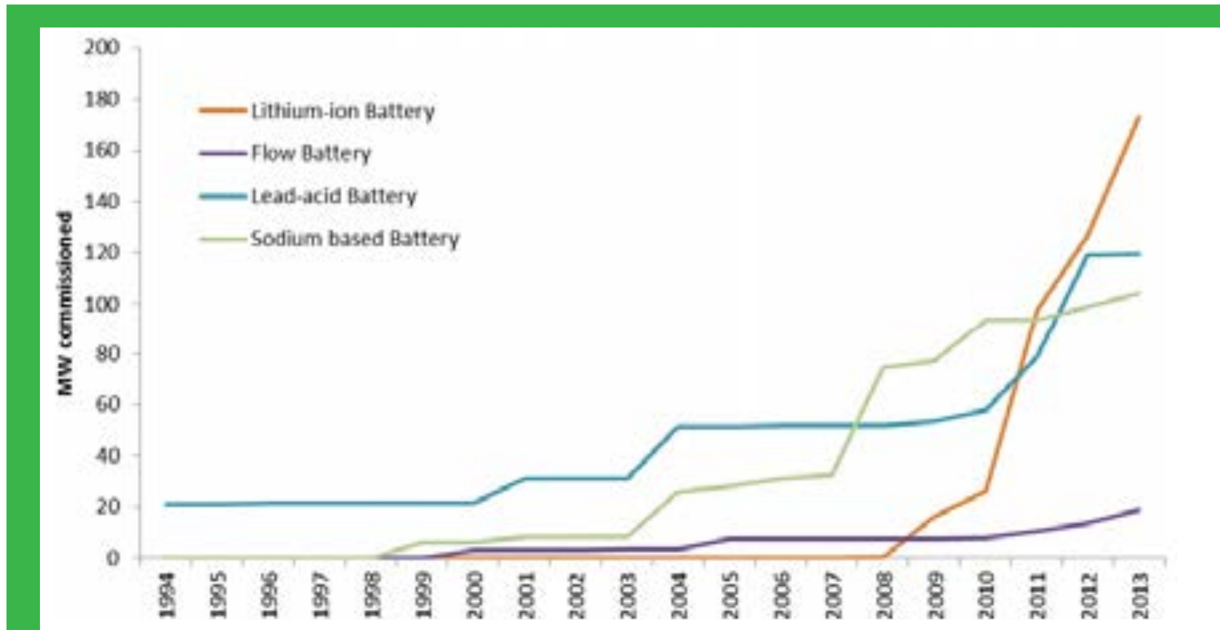


Figure 9: Megawatts of Battery Storage Commissioned Globally Since 1994[94]

Even the most conservative estimate predicts installed battery capacity is expected to grow 50-fold over the next decade, and all projections indicate renewable energy source combined with battery storage on any scale, will become cheaper than exclusively relying from the traditionally used electricity grids. (Figure 9)

The Australian Mega Shift
Due to Australia's excellent solar resources, we are expected to be one of the largest markets for battery storage – due in part to the high cost of our electricity and the large number of households with solar panels.

A rapid acceleration in battery storage uptake has actually been underway in Australia since 2008. Estimates of household/commercial battery storage uptake are expected to undergo a similar rapid expansion to solar PV - which has grown 100-fold in capacity in just six years.

Projections
Stunning projections of costs reductions (Figure 10) and uptake include:

- ARENA estimates the cost of lithium-ion batteries will fall by 60 per cent in less than five years, flow batteries by 40 per cent, and rapid uptake of batteries in Australian homes between 2017 -2018[95]
- Morgan Stanley estimates half of all households in Australia will adopt solar systems with battery storage on the basis of a $10,000 cost with a payback of 10 years, with the battery market potentially growing to $24 billion
- Bloomberg Energy Finance estimates global battery storage capacity is expected to grow 50-fold over the next decade[96] and even without any further future government intervention, Australia is predicted to have as much battery storage in 2040 as it has coal-fired electricity generation capacity today[97].

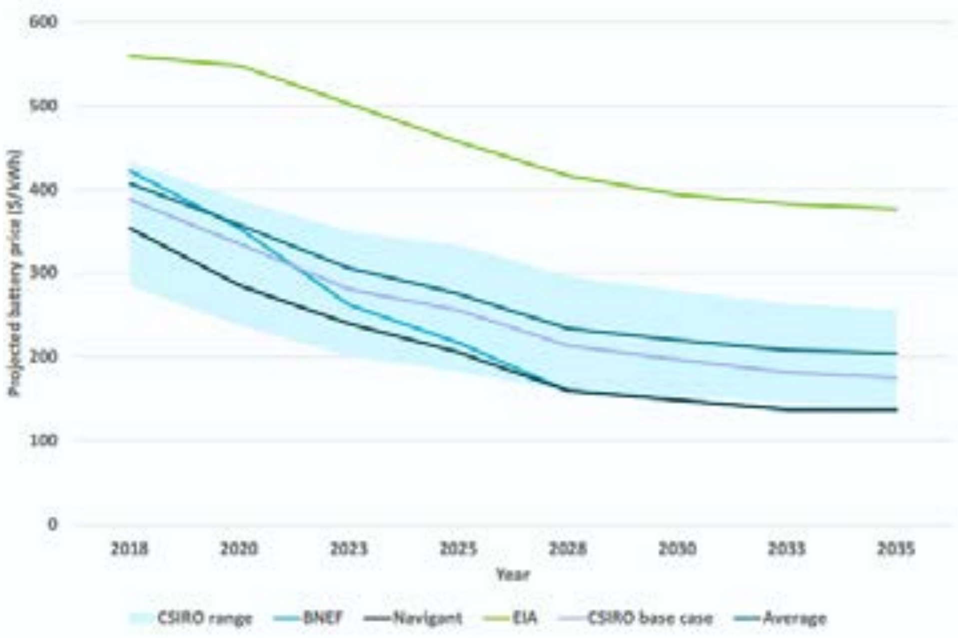


Figure 10: Projected cost reductions in battery storage 2018-2035, Source: CSIRO (2015) Future energy storage trends

Case Study: Battery Storage at the Household Scale (TESLA)
In 2015 US electric car manufacturer Tesla Motors launched the Powerwall, its home/commercial battery storage application. At a cost of about $12,000 and capable of 7 kWhrs, it received $800 million in pre-orders in its first week. It also set a new standard for battery manufacturers[99].

Tesla targeted Australia as the first market for the Powerwall due to our high electricity prices, excellent solar resources, and our very low feed in tariffs, which combined mean consumers are better off financially to store the energy they generate from their solar panels and use it later, rather than sell it back into the grid.

In order to meet overwhelming demand Tesla is now building a Gigafactory to produce large scale batteries, with production expected to commence in 2017 and ramping up to full capacity by 2020. This facility will be almost one square kilometer in size, and at full production it will produce 35 GWhrs worth of batteries every year. Production on such a massive scale will dramatically drive prices down for battery technology.

Image: The launch of the Tesla Motors' Powerwall in 2015

Battery Storage in WA: Policy Fail

As battery technology improves and prices decline, batteries will play an increasing role in optimizing the use of network infrastructure and generation as well as fostering the usage of intermittent electricity generation technologies utilizing non-polluting renewable energy. Yet prior to December 2015, Synergy prohibited the installation of battery systems.

Included in the terms and conditions of Synergy's Application for installing or upgrading a renewable energy system and bi-directional metering, was the requirement that the facilities and equipment must not incorporate a battery storage system or an electric vehicle system or both. Synergy has advised that this requirement is interpreted to mean that Synergy does not prevent customers connecting batteries or electric cars to the electrical system behind the meter, but these storage devices must not be capable of exporting the stored energy to the grid. Any electricity exported from a battery device will not be paid for by Synergy.

In WA, Synergy has advised that there are over 400 customers with battery storage devices installed, but the majority don't export to the grid.

In response to a number of complaints from consumers concerned about the limitations on installing batteries, the Minister for Energy Mike Nahan issued a media release on 16 November 2015 advising that a new agreement had been reached between Synergy and Western Power and that from 1 December 2015 "eligible customers can install battery storage or electric vehicle facilities to complement their solar PV systems and export unused electricity onto the network". The media statement also said that "batteries are required to meet technical and safety standards to connect to the grid".

Case Study: The White Gum Valley (WGV) Residential Battery Storage Project
WGV at White Gum Valley is an innovative sustainable residential development that demonstrates how renewable energy can be adopted in a strata setting, and is only the second project of its type internationally.

Utilities data is logged across a number of differing dwelling types (houses, townhouses and apartments) and used for optimising both design technology and community behaviour. The energy needs of WGV are met by a decentralised solar battery network connected as a micro-grid, which facilitates generation, storage and distribution within the strata. Each residence was also designed with world-leading energy efficient design features.

Benefits of the project expected are:

- A reduction of resident's energy bills by up to $1,200 (AUD) every year.
- The project seeks to reduce grid energy consumption of the whole development by 60%
- Some individual dwellings could achieve up to 100% (zero net) annual energy reduction
- Energy bills are paid directly to the strata, providing an additional revenue stream for the property[100]

Case study: Large Scale Commercial Battery Storage to Power Minami-Soma and Coober Pedy
Globally, Toshiba has been actively promoting battery storage applications for off-grid systems, offering isolated communities the potential to develop a self-sufficient power supply. These systems can also be used to allow the block shifting of excess renewable energy generation.

In Japan, Toshiba recently announced a 40MW large-scale battery storage system for the City of Minami-Soma's substation upgrade Project. This will provide power to the small city of slightly over 60,000 residents, which lies only a few kilometers north of the failed Fukushima nuclear power plant.

In Australia, Toshiba recently secured a contract to provide storage for the Coober Pedy renewable hybrid project, a fixed storage battery system housed within a shipping container, to deliver 1MW output with a 0.5MWh capacity, and cut diesel use by 70 per cent in the remote outback town. The battery storage unit will combine with 4MW of wind generation and 1MW of solar PV.

Toshiba hopes to replicate this project, and has been actively identifying isolated towns and communities in Australia not connected to the grid, that largely rely on third parties to deliver fuel.

Image: White Gum Valley - Australia's first 'solar precinct' residential development will cut energy grid reliance by up to 80pc. Source: Landcorp/ABC at http://www.abc.net.au/news/2016-04-13/solar-home-precinct-launched-in-white-gum-valley/7321468

Image: Minami-Soma Substation in Japan
Source: www.toshiba.co.jp/about/press/2015_04/pr2101.htm

Case study: Battery Storage Providing Power to an Entire Off Grid Suburb in NSW
The new town of Huntlee, NSW is an entirely master-planned community housing 20,000 new residents in 7500 homes, and it sets an exciting precedent.

Jointly funded by ARENA, the trial would see the entire suburb built completely off the grid and powered by renewable energy. The project aims to create an innovative controlled microgrid that integrates and controls central generation with home energy systems reliably and cost effectively.

At the time of writing this report, the development model has 10 times the average penetration of renewables for the equivalent cost of energy. It will likely set a precedent for residential developments further accelerating the uptake of renewables in Australia.

Image: Huntlee could become Australia's first off-grid suburb.
Source: www.thefifthestate.com.au/innovation/engineering/huntlee-could-become-australias-first-off-grid-suburb/78560

Case study: Australia's Largest Battery Storage Project – SA's 100MW Kingfisher Project

"It's really important to demonstrate what these batteries do in practice rather than just continue to talk about them. You need to be able to demonstrate that power generated from renewables can be dispatched with power from the batteries like baseload power, so it's not creating problems". – Lyon Dolar partner David Green

Announced in September 2016, Australia's largest battery storage project will be built in 2017 near Roxby Downs in SA as a way to overcome intermittency problems with existing wind and solar power supply.

The $400m Kingfisher project will include a 100-megawatt solar PV power plant and a 100-megawatt battery storage unit the size of a football field (and was increased from 20MW originally planned). The project missed out on ARENA funding and is fully funded by US and Asian investors "keen to invest in the Australian market". The project will be operational next year and at full capacity by 2018. If successful, the battery storage component will be increased to 400 megawatts.

The conservative Financial Review reported that:

"This is a breakthrough for renewable projects which have been unable to provide the stability of synchronous generation like coal and gas", and quoted Lyon Group as saying:

"The genie is out of the bottle. There will be a burst of activity now in large scale solar + battery projects. This is the real battery storage story coming out of Australia – batteries used to convert large scale solar to effectively baseload, or peaking plant."[101]

The Australian infrastructure investor Lyon Group which has previously invested in coal, gas and wind projects, but is now specialising in solar and storage – is reported to be looking to become a global industry leader in solar plus storage, and has also announced plans to build a $100 million, 80-megawatt solar and 20-megawatt battery storage project in North Queensland.

Case Study: 'Flow' Batteries Breakthrough in Australia
Australian company Redflow has developed the first flow battery to reach the residential market in Australia, and is the world's smallest zinc-bromine flow battery, which offers an alternative to lithium-based or lead-acid batteries.

Redflow's new battery, ZCell includes a battery made from easily recyclable or reusable components.

The ZCell allows people to 'time shift' solar power from day to night, store off-peak power for peak demand periods and support off-grid systems; comes with an energy output capacity of 10 kilowatt hours (kWh) and can discharge 100 per cent of this energy on a daily basis without any damage to the battery – so the full 10 kWh is repeatedly usable.

In contrast, a lithium ion battery requires reserved capacity to protect against fully charging or fully discharging the underlying storage cells, as these activities can damage or destroy such a battery. Lithium-based chemistries also lose capacity with age.

Redflow's research and development centre is in Brisbane[102].

Battery Storage in our Plan

Energy 2030 adopts an ambitious but realistic role for battery storage.

Scenario 1 & 2 Include:

- **8,000 MWh of battery storage capacity installed 'behind the meter' by consumers on their premises**
- **This is achieved through up to 700,000 households, small businesses and commercial users installing battery storage**

Image: An Artist impression of the 100-megawatt solar and 100-megawatt storage facility to be built in South Australia (Source: AFR 8 September 2016)

4. WIND POWER

Wind power has grown even faster than the booming solar industry and is now one of the cheapest and most commercially advanced renewable energies on the planet. Wind turbines are also incredibly reliable, with relatively few parts to maintain or repair making them available to operate 98% of the time.[103]

It's now a major power source in more than 100 countries. In 2014 global capacity of installed wind power rose by 16% [104], and wind has continued to be the fastest growing type of renewable electricity generation. In 2015 capacity grew from 319 GW to a massive 370 GW[105] (Figure 11).

Global Snapshot

- Germany has the largest installed capacity (45 GW) of all EU countries, with enough capacity to produce 100 TWhrs of energy – which would power the entire SWIS for 5 years[107]. At the end of 2014 there were 150,000 people employed in the German wind power sector.[108]
- China has installed about 45% of all new global wind power over 2014[109]. In one year alone China installed 13 Gigawatts (GW) of wind capacity, bringing it over halfway to its target of 15% renewable energy target (20GW) by 2020.
- The UK has been a world leader in offshore wind since 2008, with over half of the world's total installed offshore wind capacity. Annually, the current capacity of UK offshore wind generates 15 TWhrs – enough to power 3.5 million households[110].

The Future is Bigger and Cheaper
Larger, modern wind turbines are up to 30% more efficient, and provide cheaper electricity per kilowatt hour than their smaller counterparts as taller turbines tap into the stronger and more consistent wind speeds, and have less drag higher above the ground. Fewer large turbines also mean fewer moving parts to maintain. At the time of writing, massive 5MW and 7.5MW onshore turbines are becoming increasingly common.

For scale, the 7.5MW Enercon E126 wind turbine installed onshore at Emden in Belgium has a hub height of 138 metres and a blade length of more than 60 metres[112]. By comparison the 1.8MW turbines installed at Albany Wind Farm have a hub height of 65 metres and 30 metre blades.

Advances in innovation and technology continue to bring costs down, and include modular production, which lowers transportation costs with some models (in a disassembled form) fitting within a single shipping container; and the introduction of service robots for inspection, cleaning and maintenance ranging in application from fault detection units to autonomous 3D printers that run up and down each blade repairing wear.

Australia has amazing wind resources (Map 2) and it's estimated up to 40% of Australia's electricity could be easily met with wind power.

Make Wind Power not War

Troubled Australian steelworks and manufacturers could benefit significantly from a commitment to renewable energy. Each wind tower uses about 150 tonnes of steel, and depending on the size up to 20,000 tonnes of steel can be used across an entire wind farm project.

The wind farm industry uses much bigger volumes of steel than defense projects.

At the end of 2015 there were 76 wind farms operating in Australia, accounting for 2062 turbines.

BlueScope steel currently produces about 2.8 million tonnes of steel each year. Its troubled rival Arrium will begin to produce the first steel from its Whyalla steelworks for a 600km upgrade of railway lines under a contract announced by the Prime Minister, that will run for 2.5 years and produce 72,000 tonnes of railway lines to upgrade tracks in northern SA.

(Source: 'Arrium recovery appears on track while BlueScope looks to the wind', AFR 8)

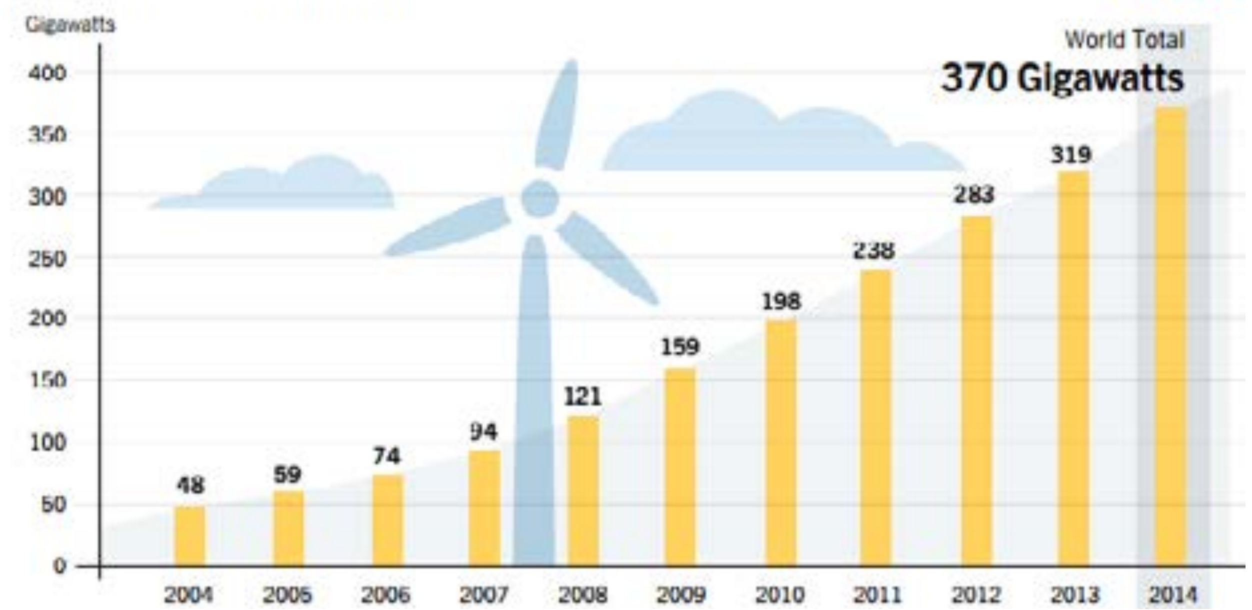


Figure 11: Wind Power Global Capacity, 2004-2014[106]

Figure 12: Wind Turbines set to reach new heights[111]

Electricity from wind now accounts for 4% of total electricity in Australia and has grown annually by 31% over the last decade.

Wind generation continues to be especially popular in South Australia, growing by 25 per cent in 2013–14[113], and now accounts for 34% of SA's total energy mix[114].

The Opportunity in WA
Wind power can provide a surprisingly large amount of our energy needs. Germany's wind turbines currently generate five times the amount of energy required by WA's SWIS.

Western Australia has abundant wind resources, yet wind currently makes up just over 8% of all electricity generated in Western Australia.

Western Australia has about 424 MW of installed wind power capacity.

There are 16 wind farms already operating in WA and another 10 proposed or under construction[115], with most of WA's wind-generated electricity comes from three large wind farms:

- Collgar, Merrdin (206 megawatts, cost $750m)
- Walkaway, Geraldton (90 megawatts, cost $210m)
- Emu Downs, Badgingara (80 megawatts)

The electricity of Albany and Hopetoun are almost entirely served by wind power, with Albany's 35MW wind farm providing 80% of Albany's electricity, and Hopetoun's providing 45%[116].

Western Australia has relatively strong and consistent winds, which mean that wind farms here run at the highest net capacity factors in the world.

Sustainable Energy Now has estimated in WA's South West there is about 500,000 sq. km with average wind speeds above 6m/second at a height of sixty metres. Just 50km x 50km of this area (2500 sq. km) would produce energy equivalent to the peak demand on the SWIS.

In some parts of Western Australia, including the Wheatbelt, winds are stronger in the afternoon and early evening, which is a period when demand typically increases. This makes a strong argument for co-locating large scale solar and wind generation, with solar providing electricity during the day and wind taking over as the power source at night.

Given Western Australia is blessed with well above-average wind resources, it makes sense that we maximise our use of this cheap, commercially-ready resource.

Given Western Australia's excellent wind resources and suitable locations for wind farms close to population centers, 40% figure seems feasible as a source of Western Australia's future electricity generation.

Wind Power in our Plan

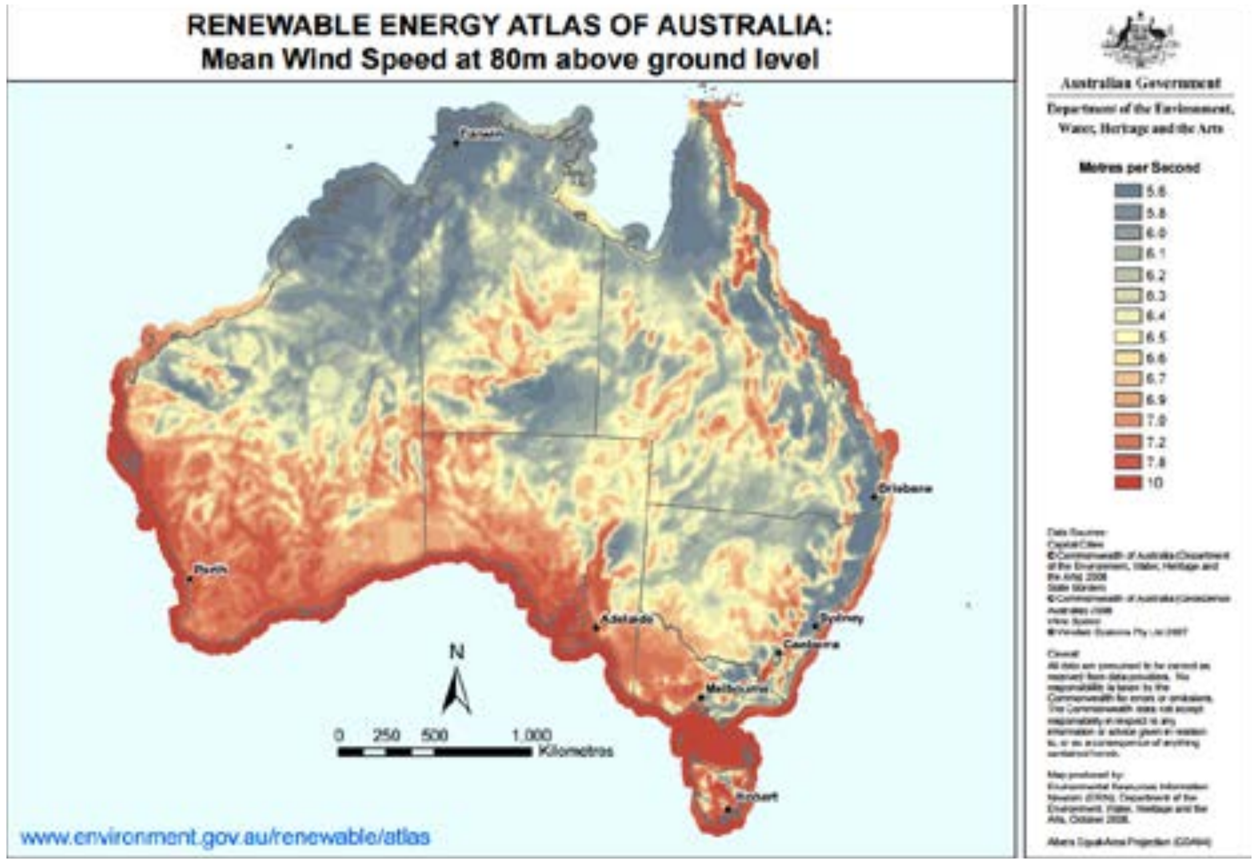
Recognising wind power technology is one of the cheapest and easiest to deploy at a large scale, Energy 2030 has adopted high targets for wind power.

Scenario 1 Includes:

- **29 wind farms with almost 5500 MW of capacity**
- **53% of the energy mix is generated by wind power, equivalent to 15,600GWh**

Scenario 2 Includes:

- **27 large wind farms with almost 6500 MW capacity**
- **62% of the energy mix is generated by wind power, equivalent to over 18,700GWh.**



Map 2: Renewable Energy Atlas of Australia: Mean wind speed at 80m above ground level, Source: Environment.gov.au/renewable/atlas

Image: WA's 200MW $750m Collgar Wind Farm, operating at a stunning 50% capacity factor (Source: Collgar Wind Farm http://www.collgarwindfarm.com.au/about-us/)

5. BIOENERGY

Bioenergy, derived from plant and organic matter (or 'biomass') is a proven renewable energy used in all countries of the world. Where other forms of renewable energy directly replace existing forms of fossil generation altogether, bioenergy can be used as an alternative fuel stock in existing fossil fuel stations – or be built alongside renewable sources.

What is Bioenergy?
Bioenergy genuinely competes with oil and gas yet uses sustainably sourced materials such as plantations of wood, rapeseed, along with biogas digesters. Bioenergy technologies produce renewable fuels (biofuels) from biomass. Organic matter can be converted into electricity in a number of ways.

The technology used is most commonly is gasification – a high temperature pyrolysis (burning in the absence of oxygen) which produces a hydrogen rich gas, liquid fuel, and small quantities of biochar and ash.

The syngas can be piped to methanation plants, in which it is converted to renewable gas - methane of suitable quality for injection into existing natural gas pipelines. The liquid fuel can be used to power turbines to generate electricity.

As a renewable gas and liquid fuel this provides a substitute for fossil fuels in applications where renewable electricity cannot be used, and is a vital part of a renewable energy strategy. For example,

- The wheat belt sites suitable for biomass plants are also suitable for solar thermal generation. At night and on cloudy days, biomass could be used to directly 'co-fire' the steam turbines of the solar plant
- Fuels are transportable beyond energy grids, providing more flexibility to the energy system. Biofuels can be piped or tankered to sites with intensive, co-generation or temporary energy demands
- Biogas turbines can be 'ramped' up and down quickly to balance fluctuation in the stationary energy system
- Biofuels provide greater energy density (energy for weight) than batteries, for some transport applications.

The benefit of renewable gas is that it can be piped directly to industrial and central city areas which have intensive demands for heating, cooling and electricity. The gas can be used for on-site co-generation, i.e. combustion in gas turbines or diesel engines to generate electricity and the heat from the exhausts is used for industrial processes or to heat and cool buildings ('tri-generation').

Tri-generation is currently being used to provide 100% of the energy needs of the borough of Woking in the UK. Co-generation is probably the most energy efficient technology for using woody biomass. It utilizes the feedstock energy at up to 80% efficiency, compared to about 40% for single cycle gas turbines and about 33% for the current WA electricity grid.

The Opportunity
About half of the global total energy consumption in 2014 went to providing heat for buildings and industry, with modern renewables (mostly biomass) generating approximately 8% of this share. In fact, of the total 19.1% of global renewable energy production traditional biomass accounted for 9%[117].

The number of homes using this technology just for heating their homes has increased tenfold in just three years[118]. In some European countries with a carbon trading scheme, it contributes 5–20% of electricity needs.

In 2014, policy uncertainty in Australia had negative effects on the biomass industry. Low oil prices in the second half of the year had some positive effects, particularly in feedstock production, but reduced turnover for some bioenergy businesses[119].

In Australia biomass currently produces less than 2% of our electricity and in WA less than 1%[120]. This is despite the fact that per head of population WA has more land suitable and available for growing biomass crops than any other state or country in the world.

Biomass makes a significantly greater contribution to total employment in renewable energy activities in Queensland than in any other state or territory. Employment in Queensland related to biomass renewable energy activities rose from 1,010 in 2009-10 to 1,150 in 2014-15 at which point it comprised 32 per cent of the state's total employment in renewable energy activities

Sources of Bioenergy: Sustainable Plantations
In WA the main potential bioenergy resources are cellulosic feedstocks: woody biomass energy crops (principally oil mallees), crop residues (straw, husks and stubble) and sustainable forestry residues (plantation residues).

Energy 2030 does not propose that land for food or fibre production be switched to fuel crops, unless as part of an integrated landcare strategy such as that outlined in the scenario below.

Biomass power plants can also be installed wherever there is a sustainable source of biogenic waste (such as resource recovery centers, abattoirs, agricultural waste centers, and algae salt ponds), or semi-arid land unsuitable for food production.

Careful consideration also needs to be given to using some types of bioenergy and some practices are not acceptable.

This study categorically excludes waste incineration which may reduce air quality, and burning of native forestry 'residues' which would incentivise further logging in native forests.

Sources of Bioenergy - Oil Mallees
Mallee eucalypts have long been recognised in Western Australia as beneficial for improving and mitigating dryland salinity. Verve Energy's 1MW Integrated Wood Processing Plant at Narrogin demonstrated that mallees could be burnt using pyrolysis to produce bio-oil and syngas for generating electricity, along with a by-product of high quality biochar – a form of charcoal that can sequester carbon from the atmosphere.

A 2011 study found that 10% of the Western Australian grain-growing region planted with oil mallees could produce more than 17% of current annual electricity generation on the grid, supplying southern Western Australia, plus 700,000 tonnes of biochar per year[121]. Even higher energy outputs could be achieved by using gasification rather than pyrolysis technologies.

The study also found that biomass-fired electricity generation technologies could be competitive with coal-fired generation at $115–170 per MWh, assuming a renewable energy certificate price of $38/tonne, a carbon price of $30/tonne and a biochar price of $240/tonne. Oil mallees would be even more competitive if existing subsidies for coal-fired power generation ended.

The study recommended building eighteen 25MW-capacity biomass plants across the Wheatbelt. It also compared potential returns to farmers of growing mallees instead of wheat and sheep. It concluded that growing oil mallees for renewable energy could be as profitable as sheep-grazing and provide a valuable diversification option to wheat growing.

Wheat prices fluctuate greatly and input costs are high, whereas woody biomass prices would be stable and input costs low. Other benefits of using land to grow oil mallees includes directly lower saline groundwater tables, soil conservation, create windbreaks (shelter for stock) and new wildlife habitats, carbon sequestration, and income from carbon credits.

This proposal avoids the problem of biofuels displacing food production, as only 10% of dryland agricultural land would be used for biomass crops.

Sources of Bioenergy - Algal Biomass
Other sources include algal biomass to produce renewable diesel fuel. This is a promising technology being researched in WA universities. It has promise for our North West coastal areas or salt lakes in the Wheat Belt where large shallow saline lagoons may be constructed to grow the algae.

Small, 2–4MW modular bioenergy plants that heat and gasify organic materials such as farm and factory waste to produce syngas have been developed in the UK and are being marketed in Australia by Refgas, and according to the company, have a payback period within five years[122].

Bioenergy in our Plan

Recognising the potential and benefits of bioenergy, Energy 2030 includes high but realistic targets for its use.

Scenario 1 Includes:

- **4 Bio-fuelled Open Cycle Gas Turbines (OCGT) plants to replace gas in existing plants, adding 1800MW capacity and accounting for 3% of total generation by 2030**
- **12 biomass co-firing plants built to support CST plants (which can be switched on in the rare case of solar droughts), adding 1200 MW capacity**

Scenario 2 Includes:

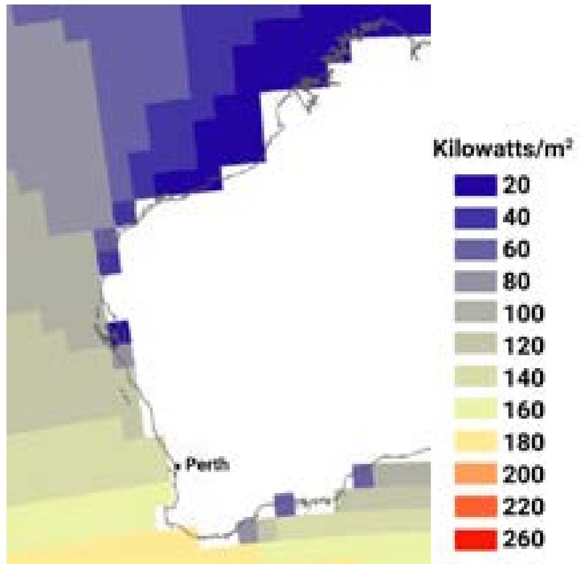
- **4 Bio-fuelled Open Cycle Gas Turbines (OCGT) plants to replace gas in existing plants, adding 1350MW capacity and accounting for up to 9% of total generation by 2030**

Image: Oil mallee intercropping in the WA Wheatbelt Credit: Cliff Winfield, http://www.abc.net.au/news/2014-05-21/mallee-tree-oil-could-be-used-for-jet-fuel/5467680

6. WAVE, GEOTHERMAL AND PUMPED HYDRO

There are a number of reliable and renewable energy sources and storage options that, unlike our 2013 and 2014 reports, have been omitted from the modeling of our 100% renewable stationary energy scenarios simply because this Plan focuses on already commercial scale technology.

Promising advances in wave, geothermal and pumped hydro technologies show these technologies hold massive potential and it's certain they'll play a part in the future energy mix.



Map: WA's wave power resources

Wave Energy

The ability to harness energy from wave power is not currently as commercially developed as the wind and solar industries, yet it has major potential as an electricity source for Western Australia and the world. Portugal, Spain, Ireland, England and Scotland are amongst the countries investing in wave energy technology. In 2010, the Scottish Government invested $6 billion and leased six sites to wave energy development, capable of producing up to 600MW of electricity.

Australia wide, it's estimated that near-shore wave energy could provide about four times our current national power needs. Harnessing just 10% of this could supply around 35% of Australia's current power demand[123]. In WA the coastline between Geraldton and Bremer Bay could produce more than five times the peak power demand on the electricity grid[124].

Fremantle-based company, Carnegie Clean Energy developed the 'CETO' Wave Energy Technology that converts ocean swell into zero-emission renewable power and desalinated fresh water. Its Perth Wave Energy Project saw three 240kW CETO 5 units which produced and sold power and water to the Garden Island Department of Defense naval base. The CETO 6 Project located at Garden Island has modules acting as a 1MW generator. Carnegie is also developing commercial scale demonstration projects off Reunion Island and Ireland with help from the French and Irish governments[125].

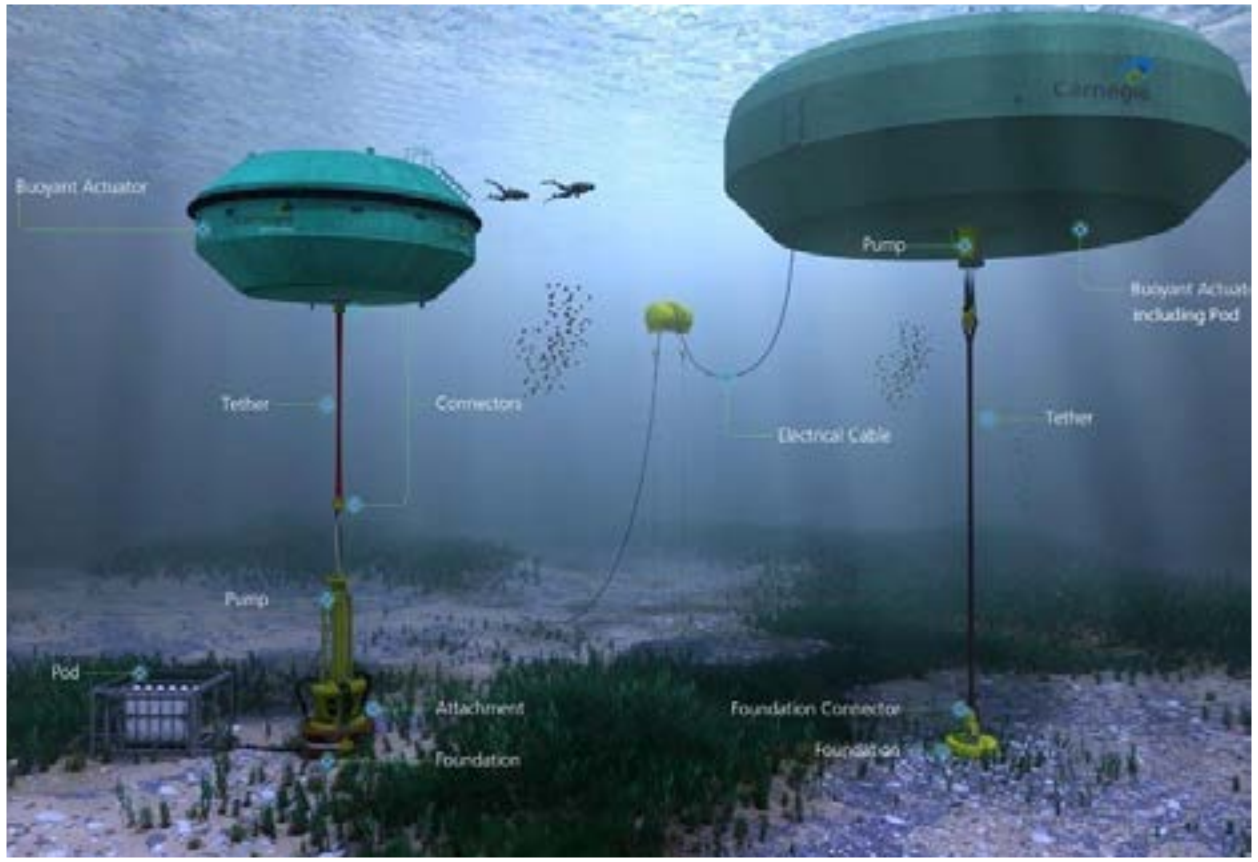


Image: Carnegie Clean Energy's 'CETO' Wave Energy Technology, Source: carnegiewave.com

Geothermal

While relatively undeveloped in Australia, geothermal energy is widely used around the world. Geothermal energy has great potential to meet WA's energy needs, either in the form of electricity or through a variety of direct use applications, where heat transfer from the Earth is used directly. Geoscience Australia calculates that there is sufficient energy within 5km of the Earth's surface to supply 2.6 million years of energy to Australia based on current energy supply[126]. Direct use geothermal also has great potential to replace both direct use gas and electricity use in Western Australia.

Geothermal or ground source heat pumps are catching on in Victoria and already popular in the USA, China and Sweden and Germany, with global use doubling since 2005. 24 countries around the world currently obtain between 15 to 22% of their electricity from geothermal energy, with the USA the biggest user, followed by the Philippines, Indonesia and Mexico. At the time of writing this report global geothermal installed capacity is 12.8 GW producing an estimated 74 TWh of electricity – four times the annual energy needs of the SWIS.

Case study – Fremantle Pool Heated with Geothermal Power
In a first of its kind in Australia, the carbon-neutral City of Fremantle implemented a cogeneration system plus a shallow aquifer geothermal heat pump when it upgraded the pool heating system at the Fremantle Leisure Centre. A 350 kW EVO water-to-water heat pump draws water from the Leederville aquifer 250 m below the ground, where it exits the aquifer at around 27°C. The warmth harvested from the underground water heats two swimming pools. At current tariffs, the anticipated cost savings are $110,000 per year, equivalent to a return on investment of around 7.3%[127].

Image: Fremantle Leisure Centre's 50m pool heated with shallow aquifer geothermal and cogeneration (Source: City of Fremantle)

Pumped Hydro

Pumped-storage hydroelectricity (or 'pumped hydro') is a type of hydroelectric power generation used as a form of power storage. Energy is stored in the form of a water reservoir held at a higher elevation which is released through turbines to produce electric power during periods of high electricity demand.

Taking into account evaporation losses from the exposed water surface and conversion losses, approximately 70% to 85% of the electrical energy used to pump the water into the elevated reservoir can be regained.

Pumped hydro is a perfect demand side management tool for complementing large scale renewable technologies. A unique solution to storing surplus renewable energy has been to co-locate them with wind farms using a dam design with pumped hydro plants on sea cliffs.

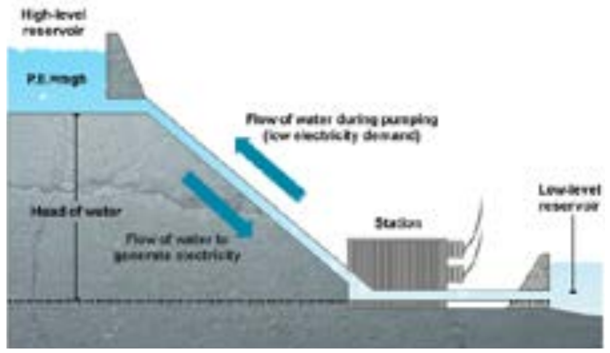


Image: Diagram of a pumped hydro energy storage station, Source: www.bbc.co.uk/bitesize/standard/physics/energy_matters/generation_of_electricity/revision/3/

Image: Yanbaru Okinawa pumped hydro energy storage station
Source: kimroybailey.com/renewable_blueprint/

Part 3: The Roadmap

The Greens commissioned modelling of three Scenarios to 2030, using the most advanced meteorological data available, and was undertaken using Western Australia's own 'SIREN' (Sustainable Energy Now's Integrated Renewable Energy Network Toolkit) and PowerBalance models, specifically for WA's electricity profile as predicted to 2030.

(A full description of the modelling and assumptions is provided at Appendix 1.)

SCENARIO 1: CST DOMINANT MIX

Scenario 1 was modelled on a diverse mix of technologies and a large proportion of concentrated solar thermal (CST) with back-up biomass. CST makes up 14% of the total generation.

Scenario 1 Demonstrates WA could Reach 100% Renewable Electricity by 2030 with:

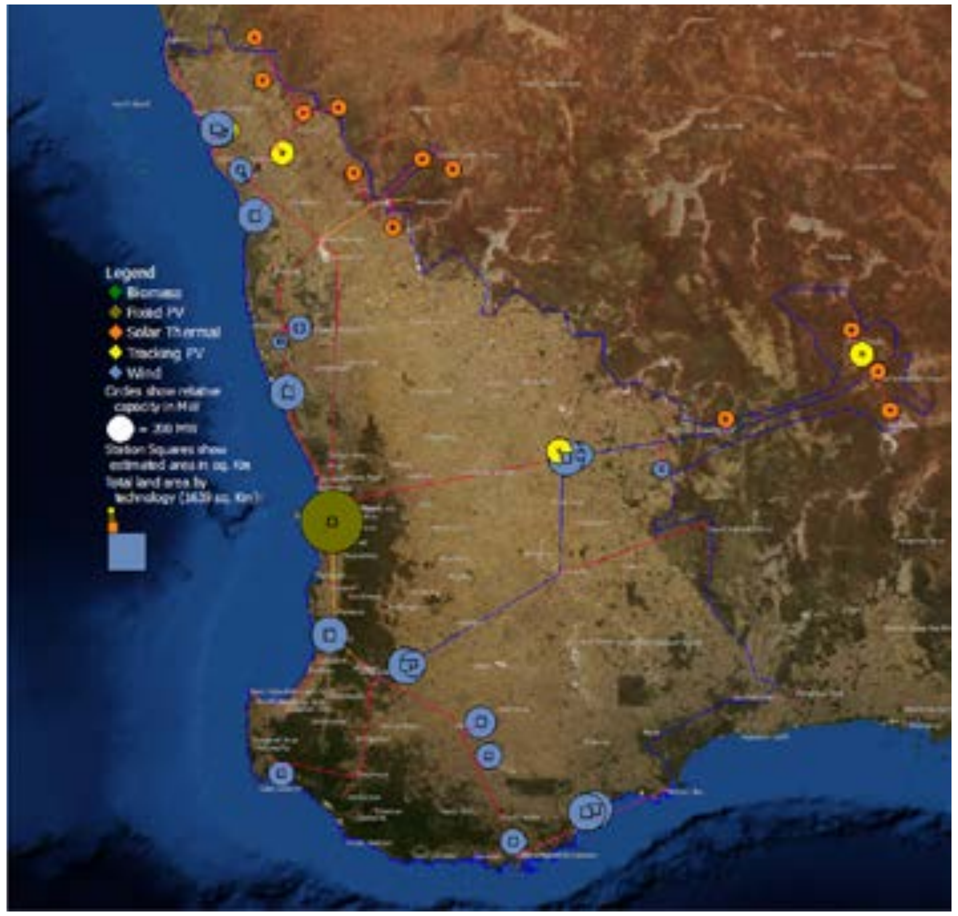
- 12 new CST stations with 1200MW capacity
- 6 Solar PV farms with 2010 MW capacity
- 29 wind farms with almost 5500MW capacity
- 4 Biomass plants with 3000MW capacity

Up to 700,000 households, small businesses and commercial users installing 1200MW roof-top PV capacity and 8000MW battery storage

This is a total of 51 power stations, of which of which 17 (12 wind, 4 biomass and 1 solar PV) already exist.

The breakdown of technologies and generation capacities is shown in Table 1.

The locations, physical footprint sizes (squares) and relative capacity (circles) of the renewable power plants are shown below:



Map: Scenario 1

TOTAL CAPACITY:	11,705 MW
Bio-fuelled OCGT	1,800 MW
Biomass co-firing	1,213 MW
Concentrating Solar Thermal (CST)	1,200 MW
Wind	5,482 MW
Solar PV (2 fixed + 4 tracking)	2,010 MW
DEMAND SIDE MANAGEMENT	550 MW
STORAGE (MOLTEN SALT)	13,000 MWH
STORAGE (BEHIND METER BATTERY)	8000MWH
PROJECTED LOAD AT 2030	23,584 GWH
TOTAL GENERATION AT 2030 BY TECHNOLOGY (GWH):	29,783 GWH
Bio-fuelled OCGT (3% total)	876 GWh
Biomass co-firing (10% total)	2,968 GWh
Rooftop PV (9% total)	2,743 GWh
Tracking PV (8% total)	2,284 GWh
Wind (53% total)	15,643 GWh
CST (14% TOTAL)	4,153 GWH
BATTERY (4% TOTAL)	1117 GWH
% SURPLUS RE GENERATION	21%
CARBON PRICE	$30/TCO2E
TOTAL ANNUAL ENERGY COST (INCLUDING CARBON PRICE)	$3,177 MILLION
TOTAL EMISSIONS	1,157 KTCO2E
CO2E EMISSIONS AS % OF BAU	8%
COST OF EMISSIONS REDUCTION FROM BAU	$14/TCO2E
WEIGHTED AVERAGE LCOE	$132/MWH
WEIGHTED AVERAGE LCOE ($/MWH) IF SURPLUS ENERGY SOLD AT $30/MWH	$125.8/MWH

Table 1: Overview of Scenario 1

The location and details of each individual power station is shown in Table 2:

STATION NAME	TECHNOLOGY	CAPACITY (MW)	NEW OR EXISTING
Albany Wind (New)	Wind	200	Scenario 1
Albany Wind Farm	Wind	22	Existing
Alinta Wind Farm	Wind	89	Existing
Badgingarra Wind	Wind	200	Scenario 1
Blair Fox Karakin Wind Farm	Wind	5	Existing
Blair Fox West Hills Wind Farm	Wind	5	Existing
Bremer Bay Wind Turbine	Wind	1	Existing
Cape Leeuwin Wind	Wind	200	Scenario 1
CST 1	Solar Thermal	100	Scenario 1
CST 2	Solar Thermal	100	Scenario 1
CST 3	Solar Thermal	100	Scenario 1
CST 4	Solar Thermal	100	Scenario 1
CST 5	Solar Thermal	100	Scenario 1
CST 6	Solar Thermal	100	Scenario 1
CST 7	Solar Thermal	100	Scenario 1
CleanTech Energy Pty Ltd	Biomass	1	Existing
Collgar Wind Farm	Wind	206	Existing
Collie East Wind 1	Wind	400	Scenario 1
Collie East Wind 2	Wind	200	Scenario 1
Denmark Community Wind Farm	Wind	1	Existing
Dongara Wind	Wind	400	Scenario 1
Emu Downs Wind Farm	Wind	80	Existing
Grasmere Wind Farm	Wind	14	Existing
Greenough River Solar Farm	Fixed PV	10	Existing
Harvey Wind	Wind	400	Scenario 1
Henderson Waste Gas	Biomass	3	Existing
Kalbarri Wind Farm	Wind	2	Existing
Kalgoorlie-Boulder CST (CST 8)	Solar Thermal	100	Scenario 1
Kalgoorlie-Boulder PV	Tracking PV	200	Scenario 1
Kambalda CST (CST 9)	Solar Thermal	100	Scenario 1
Katanning Wind	Wind	300	Scenario 1
Kojonup Wind	Wind	200	Scenario 1
Lancelin Wind	Wind	400	Scenario 1
Landfill Gas & Power - Red Hill	Biomass	4	Existing
Landfill Gas & Power - Tamala Park	Biomass	5	Existing
Menzies CST (CST 10)	Solar Thermal	100	Scenario 1
Merredin PV	Tracking PV	200	Scenario 1
Merredin Wind	Wind	400	Scenario 1
Metro PV	Fixed PV	1,200	Scenario 1
Mt Barker Community Wind Farm	Wind	2	Existing
Mullewa PV	Tracking PV	200	Scenario 1
Mumbida Wind Farm	Wind	55	Existing
Oakajee PV	Tracking PV	200	Scenario 1
Oakajee Wind1	Wind	200	Scenario 1
Oakajee Wind 2	Wind	400	Scenario 1
Southern Cross CST (CST 11)	Solar Thermal	100	Scenario 1
Southern Cross Wind	Wind	100	Scenario 1
Walkaway Station CST (CST 12)	Solar Thermal	100	Scenario 1
Walkaway Wind	Wind	200	Scenario 1
Wellstead Wind 1	Wind	400	Scenario 1
Wellstead Wind 2	Wind	400	Scenario 1

Table 2: Renewable Energy Power stations and location – Scenario 1

SCENARIO 2: WIND AND SOLAR PV HEAVY MIX

Scenario 2 was modelled on a rapid uptake of large scale wind and solar farms. Wind power makes up 62% of the total generation.

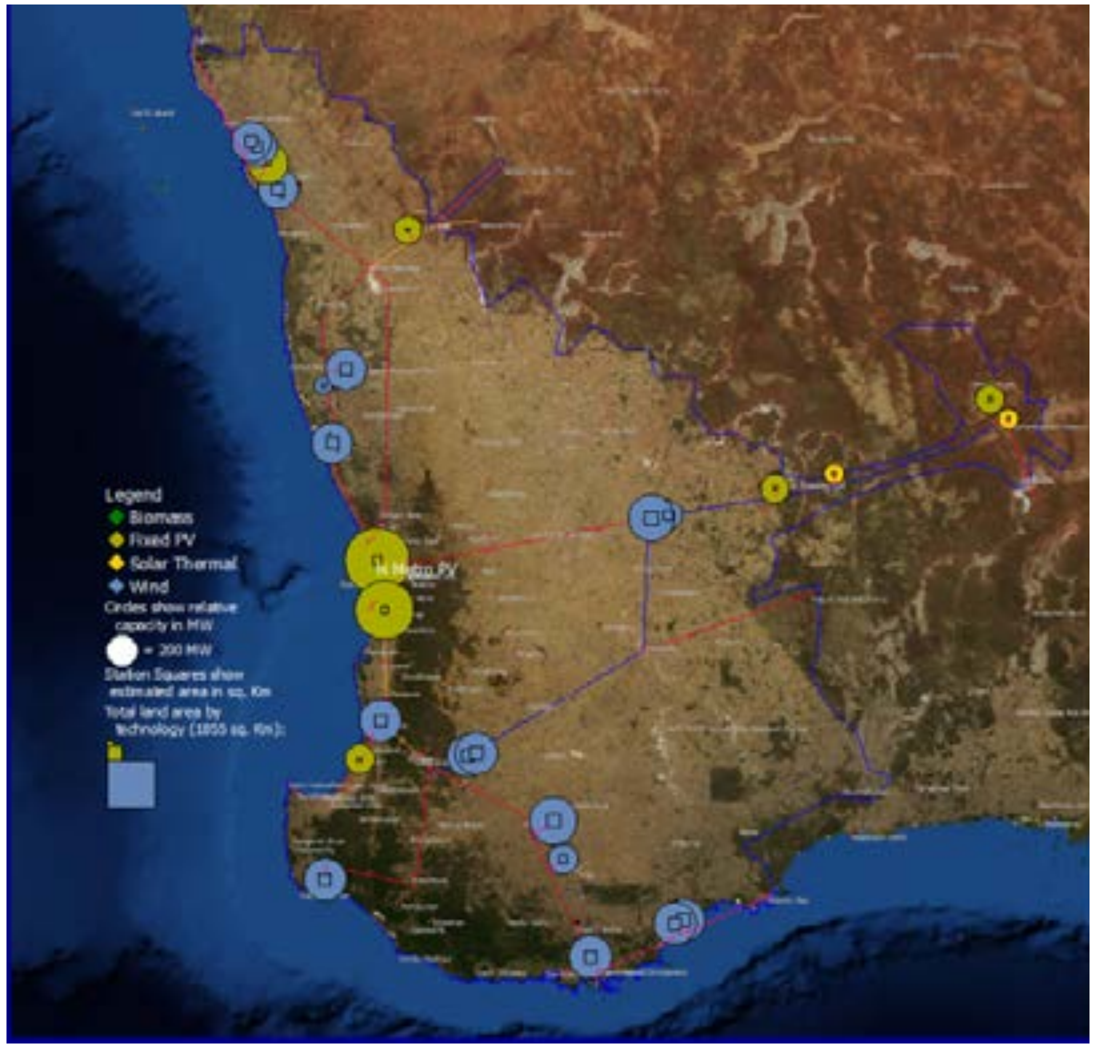
Scenario 2 Demonstrates WA could Reach 100% Renewable Electricity by 2030 with:

- 27 wind farms with almost 6500MW capacity
- 8 Solar PV farms with 1000 MW capacity
- 2 Solar thermal power stations with 200MW capacity
- 4 Biomass plants to fuel existing turbines with 1350MW capacity
- Up to 700,000 households, small businesses and commercial users installing 2000MW solar PV and 8000MW battery storage

This is a total of 41 power stations, of which 17 (12 wind, 4 biomass and 1 solar PV) already exist.

The technologies and their generation capacities modelled in Scenario 2 are shown in Table 3.

The locations, physical footprint sizes (squares) and relative capacity (circles) of the renewable electricity generation plants for Scenario 2 are shown below.



Map: Scenario 2

TOTAL GENERATION CAPACITY	11055 MW
Bio-Fuelled OCGT	1350 MW
Biomass	13 MW
Wind	6,482 MW
Rooftop PV	2000 MW
Fixed PV	1010MW
DSM (MW)	550 MW
STORAGE (BEHIND-THE-METER BATTERY)	8,000 MWH
PROJECTED LOAD AT 2030	23,584 GWH
MODELLED TOTAL GENERATION AT 2030	30,103 GWH
Bio-fuelled OCGT (9%)	2,758 GWh
Rooftop PV (15%)	4,544 GWh
Fixed PV (7.4%)	2,238 GWh
Wind (62%)	18,753 GWh
Solar Thermal (2.3%)	692 GWh
Battery (4%)	1,117 GWh
% SURPLUS RE GENERATION	22%
CARBON PRICE	$30/TCO2E
TOTAL ANNUAL ENERGY COST (INCLUDING CARBON PRICE)	$3,027MILLION
TOTAL EMISSIONS	1939 KTCO2E
CO2E EMISSIONS AS % OF BAU	13%
COST OF EMISSIONS REDUCTION FROM BAU	$8/TCO2E
WEIGHTED AVERAGE LCOE	$128/MWH
WEIGHTED AVERAGE LCOE ($/MWH) IF SURPLUS ENERGY SOLD AT $30/MWH	$121.45 /MWH

Table 3: Overview of Scenario 2

The individual stations and their generation capacities are shown in Table 4:

STATION NAME	TECHNOLOGY	CAPACITY (MW)	NEW OR EXISTING
Albany Wind (New)	Wind	400	Scenario 2
Albany Wind Farm	Wind	22	Existing
Alinta Wind Farm	Wind	89	Existing
Badgingarra Wind	Wind	400	Scenario 2
Blair Fox Karakin Wind Farm	Wind	5	Existing
Blair Fox West Hills Wind Farm	Wind	5	Existing
Bremer Bay Wind Turbine	Wind	1	Existing
Bunbury PV	Fixed PV	200	Scenario 2
Cape Leeuwin Wind	Wind	400	Scenario 2
CleanTech Energy Pty Ltd	Biomass	1	Existing
Collgar Wind Farm	Wind	206	Existing
Collie East Wind 1	Wind	400	Scenario 2
Collie East Wind 2	Wind	400	Scenario 2
Denmark Community Wind Farm	Wind	1	Existing
Emu Downs Wind Farm	Wind	80	Existing
Grasmere Wind Farm	Wind	14	Existing
Greenough River Solar Farm	Fixed PV	10	Existing
Geraldton PV	Fixed PV	400	Scenario 2
Harvey Wind	Wind	400	Scenario 2
Henderson Waste Gas	Biomass	3	Existing
Kalbarri Wind Farm	Wind	2	Existing
Kalgoorlie-Boulder CST	Solar Thermal	100	Scenario 2
Kalgoorlie-Boulder PV	Fixed PV	200	Scenario 2
Katanning Wind	Wind	500	Scenario 2
Kojonup Station	Wind	200	Scenario 2
Lancelin Wind	Wind	400	Scenario 2
Landfill Gas & Power - Red Hill	Biomass	4	Existing
Landfill Gas & Power - Tamala Park	Biomass	5	Existing
Merredin Wind	Wind	500	Scenario 2
Morawa PV	Fixed PV	200	Scenario 2
Mt Barker Community Wind Farm	Wind	2	Existing
Mumbida Wind Farm	Wind	55	Existing
North Metro PV	Fixed PV	1,000	Scenario 2
Oakajee Wind 1	Wind	400	Scenario 2
Oakajee Wind 2	Wind	400	Scenario 2
South Metro PV	Fixed PV	800	Scenario 2
Southern Cross CST	Solar Thermal	100	Scenario 2
Southern Cross PV	Fixed PV	200	Scenario 2
Walkaway Wind	Wind	400	Scenario 2
Wellstead Wind 1	Wind	400	Scenario 2
Wellstead Wind 2	Wind	400	Scenario 2

Table 4: Renewable Energy Power stations and location – Scenario 2

SCENARIO 3: THE DARK FUTURE UNDER PREMIER BARNETT

This scenario assumes the current 20% RET is included but no additional target beyond that is included. No efficiency target has been included. It also assumes electricity growth of 57% over 20 years, as outlined by WA government Strategic Energy Initiative 2031 Directions Paper.

This scenario includes the following mix of generation technologies and capacities:

- 480 MW Wind
- 1000 MW Solar PV
- 2000 MW coal
- 1500 MW gas fuelled CCGT fired with gas
- 2400 MW gas fuelled OCGT fired with gas

TOTAL GENERATION CAPACITY	7,381 MW
Coal	2,000 MW
CCGT	1,500 MW
OCGT	2,400 MW
Wind	481 MW
PV	1,000 MW
DSM (MW)	0 MW
STORAGE (MWH)	0 MW
PROJECTED LOAD AT 2030	26,142 GWH
MODELLED TOTAL GENERATION AT 2030	26,142 GWH
Coal	12,254 GWh
Natural Gas CCGT	8,623 GWh
Natural Gas OCGT	1,422 GWh
Rooftop PV	2,269 GWh
Wind	1,574 GWh
CARBON PRICE	$30/TCO2E
TOTAL ANNUAL ENERGY COST (INCLUDING CARBON PRICE)	$2,917 MILLION
TOTAL EMISSIONS	15,116 KTCO2E
CO2E EMISSIONS AS % OF BAU	100.00%
COST OF EMISSIONS REDUCTION FROM BAU	$0/TCO2E
WEIGHTED AVERAGE LCOE	$112/MWH
WEIGHTED AVERAGE LCOE ($/MWH) WITH $30/TCO2E CARBON PRICE	$129/MWH

Table 5: Overview of Scenario 3

Findings

A summary and comparison of technical differences between Scenarios 1 & 2 is shown in Table 6a.

		SCENARIO 1	SCENARIO 2
DEMAND REDUCTION	Energy Efficiency target	30%	30%
	DSM	550 MW	550 MW
SOLAR CST	% generation	14%	2%
	Capacity	1200 MW	200MW
	Generation	4153 GWh	692GWh
	# Power stations	12	2
SOLAR FARMS (PV)	% generation	17%	22%
	Capacity	2010 MW	1010 MW
	Generation	2284 GWh	2238GWh
	# Power stations	6	8
BATTERY STORAGE	% generation	-	-
	Capacity	8000 MW	8000 MW
	Generation	1117 GWh	1117 GWh
	# Power stations	700,000	700,000
WIND	% generation	53%	62%
	Capacity	5480 MW	6482 MW
	Generation	15600 GWh	18753 GWh
	# Power stations	29	27
BIOENERGY	% generation	3%	9%
	Capacity	3000 MW	1350 MW
	Generation	3844 GWh	3422 GWh
	# Power stations	4 + 12 CST co-fuelled	4
ROOFTOP PV	Generation	2743 GWh	4544 GWh
	Capacity	1200MW	2000MW
MODELLED TOTAL GENERATION BY 2030		29,783 GWH	30,103 GWH
TOTAL POWER PLANTS		51	41

Table 6a: Summary and comparison of Scenario 1&2

The summary of findings across all scenarios is shown in Table 6b:

ENERGY GENERATION SCENARIOS	SCENARIO 1	SCENARIO 2	SCENARIO 3: (BAU)
Total Generation Capacity (MW)	11,705	11,055	7,381
Demand-side Management modelled (MW)	550	550	0
Storage Moten Salt (CST) (MWh)	13,000	0	0
Storage Behind Meter Battery (MWh)	8000	8000	0
Projected Load at 2030 (GWh)	23,584	23,584	26,142
Modelled Total Generation at 2030 (GWh)	29,783	30,103	26,142
% surplus RE generation	21%	22%	0%
Carbon Price ($/tCO2e)	$30	$30	$0
Total Annual Energy Cost (including carbon price) ($ million)	$3,177	$3,258	$2,917
Total Emissions (KtCO2e)	1,157	1,939	15,116
CO2e Emissions as % of BAU	8%	13%	100%
Cost of Emissions Reduction from BAU ($/tCO2e)	$14	$8	$0
Weighted Average LCoE ($/MWh)	$132	$128	$112
Weighted Average LCoE ($/MWh) with $30/tCO2e carbon price	-	-	$129
Weighted Average LCoE ($/MWh) if surplus energy sold at $30/MWh	$125.80	121.45	-

Table 6b: Comparison of modelling and costs across 3 Scenarios

The weighted average LCoE for Scenario 1 was modelled to be $132/MWh, while Scenario 2 was slightly cheaper at $128/MWh.

Scenario 1 had the lowest carbon emissions profile; almost half the emissions of Scenario 2, due to Scenario 2 requiring more OCGT balancing to make up for the extended periods of shortfalls during the winter months.

Scenario 3 or Business As Usual (BAU) was modelled to be $112/MWh, however, when a carbon price of $30/tCO2e was added the LCoE would increase to $129/MWh, demonstrating that both Scenario 1 and Scenario 2 are cheaper in a more realistic carbon constrained framework.

Furthermore, if the surplus RE generation in Scenarios 1 and 2 were sold at $30/MWh, this would reduce their weighted average LCoE by $6.20/MWh and $6.55/MWh respectively, making both Scenarios 1 and 2 cheaper than the BAU case with a carbon price.

Scenario 1 had the lowest carbon emissions profile with almost half the emissions of Scenario 2, due to Scenario 2 requiring more OCGT balancing to make up for anticipated shortfalls during winter months.

It is conceivable to see future costs of renewable technologies fall even further if current trends continue. Many other studies have found 100% renewable energy would produce electricity prices at an amount similar to business as usual if there is at least some global action on climate change, including reports by the independent analysis from the Centre for Energy and Environmental Markets at the University of NSW[128] and the AEMO[129].

Impact on Power Bills

The cost of our current power bills at January 2017 is 26.474 c/kWh (Synergy A1 Tariff).

Modelling of the cost of electricity for each Scenario by 2030 (Table 7) shows that going to 100% renewable electricity will have no impact on people's power bills.

Put simply, the costs to the consumer by 2030 will be the same as business as usual.

The cost for Scenario 1 and 2 is 26.97c/kWh and 26.7c/kWh; compared with the cost of business as usual of 26.53c/KWh. Rounded to the nearest decimal place, all scenarios will cost us 27c/kWhr.

This means for the same cost as doing nothing, we can achieve 100% renewable stationary energy for the SWIS.

Over the longer term however the average household power bill would be significantly less given there will be no fuel costs. Recent studies have shown that billions could actually be saved from the transition to renewables over the long term.

For example, the Homegrown Power Plan, a roadmap to transition Australia to 100% renewable power by 2050, found investment in fuel-free electricity starts paying itself off in lower prices as early as 2025, and by 2040 at the latest, and the cost of moving all electricity onto renewables would save $90 billion by 2050[130,131].

COSTS (C/KWH)	SCENARIO 1	SCENARIO 2	SCENARIO 3
Energy Generation Costs	13	12.833	11.2
Network Costs	11.6	11.595	10.8
Retail Costs	1.37	1.372	1.3
Regulation and Fees	1.03	1.028	3.234
TOTAL COST TO CONSUMER	26.97	26.7	26.5

Table 7: Modelled Cost per unit of energy (c/kWh) to the consumer 2030
(Assumptions and definitions of each cost component are at Appendix A)

Jobs Under our Plan

Using the most recent and credible figures used in global analysis for the number of jobs created per MW for different energy technologies[132] the number of jobs have been calculated for Scenario 1&2.

Depending on the scenario:

- 79,000 – 87,000 new jobs* are created in construction and installation (C&I)[133]
- 6000 - 8000 new jobs are created in in operations and maintenance (O&M); and
- 49,000 – 55,000 new jobs are created in manufacturing.

(*Note the calculations are in job years, which means one year of one job.)

This is a total of between 151,000 – 156,000 new jobs; roughly 12,000 new jobs each year.

This is higher than the number of people employed at the height of WA's mining boom of 127,221 including construction, extraction, exploration, operations, administration and maintenance.[134]

These figures don't include the massive numbers of new jobs that would be created through a 30% energy efficiency target.

Many of these jobs will be located in regional areas and would provide massive economic opportunities and new training and trades worker opportunities for local communities.[135]

Just over 60 percent of these jobs are in construction, with the remaining split between manufacturing (35%) and permanent ongoing operation and maintenance jobs.

There will not only be a growth in jobs but also a diversification, creating opportunities for trades workers as well as highly skilled engineers and other university graduates.

Carnegie Wave Energy, the developers of the Perth Wave Energy Project reportedly tried to source from local manufacturers but found this difficult, stating that "it is more advantageous to have [the system] built in Victoria and transported across".[136]

Scenario 1 creates a total of 156,497 jobs to 2030, or over 12,000 new jobs each year:

TECHNOLOGY	C & I (JOB YRS./MW)	O & M (JOB YRS./MW)	MANUF. (JOBS/ MW)	CAPACITY (MW)	C & I JOBS	O & M JOBS	MANUF. JOBS	TOTAL JOBS
Roof-top PV	13.0	0.7	6.7	1,210	15,730	847	8,107	25,894
Solar Thermal Farm (CST)	1.3	0.6	0.9	1,200	1,560	720	1,116	4,596
Tracking Solar PV Farm	13.0	0.7	6.7	800	10,400	560	5,360	17,120
Wind Farm	3.2	0.3	4.7	5,482	17,542	1,645	25,765	50,434
Biomass Facility	14.0	1.5	2.9	3,013	42,182	4,520	8,738	58,452
TOTAL JOBS	-	-	-	-	87,414	8,291	49,086	156,497

Table 8: Renewable energy jobs - Scenario 1

Scenario 2 creates a total of 151,257 new jobs to 2030, or about 11,600 new jobs each year:

TECHNOLOGY	C & I (JOB YRS./MW)	O & M (JOB YRS./MW)	MANUF. (JOBS/ MW)	CAPACITY (MW)	C & I JOBS	O & M JOBS	MANUF. JOBS	TOTAL JOBS
Roof-top PV	13.0	0.7	6.7	2,000	26,000	1,400	13,400	42,800
Solar thermal Farm (CST)	1.3	0.6	0.9	200	260	120	186	766
Fixed Solar PV Farm	13.0	0.7	6.7	1,010	13,130	707	6,767	21,614
Wind Farm	3.2	0.3	4.7	6,482	20,742	1,945	30,465	59,634
Biomass Facility	14.0	1.5	2.9	1,363	19,082	2,045	3,953	26,442
TOTAL JOBS				11,055	79,214	6,216	54,771	151,257

Table 9: Renewable energy jobs - Scenario 2

Part 4: The Phase-out Plan – A Timetable for a Staged, Stable Closure of Fossil-Fueled Power Stations

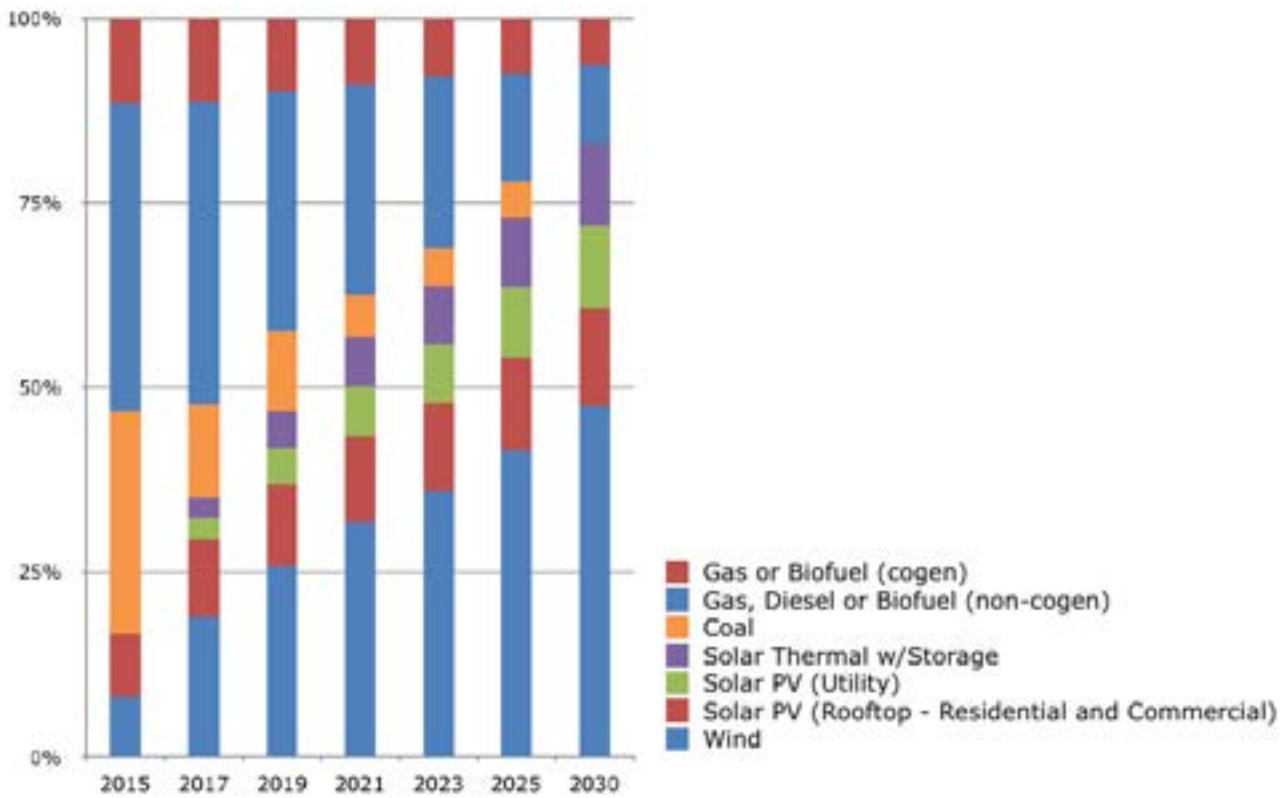
The transition can be achieved in an orderly fashion, phasing in renewables as we retire our fossil fueled power stations, starting with our dirty and uneconomic coal generators first, many of which are reaching the end of their useful lives (without major refurbishment and upgrade costs needed to extend them for perhaps another decade), and winding down our gas powered stations in the final phase.

The transition from our existing primarily fossil-fueled electricity generation system to a 100% renewable electricity grid will ensure a reliable and economically affordable supply as all the existing coal plants are retired, and the gas plants are reduced and modified to run on biomass fuel supply. The renewable mix will consist of wind, solar PV, solar thermal and biomass.

The transition would require about 500MW of renewable energy capacity to be installed annually through to 2030.

This is a relatively modest implementation rate when compared to the Zero Carbon Australia Stationary Energy Plan by Beyond Zero Emissions[137], which showed there was no technical or engineering barrier to achieving 100% renewable stationary energy in Australia by 2020 and our Plan is therefore believed to be achievable for Western Australia.

Model 1: Energy 2030 Phase Out Plan



POWER STATION	LOCATION	YEAR BUILT	FUEL	CAPACITY (MW)	GWH	CARBON EMISSIONS (TONNES PA)**	RETIRE
Muja AB (G1, G2, G3, G4)*	Collie	1965	Coal	220	289		2017
Muja C (G5, G6)	Collie	1981	Coal	385	1349	5,746,700	2017
Muja D G7, G8)	Collie	1985	Coal	422	1479		2017
Pinjar Small	Pindar	1989	Gas-Diesel	211	92	-	2019
Collie	Collie	1990	Coal	317	2222	2,592,300	2019
W. Kalgoorlie (GT2, GT3)	Kalgoorlie	1984	Diesel	53	5	36824	2019
Kwinana Cogeneration Plant (BP Kwinana refinery)	Kwinana	2003	Gas Cogen	80	385	197,500	2023
Alcoa Wagerup	Wagerup	1994	Gas/Diesel OCGT	25	33	216,190	2023
Mungarra	Munarra	1990	Gas	95.5	502	41,886	2023
Pinjar Large	Pindar	1991	Gas	337	236	356,590	2023
Kwinana GT	Kwinana	2010	Gas OCGT	109	191	4,666,200	2024
Merredin peaking plant	Merredin	2013	OCGT on Diesel	82	0	-	2024
Goldfields		1996	Gas OCGT	61.4	430	-	2026
Kemerton 11	Bunbury	2005	Gas	146	64	116,550	2025
Kemerton 12	Bunbury	2005	Gas	146	64		2027
Bluewaters 1	Collie	2009	Coal	217	1521	2,414,600	2029
Bluewaters 2	Collie	2009	Coal	217	1521		2029
Tiwest Co-gen	Kwinana	1999	Gas Cogen	33	231	167820	2030
Southern Cross Energy (BHP Goldfields)	Kalgoorlie	1996	Gas Cogen	23	165	243,580	2030
Alinta Pinjarra 1 (Alcoa)	Pinjarra	2006	Gas Cogen	129	1017	1,458,200	2030
Alinta Pinjarra 2 (Alcoa)	Pinjarra	2006	Gas Cogen	128	1009		2030
Alinta Wagerup 1	Wagerup	2007	Gas Cogen	181	79	1,435,000	2030
Alinta Wagerup 2	Wagerup	2007	Gas Cogen	181	79		2030
Cockburn***	Kwinana	2003	Gas CCGT	232	1727	495,530	2033
Neerabup	Neerabup	2008	Gas OCGT	331	87	-	2038
NewGen Kwinana	Kwinana	2008	Gas CCGT	320	1402	734,230	2038
Tesla Diesel*	Northam	2013	Diesel/ biofuel	39.6	0	-	2043
Kwinana GT2, GT3, HEGT**	-	2012	Gas	190	250	-	2042

Table 10: Retirement schedule of fossil fuel power stations to 2030

*Of all of Muja's coal-powered steam turbines, Muja A&B were the smallest and least efficient units and were closed in April 2007. In June 2008 it was announced these would be recommissioned due to a statewide gas shortage. In June 2013 after spending $250m, Premier Barnett announced the older generators will be mothballed. At 2014 Muja & B are used intermittently, primarily during summer peak times. According to the NPI, Muja Power station is one of the biggest emitters of air pollution in Australia.
**Data from Carbon Monitoring for Action (CARMA) using 2009 figures at www.carma.org

RENEWABLE GENERATORS	YEAR BUILT	FUEL	ENERGY GENERATION (GWH)						
			2015	2017	2019	2021	2023	2025	2030
Walkaway	2006	Wind	312	312	312	312	312	312	312
Albany	2001	Wind	55	55	55	55	55	55	55
Collgar	2011	Wind	650	650	650	650	650	650	650
Emu Downs	2006	Wind	210	210	210	210	210	210	210
Grasmere	2012	Wind	40	40	40	40	40	40	40
Mumbida	2013	Wind	154	154	154	154	154	154	154
Other existing - small	-	Wind	38	38	38	38	38	38	38
Wind - new	-	Wind	0	1537	3075	4612	6150	7687	10762
WIND SUBTOTAL	-	-	**1459**	**2997**	**4534**	**6072**	**7609**	**9146**	**12221**
Solar PV(rooftop)	-	Solar	876	1107	1335	1559	1779	1996	2423
Solar PV (Utility/Farms)	-	Solar	18	175	330	482	632	780	1070
Solar Thermal w/Storage	-	CST	0	596	1191	1787	2383	2978	4170
SOLAR SUBTOTAL	-	-	**894**	**1878**	**2856**	**3828**	**4794**	**5754**	**7662**
RE SUBTOTAL	-	-	**2353**	**4875**	**7390**	**9900**	**12403**	**14900**	**19884**
TOTAL GENERATION	-	-	**18782**	**19361**	**19932**	**20597**	**21210**	**21872**	**23408**
TOTAL DEMAND	-	-	**18731**	**19335**	**19959**	**20603**	**21267**	**21953**	**23392**
NET GAP (TOTAL GENERATION - DEMAND)	-	-	**51**	**26**	**-27**	**-6**	**-57**	**-82**	**16**

Table 11: Phase in of Renewable Generators to 2030

WA's existing grid includes coal, gas, co-generation such as combined heat and power (CHP) and minor amounts of wind and Solar PV.

The phase out schedule shows by 2030 all coal generation has been phased out, and some gas-turbines have been retained and modified to run on bio-fuels during potential shortfall periods of low solar and wind supply.

% TOTAL	2015	2017	2019	2021	2023	2025	2030
Coal	45	27	22	14	13	7	0
Gas & Diesel Non-Cogen	29	34	28	26	17	13	0
Gas & Diesel Cogen only	14	13	13	13	12	12	0
Bio-fuelled turbines	0	0	0	0	0	0	15
Renewables	13	25	37	48	58	68	100
TOTAL %	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 12: Energy mix during the phase out in percentages of the total: 2015-2030

Conclusion

The modelling of the two RE scenarios demonstrates that the 2030 projected load demand on the South West Interconnected System can be supplied from 100% renewable sources.

The transition can be achieved in an orderly fashion and is appropriate to retire the majority of the coal generators as they are reaching the end of their useful lives (without major refurbishment and upgrade costs to extend for perhaps another decade).

Approximately 500 MW of RE capacity installed annually through to 2030 would be required to transition towards 100% renewable stationary energy. This is a relatively modest implementation rate when compared to the Zero Carbon Australia Stationary Energy Plan by Beyond Zero Emissions Wright and Hearps 2010 and therefore believed to be achievable for Western Australia.

The weighted average LCoE for the two RE scenarios were modelled to be $132/MWh and $128/MWh respectively, while the BAU scenario cost $112/MWh. However, when a carbon price of $30/tCO2e was added to the BAU scenario it pushed the LCoE to $129/MWh demonstrating that both Scenario 1 and Scenario 2 are cost competitive in a more realistic carbon constrained framework.

Scenario 1 had the lowest carbon emissions profile.

Furthermore if the surplus RE generation in Scenarios 1 and 2 were sold at $30/MWh, this would reduce the their weighted average LCoE by $6.20/MWh and $6.55/MWh respectively, making both Scenario 1 and Scenario 2 cheaper than the BAU case in a carbon constrained environment.

It is conceivable to see future costs of renewable technologies fall a further if current trends continue.

Senator Scott Ludlam at the top of the Solar Reserve CST plant under construction in Nevada USA

Appendices

APPENDIX A: ASSUMPTIONS AND BACKGROUND TO THE SCENARIO BUILDING MODELS USED

Background: SIREN Model

Modelling of the three scenarios was undertaken using Sustainable Energy Now's (SEN) Integrated Renewable Energy Network (SIREN) Toolkit, together with PowerBalance which make up the simulation software.

SIREN uses hourly NASA MERRA global meteorological data and the System Advisor Model (SAM)[138] to calculate hourly electricity generation for renewable energy scenarios over any given year from 1979 to 2015.

The generation data is then integrated with load data to produce an electricity profile, which predicts hourly surpluses and shortfalls, for the year being analysed. In this case the 2014 South West Integrated System (SWIS) actual load data used was obtained from publically available information from the Independent Market Operator (IMO)[139].

The hourly surplus/shortfall outputs from SIREN then become the inputs to PowerBalance, which enables the modelling of additional dispatchable storage and generation required to produce balanced scenarios for reliable and stable electricity grids, with generation equaling load for each hour of the year.

Further information and a detailed description of the methodology can be found at www.sen.asn.au.

Technical Assumptions Across All 3 Scenarios

1. Cost of capital rates:
   - 10% - All generation assets (BREE 2012);
   - 6% - All transmission assets (Government low risk rate);
   - 5% - All 'behind the meter' PV and battery storage (SEN 2016);
2. A singular load centre located in the Perth Metropolitan Area;
3. Wind and solar energy costed is the energy transmitted to the major load centre (i.e. generated energy minus transmission losses);
4. Transmission losses in the 330 kV AC lines modelled are low - maximum 3% in the longest lines modelled - and proportional to the length of the line;
5. Dispatchable (balancing) power and storage are costed using a fixed annual cost per MW capacity installed plus variable costs (including fuel) for each MWh of energy generated;
6. Wind and solar generation surplus to load is still fully costed in the Levelised Cost of Electricity (LCoE), even though in reality it may be curtailed or sold more cheaply.

Discount Rates

All three scenario updates used the following common general assumptions in their modelling:

The following discount rates were used in the LCoE calculations:

- 10% - All generation assets (BREE 2012);
- 6% - All transmission assets (Government low risk rate);
- 5% - All 'behind the meter' PV and battery storage (SEN 2016);

The LCoE calculations for the various scenarios require a discount rate to be applied to the cost of capital. This is the minimum return that investors expect for providing that capital.

Projected Energy Growth Forecasts

The following energy growth forecasts and projections were used.

The peak demand and energy forecasts for the period 2015-16 to 2024-25 used in the SIREN modelling uses an average annual growth rate of 1.6%.

This is made up of the expected 10 year average annual growth rate of 1.3% taken from Table 4.6 of the 2014 Electricity Statement of Opportunities report[140], as shown below in Table A, and an additional 0.3% for the uptake of electric vehicles (EV). For insights into the projected growth rates of EVs the AEMO Insights report[141] is referenced.

The factors used by the IMO in determining the forecasts include economic outlook, population growth, electricity prices, block loads, embedded generation (PV systems and battery storage) and Individual Reserve Capacity Requirement. Energy efficiency measures are considered within population and its corresponding influence on peak demand growth.

Details are provided in Section 3.2 and 4 of the IMO report[142].

SCENARIO	2015-16 (GWH)	2016-17 (GWH)	2017-18 (GWH)	2018-19 (GWH)	2019-20 (GWH)	5 YEAR AVERAGE ANNUAL GROWTH	10 YEAR AVERAGE ANNUAL GROWTH
High	18,986	19,498	20,349	20,349	20,543	2.0%	2.5%
Expected	18,731	19,015	19,353	19,548	19,625	1.2%	1.3%
Low	18,541	18,705	18,931	18,970	18,893	0.5%	0.5%

Table A: Energy forecasts (IMO 2015)

Scenario 1 & 2
The projected energy demand is based on the 2014 SWIS load of 18,587 GWh, increasing at an annual growth rate 1.6%/yr. This resulted in a total projected demand of 23,584 GWh in 2030.

Scenario 3
The projected energy demand is based on the 2014 SWIS load of 18,587 GWh, increasing at an annual growth rate 2.3%/yr. This resulted in a projected demand of 26,142 GWh in 2030.

Costs

Fundamentally, modelling is based on calculating the overall Levelised Cost of Electricity (LCoE) for each of the scenarios, which allows for an effective comparison of the true costs of each scenario.

The LCoE for each scenario was calculated using the following principles:

1. Costs of the electricity generation and storage components were based on new-build costs of the entire generation and storage assets;
2. Costs for transmission lines and substations were based only on new-build costs of additional transmission and substation assets which are additional to the existing infrastructure;
3. Costs of the distribution system were excluded in the updated scenarios;
4. LCOE costs projected for 2025 were used in the PowerBalance model, and were derived from the CO2CRC Australian Power Generation Technology Report of 2015 (Table B)[143].

CONCENTRATED SOLAR THERMAL	$110
Fixed PV (Utility)	$90
Tracking PV	$70
Wind	$70
Residential rooftop PV	$65

Table B: Projected cost at 2025 ($/MWh) (Co2CRC 2015)[144]

The costs associated with new 330kV transmission lines are listed in Table C:

TRANSMISSION - NEW 330 KV LINES REQUIRED FOR RE SCENARIOS	$/MWH
Transmission cost at 2030	$7 - 9

Table C: Cost of new transmission lines for RE Scenarios, Source: Sustainable Energy Now (2016) Clean Electricity Western Australia 2030: Modeling Renewable Energy Scenarios for the South West Integrated System. At http://www.sen.asn.au/

Renewable Energy Scenarios

Both renewable energy scenarios included the following assumptions:

- Adoption of a carbon price, nominally $30/tCO2e
- Reduction in electricity demand growth of 30% due to energy efficiency targets and uptake of solar PV and other measures resulting in 1.6%/yr. actual growth instead of a forecast growth of 2.3% (The IMO's current projected growth rates as per IMOs' 2014 Electricity Statement of Opportunities published in June 2015) resulting in total demand of 23,000 GWh in 2030.
- An overall reduction in electricity consumption of at least 30% (through further uptake of residential solar PV and a 30% energy efficiency target is effectively cancelled out by the parallel increase in population of 500,000 (or 328,000 new households) forecast by the state government which estimates the WA population will reach 2.2 million by 2031, and increased consumption through rapid electrification of the transport, manufacturing and mining sectors.
- Household battery storage uptake based on forecasts including;
  - EMO prediction that 40% of Australian households could have storage within 20 years with 11,200MW installed by 2035
  - Greentech Media prediction that households will have installed more than 800MW by 2020, a jump from 1.9MW in 2015

Scenario 1

- Total demand of 23,000 GWh in 2030 includes energy growth reduction of 30% (or better) relative to BAU projections due to energy efficiency targets and uptake of residential PV
- 550MW demand side management (DSM) included
- 1200MW roof-top PV capacity is modelled and is based on an annual growth rate of approximately 7% per year from the existing capacity of about 510 MW, and based on conservative estimates from the 2014 Electricity Statement of Opportunities (IMO 2015)
- 8000MW battery storage embedded 'behind the meter' included, based residential, small business and commercial consumers
- All wind turbines are onshore, and 2MW Vesta class III are modelled which are the most efficient in low wind conditions
- All CST plant uses 100MW central tower technology, and have 6 hours molten salt storage at 100MW power (i.e. 600MW storage)
- The model assumes CST charging during the day and generation at night by offsetting CST generation by 10 hrs

TECHNOLOGY	CAPACITY (MW)	CAPACITY AS % OF TOTAL
Bio-fuelled OCGT	1,800	15%
Biomass co-firing	1,213	10%
Fixed PV	1,210	11%
Solar Thermal	1,200	10%
Tracking PV	800	7%
Wind	5,482	47%
TOTAL	11,705	100%

Table D: Scenario 1 – Summary of technologies and capacities modelled

- Co-firing by biomass is costed separately, cost of additional storage tanks is for tank only as CST generation and piping infrastructure already in place, and cost of rail infrastructure for biomass and gas pipeline for gas co-firing excluded from modelling

Scenario 2

- Total demand of 23,000 GWh in 2030 includes energy growth reduction of 30% (or better) relative to BAU projections due to energy efficiency targets and uptake of residential PV
- 550MW demand side management (DSM) included
- 200MW CST is included
- 8,000 MWh of battery storage 'embedded' in the distribution grid, installed 'behind the meter' by consumers on their premises. This was modelled on the basis that up to 700,000 residential and small business customers would install 10 kWh systems and 1,000 commercial users would install 1 MW systems, and would account for approximately 50% of Western Australian households (according to household growth projections by the ABS, 2015, and is in line with other projections reported recently[145].
- 2000MW of rooftop PV capacity is modelled, based on an annual growth rate of 11% per year from existing capacity of about 510MW, and is based on optimistic estimates from the 2014 Electricity Statement of Opportunities[146].
- All wind turbines are onshore, and 2MW Vesta class III are modelled which are the most efficient in low wind conditions
- All CST plant uses 100MW central tower technology, and have 6 hours molten salt storage at 100MW power (i.e. 600MW storage)
- The model assumes CST charging during the day and generation at night by offsetting CST generation by 10 hrs
- Co-firing by biomass is costed separately, cost of additional storage tanks is for tank only as CST generation and piping infrastructure already in place, and cost of rail infrastructure for biomass and gas pipeline for gas co-firing excluded from modelling

The specific breakdown of technologies and generation capacities modelled are in Table E.

TECHNOLOGY	CAPACITY (MW)	PERCENTAGE OF TOTAL
Bio-fuelled OCGT	1,350	12%
Biomass	13	0.1%
Solar Thermal	200	2%
Rooftop PV	2,000	18%
Utility Fixed PV	1,010	9%
Wind	6,482	59%
TOTAL	11,055	100%

Table E: Scenario 2 - Capacities of modelled technologies

Scenario 3
The business as usual scenario included the following assumptions:

- The current 20% RET is included but no additional RE target beyond that is included
- No energy efficiency target has been included
- Electricity growth of 57% over 20 years, or 2.3% per year, as outlined by WA government Strategic Energy Initiative 2031 Directions Paper (2011), reaching a total 26,000 GWh in 2030.
- The capacities of the technologies have been adjusted to meet a forecast demand of 26,142 GWh in 2030 based on electricity demand and growth of 2.3% per year outlined in the WA government Strategic Energy Initiative 2031 Directions Paper of 2011
- Coal generators assumed to be 500MW capacity, with 4 coal generators including one on standby most of the time, and ramping in steps of 50% at maximum generator capacity (250MW steps)
- Wind generation capacity remains at current levels
- Rooftop solar PV increases to 1000 MW (from about 500 MW in 2016)
- No battery or other storage is included
- Demand side management (DSM) is excluded
- Gas powered OCGT balancing power capacity is set at 2400MW
- The proportion of coal and gas is the same as the 2016 mix

The specific breakdown of technologies and their generation capacities modelled are in Table F.

TECHNOLOGY	CAPACITY (MW)	PERCENTAGE
Coal	2,000	27.1%
OCGT (natural gas)	2,400	32.5%
CCGT (natural gas)	1,500	20.3%
Rooftop PV	1,000	13.5%
Wind	481	6.5%
TOTAL	7,381	100.0%

Table F: Capacities of modelled technologies - Scenario 3

Battery Storage Uptake and Modelling

In April 2015 Tesla Motors launched the Powerwall, its home battery storage product. Since then there has been a number of studies and reports attempting to predict the future uptake of battery storage in Australia[147]. However, the technology is still in its infancy from a commercial point of view and historic installation data for Australia is limited, making it difficult to accurately predict future battery storage trends (AEMO 2015). As such the main reporting variable to make predictions about the uptake of future battery storage is economic modelling, in particular using the payback period[148,149].

Scenario 1 and 2
8,000 MWh of battery storage 'embedded' in the distribution grid and installed 'behind the meter' by consumers on their premises has been included.

This figure is in line with other projections reported in the media recently (Parkinson 2015). It translates to up to 700,000 residential and small business customers would install 10 kWh systems and 1,000 commercial users would install 1 MW systems by 2030, and would account for approximately 50% of Western Australian household, according to household growth projections by the ABS (2015)[150].

Carbon Intensities of Generation Technologies

Table G lists the carbon intensities of the different electricity generation technologies used in the three scenarios modelled for the purposes of calculating the total CO2e emissions and their costs for those scenarios with a carbon price.

COMMERCIAL TECHNOLOGIES	CARBON INTENSITY (GCO2E/KWH)	REFERENCE
Coal	820	IPCC Annex iii(median)
Coal sub-critical SWIS (Blue Waters)	920	Griffin Power, 2008
Gas – combined cycle	490	IPCC Annex iii (median)
Gas – OCGT	515	IPCC Annex iii (median)
Bio-oil – OCGT	280	Steele et al, 2012
Biomass – dedicated	130	IPCC Annex iii (low)
Solar PV utility	48	IPCC Annex iii (median)
Solar PV rooftop	41	IPCC Annex iii (median)
Conc. Solar thermal	27	IPCC Annex iii (median)
Wind onshore	11	IPCC Annex iii (median)

Table G: Carbon intensity values for various generation technologies used in scenarios. Source: Schlömer et al. (2014)

Impact on Power Bills – Cost per Unit of Energy

- Generation costs are based on the weighted average LCoE of generation for each scenario modelled
- Network costs for Scenario 1 and 2 are calculated from the current BAU network costs plus 0.8c/kWh for the additional transmission lines required;
- Retail & profit costs are estimated by keeping that cost element at 5% of the total costs (as per current breakdown)
- Regulation costs and fees were kept constant at 1.028c/kWh (as per the current breakdown).

References

1. Western Australian Government Public Utilities Office. At http://www.finance.wa.gov.au/cms/content.aspx?id=15108 ; According to the International Energy Agency's Key World Energy Statistics 2015 and the REN21 report Renewables 2015 Global Status Report gives a similar figure of 19.1%.

2. Question on Notice 11 October 2016 by Robin Chapple MLC, to the Minister for Energy, using Commonwealth Department of Environment, based on 2016 State and Territory Greenhouse Gas Inventories 2014. Accessed 17 October 2016.

3. Independent research by the Office of Robin Chapple MLC has shown with a further 3 projects, the Browse Basin, Prelude and Wheatstone projects due to come online this will add another 24mtpa. See http://www.robinchapple.com/wa-co2e-emissions-estimates-2012

4. See previous studies which provided costed roadmaps to 100% Stationary energy in WA Energy 2029 (2013) and Energy 2029 Redux (2014) by the Office of Scott Ludlam at http://greens.org.au/wa/wa2.0/energy2029

5. http://www.climatechange.gov.au/reducing-carbon/aemo-report-100-renewable-electricity-scenarios

6. This includes construction, extraction, exploration, operations, administration and maintenance of 127,221. ABS Catalogue 8415.0 'Mining Operations' employment figures 2014-15 (Released May 2016) and ABS Mining construction sector employment (using 2011 Census figures).

7. Clean Energy Council, 'Clean Energy Career Hub', Clean Energy Council website, 2014, accessed 11 April 2016.

8. Dr Jenny Riesz, Ben Elliston, Assoc. Prof Iain MacGill, Assoc. Prof Mark Diesendorf (2013). Submission on 100 per cent Renewables Study – Draft Modelling Outcomes Report. Centre for Energy and Environmental Markets University of NSW.

9. http://www.climatechange.gov.au/reducing-carbon/aemo-report-100-renewable-electricity-scenarios

10. http://cdn.getup.org.au/1499-Homegrown_Power_Plan_-Full_Report.pdf

11. See also the Guardian's summary of report: http://www.theguardian.com/environment/2016/apr/19/modelling-shows-move-to-100-renewable-energy-would-save-australia-money

12. Our model proposed is that once a power station is above the set pollution target, it becomes subject to the direction of the energy regulator who will have the statutory power to order that part or all the units of a generator are decommissioned. Once a generator exceeds the standard, they will not automatically be shut down; instead they will be subject to direction of Australian Energy Market Operator (AEMO) in consultation with RenewWestern Australia to manage a stable energy transition from dirty to clean sources.

13. Solar Citizens and Get Up! Home-Grown Power Plan: 100% Renewable Australia (2016) http://cdn.getup.org.au/1499-Homegrown_Power_Plan_-Full_Report.pdf; See also the Guardian's summary of report: http://www.theguardian.com/environment/2016/apr/19/modelling-shows-move-to-100-renewable-energy-would-save-australia-money

14. Beyond Zero Emissions 2010. 'Zero Carbon Australia Stationary Energy Plan 2020'

15. Solar Citizens and Get Up! Home-Grown Power Plan: 100% Renewable Australia (2016) At http://cdn.getup.org.au/1499-Homegrown_Power_Plan_-Full_Report.pdf;

16. See also the Guardian's summary of report: http://www.theguardian.com/environment/2016/apr/19/modelling-shows-move-to-100-renewable-energy-would-save-australia-money

17. Department of the Environment (2013) 100 Percent Renewables Study – Modelling Outcomes. Retrieved from http://www.environment.gov.au/system/files/resources/d67797b7-d563-427f-84eb-c3bb69e34073/files/100-percent-renewables-study-modelling-outcomes-report.pdf

18. Ren21 Global Status Report at http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf

19. Western Australian Government Public Utilities Office. At http://www.finance.wa.gov.au/cms/content.aspx?id=15108

20. Ren21 Global Status Report at http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf and according to the International Energy Agency's Key World Energy Statistics 2015 the REN21 report Renewables 2015 Global Status Report gives a similar figure of 19.1%.

21. Ren21 Global Status Report at http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf

22. Ren21 Global Status Report at http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf

23. IPCC, 2011 Special Report Renewable Energy Sources – Summary for Policy Makers at http://srren.ipcc-wg3.de/report/IPCC_SRREN_Full_Report.pdf

24. ABARE, 2010. Energy in Australia 2010, P12. http://www.abare.gov.au/publications_html/energy/energy_10/energyAUS2010.pdf and WA Office of Energy, 2011. Strategic Energy Initiative 2031 Directions Paper, P13 http://www.energy.wa.gov.au/0/3312/3312/strategic_energy_initiative.pm

25. Government of Western Australia (2011) Energy 2031. Strategic Energy Initiative Directions Paper, at http://www.parliament.wa.gov.au/publications/tabledpapers.nsf/displaypaper/3813100cb1e5bc616f7914cc48257855000f71a1/$file/3100-15.03.11.pdf

26. For example, Western Australian Chamber of Minerals and Energy. 2011. 'WA State Growth Outlook 2011' https://www.cmewa.com/policy-and-publications/annual-reports-special-publications

27. In late 2012 Western Australia had almost 77 megawatts of peak PV solar installed - since then it has gone up. Select Senate Committee Inquiry on Electricity Prices in Australia, WA Hearing October 2, 2012.

28. AEMO (2015) 2014 Electricity Statement of Opportunities Retrieved from http://wa.aemo.com.au/docs/default-source/Reserve-Capacity/2014-electricity-statement-of-opportunities76EBFFC3E047.pdf?sfvrsn=0

29. Clean Energy Council (2014) RET Policy Analysis. At https://www.cleanenergycouncil.org.au/policy-advocacy/renewable-energy-target/ret-policy-analysis.html

30. Australian Greens (2015) RenewAustralia – Powering the New Economy at http://renewaustralia.org.au/wp-content/uploads/

sites/16/2015/11/2015_11_Renew_Australia.pdf

31. http://reneweconomy.com.au/2016/wa-takes-lead-and-tells-utility-to-close-down-fossil-fuel-generation-42982

32. WA Electricity Market Review at https://www.finance.wa.gov.au/cms/uploadedFiles/Public_Utilities_Office/Electricity_Market_Review/electricity-market-review-discussion-paper.pdf

33. http://reneweconomy.com.au/2012/dumb-and-dumber-energy-choices-in-the-wild-west-64327

34. Based on the Barnett government paying around $180,000 per MW per year for available capacity, See WA Electricity Market Review Briefing 08 December 2015 at https://www.finance.wa.gov.au/cms/uploadedFiles/Public_Utilities_Office/Electricity_Market_Review/Industry-Briefing-Forum-08-December-2015.pdf and 2005/6 to 2015/16, QON 3216

35. http://reneweconomy.com.au/2016/wa-takes-lead-and-tells-utility-to-close-down-fossil-fuel-generation-42982

36. Legislative Council Question on Notice 4463 Tuesday 11 October 2016 Hon Robin Chapple MLC to the Minister for Energy

37. Legislative Council Question on Notice 4463 Tuesday 11 October 2016 Hon Robin Chapple MLC to the Minister for Energy

38. RenewEconomy (2016) WA takes lead and tells utility to close down fossil fuel generation. Giles Parkinson, 8 April 2016 at http://reneweconomy.com.au/2016/wa-takes-lead-and-tells-utility-to-close-down-fossil-fuel-generation-42982

39. The model proposed is that once a power station is above the set pollution target, it becomes subject to the direction of the energy regulator who will have the statutory power to order that part or all the units of a generator are decommissioned. Once a generator exceeds the standard, they will not automatically be shut down; instead they will be subject to direction of Australian Energy Market Operator (AEMO) in consultation with RenewAustralia to manage a stable energy transition from dirty to clean sources.

40. The Australian Energy Market Operator (AEMO) provides an estimate of the emissions intensity of power stations on the National Electricity Market (NEM) based on information collected by the National Greenhouse and Energy Reporting scheme.

41. Government of Western Australia Department of Finance (2015) Electricity Market Review Phase 2 at https://www.finance.wa.gov.au/cms/Public_Utilities_Office/Electricity_Market_Review/Electricity_Market_Review_-_Phase_2.aspx

42. https://www.theguardian.com/environment/2017/jan/18/2016-hottest-year-ever-recorded-and-scientists-say-human-activity-to-blame?CMP=Share_iOSApp_Other

43. RenewEconomy (2015) Greens call for emissions target of zero-net pollution by 2040. Sophie Vorrath 27 April 2015 at http://reneweconomy.com.au/greens-call-for-emissions-target-of-zero-net-pollution-by-2040-12337/

44. Water Corporation of Western Australia figures at http://www.watercorporation.com.au/water-supply-and-services/rainfall-and-dams/streamflow/streamflowhistorical

45. "An emissions reduction target is not considered appropriate for Western Australia, as the State falls under the overall national targets which will allow abatement to occur across the nation in the least-cost and most economically efficient manner. It is therefore clear that the bulk of mitigation policy will occur at the national level." Western Australian Government Climate Change Strategy (2012) Adapting to our changing climate at https://www.der.wa.gov.au/images/documents/your-environment/climate-change/adapting-to-our-changing-climate-october-2012.pdf

46. According to Department of Finance and confirmed by questions in Parliament the Government initiated the generous net feed-in tariff on 1 July 2010, but closed it on 1 August 2011 when the funding cap was breached. The net feed-in tariff was available to eligible customers for a period of 10 years from the date of contract and the rate depended on the date of their application or, for customers committed to purchase a system, the date of their contract. For relevant dates before 1 July 2011, the rate was 40cents/kWh and for relevant dates between 1 July 2011 and 1 August 2011 it was 20 cents/kWh.

47. Question on Notice 11 October 2016 by Robin Chapple MLC, to the Minister for Energy, using Commonwealth Department of Environment 2016 State and Territory Greenhouse Gas Inventories 2014. Accessed 17 October 2016.

48. Question on Notice 11 October 2016 by Robin Chapple MLC, to the Minister for Energy, using Commonwealth Department of Environment 2016 State and Territory Greenhouse Gas Inventories 2014. Accessed 17 October 2016, compared with Australian National Greenhouse Accounts, 2010. State and Territory Greenhouse Gas Inventories 2008. http://www.climatechange.gov.au/~/media/3EECC5A54EB54255A62A4EA0F94736B4.ashx

49. Independent research by Robin Chapple MLC at http://www.robinchapple.com/wa-co2e-emissions-estimates-2012

50. Department of State Development (WA) Annual Report 2014-2015 puts these figures as 142 FT (P30) and an annual budget of 453.4M as cost to services (P27). http://www.dsd.wa.gov.au/docs/default-source/default-document-library/annual-report---department-of-state-development-(dsd)---2014-15.pdf

51. Department of State Development Budget Paper, 2010-2011 at http://www.dtf.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2011_12/2011-12_bp2_v1.pdf

52. Government of Western Australia 2011-12 Budget Paper No 2. Part 4: Minister for Mines and Petroleum. http://www.treasury.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2010_11/bp2_vol1.pdf p222

53. Government of Western Australia 2011-12 Budget Paper No 2. Part 4: Minister for Mines and Petroleum p222. http://www.treasury.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2010_11/bp2_vol1.pdf p222

54. http://www.dmp.wa.gov.au/7743.aspx

55. Australian Government 2010. 'Report of the Prime Minister's Task Group on Energy Efficiency' http://www.climatechange.gov.au/~/media/submissions/pm-taskforce/report-prime-minister-task-group-energy-efficiency.pdf

56. International Energy Agency (2014). Energy Efficiency Market Report at http://www.iea.org/topics/energyefficiency/publications/energyefficiencymarketreport2014/

57. International Energy Agency (2015) Energy Efficiency Market Report 2015 p16 at https://www.iea.org/publications/freepublications/publication/MediumTermEnergyefficiencyMarketReport2015.pdf

58. Beyond Zero Emissions 2010. 'Zero Carbon Australia Stationary Energy Plan 2020' (P14)

59. Seifried, Dieter, and Walter Witzel (2010) Renewable energy: the facts. Routledge, 2010.

60. Energiewende [German for Energy transition] Blog (2015). Lower energy consumption in Germany explained. Retrieved from http://energytransition.de/2015/03/lower-energy-consumption-in-germany-explained/

61. Office of Senator Ludlam (2013) Energy 2029. The Greens 100% Renewable Stationary Energy Plan for WA.

62. Office of Senator Ludlam (2013) Energy 2029. The Greens 100% Renewable Stationary Energy Plan for WA.

63. Natural Resources Defense Council (2014) California's Energy Efficiency Success Story. Retrieved online http://www.nrdc.org/energy/ca-efficiency-success-story.asp http://faculty.georgetown.edu/aml6/pdfs&zips/CaliforniaEnergy.pdf

64. http://www.smh.com.au/business/carbon-economy/californian-lessons-for-australias-energy-plans-20121204-2asuf.html#ixzz2EdnzFMjY

65. http://faculty.georgetown.edu/aml6/pdfs&zips/CaliforniaEnergy.pdf

66. http://reneweconomy.com.au/2016/wa-takes-lead-and-tells-utility-to-close-down-fossil-fuel-generation-42982

67. Office of Senator Ludlam (2013) Energy 2029. The Greens 100% Renewable Stationary Energy Plan for WA.

68. International Renewable Energy Agency's Renewable Capacity Statistics 2016,

69. According to the National Renewable Energy Agency

70. National Renewable Energy Laboratory - Concentrating Solar Power Projects http://www.nrel.gov/csp/solarpaces/

71. Beyond Zero Emissions (2010). Zero Carbon Australia Stationary Energy Plan. Retrieved from http://bze.org.au/

72. Australian Solar Institute (2012) Realising the Potential of Concentrating Solar Power in Australia. Prepared by IT Power (Australia) Pty Ltd for the Australian Solar Institute May 2012. At http://www.australiansolarinstitute.com.au/SiteFiles/australiansolarinstitutecomau/CSP_AUST_Final_May2012.pdf

73. Next Energy, 2006. 'Supply side options for WA stationary energy – An assessment of alternative technologies and development support mechanisms. Final report to WA Greenhouse and Energy Taskforce. P52 http://portal.environment.wa.gov.au/pls/portal/docs/PAGE/DOE_ADMIN/GREENHOUSE_REPOSITORY/TAB6327544/GETF%20-%20LOW%20EMISSIONS%20TECHNOLOGIES%20BY%20NEXT%20ENERGY.PDF

74. Lucas Dawson and Peter Schlyter (2012) Less is more: Strategic scale site suitability for concentrated solar thermal power in Western Australia, Department of Physical Geography and Quaternary Geology, Stockholm University, Stockholm SE-106 91, Sweden Energy Policy Volume 47, August 2012, Pages 91–101

75. According to the REN21 Renewables 2015 Global Status Report

76. REN21 (2015) Renewables 2015 Global Status Report, at http://www.ren21.net/

77. REN21 (2015) Renewables 2015 Global Status Report, at http://www.ren21.net/

78. Franke, A (2015, November 22) Germany adds 81 MW of solar PV capacity in October as total reaches 39.5 GW. Platts McGraw Hill Financial. At http://www.platts.com/

79. Clean Energy Regulator (2016) at http://pv-map.apvi.org.au/historical#4/-26.67/134.12

80. IRENA (2015) Renewable Generation Costs in 2014. Retrieved from http://www.irena.org/

81. Image retrieved http://geenergyfinancialservices.com/press_releases/view/24

82. "Australia's first utility-scale solar farm officially opened in WA", Giles Parkinson 10 October 2012 in Renew Economy. http://reneweconomy.com.au/2012/australias-first-utility-scale-solar-farm-officially-opened-in-wa-70785 And http://smartmidwest.com/Portals/0/Science/2010Summit/5-Mark%20Rayner-%20Greenough%20River%20Solar%20Farm.pdf

83. http://reneweconomy.com.au/2012/australias-first-utility-scale-solar-farm-officially-opened-in-wa-70785

84. Renew Economy 'WA takes lead and tells utility to close down fossil fuel generation', Giles Parkinson 8 April 2016 at http://reneweconomy.com.au/wa-takes-lead-and-tells-utility-to-close-down-fossil-fuel-generation-42982/

85. International Energy Agency (2011) Renewable Energy Technologies: Solar Energy Perspectives at http://iea.org/publications/freepublications/publication/Solar_Energy_Perspectives2011.pdf

86. REN21 (2015) Renewables 2015 Global Status Report. Retrieved from http://www.ren21.net/

87. "Australia's first utility-scale solar farm officially opened in WA" Giles Parkinson 10 October 2012 in Renew Economy. http://reneweconomy.com.au/2012/australias-first-utility-scale-solar-farm-officially-opened-in-wa-70785

88. Bloomberg New Energy Finance (2015) Solar 3.0: A Distributed Energy Future? Disruption and the Energy Industry. At http://about.bnef.com

89. Australian Renewable Energy Agency [ARENA]. (2015). Energy Storage Study. Retrieved from http://arena.gov.au/news/sharing-knowledge-on-energy-storage/

90. Australian Renewable Energy Agency [ARENA]. (2015). Energy Storage Study. Retrieved from http://arena.gov.au/news/sharing-knowledge-on-energy-storage/

91. http://www.aemc.gov.au/Major-Pages/Integration-of-storage/Documents/CSIRIO-Future-Trends-Report-2015.aspx

92. http://www.abc.net.au/news/2016-04-13/solar-home-precinct-launched-in-white-gum-valley/7321468

93. http://reneweconomy.com.au/2016/worlds-biggest-solar-storage-projects-planned-australia-95528

94. http://arena.gov.au/files/2015/07/AECOM-Energy-Storage-Study.pdf

95. Australian Renewable Energy Agency [ARENA]. (2015). Energy Storage Study. Retrieved from http://arena.gov.au/news/sharing-knowledge-on-energy-storage/

96. Bloomberg New Energy Finance (2015) Solar 3.0: A Distributed Energy Future? Disruption and the Energy Industry. Retrieved from http://about.bnef.com

97. Bloomberg New Energy Finance (2015) Solar 3.0: A Distributed Energy Future? Disruption and the Energy Industry. Retrieved from http://about.bnef.com

99. Randall, T (2015) "Tesla's Battery Grads $800 Million in its First Week", Bloomberg Business, Available at http://www.bloomberg.com/news/articles/2015-05-08/tesla-s-battery-grabbed-800-million-in-its-first-week and Tesla (2015) Tesal Powerwall. Tesla Motors. Accessed 21/04/2016, https://www.teslamotors.com/en_AU/powerwall.

100. http://www.abc.net.au/news/2016-04-13/solar-home-precinct-launched-in-white-gum-valley/7321468

101. http://reneweconomy.com.au/2016/worlds-biggest-solar-storage-projects-planned-australia-95528 and Australian Financial Review 8 September 2016Redflow Advanced Energy Storage (2017) http://redflow.com/about-us/

102. Redflow Advanced Energy Storage (2017) http://redflow.com/about-us/

103. Renewables Global Status Report 2015 p11

104. Renewables Global Status Report 2015 p09

105. Retrieved from Renewables Global Status Report 2015 p24

106. Image retrieved from Renewables Global Status Report 2015 p24

107. http://www.ewea.org/fileadmin/files/library/publications/statistics/EWEA-Annual-Statistics-2015.pdf

108. http://www.wind-energie.de/en/infocenter/statistiken/deutschland/number-employees-wind-sector

109. Renewables Global Status Report 2015 p70

110. Renewable UK (2016) Offshore Wind Energy. Retrieved from http://www.renewableuk.com/en/renewable-energy/wind-energy/offshore-wind/

111. http://www.k2management.com/about-k2-management/news/news-q1-2016/towers-set-to-reach-mega-heights/

112. P6, http://www.enercon.de/p/downloads/WB-0407-en.pdf

113. Office of the Chief Economist. 2015. Australian Energy Statistics. Retrieved from Clean Energy Australia Report 2015".

114. http://www.energy.wa.gov.au/cproot/1684/2/Renewable%20Energy%20Fact%20Sheet%20January%202010.pdf

115. Government of Western Australia (2010) Renewable Energy Handbook Western Australia

116. Government of Western Australia (2010) Renewable Energy Handbook Western Australia p13

117. http://www.ren21.net/status-of-renewables/global-status-report/ page 27

118. Seifried and Witzel (2010) Renewable Energy – The Facts. Earthscan. http://ekowidaryanto.lecture.ub.ac.id/files/2012/03/Renewable_Energy___The_Facts.pdf

119. http://www.ren21.net/status-of-renewables/global-status-report/

120. http://www.ren21.net/status-of-renewables/global-status-report/

121. Rose 9 (2011) 'Large Scale Pyrolysis for Dry Land Agriculture' Chapter 18 in The Biochar Revolution, Transforming Agriculture and the Environment' at www.thebiocharrevolution.com

122. http://www.refgas-uk.com

123. http://awsassets.wwf.org.au/downloads/fs053_power_to_change_australias_wave_energy_future_10jun09.pdf

124. Sustainable Energy Now (2011) www.sen.asn.au citing Dr Laurie Mann of Carnegie.

125. https://carnegiewave.com/ceto-overview/

126. Office of Energy Renewable Energy Handbook 2010

127. 'Fremantle Leisure Centre gets into hot water with Evoheat', Pool and Spa, 23 May 2014 at http://www.poolandspareview.com.au/content/commercial/case-study/fremantle-leisure-centre-gets-in-to-hot-water-with-evoheat-1327262120#ixzz4VuFWgPfc

128. Dr Jenny Riesz, Ben Elliston, Assoc. Prof Iain MacGill, Assoc. Prof Mark Diesendorf (2013). Submission on 100 per cent Renewables Study – Draft Modelling Outcomes Report. Centre for Energy and Environmental Markets University of NSW.

129. http://www.climatechange.gov.au/reducing-carbon/aemo-report-100-renewable-electricity-scenarios

130. http://cdn.getup.org.au/1499-Homegrown_Power_Plan_-Full_Report.pdf

131. http://www.theguardian.com/environment/2016/apr/19/modelling-shows-move-to-100-renewable-energy-would-save-australia-money

132. Greenpeace International, Global Wind Energy Council and Solar Power Europe (2015) World Energy Scenario Report 5th Edition 2015. Table 7.1 Summary of Employment Factors Used in Global Analysis 2015, by Rutovitz, Dominish, and Downes (2015) Calculating global energy sector jobs: 2015 Methodology update prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology, Sydney at http://www.greenpeace.org/international/Global/international/publications/climate/2015/Energy-Revolution-2015-Full.pdf

133. Clean Energy Council, 'Clean Energy Career Hub', Clean Energy Council website, 2014, accessed 11 April 2016.

134. ABS Catalogue 8415.0 'Mining Operations' employment figures 2014-15 (Released May 2016) and ABS Mining construction sector employment (using 2011 Census figures).

135. Australian Greens (2015) RenewAustralia

136. C Goldsmith, 'Fighting the tide', Australian Manufacturing Technology, April 2015, accessed 11 April 2016.

137. Wright, Mathew and Patrick Hearps. 2010. Zero Carbon Australia Stationary Energy Plan. Melbourne, VIC: University of Melbourne and Beyond Zero Emissions. http://media.bze.org.au/ZCA2020_Stationary_Energy_Report_v1.pdf.

138. SAM is a performance and financial modelling tool developed by the National Renewable Energy Laboratory (NREL) with the support of the US Department of Energy (USDoE). The generation data is then integrated with load data to produce an electricity profile, which predicts hourly surpluses and shortfalls, for the year being analysed. In this case the 2014 South West Integrated System (SWIS) actual load data used was obtained from publically available information from the Independent Market Operator (IMO) (SEN 2016). The hourly surplus/shortfall outputs from SIREN then become the inputs to PowerBalance, which enables the modelling of additional dispatchable storage and generation required to produce balanced scenarios for reliable and stable electricity grids, with generation equalling load for each hour of the year. Further information and a detailed description of the methodology can be found at http://www.sen.asn.au/

139. IMO (2015) 2014 Electricity Statement of Opportunities. Perth, Western Australia: Independent Market Operator. http://wa.aemo.com.au/home/electricity/electricity-statement-of-opportunities.

140. IMO (2015) 2014 Electricity Statement of Opportunities. Perth, Western Australia: Independent Market Operator. http://wa.aemo.com.au/home/electricity/electricity-statement-of-opportunities.

141. AEMO and Energeia. 2016. Electric Vehicle Insights. https://www.aemo.com.au/Media-Centre/AEMO-Insights---Electric-Vehicles.

142. IMO. 2015. 2014 Electricity Statement of Opportunities. Perth, Western Australia: Independent Market Operator. http://wa.aemo.com.au/home/electricity/electricity-statement-of-opportunities.

143. CO2CRC (2015) Australian Power Generation Technology Report (supported by CSIRO, The Office of the Chief Economist, ARENA and ANLEC R&D) released November 2015 at http://www.co2crc.com.au/wp-content/uploads/2016/04/LCOE_Report_final_web.pdf

144. CO2CRC (2015) Australian Power Generation Technology Report (supported by CSIRO, The Office of the Chief Economist, ARENA and ANLEC R&D) released November 2015 at http://www.co2crc.com.au/wp-content/uploads/2016/04/LCOE_Report_final_web.pdf

145. IMO. 2015. 2014 Electricity Statement of Opportunities. Perth, Western Australia: Independent Market Operator. http://wa.aemo.com.au/home/electricity/electricity-statement-of-opportunities.

146. Parkinson, Giles. 2015. Home Battery Storage Market Expected to "Explode" in Australia in 2016. Renew Economy. 13/11/2015 http://reneweconomy.com.au/2015/home-battery-storage-market-expected-to-explode-in-australia-in-2016-2016.

147. See AEMO (2015) Emerging Technologies Information Paper: National Electricity Forecasting Report. Australia: AEMO at http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report/NEFR-Supplementary-Information; Brinsmead, Graham, Hayward, Ratnam and Reedman (2015) Future Energy Storage Trends: An Assessment of the Economic Viability, Potential Uptake and Impacts of Electrical Energy Storage on the NEM 2015–2035. Australia: CSIRO; Stock, Andrew, Stock and Sahajwalla (2015) Power Potential: Battery Storage for Renewable Energy and Electric Cars. Australia: Climate Council of Australia. https://www.climatecouncil.org.au/batterystoragereport2015

148. AEMO and Energeia. 2016. Electric Vehicle Insights. https://www.aemo.com.au/Media-Centre/AEMO-Insights---Electric-Vehicles.

149. CO2CRC (2015) Australian Power Generation Technology Report (supported by CSIRO, The Office of the Chief Economist, ARENA and ANLEC R&D) released November 2015 at http://www.co2crc.com.au/wp-content/uploads/2016/04/LCOE_Report_final_web.pdf

150. ABS. 2015. 3236.0 - Household and Family Projections, Australia 2011 to 2036. Australian Bureau of Statistics. 19/03/2015 http://www.abs.gov.au/AUSSTATS/abs@.nsf/Latestproducts/3236.0Main%20Features82011%20to%202036?opendocument&tabname=Summary&prodno=3236.0&issue=2011%20to%202036&num=&view=.

Authorised & Printed by S. Ludlam
8 Cantonment St Fremantle