ENERGY 2029

The Greens 100% Renewable Stationary Energy Plan for WA

2013

"The dark clouds on the horizon do indeed have a silver lining of sorts. Behind them is a blue sky and a shining sun. The fourth industrial revolution of efficiency and solar power will make our energy supply safer. No longer will we fight for oil, and the battle against poverty will be won. Millions of new jobs will be created, and national economies and countries will face less of a financial burden. The only thing to fear is inaction."

RAINER GRIESSHAMMER, GERMAN ADVISORY COUNCIL ON GLOBAL CHANGE

THE GREENS

TRUE PROGRESS

Acknowledgements

Produced by the office of Australian Greens Senator Scott Ludlam

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Steve Gates, Angus King, Tim Barling, Ben Rose – Sustainable Energy Now
Professor Ray Wills – former CEO, Sustainable Energy Association
Robin Chapple MLC and **Melanie Bainbridge**

We gratefully acknowledge the work of Beyond Zero Emissions, the Australian Youth Climate Coalition, and individuals at all levels of society and Government working towards a safe climate future. You know who you are.

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Cover image Scott Ludlam

For Riley

And all the others who inherit the consequences of our decisions.

—

"...the early 21st century is not the best period in history to engage in long-range linear projections of any kind, let alone those involving highly energy-sensitive phenomena..."

PETER DROEGE 2006

Contents

Executive Summary

This report is more than a year in the making, and is written with a very simple intent. It canvasses technology options for the rapid decarbonisation of the electricity grid that lights up the South West of Western Australia.

The scenarios drawn here describe our state in the year 2029, a year in which the final legacy fossil fuel generators are decommissioned, forever eliminating our reliance on depleting coal, oil and gas. Instead, we set our course by the colossal abundance of the sun and the wind, the swells of the ocean, the regenerative potential of our wheatbelt and the heat of deep geology.

These are just scenarios: they are a description of the financial costs, benefits, drawbacks, compromises and potentials of following different courses of action in pursuit of a singular goal. Whether we like it or not, the task of this present generation is to eliminate the unregulated combustion of fossil fuels in concert with peoples around the world, in time to prevent the worst of the gathering consequences of climate change.

This study is a project that we should not have had to undertake. It was born out of the realisation that the Western Australian Government is fundamentally disinterested in confronting the damage caused by our ever increasing dependence on fossil fuels, imagining perhaps that these costs will be picked up by someone else.

We undertook this study because the State Government has abolished the agency with responsibility for renewable energy left to it by the previous government, instead ploughing resources into the Department of State Development with a mandate to exploit Western Australian fossil resources as rapidly as technology allows.

The document you are reading has therefore not been prepared by a well-resourced public sector agency with a big budget and backing from a senior Minister in State Cabinet. It has been coordinated by my office, with the assistance and technical guidance of a network of volunteers and practitioners from industry and civil society. In particular we are indebted to Sustainable Energy Now, a Western Australian research and advocacy organisation who combine a depth of engineering expertise with a spirit of inquiry and innovation. At our request SEN undertook to model the quantitative scenarios presented here. Their full technical paper is available at **greenswa.net.au/energy2029**

A debt is also owed to Professor Ray Wills, former CEO of the WA Sustainable Energy Association whose well-informed enthusiasm for the sector he represents is utterly infectious.

This report takes the following structure. Chapters 1 and 2 outline the scope of this work and then offer a blunt analysis of the Western Australian energy sector and the size of the challenge. Chapter 3 details the greatest potential for carbon reductions available, the assortment of energy efficiency and demand reduction techniques and innovations.

Chapters 4 through 9 walk through the fast-moving world of renewable energy: the runaway uptake of rooftop solar, the astonishing solar concentrator fields of Andalucia and Nevada, and innovations in wind, wave, geothermal and bioenergy.

There are surprises here: metropolitan Perth is now the State's largest renewable energy generator; we can build solar plants that run for hours without sunlight; restoring the ragged ecosystems of the wheatbelt can also provide a sustainable energy crop.

Chapters 10 - 12 summarise the scenarios developed by Sustainable Energy Now to lay out alternative pathways to a 100% renewable energy network, using only technologies available today. They present costs, labour force requirements and thumbnail sketches of plant locations based on load, infrastructure and best fit for local renewable energy resources.

There is no doubt that these are approximations, that errors and assumptions will see reality diverge from these highly educated guesses before long. The sheer speed with which innovation in the renewable energy space is occurring make any predictions haphazard. We have reached a tipping point, the same threshold reached when personal computers began their exponential ascent in speed and capability past the lumbering mainframes of the mid-20th century.

There is no place in this study for the obsolete failures of the nuclear industry, or for the scramble of the unconventional gas explorers whose endeavours threaten to compromise our water resources and farming country. Get this transition right, and we liberate ourselves for the most part from the concept of fuel itself. Some of the initial capital costs are high, albeit falling fast, but the fuel costs are zero, forever.

Perhaps people who come across this document deeper into the age of climate change will shake their heads at the degree to which we have to contend with the monetary costs of the transition.

If you presently believe we can't afford to make this transition, we can only invite you to contemplate the costs of not making it; the financial, ecological and human costs of rolling the dice with something as violent and capricious as the climate itself.

The transition to a renewable economy is well underway elsewhere in the world; it is long past time we got serious on our home ground in Western Australia.

SENATOR SCOTT LUDLAM

PART 1
The Problem: Setting the context

Foreword

“The challenges in front of us are severe. In Western Australia, our electricity grid is sparse and is premised on depleting vulnerable point source coal and gas supplies. Regional communities and industries are heavily exposed to rising gas and distillate prices, and the Varanus Island gas plant explosion vividly demonstrated to us the risks of highly centralised fossil fuel infrastructure.


Model by Scott Ludlam

The greatest liability that we have, particularly in this building, is the institutional mindset that holds that the present state of exponentially-increasing resource extraction and the consequent political paralysis that comes with it must remain the case forever. Snap out of it. The challenge before us is this: to turn Western Australia’s sun drenched hinterland into a national resource—to turn our windswept coast and farms into generators and our unmatched wave resource into an energy asset. We have long had the desire to do it. The passage of these bills gives us the tools.

Consider the Western Australian goldfields, a hub of engineering and fabrication skills drenched in one of the best solar resources on the planet, day in, day out, with a high capacity transmission line running back towards the Perth metropolitan area. Goldfielders know a few things about success in the face of unlikely odds and ambitious infrastructure projects. So let us set a date for the commissioning of the CY O’Connor solar thermal power station and bring utility-scale baseload solar power to Western Australia. The design will be based on plants already up and running in California and Spain, but the fabrication and the maintenance must all be local.

The start-up of one, single, large power station of this kind will do more than anything else to blow away the tired myth that this cannot be done, and the fossil industry knows that when the baseload myth disintegrates in the face of an actual commissioned plant in Australia, their arguments will not have anything left in them. We can finally cut our ties with an economy based on digging up and burning stuff. Concentrating solar thermal plants in the goldfields of the mid-west and the Murchison Gascoyne are the baseload platform on which a whole range of variable renewable energy technologies can at last take their place.

The Greens know that this package is only the first step but that this is the real thing. It is the first turning of the ship away from a fossil dependent economy towards a society whose prosperity is founded on the gigantic and essentially infinite flows of renewable energy.”

SENATOR SCOTT LUDLAM
SENATE SPEECH DURING THE DEBATE OF THE CLEAN ENERGY ACT
TUESDAY 1 NOVEMBER 2011

CHAPTER 1

Introduction

Western Australians live in one of the most energy-intensive states in the world. Our technologies consume more energy per person each year than most other developed nations and all other Australian States and Territories.[1]

Nearly all of that energy is consumed as gas, coal and oil. Despite being blessed with some of the world's best renewable energy resources, and available land on which to build the infrastructure, Western Australia trails the world when it comes to renewable energy. In 2012, just 6% of our state's electricity came from renewable sources[2], much lower than the rest of the world which is now runs on 18% renewable energy.[3]

Western Australia has an abundance of many different renewable energy resources and is in one of the best positions in the world to generate energy from solar, wind, wave, geothermal, and sustainable biomass resources. WA has one of the highest solar radiation levels in Australia, and a vast coastline of 12,900km making wave and wind energy viable. WA is the third windiest region in the world, with average wind speeds along the coast of 27km/hr. The Perth Basin geology is ideally suited to offer a reliable source of shallow geothermal energy. Besides these plentiful natural resources, WA produces one of the highest amounts of waste per capita, which presents a great opportunity to generate energy from landfill gas to biogas[4].

Fossil fuels are finite and becoming increasingly expensive to extract - not just in terms of the economic costs but of course to the environment and local communities impacted by gas, coal and oil projects.

Energy 2029 looks ahead to the 200th anniversary of the founding of the Swan River Colony and asks the questions that the State and Federal governments have so far avoided answering:

- **What happens when our business-as-usual approach, based on continued reliance on polluting and ever more expensive fossil fuels, is no longer affordable?**
- **What can we do now to shift towards a future energy scenario that is energy-efficient and reliant on renewable energy sources?**

1 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

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

3 Ren21, 2011. Renewables 2011 Global Status Report, P11 http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf and WA Office of Energy, 2010. Electricity from Renewable Energy fact sheet, P1.

4 Marcus Tang (2012) "Energy solution lies in our own backyard". Opinion. The West Australian Monday October 8 2012.

To answer these questions, this plan analyses Western Australia's current energy use, examines projected energy demand to 2029, and puts forward credible, proven options for meeting this demand entirely through energy efficiency and fuel-switching measures, and a range of renewable technology.

There is no single way to meet this goal, and this report will no doubt be overtaken by events and rapid advances in technology. To underscore this point, rather than advancing a single 'way forward' we have proposed a number of scenarios to illustrate some of the options available to us. In this endeavor we are strongly indebted to the independent research and advocacy organisation 'Sustainable Energy Now', whose modeling and engineering was invaluable.

One thing that came through strongly in the preparation of this work is the total abandonment of climate change mitigation or adaptation efforts by the State Government. 21 years after Australia signed the Framework Convention on Climate Change, against the backdrop of record-breaking January 2013 heat wave, the Barnett Government's total capitulation to fossil fuel interests has been one of the starker findings of this research project.

Emu Downs Wind Farm (Image by Brendan Ryan)

A focus on WA's stationary energy

This document focuses on Western Australia's **stationary energy use.** 'Stationary energy' refers to energy used for electricity generation and all other non-transport energy use, including energy used in mining and manufacturing facilities, and the combustion of fuels such as gas for heating buildings and driving industrial processes.

This study focuses primarily on the South West Interconnected System (SWIS), which accounts for roughly half the electricity generated in Western Australia. Some of the most interesting potential for renewable energy occurs in off-grid applications including mining centres, where the astronomical cost of trucking gas and distillate to remote plants is spurring a new look at renewable energy on economic grounds alone. However, we acknowledge that the most urgent challenge for Western Australia lies in transforming the SWIS to a distributed, renewable system as rapidly as possible.

Our Plan recommends rapid and widespread adoption of renewable energies including solar thermal, solar photovotaics (PV), wind, wave, geothermal and biomass.

This report draws on credible research and global best practice to demonstrate an alternative future to unconstrained energy consumption and the extraordinary harm which this brings. There are now many countries, regions and cities which have 100% renewable energy plans.

In an Australian context, this plan draws on the work of Government, industry and non-government research, principally including the following:

- **Beyond Zero Emissions (www.beyondzeroemissions.org)** and the **University of Melbourne Energy Research Institute** who produced the groundbreaking ***Zero Carbon Australia Stationary Energy Plan in 2010.*** **This provided a costed, technologically credible path to Australia achieving a 100% renewable energy for all of the nation's stationary energy by 2020, for little or no extra costs to households than the business-as-usual scenario based on fossil fuels[5].**

  Since its release the Plan has received accolades and endorsements from leading economists, scientists, politicians and industrialists around Australia, as well as the influential International Energy Agency. The Plan found Australia could entirely transition to renewable energy within the 2010 decade by building 12 very large scale solar power plants (3500 MW each), which would provide 60% of electricity used, and 6500 7.5 MW wind turbines, which would supply most of the remaining 40%, and biofuel use increases from 2 PJ in 2010 to 51 PJ/year for modes of transportation not easily electrified, along with some hybrid vehicles.

  The Plan also showed there are no technical or economic barriers to a complete decarbonisation of Australia's energy sector, and for the first time debunked the conventional myth that renewable energy cannot provide baseload power. Its total cost was A$370 billion, or about $8/household/week over a decade to create an infrastructure that will last a minimum of 30 to 40 years.

- **Western Australian organisation Sustainable Energy Now Inc. (SEN) (www.sen.asn.au) has been developing the case for renewable energies since 2007, with a particular focus on how Western Australia's South West Interconnected System could accommodate increasing fractions of renewable energy. Its 2011 Report "*Renewable Energy Scenarios for Western Australia – A Discussion Paper*" outlined how Western Australia could achieve 30% renewable energy by 2030 and 80-100% renewable energy by 2050.**

5 Beyond Zero Emissions (2010) Zero Carbon Australia Stationary Energy Plan at http://media.beyondzeroemissions.org/ZCA2020_Stationary_Energy_Report_v1.pdf . Note that the BZE Study calculated the cost only to implement the Plan, not to compensate for retirement of existing generation.

- In 2007 **CSIRO** and the **Australian Conservation Foundation (ACF)** separately investigated the adoption of a 25% renewable energy target by 2020. The ACF report found If combined with basic energy efficiency measures, such a target could deliver 15,000MW new renewable power capacity, $33billion in new investment, 16,600 new jobs, and 69 million tonnes reduction in electricity sector greenhouse gas emissions.[6]
- In 2008 **Greenpeace** released a report called "*Energy [r]evolution: A Sustainable Energy Australia Outlook*", detailing how Australia could produce 40% of its energy through renewable energy by 2020 and completely phase out coal-fired power by 2030 without any job losses.[7]
- As a condition of the passage of the Clean Energy Act and associated bills in 2011, the Federal Government agreed to commission the **Australian Energy Market Operator (AEMO)** to inquire into the potential for the national electricity grid (excluding WA and the NT) to transition to 100% renewable energy. At the time this report goes to press, this study is still under way although it has already generated a valuable collection of collateral and supporting material.[8]

The Australian Greens and Greens WA applaud the work that these organisations are doing and have produced this study to show how Western Australia's stationary energy could be reliably powered by a combination of renewables by 2029.

6 Australian Conservation Foundation (2007). A Bright Future: 25% Renewable Energy for Australia by 2020. See also CSIRO (2007). Rural Australia Providing Climate Solutions p.1

7 Energy [r]evolution: A Sustainable Energy Australia Outlook (2008) Teske, Sven and Vincent, Julien, Greenpeace International.

8 http://www.climatechange.gov.au/government/initiatives/aemo-100-per-cent-renewables.aspx

Is 100% renewable energy realistic?

Numerous credible research organisations around the world, including the influential International Energy Agency believe that high targets for renewable energy are possible and necessary. While the dates and targets vary, most studies have agreed the hurdles to switching to renewable energy are social and political, rather than technical or economic.

- **Intergovernmental Panel on Climate Change:** The IPCC's 2011 Special Report Renewable Energy Sources examined likely future scenarios for renewable energy globally, and found that up to 77% of the world's energy was likely to be supplied by renewable energy by 2050.[9] The report noted that: "total global technical potential for renewable energy is substantially higher than global energy demand" and "technical potentials will not be the limiting factors for the expansion of RE at a global scale".
- **US academics Delucci and Jacobson:** A 2010, peer-reviewed study by Mark Delucci and Mark Jacobson found that a 100% renewable energy global target by 2030 was possible. Published in the journal ***Energy Policy***, the study titled 'Providing all global energy with wind, water, and solar power. Parts I and II' found that the cost of energy in a 100% global renewable energy scenario relying only on wind, water and sunlight would be similar to the cost of electricity today.
- **The German Government:** In 2009, the German Government set an aspirational target and Plan for sourcing 100% of Germany's electricity from renewable energies by 2050, using offshore wind, hydropower (including pumped hydro), solar photovoltaic and solar thermal sourced from Africa[10]. Despite Germany's natural disadvantages compared to Australia (for example, less sun and available land) Germany is now well ahead of Australia in renewable energy installation and energy efficiency. It has created 300,000 direct jobs in renewable energy and has a renewable energy industry with an annual turnover of AU$50 billion.[11]
- **The Scottish Government:** In 2011, the Scottish Government raised its previous 2020 target of 80% of electricity from renewable sources to 100%. ([12]) This followed Scotland exceeding its short-term target of 31% of electricity to be supplied from renewable sources (from mainly wind, wave and tidal energy) in 2011.

9 IPCC, 2011 Special Report Renewable Energy Sources – Summary for Policy Makers at http://www.ipcc.ch/news_and_events/docs/ipcc33/SRREN_FD_SPM_final.pdf

10 http://www.renewableenergyworld.com/rea/news/article/2009/04/germany-the-worlds-first-major-renewable-energy-economy

11 Oschmann, V. (2010) 'Going Renewable: Germany's Energy Future'. Presentation by Dr Volker Oschmann, Senior official, German Ministry for the Environment, Nature Conservation and Nuclear Safety to Sustainable Energy Now, 2010. http://sen.asn.au/events/pastpresentations

12 http://www.theclimategroup.org/our-news/news/2011/5/20/scotland-100-renewable-electricity-by-2020/

Key features of Energy 2029

The switch to 100% renewable energy is a complex task, and also involves a number of underlying assumptions and key principles. This report builds on five such principles:

1. Harnessing WA's vast and abundant renewable resources

WA receives more solar radiation than most places on earth, yet has amongst the lowest solar electricity generation of all sunny states. In addition, WA is blessed with plentiful wind, wave, geothermal and biomass energy. Storage technology is now proven around the world to overcome intermittency issues associated with solar and wind. By drawing on a variety of renewable energy forms, we can more than meet our future energy needs.

2. Achieving 'better than baseload' generation

'Baseload' electricity generators such as coal-fired power plants are designed to operate continuously at maximum output to meet underlying minimum electricity demand. Over time, the concept of 'baseload' has taken on something of a life of its own, and is routinely cited as a reason why renewable energy will never be competitive with fossil generators that operate regardless of weather conditions.

One example from close to home demonstrates that this is incorrect.

The small township of Denham in Shark Bay is not served by the SWIS, and has become a showcase for how wind energy can provide a very high proportion of renewable wind energy on an isolated grid. Four turbines are backed by low-load diesel generators providing between 40% and 70% of the town's electricity year-round, with occasional 100% wind generation at low load. This is a demonstration of wind providing a very high proportion of reliable energy, with backup generators providing the balance.

This model turns the 'baseload' question upside down. Rather than coal generators providing a fixed amount of energy and gas generators picking up the surplus, renewable sources should provide as much energy as they are capable of producing, and controllable (dispatchable) sources (including biomass, geothermal and pumped hydro and wave generators) then pick up the remainder.

This reformulation of the baseload concept exposes how coal generators are rapidly becoming part of the problem. They are inflexible in responding to demand and make a poor match for variable renewable output. Wind and solar can supply energy during much of our summer demand periods; flexible biomass and biogas, wave energy and thermal storage from solar plants can ramp up and down quickly, adjusting to peak demands.

Baseload is effectively a 20th century concept - in a world of smart grids, demand management and distributed energy storage, the sooner the 'baseload myth' is laid to rest, the better.

3. Flattening our peak demand profile

Western Australia has a particularly problematic electricity demand pattern with extreme peaks in demand on hot days and cold evenings and lower overnight 'baseload' needs. There are many ways to reduce the peak demand which include installation of rooftop PV systems (if one quarter of WA houses were fitted with 1.5kW PV systems this would provide 230MW, or the equivalent to a coal fired station[13]), retrofitting buildings with insulation, construction of housing and buildings which aren't dependent on extremely energy intensive heating and cooling during peak times, and introducing smart metering which allows us to shift when we use electricity. Using a combination of initiatives, we can flatten our demand profile and avoid new coal or gas powered stations being built altogether.

13 Sustainable Energy Now (2011) Renewable Energy Scenarios for Western Australia. A Discussion Paper. At www.sen.asn.au

4. Deep cuts to energy demand through energy efficiency and fuel switching

Overall primary energy requirements can be reduced by up to 50% through energy efficiency measures[14]. Although overall energy consumption in WA is increasing, much of this is driven by energy inefficiency. Much can be done to cut our energy needs while still maintaining quality of life.

5. A greater reliance on electricity from sectors dependent on liquid fuels

Although this report plans for a reduction in overall primary energy demand, it also proposes more sectors including transport will be powered by electricity sourced from renewable energy. This plan proposes greater reliance on electricity from sectors currently dependent on liquid fuels, such as transport, mining and manufacturing. By 2029 we aim to reduce the volume of liquid fossil fuels consumed in these industries by 30-50% through switching to renewable energy.

6. Adopting diverse, highly localised embedded generation and moving away from highly centralised, inefficient 'peak capacity' generators

Goals of our Plan

WA Energy 2029 describes a number of scenarios to replace virtually all our stationary energy with renewable energy.

Drawing on these principles, Energy 2029 proposes two goals. These are:

- **Halving our total energy demand through energy efficiency, fuel switching and energy conservation by 2029; and**
- **Powering notionally 100% of our stationary energy demand (electricity) by renewable sources by 2029.**

14 Energetics (2006) Energy efficiency potential in Western Australia - Report prepared for the WA Department of the Environment

CHAPTER 2

Our future under business as usual

Setting the context – urgent action for a safe climate and harnessing opportunities clean energy future.

A safe climate

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. For 20 years the UN climate process has been working to develop a comprehensive international climate treaty, while global emissions from energy rose by 50%[15].

To avoid warming above the arguably 'safe' level of 2°C, global emissions need to peak before 2020 and decline rapidly towards zero before 2050. Only one eighth of the world's remaining fossil fuel reserves can be burned before the 2°C 'carbon budget' is breached[16] , and by2013 we have already emitted almost half of his budget. We are on track to use it entirely by 2025, which would lead to an eventual rise in global temperatures of 6°C[17].

Australia is ideally placed to lead the world in meeting this challenge, and the Greens are committed to Australia taking that lead. It is time to urgently develop new models of cooperation and technologies to make large scale emissions reductions in the timeframe required to preserve a safe climate.

The Australian government has adopted targets under its "Clean Energy Future" plan to cut carbon pollution by at least five per cent compared with 2000 levels by 2020—which will require cutting net expected pollution by at least 23 per cent in 2020 and 80 per cent below 2000 levels by 2050[18].

The Greens do not believe this is strong enough and are advocating for Australia to achieve net zero greenhouse gas emissions by no later than 2050, with a minimum of 40% reduction on 1990 levels by 2020.

We have enormous opportunity and a generation-defining challenge before us. It's time to harness the opportunities – for jobs, manufacturing, new export industries, and for a clean energy future.

15 US Energy Information Administration, "International Energy Statistics" between 1992-2010. Cited Beyond Zero Emissions (2012) "From Laggard to Leader, p6.

16 Note that the 2°C limit can also be expressed in terms of the amount of Co2 in gigatonnes the global community can release before this temperature guardrail is breached, known as the "carbon budget", or 1000 Gt of Co2.

17 Beyond Zero Emissions (2012) "From Laggard to Leader" Report. How Australia Can Lead the World to Zero Carbon Prosperity., p6.

18 Australian Government Department of Climate Change and Energy Efficiency (2012) "What the government is doing" http://www.climatechange.gov.au/government.aspx

The economic imperative

In addition to the climate threat is the additional problem that the Australian and Western Australian economies are reliant on a narrow and unsustainable export commodity base of coal, gas, oil and minerals.

As the world's ninth-largest energy producer we tripled our energy exports from $24 billion in 2004–05 to $69 billion in 2010–11, and this accounted for a third of Australia's total commodity exports.

Australia's oil, gas and coal reserves are finite and are becoming increasingly costly to extract. The price of these fossil fuels will continue to rise due to growing demand, dwindling supplies and rising costs of extraction. This in itself provides a strong economic incentive to shift to renewable energy supply.[19]

The depletion trap

The reality of peak oil and gas – the halfway mark of resource depletion – is still being resisted by state and federal governments.

We have already reached the peak of 'conventional' oil. Today oil reserves are reported to be 1200 billion barrels (a barrel contains 159 litres) and the statistical range is reported as 42 years[20]. Current estimates predict we will reach peak gas in 2021[21]. At current rates of consumption it's estimated that natural gas will be depleted in full in 63 years, and brown coal in 220 years[22].

"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 the debate
of the Clean Energy package

19 See International Energy Agency, 2011. World Energy Outlook 2011 at http://www.worldenergyoutlook.org/

20 BP Statistical Review of World Energy, June 2006, cited Seifried and Witzel 2010 p18. See also explanatory videos on peak oil and climate destabilization at Beer (2112) "Running the Climate Experiment" at http://climateexperiment.com/

21 Campbell and Heaps (2009) modeled natural gas production and predicted that the peak would arrive in 2021 at 2.84 trillion cubic meters.

22 Source: Goetzberger and Wittwer, Sonnenergie; Bundesamt fur Geowissenschaften und Rohstoffe, 2006 cited in Seifried and Witzel, Renewable Energy: The Facts, 2010 Figure 1.5 p25

The world turns away

Meanwhile global use of renewable energy is growing strongly.

Renewable energy now accounts for 18% of China's total electricity generation, 14% in Indonesia and Mexico[23], 20% in Germany[24] 27% in Denmark and Argentina, 30% in Spain, and 60% in Sweden[25]. Many countries have already reached the 90-100% mark, including Albania, Belize, Costa Rica, Iceland, Nepal, and Norway[26].

Global investment in renewable energy is also increasing rapidly. Investment has increased from $39.5 billion in 2004 to $257.5 billion in 2011 - an increase of 552% in just 7 years.

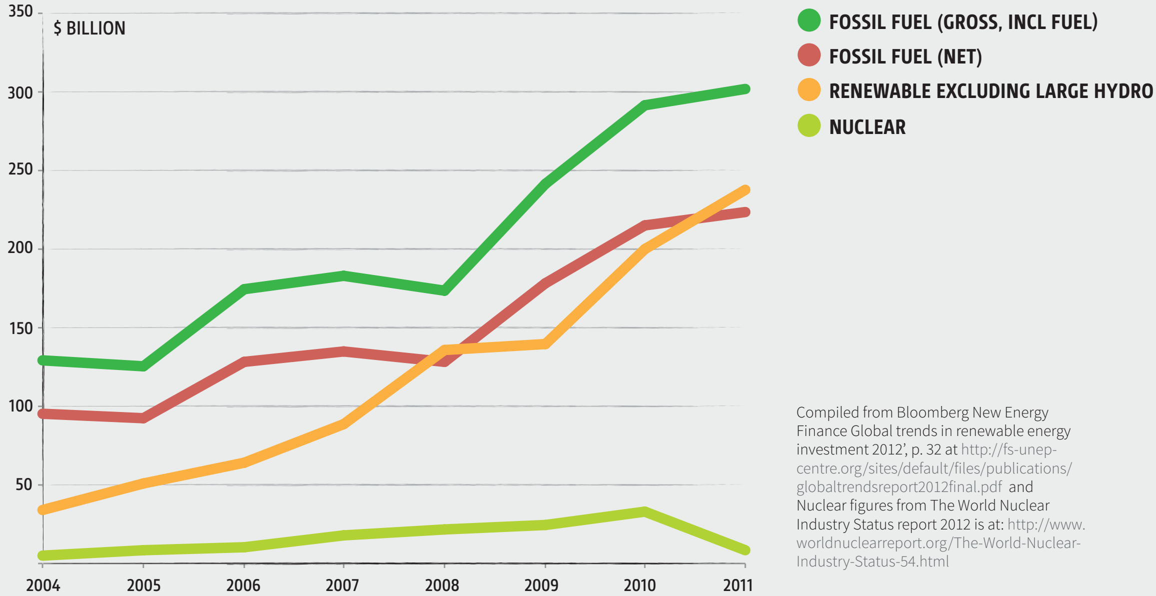
Global investment in renewable power and fuels increased 17% to a new record of $257 billion in 2011. This was more than six times the figure for 2004 ($39.5 billion), and 94% more than the total in 2007, the last year before the acute phase of the world financial crisis[27].

Global investment in renewable energy has now also outstripped that of fossil fuel sources of energy. In 2010 (Figure 1) investment in renewable energy (excluding large hydro) reached parity with that of fossil fuels, but in 2011 it surpassed it.

"At some point beyond 2017 we must begin to cope with the longer-term task of replacing oil as a source of energy. Given the inertias inherent in energy systems and vehicle fleets, the transition will be necessarily challenging to most economies around the world."

Leaked Draft Report 117, from federal Minister Anthony Albanese's Bureau of Infrastructure, Transport and Regional Economics ITRE), 2009. This report was blocked from publication and only exists in leaked form online.

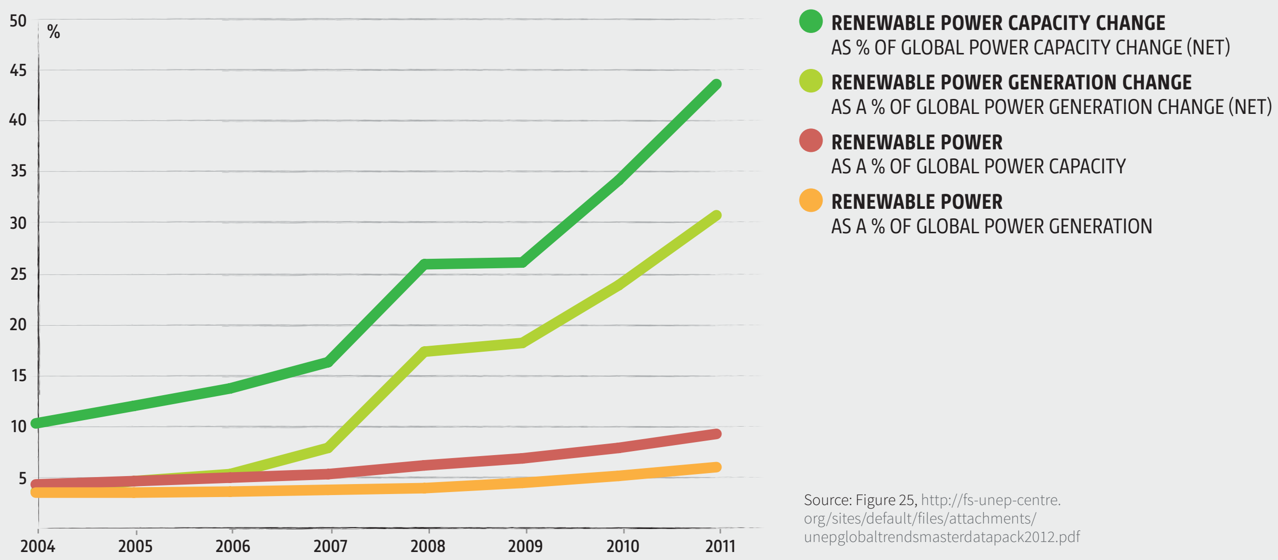
Figure 1 Investment in electricity generation capacity by technology 2004-2011
(*Note the fossil fuel gross figure includes fuel; figures do not include Research and Development)



Compiled from Bloomberg New Energy Finance Global trends in renewable energy investment 2012', p. 32 at http://fs-unep-centre.org/sites/default/files/publications/globaltrendsreport2012final.pdf and Nuclear figures from The World Nuclear Industry Status report 2012 is at: http://www.worldnuclearreport.org/The-World-Nuclear-Industry-Status-54.html

23 Ren21, 2011. Renewables 2011 Global Status Report, P11 http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR2011.pdf p11.
24 b Böhme, Dieter (23 March 2012). "Entwicklung der erneuerbaren Energien in Deutschland im Jahr 2011 [Development of renewable energies in Germany 2011]" (in German) (PDF). Federal Ministry for Environment, Nature Conservation and Nuclear Safety. http://www.erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/ee_in_deutschland_graf_tab.pdf. Retrieved 4 March 2012.
25 http://en.wikipedia.org/wiki/List_of_countries_by_renewable_electricity_production#cite_note-BMU2012-7
26 http://en.wikipedia.org/wiki/List_of_countries_by_renewable_electricity_production
27 Bloomberg (2012) 'Global trends in renewable energy investment 2012', at http://fs-unep-centre.org/sites/default/files/publications/globaltrendsreport2012final.pdf

Figure 2 Proportion of global power generation and capacity that is renewable 2004-2011



Source: Figure 25, http://fs-unep-centre.org/sites/default/files/attachments/unepglobaltrendsmasterdatapack2012.pdf

Figure 1 shows that ***gross*** investment in fossil-fuel capacity continued to run ahead of renewable power excluding large hydro in 2011 – at $302 billion against $237 billion. (Note these figures do not include research and development). However, a significant part of the gross investment in fossil-fuel capacity is actually to replace clapped-out coal and oil-fired capacity with newer fossil plants. A more accurate way of looking at the investment comparison is to look at net investment – because if we look at the amount of money invested in additional fossil-fuel capacity and compare it to the amount invested in renewables capacity (excluding large hydro), then the figures concerned are $223 billion and $237 billion – a gap in favour of renewables of $14 billion[28].

An equally compelling picture is the proportion of global power generation and capacity now coming from renewables. Figure 2 shows renewable capacity as a share of total capacity has increased from 3.6 per cent in 2004 to 9.2 per cent in 2011. Renewable power has also accounted for a higher share of new capacity, accounting for 10.3 per cent of new capacity in 2004 and 43.7 per cent in 2011.

In 2011 year our biggest customer for fossil fuel exports – China – also became the world leader in renewable energy, with the most installed renewable power and the largest investment[29]. It does not seem to have yet dawned on Australian policy makers that every kilowatt of renewable generation installed permanently eliminates future fuel demand.

As global investment in renewable energy is increasing, the costs of renewable technologies have been significantly decreasing - to the point at which they are starting to challenge fossil-fuel alternatives, even without climate, health and other benefits factored in. The best example is the plunge in prices along the PV supply chain caused by increased competition particularly from China, leading to severe, global excess capacity. Sale prices of PV cells fell from $1.50 per Watt in September 2010, to just over $0.60 per Watt by the end of 2011. Overall, PV module prices at the start of 2012 were nearly 50% down on a year earlier, and some 76% below their level in the summer of 2008, when the Spanish PV boom was at its height[30].

28 Bloomberg (2012) 'Global trends in renewable energy investment 2012', at http://fs-unep-centre.org/sites/default/files/publications/globaltrendsreport2012final.pdf p32 Note, these figures do not include research and development.

29 The Australian Government Climate Commission (2012) 15th Report: The Critical Decade: Generating a renewable Australia at http://climatecommission.gov.au/report/the-critical-decade-generating-renewable-australia/

30 http://fs-unep-centre.org/sites/default/files/publications/globaltrendsreport2012final.pdf p33

Australian Government action and mixed signals

The Australian Government has made positive but contradictory efforts to increase investment in the clean energy economy in recent years.

The federal government adopted a 20% Mandatory Renewable Energy Target by 2020[31]. The 15th Climate Commission report - ***Critical Decade: Generating a Renewable Australia*** – highlighted the enormous but underutilised potential for renewable energy in Australia, and showed that solar and wind could be cheaper than coal by 2030, and renewables could entirely power the country in coming decades[32]. The report calls for large and sustained expansion of renewable energy. In the year to October 2011, just under 10% of Australia's electricity came from renewable energy.[33]

As a result of negotiation with the Greens, the Australian Government now also has the long-term goal of reducing Australia's greenhouse gas emissions to 80 per cent below 2000 levels by 2050, and introduced a price on carbon on July 1 2012. In 2050, greenhouse gas emissions from the electricity sector are expected to be 76% below what they would have been without a carbon price. In January 2013 it was reported that the Clean Energy Act has resulted in a measurable decrease in electricity consumption and greenhouse gas emissions, and a lift in renewable energy generation. In the first six months of the carbon price at January 2012 carbon emissions from the electricity sector had fallen by 8.6%, with greater use of renewable energy and cutbacks in consumption. Emissions are 7.5 million tonnes lower compared to the same half of 2011.[34]

However these steps forward are inconsistent with a range of contradictory policies and actions.

The government continues to provide massive subsidies for fossil fuel consumption and production. In November 2012 Treasury modeling commissioned by the Australian Greens showed that diesel fuel subsidies for the mining industry were worth $5.1 billion to 2016[35]. A 2011 report by the Australian Conservation Foundation found the Australian government was spending $11 billion more on subsidies that encourage greenhouse pollution than on programs to tackle climate change. Its report showed just $1,078.8 million was spent on climate policy and support for renewable energy for the 2010-2011 year, while total fossil fuel incentives was more than ten times greater at $12.173 billion.[36,37]

The Australian government's White Paper on Energy was a disappointing and contradictory manifesto for fossil fuels to dominate our energy mix for next 20 years.

It reported that by 2050 "most of Australia's conventional fossil fuel power generation is likely to have been replaced with clean energy technologies in the form of wind power; utility-scale and distributed solar power; geothermal energy; and coal- and gas-based carbon capture and storage systems."[38] On the other hand, it also projects over the next 25 years Australia's fossil energy production will more than double, largely due to export growth. The White Paper boasts we are already the world's largest coal exporter and third-largest uranium producer, and in future years we will become the world's second-largest liquefied natural gas (LNG) exporter. It also projects:

- **Coal production to grow by 8% pa from a value of $14 billion in 2010–11 to an estimated $20 billion by 2016–17;**
- **Gas production to increase by 19% per year to quadruple by 2017 (BREE 2012b), with more than $175 billion in capital expenditure committed to onshore and offshore Australian LNG projects since 2007; and**

31 Australian Government: Office of the Renewable Energy Regulator http://www.orer.gov.au/legislation/index.htmlv

32 http://climatecommission.gov.au/report/the-critical-decade-generating-renewable-australia/

33 Cited in Cleaner Energy Australia Report, Table 1: Annual renewable electricity generation. Electricity generated between 1 October 2010 and 30 September 2011. Source: Clean Energy Council Renewable Energy Database, ABARE 2011, REC Registry, AEMO, IMO, IES.

34 Electricity production fell by 2.7%, and greater use of renewables has caused emissions to drop by 6% in the first six months of the carbon price. In Australian "Emissions drop signals fall in carbon tax take" – January 23 2012, At http://www.theaustralian.com.au/national-affairs/climate/emissions-drop-signals-fall-in-carbon-tax-take/story-e6frg6xf-1226559632995

35 http://www.theaustralian.com.au/news/scrapping-diesel-rebate-for-mining-would-save-51b-say-greens/story-e6frg6n6-1226519143643

36 http://www.acfonline.org.au/sites/default/files/resources/climate_expenditure_and_subsidies.pdf See also http://yes2renewables.org/renewables-faq-and-mythbusting/renewables-need-subsidie/ which draws together all the main analysis updates done since the comprehensive "2007 Energy and transport subsidies in Australia" report by Chris Riedy, Institute of Sustainable Futures, UTS 2007.

37 Watson, John (10 March 2011). "Twelve billion holes in plan to cut carbon." The Age.

38 Australian Government Department of Energy (2012) *Energy White Paper 2012, Australia's energy transformation at* http://www.ret.gov.au/energy/facts/white_paper/Pages/energy_white_paper.aspx

- ↗ **Gas production to be boosted by 'unconventional' gas, particularly coal-seam gas (CSG) and potentially shale and 'tight' gas. Australian CSG production increased from 2% to 11% of total gas production in the five years to 2010–11, and future output will be bolstered by three CSG-to-LNG projects, worth $50 billion, being built near Gladstone[39].**

The Australian Government is a perfect example of the self-defeating contradiction at the heart of modern climate politics.

It is hard to imagine a starker act of institutional cognitive dissonance than investing in renewable energy to prevent climate change, while simultaneously promoting a massive and unregulated expansion of fossil fuel exports.

WA government action – our stormy future under business as usual

Under the Barnett state government WA has a Climate Change strategy that doesn't have an emissions reduction target, and a 20 year energy plan that locks us into a fossil future.

WA's total annual greenhouse gas emissions are 79.5mtpa, including 48.5mtpa from the stationary energy sector[40]. Until the 2008 election the WA Government was committed to reducing greenhouse gas emissions to approximately 26 million tonnes by 2050. Under the Barnett government WA has no emissions reduction target. WA's Climate Strategy is a mere 12 pages long and says;

"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. However, the State Government sees a role for 'complementary action' which assists the national mitigation effort.[41]"

Table 1 New gas projects (extraction) proposed for Western Australia

PROJECT	PROPONENT	PLANNED FIRST PRODUCTION	PROJECTED GREENHOUSE GAS EMISSIONS (MTPA)
Gorgon (Barrow Island)	Chevron, Exxon Mobil, Shell	2014	**5.45 – 8.81** Range depends on whether geo-sequestration occurs[42]
Pluto (Burrup Peninsula)	Woodside	2011 -2016	**1.8 – 4.1[43]** Based on production levels: 4.8mtpa 2011 - 12mtpa 2016
Browse Basin (James Price Point)	Woodside	2011- 2015	**7.1 – 32** Based on production levels: 11mtpa 2011 - 50mtpa 2015[44]
Wheatstone (Ashburton North)	Chevron	2016	**10 – 15** Based on production levels: 25mtpa[45]
Prelude (Floating offshore processing)	Shell	2016	**2.3**[46]
Potential additional annual GHG emissions by 2016:			**58.85mtpa**

39 Australian Government Department of Energy (2012) Energy White Paper 2012, Executive Summary: Australia's energy at http://www.ret.gov.au/energy/facts/white_paper/summary/future/Pages/index.aspx

40 Australian National Greenhouse Accounts, 2010. State and Territory Greenhouse Gas Inventories 2008. http://www.climatechange.gov.au/~/~/media/3EECC5A54EB54255A62A4EA0F94736B4.ashx

41 Western Australian Government Climate Change Strategy (2012) Adapting to our changing climate at http://www.dec.wa.gov.au/our-environment/climate-change.html

42 P30 http://www.epa.wa.gov.au/docs/2937_Rep1323GorgonRevPer30409.pdf and P31 http://www.gorgon.com.au/review/FromClient/Gorgon_Revised_Proposal_PER_Final_Main_Report_20080909.pdf.

43 P31 of http://www.epa.wa.gov.au/docs/2533_Bull1259.pdf

44 P81-82 & P93 http://www.dsd.wa.gov.au/documents/NEW_Browse_LNG_Precinct_-_Public_Information_Booklet.pdf

45 P5: http://www.epa.wa.gov.au/docs/3008_WS0-0000-HES-RPT-CVX-000-00003-00Rev3_2nd.pdf

46 P169 http://www-static.shell.com/static/aus/downloads/about_shell/prelude/completeeisdoclowres.pdf

Under current government policy, 'Complementary Action' is defined as promotion of industrial development which will double WA's greenhouse gas emissions **by 2016.**

Five new proposed gas projects proposed for WA will increase our emissions by 58.85mtpa (Table 1). It's worth noting these figures are for the five largest emitting projects and count extraction only, not the emissions arising once the fuel is burnt. The Browse Basin gas fields will emit the same annual emissions as Singapore; or 32mtpa[47]. It is also more than Australia's 5% annual emission reduction. [48]

The state government also proposes five major new coal fired projects (Table 2) which will add another 12mtpa.

Table 2 Five new coal-fired projects proposed for Western Australia

PROJECT	PROPONENT	PLANNED FIRST PRODUCTION	PROJECTED GHG EMISSIONS (MTPA)
Urea plant using coal gasification (Collie)	Perdaman Chemicals & Fertilizers	2013[48]	**3.48**[49]
Bluewaters 3 Power station (Collie)	Griffin Energy	2013[50]	**1.5**[51]
Bluewaters 4 Power station (Collie)	Griffin Energy	2015	**1.5**
Muja A-B Power Station Refurbishment (Collie)	Verve	2012/13	**1.3**[52]
Coolimba Power station (Eneabba)	Aviva	2013	**4.2**[53]
Potential annual GHG emissions from new coal projects by 2016			**11.9mtpa**

47 http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=749&crid=
48 http://www.perdaman.com.au/our-operations/collie-urea-manufacturing/project-timeline.aspx
49 P25 of http://www.epa.wa.gov.au/docs/1358/Rep1358PerdamanPER10510.pdf
50 http://www.griffinenergy.com.au/default.aspx?MenuID=310
51 P6 of http://www.epa.wa.gov.au/docs/1349/Rep1349Blue3_4PER8310.pdf
52 Inferred from http://www.parliament.wa.gov.au/hansard%5Chansard.nsf/0/997612 1b1cdc74a8482576e000151958/$FILE/C38%20S1%2020100302%20p357b-357b.pdf
53 http://www.coolimbapower.com.au/images/stories/pdf/PER/8_-_Pollution_Impacts_v4.pdf

WA Emissions to 2016 under business as usual

A combination of these ten projects, including four new power stations and five new LNG hubs, will add 73mtpa by 2016. Combined with likely emissions resulting from Western Australia's increasing per capita energy demand, projected population increase and the emissions of numerous planned smaller resources projects, the State Government appears to be comfortable with an effective doubling of WA's emissions to 2016.

State government energy outlook

Despite being blessed with some of the world's best renewable energy resources, and available land on which to build the infrastructure, Western Australia trails the world when it comes to renewable energy.

Western Australian is one of the most energy-intensive states in the world. We consume more energy per capita per year than most other developed nations and all other Australian states and territories.[54] Nearly all of that energy is consumed as gas, coal and oil.

In 2011/12, renewable energy accounted for:

- **9.2% of all electricity consumed on Western Australia's main electricity grid, the South West Interconnected System (the 'SWIS'); and**
- **An estimated 6% of all electricity consumed in Western Australia[55].**

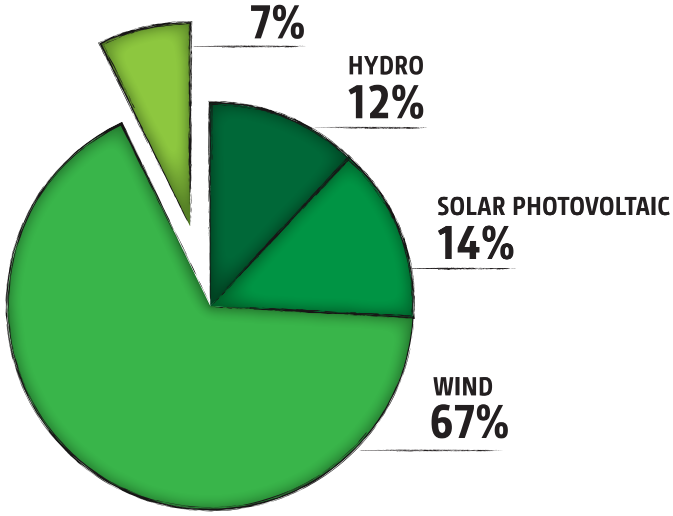


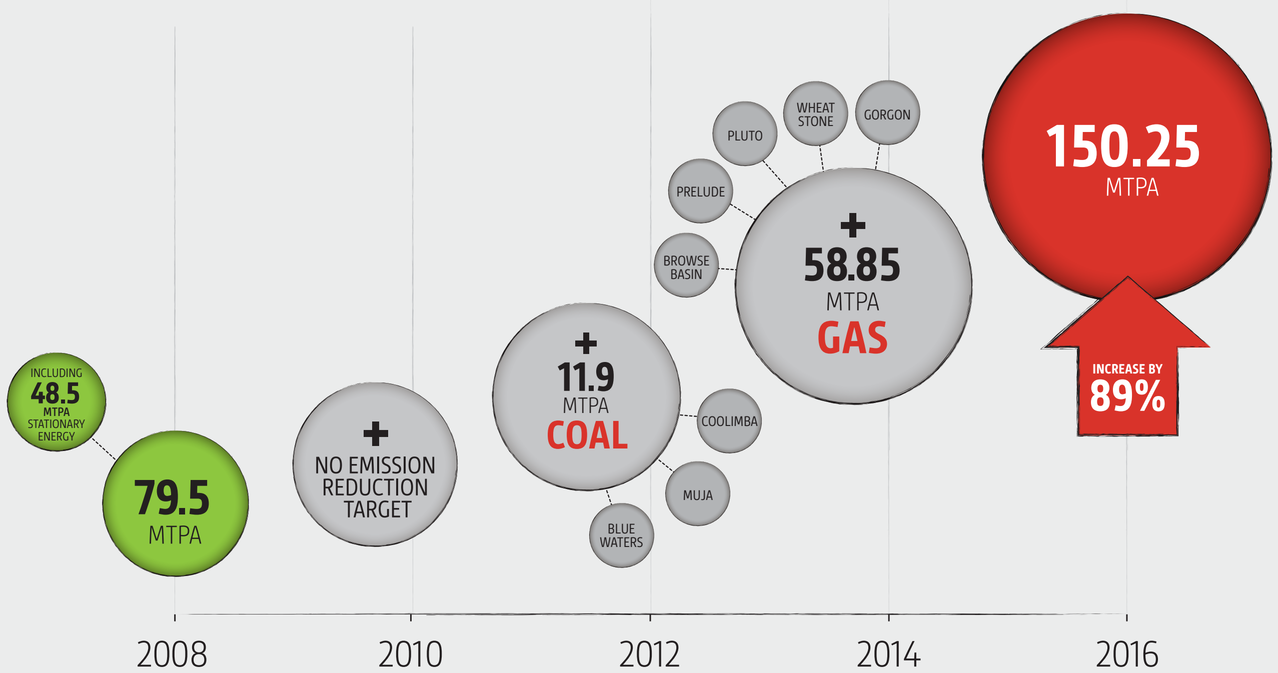
Figure 3 State renewable energy mix 2011/12

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

54 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

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

Figure 4 WA Emissions to 2016 under business as usual



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 in Geraldton[56].

With a touch of irony, Premier Colin Barnett used the occasion to call for the abolition of the federal 20% Mandatory Renewable Energy Target (MRET) in the same week. His voice joins with those of the Premiers in Coalition-ruled states of Queensland, Victoria, New South Wales[57] where simple denial is replacing tokenistic lip-service as official state climate policy.

A 20 year vision?

In 2011 the Barnett government released a 20 year energy plan that seeks to lock WA into another two decades of dependence on fossil fuels.

The *Strategic Energy Initiative Energy 2031* proposes increases in energy demand and reliance on fossil fuels, including coal and conventional and unconventional gas. It predicts:

- **Primary energy demand in Western Australia is likely to rise by 60%;**
- **Electricity supply would increase by 59% and be provided mainly by new gas-fired generation; and**
- **The share of renewables in electricity generation will reach 20% by 2019–2020 but stay at this level for the following decade[58].**

The section titled "*Diverse and secure energy supply - Vision for 2031*" is bizarre and contradictory. It states:

"By 2031, a significant and continually growing proportion of Western Australia's energy needs will be met from renewable energy sources. The State's gas needs will be met with supplies from offshore fields and an increasing proportion of onshore fields, including unconventional onshore sources such as 'tight gas' and shale gas reserves, with appropriate management of environmental impacts. Delivery to end-users will occur through an expanding, integrated network of pipelines.

Coal will continue to supply Western Australia's electricity generation portfolio in conjunction with emissions reduction technologies. Transport energy requirements will be met by a much greater range of fuel sources, including electricity. The improved availability and uptake of alternative fuels, combined with a shift towards the use of more efficient vehicle technologies and energy efficient modes of transport, will strengthen the resilience of the transport system in responding to the impacts of global oil prices and supply volatility.

This diverse energy mix will enhance Western Australia's economic resilience in responding to changes in global energy markets[59]".

Apart from having a state energy strategy that locks us into a fossil future, we also have an economy that is precariously dependent on the mining and petroleum sector.

56 http://reneweconomy.com.au/2012/australias-first-utility-scale-solar-farm-officially-opened-in-wa-70785
57 http://jameswight.wordpress.com/2012/10/14/terrible-week-for-climate/
58 WA Office of Energy, 2011. Energy 2031 – Strategic Energy Initiative Directions Paper , using modelling by the Australian Bureau of Agricultural and resource Economics (ABARE) p18 http://www.energy.wa.gov.au/0/3312/3312/strategic_energy_initiative.pm

59 WA Department of Finance - Public Utilities Office (2012) Strategic Energy Initiative Energy2031 Building the Pathways for Western Australia's Energy Future August 2012 at http://www.finance.wa.gov.au/cms/uploadedFiles/Public_Utilities_Office/WAs_Energy_Future/Strategic_Energy_Initiative_Energy2031_Final_Paper.pdf p13

An insecure and volatile state economy

The 2012-13 state budget reported:

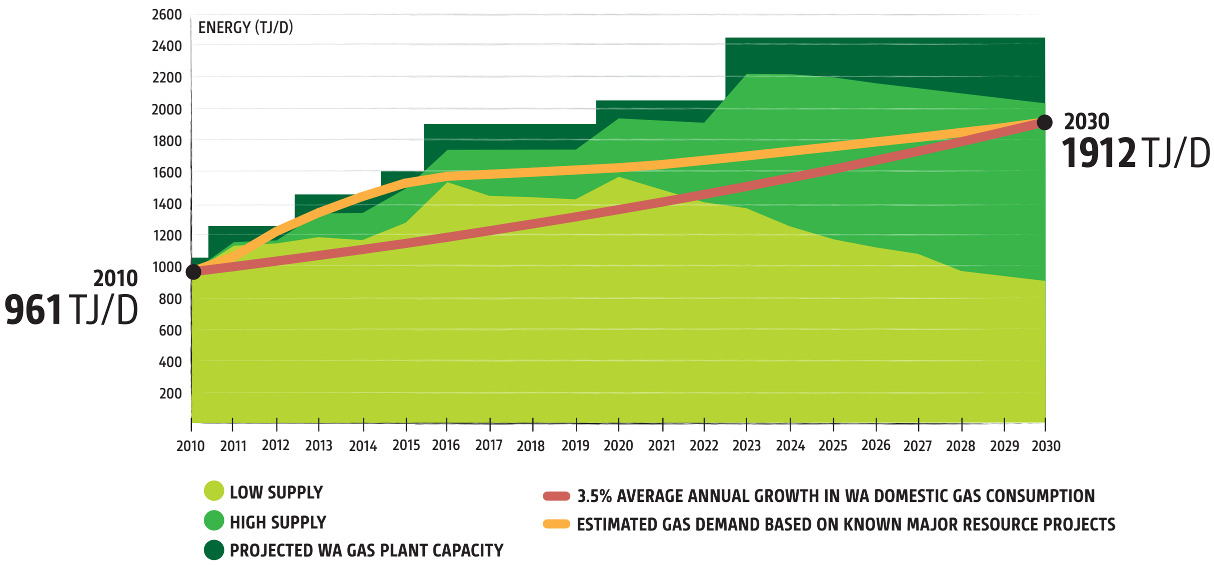
- **Mineral and petroleum exports contributed towards a significant proportion (92% of Western Australian and 46% nationally) of total merchandise exports in 2011;**
- **The value of Western Australia's resources sector grew 16% in 2011 to reach a new high of $107 billion. Of this, petroleum products accounted for 22% ($23.5 billion);**
- **Western Australian mineral exploration increased 30% from 2010 levels to $1.8 billion in 2011; and**
- **The estimated value of resource projects that are under construction, committed and/or planned in WA is over $300 billion.[60]**

Extracting gas will become increasingly expensive and harmful to the environment as the most accessible resources are used up and deeper offshore fields become necessary. This is in addition to using hydrological fracturing or 'fracking' for unconventional gases, such as shale, tight and coal seam gas.

Even then, domestic gas reserves will still come to an end.

The Western Australian Government's own projections, assuming new gas reserves are discovered and come on line, shows domestic conventional and unconventional gas supplies peaking around 2020–2023 (Figure 3). From that point, there is a risk of Western Australia having a large amount of expensive stranded gas infrastructure assets, as by then, many other countries including our key export markets are likely to have shifted to using their own renewable energy supplies.

Figure 5 Western Australia's potential domestic gas demand and supply, 2010–2030.



Source: Government of Western Australia, Office of Energy. Energy 2031: Strategic Energy Initiative Directions Paper March 2011 (Figure 9 page 20) at http://www.parliament.wa.gov.au/publications/tabledpapers.nsf/displaypaper/3813100cb1e5bc616f7914cc48257855000f71a1/$file/3100-15.03.11.pdf

Note: The graph, while appearing on the Department of Finance's Public Utilities Office website, was produced by the Department for Mines and Petroleum, who have noted that the graph is now more than two years old and, as such, may not represent the Department's current view of the State's domestic gas supply.

60 Government of Western Australia Budget 2012-13 – Part 4 – Minister for Mines and Petroleum, p170 http://www.treasury.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2012_13/2012-13_budgetpaperno2_v1.pdf

Box 1: Some 'clean natural gas' myths – the problem of substituting gas for coal

The state and federal governments, along with the natural gas industry have been arguing gas is a "clean energy" with far fewer greenhouse gas emissions than coal.

At best, natural gas may emit between 7 - 55% fewer greenhouse gas emissions than coal over a full life cycle analysis, once the extraction, processing and transport of the fuels is taken into account, in addition to the emissions from combustion.[61]

Another common claim by Liquefied natural gas (LNG) and Coal Seam Gas (CSG) proponents is that gas is able to contribute to the direct reduction of greenhouse gas emissions when it's used to replace more emissions intensive fuels such as coal being used in other countries.[62] For example the "Benefits of LNG" page on Woodside's website states:

"For every tonne of carbon dioxide emitted in the production of LNG in Australia, at least four tones of carbon dioxide emissions in customer countries are avoided when LNG is used to displace coal-fired power generation. This is even greater in China, where the impact of displacing coal with LNG for power generation ranges between 5.5 and 9.5 tonnes."[63]

This claim is false for three reasons. It firstly compares the emissions caused by LNG and CSG *production only* against the *entire life cycle* emissions of coal (that is production plus transport and combustion). Secondly it ignores the fact that increasingly impure gas fields are now being tapped, and these contain very high levels of reservoir carbon dioxide, which in most cases are proposed to be vented straight to the atmosphere. Thirdly, the claim that displacement of coal-fired power generation occurs is yet to be backed by any evidence; in fact it is far more likely that cheap, available fuel increases energy demand rather than displaces it.

There is also very little hope that carbon geo-sequestration – the storage of greenhouse gases in underground rock strata – will be a viable option for most gas projects. While technology is being developed to geo-sequester a small portion of the emissions from the Gorgon project in WA's North-West, there are no indications that any other large gas projects will attempt to geo-sequester their emissions, nor has any government indicated it would make this a binding condition for approval.

Peer-reviewed published research has found that unconventional gas, such as shale gas, is far more greenhouse gas-polluting than conventional gas, oil and even coal.[64] This is alarming given the WA Government's *Strategic Energy Initiative 2031 Directions Paper* proposes to rely on shale gas to meet growing domestic gas demand, not to mention the strong community opposition to fracking.

We also need to be wary of the "*Transition Gas"* myth – which involves the claim that building, operating and maintaining *new* combined cycle gas plants is a cleaner option than using existing coal stations and replacing them incrementally with renewables over the next 10 years. The emissions intensity of such gas plants over 60 years (without taking into account massive upstream fugitive emissions that are left out of officially recognised accounting) is greater than 0.5 tonnes of CO2 per megawatt-hour electrical. So in the large scale shift to gas scenario being promoted, a 60 year gas plant will produce far greater than 240 million tonnes of CO2 in its life time. Whereas an existing fleet of 20th century coal plants that run for an average of 10 years before being replaced with renewables will produce just 60 million tonnes of CO2 (when phased-out over 10 years) - a saving of over 75 per cent[65].

The expanding WA natural gas industry – and the proposal to build 'transition' gas fired power stations is not clean and poses a major threat to Australia's emissions reduction targets.

61 Jaramillo et al, 2007. Comparative Life-Cycle Air Emissions of Coal, Domestic Natural Gas, LNG, and SNG for Electricity Generation; and ISA, The University of Sydney, 2006, Life-Cycle Energy Balance and Greenhouse Gas Emissions of Nuclear Energy in Australia.

62 For example, APPEA, 2010. The Environmental Performance of the CSG Industry fact sheet http://www.appea.com.au/images/stories/mb_files/CSG_environment.pdf);and Woodside, 2011. Benefits of LNG webpage at www.woodside.com.au/our-approach/climate-change/pages/benefits-of-lng.aspx

63 Source: Worley Parsons (2008, modified for public release March 2011) Greenhouse Gas Emissions Study of Australian LNG

64 Howarth, R. et al (2011) 'Methane and the greenhouse-gas footprint of natural gas from shale formations' in Climate Change http://www.springerlink.com/content/e384226wr4160653/

65 Wright, Matthew (2012) Gas: not a transition fuel, more a fossil fuel prison cell. Climate Spectator. At http://www.climatespectator.com.au/commentary/gas-not-transition-fuel-more-fossil-fuel-prison-cell

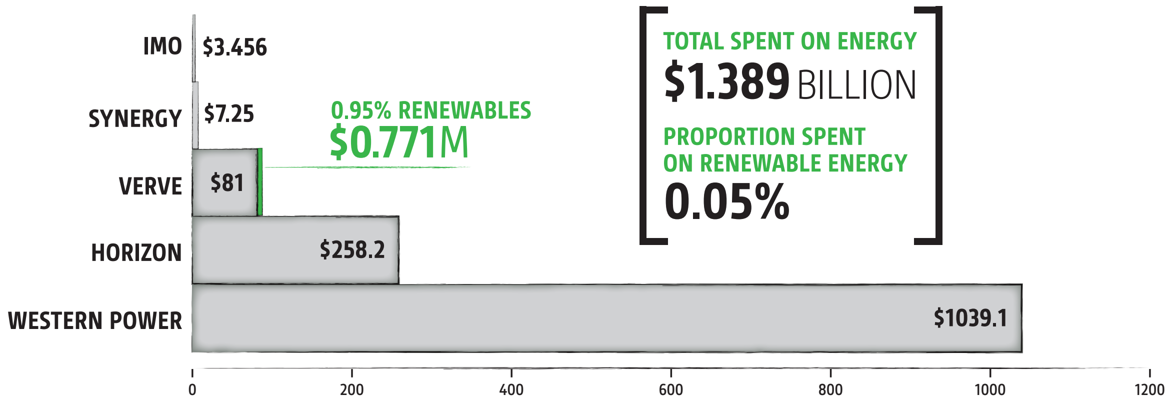
What is the cost of business as usual?

Spending in the Energy Portfolio

Each year the state government spends about $1 billion on energy infrastructure.

One of the biggest line item of government energy spending is the cost of maintaining, improving and expanding WA's electricity distribution network, operated by Western Power. In the 2012-13 budget Western Power spent $863m on 'poles and wires' alone, out of a total investment program for that year worth $1.039 billion[66]. The same budget allocated not one dollar towards specific renewable assets or infrastructure.

Figure 6 You get what you pay for: Total Energy Portfolio expenditure 2012-13

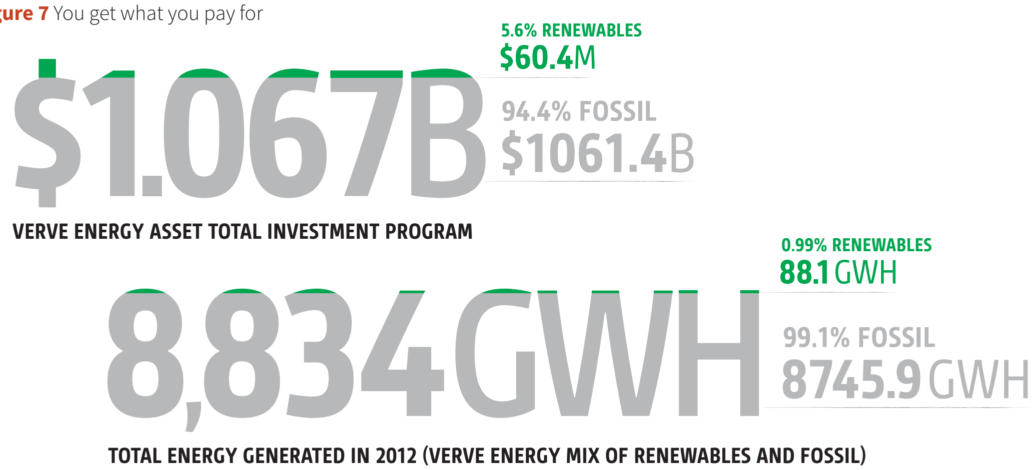


Over the three years between 2010- 2013 an astonishing **$3.8 billion** was allocated to supporting, maintaining, and upgrading our existing fossil-powered electricity assets[67] (See Appendix – Table 17 for full breakdown).

Of this, the total asset investment program for Verve Energy – WA's biggest electricity provider which supplies 60 per cent of electrical capacity on the SWIS – was worth $1.067 billion. Just $60.4 million (5.6%) was allocated to sustainable energy of this amount (Figure 7).

It's not surprising that at 2012 less than 1% of Verve's electricity generation was sourced from renewable energies[68] (Figure 7). Nothing is allocated in forward estimates from 2013-2016 for renewables[69].

Figure 7 You get what you pay for



Verve Energy Annual Report June 30 2012 p11-12 at http://www.parliament.wa.gov.au/publications/tabledpapers.nsf/displaypaper/3815402a1004757bb5d4f75a48257a8600094319/$file/5402.pdf

66 http://www.treasury.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2012_13/2012-13_budgetpaperno2_v2.pdf
67 Source: Office of Energy Budget Paper, 2010-2011 at http://www.dtf.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2010_11/00_part_11_0_energy.pdf
68 Figures from 2009 - 12 Verve Energy Annual Reports 2009-2010 p9; 2010-11 p11; 2011-12 p11-12
69 NOTE point 2 on page 53 of this report. The Warradarge wind farm to be built by Verve Energy between 2014 to 2020 at a cost of 600 million but not included in this budget. http://www.treasury.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2012_13/2012-13_budgetpaperno2_v2.pdf p597

Spending in the Office of State Development

The Office of State Development has an annual budget worth $80.9 million per year and 180 full time employees[70].

Many Western Australians would be unaware of the significant level of funding allocated in our state budget to assist the LNG and petroleum mining industries. For example, **$105.5 million** will be spent over the next four years just 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[71]. (Appendix Table 18).

Spending in the Department of Mines and Petroleum portfolios

The Mines and Petroleum Department has an annual budget of about $88 million per year, with 641 employees.[72]

Between 2010-2014 **$94 million** was allocated to assisting (mostly through regulation) the petroleum and uranium industries,[73] and another **$80m** over five years was allocated to the Exploration Incentive Scheme (EIS) in which the government literally co-funds miners' drilling costs of up to $200,000 for each exploration hole[74]. (Appendix, Table 19)

Spending in the Climate Change Unit

The future of the Climate Change Unit, Western Australia's key agency to address climate change and responsible for the 'whole of State Government coordination of policy and strategy regarding the economic, environmental and social impacts of climate change', is in peril under the Barnett Government.

Recently the Unit's operating budget was cut from an average of $8.8 million per annum to just **$620,000**, reducing the number of full time staff from 23 in 2009-10 to 4.8 in 2012-13.[75][76]

This brief section of budget analysis provides a clear and sobering illustration of where our government's vision and priorities lie.

70 Figures averaged over 2009/10 – 2013/14 budgets, at Government of Western Australia 2011-11 Budget Paper No 2 http://www.treasury.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2010_11/bp2_vol1.pdf p166

71 Source: 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

72 See 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

73 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

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

75 Government of Western Australia 2010-11 Budget Paper No.3 Part 17: Minister for Environment, Figures for 2010-2014 'Coordinate the Response to Climate Change' at http://www.treasury.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2010_11/bp2_vol3.pdf p818

76 http://walabor.org.au/news/2012/11/01/barnett-government-goes-cold-on-climate-change-unit

CHAPTER 3

Reducing our energy demand by 30-50%

The first step in the path toward 100% renewable energy is to reduce the amount of energy needed to provide goods and services.

Efficient energy use means meeting energy needs through increasing efficiency rather than increasing production. It is a largely untapped solution to a renewable powered future. Energy efficiency and renewable energy are considered twin pillars of a sustainable energy policy.

If business as usual continues in WA, we will see total demand for energy increase by 60% by 2029, with no energy efficiency target. Others put future growth in Western Australian energy demand even higher – largely due to the demands of the mining industry[77]. Our energy demand has already doubled over the past 20 years[78].

Western Australia's current energy demand and profile

Western Australia's current total energy demand is around 942 petajoules (PJ) a year (Appendix, Table 19). Of this, 55% (500PJ) is consumed in the form of gas, 13% (119PJ) is sourced from thermal coal, mainly for electricity generation, and 32% (305PJ) is consumed as oil and other petroleum products, largely for transport[79]. (Figure 9)

When we look at the demand for energy ***by sector*** (Figure 5) the biggest demand for energy comes from mining (23%) manufacturing (27%) and transport (21%) sectors. Electricity generation accounts for 26% (including 19% generation, plus 4% from residential and 3% commercial demand).

There are significant opportunities that must be taken to make deep cuts to total consumption in these three areas.

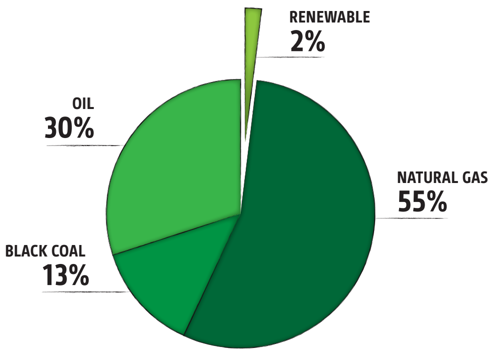


Figure 8 Western Australia's total energy consumption by fuel type (including electricity)

Source: Government of Western Australia, Office of Energy Energy 2031: Strategic Energy Initiative Directions Paper March 2011 at Figure 2 page 13 'Primary energy fuel mix in Western Australia 2007-2008' at http://www.energy.wa.gov.au/cproot/2410/2/Strategic%20Energy%20Initiative%20Directions%20Paper_web.pdf

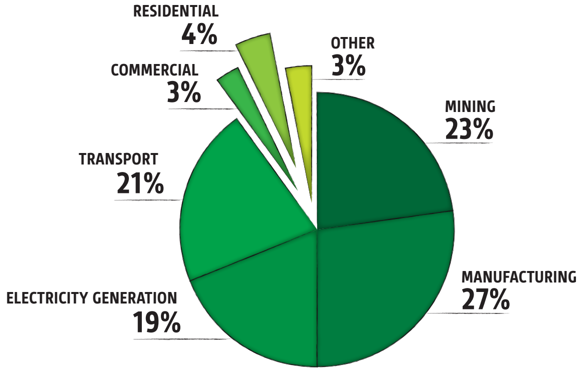


Figure 9 Western Australian primary energy demand by sector

Source: Government of Western Australia, Office of Energy Energy 2031: Strategic Energy Initiative Directions Paper March 2011 Figure 5 page 15 Western Australian primary energy demand by sector p15 (ABARE 2010 data) http://www.parliament.wa.gov.au/publications/tabledpapers.nsf/displaypaper/3813100cb1e5bc616f7914cc48257855000f71a1/$file/3100-15.03.11.pdf

77 For example, Western Australian Chamber of Minerals and Energy. 2011. 'WA State Growth Outlook 2011' http://cmewa.com.au/UserDir/CMEPublications/CME%20State%20Growth%20Outlook%202011%20-%20Full%20Report251.pdf

78 Australian Bureau of Agricultural and Resource Economics (ABARE) 2010. 'Australian energy projections to 2029-30, ABARE research report 10.02' (P28-30, http://www.abare.gov.au/publications_html/energy/energy_10/energy_proj.pdf)

79 ABARE 2008 – 2009 data (from P3 of 'Energy use in Western Australia' library brief); and ACIL Tasman 2010. 'Gas prices in Western Australia - Review of inputs to the WA Wholesale Energy Market', prepared for the Independent Market Operator (P5 of http://www.imowa.com.au/f2138,484255/484255_ACIL_Tasman_Final_Report_-_Updated.pdf

How can we achieve such an ambitious cut in current energy demand?

This Plan ambitiously aims to halve our overall energy demand. There are three 'untapped solutions' to make this possible:

1. **Phasing out natural gas and coal by switching to renewable sources. Energy 2029 proposes that the use of petroleum products, including oil, LPG, diesel and petrol can be greatly reduced by 2029 and eventually replaced altogether.**
2. **Reducing overall energy consumption in the three largest consuming sectors: Mining, Transport and Manufacturing.**
3. **Cutting our electricity demand by at least one third through Energy Efficiency. Energy efficiency is the most important and cost-effective option to reduce energy demand.**

STEP ONE
Phasing out demand for natural gas and coal almost entirely by switching fuels

Phase out natural gas in the domestic energy mix and replace it with renewable gas

Gas is by far Western Australia's biggest energy source currently and the Western Australian Government envisages even greater reliance on it in the future. It currently accounts for 53% of our total energy consumed. Under ***Energy 2029,*** natural gas is almost entirely replaced by 2029 with more efficient electrical systems powered by renewable energy including biogas, direct use geothermal and solar for heating, cooling, and water heating and industrial processes.

Phase out thermal coal

Black coal accounts for 13% of total energy consumed in WA. Almost all (86%) of this is used to produce electricity. By eliminating the use of coal in WA by 2029 we will also make significant energy savings through avoiding energy losses from the coal-fired power generation industry. About 2/3 of the fuel energy that is currently lost due to the relative inefficiency of thermal coal generation and high transmission losses from the centralized grid will be virtually eliminated by the proposed decentralized renewable energy grid. This includes about 0.23 gigajoules (GJ) of onsite energy per tonne of coal mined; this alone accounts for 28PJ a year being saved.[80] Significant savings will also result from the greater efficiency of dispersed renewable generation compared to current grid, which is only about 33% efficient. 66% of energy used in the existing centralized natural gas and coal fired electricity grid is lost as waste heat and transmission losses.

STEP TWO
Dramatically reducing energy consumption in the three largest consuming sectors

There are three steps that must be taken to dramatically reduce fossil fuel consumption across the three biggest users.

Manufacturing and Industrial processes

Manufacturing processes, including industrial processes that produce petroleum and coal product manufacturing, and the manufacturing of some metal and mineral based products account for 27% of our overall energy demand, the majority of it from natural gas and petroleum products.

Coal, gas and petroleum products currently used for high-temperature heat and steam and electricity in major industrial plants could be largely replaced by 2029 through a combination of fuel-switching to renewable-sourced electricity and steam or heat sourced via co-generation. Where methane is used as a feed stock for the production of chemicals such as methanol and ammonia-based fertilizer, biogas could be used instead.[81]

This was demonstrated in the Zero Carbon Australia 2020 Stationary Energy Plan, where coal, coal-fired electricity and gas currently used to power Queensland's Gladstone Alumina Refinery can be

80 Beyond Zero Emissions, 2010. Zero Carbon Australia Stationary Energy Plan 2020 P70. http://beyondzeroemissions.org/zero-carbon-australia-2020P133.
81 Beyond Zero Emissions, 2010. Zero Carbon Australia Stationary Energy Plan 2020 P70. http://beyondzeroemissions.org/zero-carbon-australia-2020P70

replaced with four 220MW solar thermal plants modified to include back pressure turbines meeting all of the plant's steam requirements and 61% of its electricity requirements, plus one additional unmodified 220MW solar thermal plant to meet the remainder of its electricity needs.[82] Most remarkably, this case study demonstrated an eight year payback time, by which time the operators would have repaid their initial investment, eliminated all future fuel costs at the refinery and added a valuable solar energy asset to their portfolio.

Mining

The Mining sector is a huge consumer of energy, and uses almost a quarter (23%) of the total energy consumed in Western Australia. Most of the energy it consumes (77%) is in the form of natural gas and the volume (162 petajoules) represents almost a third of all natural gas consumed in the state. The rest is mostly petroleum (42 petajoules) - representing 14% of the total consumed in the state.

By 2029 we could see improvements in the processes and transport systems used in mining and industry to reduce energy intensity by at least 20%. This could be achieved through:

- **Renewable remote generators;**
- **Electrictrification / use of biodiesel in transport; and**
- **Introduce laws preventing fugitive emissions / losses from gas flaring; which could prevent up to 10% of natural gas extracted being lost every year to flaring.**

Transport

Our transport sector accounts for 21% of the total energy demand in the state and 63% of demand for petroleum products.

Switching our transport task to an electric system, powered by renewable energy, represents one of the most significant reductions we could make in our overall energy demand. In fact a significant and major portion of the task to halve our overall energy demand will be achieved by electrification of our transport systems.

Demand side incentives and disincentives would be implemented to achieve this, such as cheaper public transport, increased fuel taxes, and accident insurance levied on fuel and vehicle efficiency standards.

By 2029 we propose:

- **Inefficient and polluting petrol, diesel and gas internal combustion engines used in automotives would be substantially replaced by electric vehicles, and 'plug in' biofuelled hybrid electric vehicles.**
- **Natural gas used in transport is replaced. This would mean that the target of 203PJ/year of oil and gas based fuels currently used for transport in Western Australia could be more than halved, and replaced with a more efficient use of transport and electricification of the fleet, sourced from renewable energy and the use of biofuels.**
- **Electrification of our public transport systems – switching our buses to energy-efficient electric vehicles (EEEVs). Electric vehicles are 3–5 times more efficient than internal combustion engine (ICE) vehicles, whether fueled by gasoline, compressed natural gas (CNG), or liquefied petroleum gas (LPG).[83]**
- **Electrification of some of our rail freight network. Electric trains don't require heavy diesel engines or fuel loads as energy is supplied through overhead cables and are therefore faster and more efficient. Travel times on the 250 kilometre London to Swansea line was reduced by 19 minutes once electrified compared to the previous network.[84]**
- **A combination of electrified heavy and light rail, electric buses, as well as cycling, car pooling and walking trips could more than double to over 50% of all trips.**

The implication of electrification of our transport system means the overall demand for electricity will increase while the demand for liquid energy is reduced. Accelerated installation of renewable electricity generation will be required to power the increasing fleet of electric vehicles.

82 Beyond Zero Emissions, 2010. Zero Carbon Australia Stationary Energy Plan 2020 P70. http://beyondzeroemissions.org/zero-carbon-australia-2020 P72.

83 The Government of the Philippines (2012) Clean Technology Fund Country Investment Plan. July 2012. At http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/Philippines%20Revised%20CTF%20Investment%20Plan_July%202012%20(without%20highlights).pdf

84 Rail Express (2012) "South Australia: a 'missed opportunity'". Jun 20, 2012 at http://www.railexpress.com.au/archive/2012/june/june-20-2012/top-stories/south-australia-a-2018missed-opportunity2019

STEP THREE
Cutting our electricity demand by at least one third through Energy Efficiency

The untapped role energy efficiency and energy conservation can play.

The first part of the path toward 100% renewable energy is to reduce the amount of energy needed to provide goods and services. Energy efficiency and energy conservation are one of the biggest untapped energy sources – and considered twin pillars of a sustainable energy policy.

Energy efficiency means we can meet our energy needs through increasing efficiency rather than increasing production. Energy efficiency simply means using less energy to provide the same service or achieve the same result. It is a largely untapped solution to a renewably powered future.

Under business as usual our demand for energy will increase by 60% by 2029[85], with no energy efficiency target.

The economic case should be motivation enough: the price of all finite energy fuels will continue to rise. The price of electricity in WA has risen by 57% in just the last three years to 2012, and petrol prices have reached record highs.

Energy 2029 proposes deep cuts to our energy use through significant increases in energy efficiency and energy conservation. We propose 20-50% cuts can be achieved, which would mean a reduction of about 470 petajoules by 2029.

How can we achieve such an ambitious cut in current energy demand?

85 ABARE 2010. 'Australian energy projections to 2029-30, ABARE research report 10.02' (P28-30, http://www.abare.gov.au/publications_html/energy/energy_10/energy_proj.pdf)

Energy Efficiency

The foundation of the new energy economy rests only in part on renewable energy sources. Of equal importance is the need for a major investment in energy efficiency through every sector of society.

In 2010 the Prime Minister's Task Group on Energy Efficiency noted[86] :

"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[87]."

The Task Group recommended Australia adopt an aspirational target of 30% improvement in energy intensity (defined as the quantity of energy used per unit of economic output produced) between 2010 and 2020.

The Government's response was to "note" the recommendation and its finding that there are opportunities for Australia nationally to significantly improve its energy efficiency by up to 30 per cent over the coming decade, "but does not support proceeding, at this time, with an aspirational national target.[88]

Consistent with the Barnett Government's approach to energy issues generally, Western Australia has no energy efficiency target.

"The worst energy efficiency program you can come up with, the least cost-effective, will still be a cheaper way to abate [emissions] than the best renewable energy program."

Dr George Wilkenfeld,
Australian energy and planning policy consultant

This remarkable policy paralysis falls short of strong commitments made by other nations which have already introduced binding energy intensity reduction targets. This includes:

- **China** - **20% improvement in energy intensity below 2005 levels by 2010;**
- **Russia** - **40% improvement in energy intensity below 2007 levels by 2020;**
- **France** - **2% energy intensity improvement per year to 2015;**
- **Germany** - **9% reduction on 2007 total energy consumption by 2016 (equal to 933PJ – almost as much our total yearly energy consumption); and**
- **UK** - **9% reduction on 2007 total energy consumption by 2016.[89]**

86 Australian Government 2010. 'Report of the Prime Minister's Task Group on Energy Efficiency' (P25 and 27 of http://www.climatechange.gov.au/~/media/submissions/pm-taskforce/report-prime-minister-task-group-energy-efficiency.pdf)

87 Australian Government 2010. 'Report of the Prime Minister's Task Group on Energy Efficiency' (P25 and 27 of http://www.climatechange.gov.au/~/media/submissions/pm-taskforce/report-prime-minister-task-group-energy-efficiency.pdf) P1

88 Securing a Clean Energy Future: Chapter 8 – Improving energy efficiency. Response to the report of the Prime Minister's Task Group on Energy Efficiency at http://www.cleanenergyfuture.gov.au/clean-energy-future/securing-a-clean-energy-future/#content09

89 Ibid (P217)

A number of studies have shown it is possible to at least cut our energy demand in half through energy efficiency. These include:

- **Beyond Zero Emissions' *Zero Carbon Australia 2020 Stationary Energy Plan*[90] showed a broad range of efficiency improvements, such as insulation, upgraded appliances, and improved industrial processes can reduce total end-use energy by 20–30%.[91] It also argued we can go much further than even these targets listed above and cut our national energy consumption by half by 2020.**
- **The 11th German Parliament's Commission on Protecting the Earth's Atmosphere found energy savings of 35-40% are feasible.[92]**
- **The WA Government commissioned energy efficiency study by Insight Economics and Energetics (2006) detailed the potentials for energy efficiency in Western Australia, with particular emphasis on the energy intensive mining and mineral processing sectors. These reports examined a range of scenarios, based on measures with payback periods between 2 years and 6 years (equating to real internal rates of return between 50% and 16% respectively), and potential carbon prices ranging from $0 per tonne to $40 per tonne.[93]**
- **Sustainable Energy Now (2011) "Renewable Energy Scenarios for Western Australia" models 20-30% energy efficiency.[94]**
- **Freiburg's Institute of Applied Ecology (1980) 'Energiewende' (Energy Transition) scenario for the transition to a solar future concluded we can reduce our primary energy consumption by nearly 50% over a number of fields over the next 40-50 years and continue to improve our standard of living.**
- **The new report to the Club of Rome *'Factor Four: Doubling wealth, Halving Resource Use'* demonstrates how living standards could be doubled as energy consumption is cut in half.[95]**

Case Study

Perth's Western Power Energy Efficiency Program

As part of the Perth Solar City program, Western Power ran a series of energy efficiency trials that showed that even with no cost to the householder electricity bills can be easily reduced by nearly 10%.

Schools that had access to real time energy use information (rather than a bill every 60 days) saved up to 54% on their energy costs by better understanding and changing how they used energy. The seven schools that participated in the school's

Energy Efficiency: the practical reality

Households can improve energy efficiency in a variety of ways.

Up to 80% of the energy used for lighting can be saved by using more efficient technologies, and high efficiency LED lighting has the potential to save up to 90%. Heating water accounts for about a quarter of total energy but can be reduced with a more efficient hot water system or using water efficiently. Space heating and cooling makes up around 38 per cent of the average household's energy use, and can be reduced with insulation and draught-proofing the home. Appliances can account for up to 30 per cent of home energy use. Smarter appliances have improved the energy efficiency and have successfully removed the most inefficient appliances and equipment from the market.

Buildings currently account for 20% of energy use, one third of which could be easily reduced for low or zero cost, according to the 2008 Garnaut Report[96].

90 Beyond Zero Emissions 2010. 'Zero Carbon Australia Stationary Energy Plan 2020' (P14); Western Australian Office of Energy 2011. 'Strategic Energy Initiative Directions Paper' (P16) http://www.energy.wa.gov.au/0/3312/3312/strategic_energy_initiative.pm
91 Beyond Zero Emissions 2010. 'Zero Carbon Australia Stationary Energy Plan 2020' P15.
92 Ref 22 chpt 1 Seifried and Witzel 2010 p28
93 Energetics (2006) Energy efficiency potential in Western Australia - Report prepared for the WA Department of the Environment
94 Sustainable Energy Now (2011) Renewable Energy Scenarios for Western Australia – A discussion paper. At www.sen.asn.au
95 Ref 23 chapt 1 Seifried and Witzel 2010 p28

96 http://www.garnautreview.org.au/index.htm

project saved a total of $16,000 off their power bills in seven weeks.

Households were able to save 8.5% on their power bill by very simple cost free actions like turning off lights and appliances when not in use. Households that invested in solar energy reduced their power bills by 58%.

The benefits are summarised here:

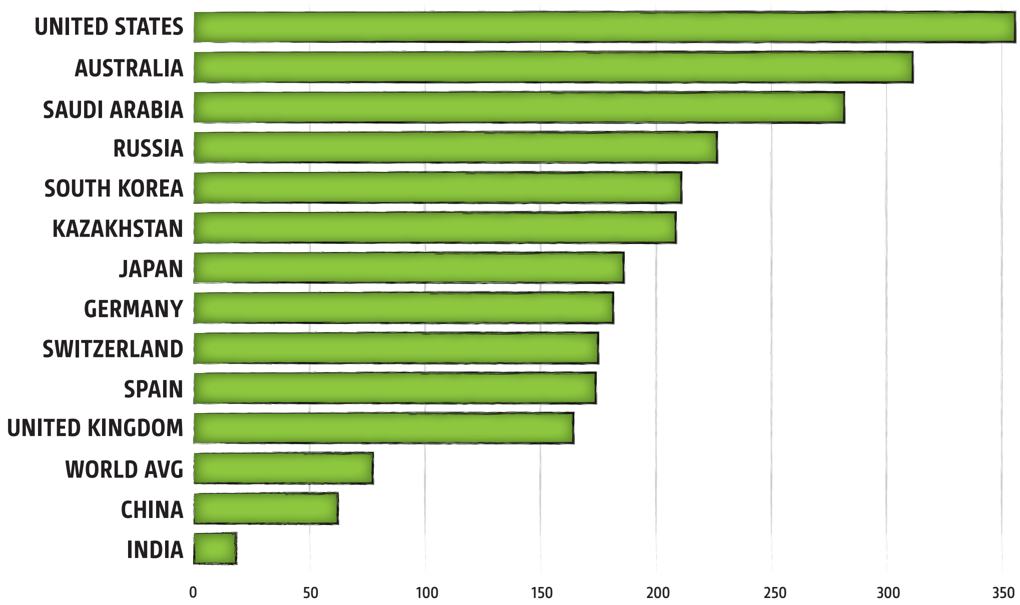
Program	Outcome
In Home / In School Displays	Early evidence showed that access to real time energy use data assisted in reducing electricity use by residential in-home display users (6.82%), and schools (54%)
Demand Management (Air-Conditioner Trial)	20% reduction in electricity use at peak time during year one
Time-of-Use Tariff (PowerShift)	11% reduction in electricity use during the 'super peak' period
Residential solar PV systems	58% reduction in average daily electricity use (from the grid), or 11.36 kWh per day
Residential solar hot water systems	15% reduction in average daily electricity use
Behaviour change (Living Smart)	8.5% reduction in average daily electricity use

Retrofitting of buildings and applying more rigorous building performance standards. The Building Code of Australia was also recently changed to include minimum energy efficiency standards for all classes of commercial building in Australia. This standard will eliminate poor energy performance in new buildings and major refurbishments.

How other countries are tackling energy efficiency

Many other developed economies already use only half to two-thirds of our per capita energy consumption**.** This is demonstrated by Figure 4, below.

Figure 10 International comparison of per capita primary energy consumption in gigajoules, 2007



Source: Beyond Zero Emissions Zero Carbon Australia Stationary Energy Plan Fig 2.8 from p14 of ZCA 2020 at http://beyondzeroemissions.org/zero-carbon-australia-2020

Average Western Australian household electricity consumption has risen sharply since the mid-1990s, driven by increased use of reverse cycle air conditioners and standby power.[97] Western Australia's population is also projected to grow from 2.2 million people to around 2.8 million by 2029, and to 4.9 million by 2050[98]. To achieve greater energy efficiency we are going to need to adopt ways to reduce the amount of energy we each use in order to stop Western Australia's energy demand growing out of control.

California

California was among the first regions anywhere to introduce large-scale energy-efficiency programs and has made reform to its energy program over the last 35 years. It is also able to demonstrate the rule of thumb where for every $1 billion spent on efficiency measures, from upgrading lighting to improving building insulation, $2 billion is saved. By moderating consumer behaviour on peak-load days, California avoided building expensive gas-fired peaking power stations that would have been used for fewer than 50 hours a year. The release of smart meters was not necessary for many of the reforms. Instead 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[99].

Germany

Over five years Germany has committed to reducing almost as much of its annual energy use (933 PJ/year) as Western Australia uses in an entire year (945 PJ/year) – through energy efficiency alone. Compared to this effort, halving our overall energy use by around 470PJ over the next 18 years to 2029 seems entirely achievable and far less ambitious.

Germany and Australia have similar per capita gross domestic product, and have a comparable modern economy with metal refining industries, including five aluminum smelters and car manufacturing. However, Germans currently use about 36% less end-use delivered electricity than Australians (7.2MWh of electricity per capita is used annually in Germany compared to 11.2MWh per capita in Australia).[100]

Germany plans to improve its use of energy still further, through the implementation of a National Energy Efficiency Action Plan which includes such measures as:

- **Rapid rollout of smart metering;**
- **Increased investment in energy efficiency for public buildings;**
- **New guidelines emphasising energy efficiency in government procurement processes;**
- **Long-term, low-interest loans for retrofitting of old residential buildings;**
- **Subsidies for new low energy houses;**
- **Employment of 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.**

Conclusion

These steps outlined in this chapter to reduce Western Australia's total energy demand by up to half will see an increase in our total electricity demand but a major decrease in the State's overall energy demand.

The alternative – a high-energy demand, high-fossil fuel business-as-usual scenario favoured by the current Western Australian Government will significantly increase our per capita contribution to global greenhouse gas emissions, while leaving us stranded in the near future with obsolete fossil fuel infrastructure. Our energy costs will increase while other countries enjoy the benefits of greater energy efficiency and established local renewable energy industries.

97 Western Australian Office of Energy 2011. 'Strategic Energy Initiative 20131 Directions Paper' P12.
98 WA Department of Transport (2012) Western Australian Bicycle Network Plan 2012 – 2021 Draft for consultation
99 http://www.smh.com.au/business/carbon-economy/californian-lessons-for-australias-energy-plans-20121204-2asuf.html#ixzz2EdnzFMjY
100 Beyond Zero Emissions 2010. 'Zero Carbon Australia Stationary Energy Plan 2020' P15.

PART 2
Types of Renewable Energy

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

Technologies assessed are:

1. **Concentrating Solar Thermal (CST)**
2. **Solar Photovoltaic (PV)**
3. **Wind Energy**
4. **Wave Energy**
5. **Geothermal Energy**
6. **Bioenergy**

CHAPTER 4

Solar Energy

On average, Western Australia receives 8–10 hours of sunshine daily, making it one of the sunniest places in the world.

Germany receives just half our sunshine, yet as of 2010, had more than 50 times Australia's installed solar electricity capacity.[101] The north-west's proximity to the equator is one factor explaining our extraordinary solar resource.

Under Beyond Zero Emissions' costed proposal, up to 60% of Australia's electricity needs by could be met using solar technology by 2020.

Many people think of rooftop solar panels when they think of solar energy, yet the sun's power can also be harnessed for large-scale, 'better than baseload' energy generation. The world's biggest existing solar energy farms 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 energy technologies generate electricity using energy from the sun. There are two main types:

- **Concentrating solar thermal (CST) energy systems – 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 – convert solar energy directly into electricity by producing an electric current when exposed to sunlight.**

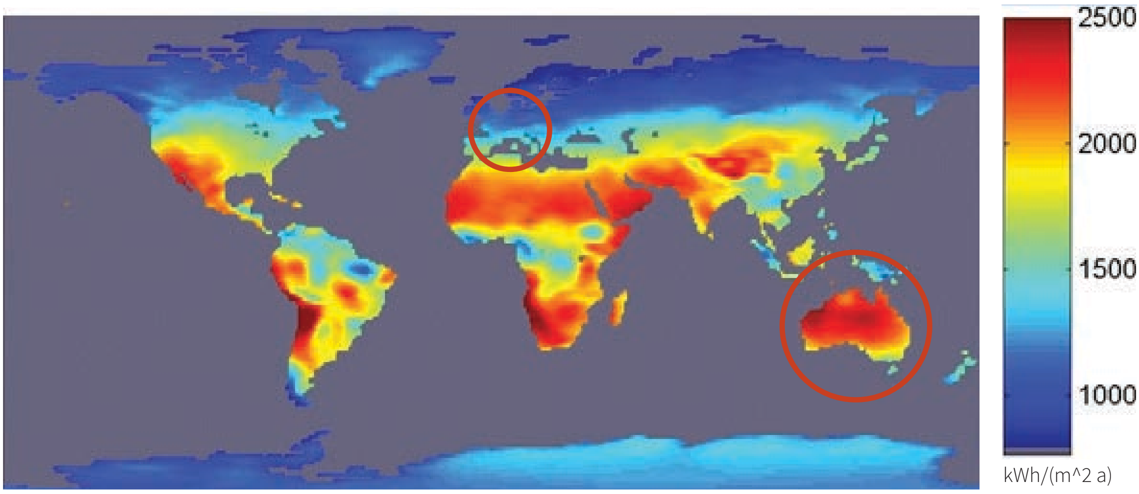


Figure 11 World solar resources. Solar irradiance comparing Germany v. Australia

Adapted from Dr Volker Oschmann (2010) Going Renewable: Germany's Energy Future. Presentation to Sustainable Energy Now –June 14th 2010 Slide 4 of presentation, at http://sen.asn.au/images/pages/presentations/Oschmann/SEN_OschmannSlides_June14.pdf At http://www.iset.uni-kassel.de/abt/w3-w/folien/Solarenergie/global_horizontal_strahlung83-92_b.jpg

101 Germany had 17GW installed capacity of solar PV by 2010 (source: http://www.reuters.com/article/2011/02/24/germany-solar-idUSLDE71N2KG20110224) compared to Australia's 300MW (http://www.cleanenergycouncil.org.au/cec/technologies/solarpv.html)

Senator Scott Ludlam at 19mW Gemasolar CST Plant, Andalucia, Spain (Photograph by Santiago Arias, Torresol, December 2012)

4.1 Concentrating Solar Thermal (CST)

Developed in the 1970s, solar thermal technology uses mirrors or lenses to concentrate sunlight onto a single point or receiver, use a heat transfer fluid (usually water, molten salt or oil) to transfer the energy to a central power system to make steam for powering an electrical generator.

Typical CST plants use standard steam turbines and often integrate thermal energy storage[102]. Stored solar thermal energy (heat) can continue to be used to run a turbine and generate electricity many hours after the sun has gone down or during extended cloudy periods. This was first developed at a commercial scale at the Andasol and Torresol plants in Spain and is now being deployed around the world.

There are currently 61 CST plants in operation around the world, with another 22 under construction at commercial scale between 14-370MW[103], and a further 16 under development with signed agreements but construction pending (see Appendix for full list).

A 2012 report commissioned by the Australian Solar Institute (ASI) found concentrating solar power could provide about 30 per cent of Australia's total current electricity generation capacity with only modest extensions to the national electricity grid, if forecast cost reductions are achieved. The report also found there is a significant cost-revenue gap that is deterring investment in the technology that can be closed over the next decade with concerted policy responses. Australian CST deployment could realistically reach 2,000 megawatts by 2020. By then around 4,000 people would be employed in construction and ongoing operations, with the majority of these jobs in regional areas[104].

The report also found:

- **CST is proven and available – global installed capacity has grown by 40% annually since 2005 and is predicted to reach 2GW in 2013, led by Spain and the US;**
- **Australia has just over 50GW in electricity capacity – it would be technically feasible to add up to 15GW of CST capacity with only modest grid extensions;**
- **Adding 10GW CST capacity would reduce Australia's carbon emissions by roughly 30Mt per year - about 15% of current electricity sector emissions;**
- **Hybrid systems within existing fossil fuel plants, and smaller plants for off-grid mines and towns are important near term applications;**
- **Future 'nation building' grid extensions will unlock more of our world leading solar resource; and**
- **Every 100MW system creates at least 500 jobs during construction, 38 permanent jobs during operation and a further 56 indirect permanent jobs – mostly in regional areas.[105]**

102 Australian Solar Institute (2012) Realising the Potential of Concentrating Solar Power in Australia – Summary for Stakeholders. p8.
103 National Renewable Energy Laboratory - Concentrating Solar Power Projects http://www.nrel.gov/csp/solarpaces/
104 The Australian Solar Institute is a $150 million commitment by the Australian Government to support the development of photovoltaic and concentrating solar power technologies in Australia. 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
105 Stoddard, Abiecunas, O'Connell (2006). Economic, Energy, and Environmental Benefits of Concentrating Solar Power in California. Black & Veatch Overland Park, Kansas, April 2006; and ASI (2012) Summary for Stakeholders. p4

Table 3 Types of solar thermal technologies currently in use

CSP TECHNOLOGY		EXAMPLES
	**Heliostat tower** An array or field of heliostats (flat mirrors which track the sun) concentrate solar radiation onto a central receiver at the top of a tower. The heat is transferred via water or molten salt, generating steam to drive a turbine. 60 MWe installed at 2011	**Operating:** The Andasol 1 and Andasol 2 solar thermal power plants in Andalucía, Spain, are two 50MW-capacity facilities built in 2008 and 2009. Each consists of a 510,000sq m field of solar collectors, a heliostat tower and 28,500 tons of molten salt storage. The salt storage enables the plants' steam turbines to operate for up to 7.5 hours after dark.[106 107] **Planned:** Brightsource Energy is building Ivanpah, a 392MW-cpacity, utility-scale solar thermal plant consisting of three heliostat towers on 15sqkm in south-eastern California. Expected to begin operations in 2014, Ivanpah will nearly double the USA's solar thermal electricity capacity.[108]
	**Parabolic trough** Parabolic mirrors reflect the sun onto a receiver tube, which runs parallel to the mirrors and contains a fluid such as oil, used to heat water and make steam. The most mature and common CST technology, with 1400 MWe installed by 2011.	**Operating:** Solar Energy Generating System (SEGS) are nine solar thermal plants in the Mojave Desert, California, with the first built in 1985. Consisting of more than 900,000 mirrors spread over a 6.5sq km area, the plants have a total installed capacity of 354MW. At a capacity factor of 21%, the plants produce an average 75MW – enough electricity to power 232,500 homes from the sun.[109] **Planned:** Solar Millennium AG is seeking approval for two, 250MW-capacity solar thermal plants using parabolic troughs in Nevada and California.[110]
	**Linear Fresnel Reflector** Long rows of flat or curved mirrors track the sun and reflect energy to fixed linear receivers running above or parallel to the mirrors and contains a fluid such as water or oil. 38MW installed at 2011	**Operating:** 5MW Kimberlina plant in California, Liddell Power Station in New South Wales, a 3MW-capacity plant which displaces a small amount of the power station's coal consumption. **Planned:** Midwest Energy developed a proposal for two LFR plants of 100MW capacity each at Perenjori in WA. The company predicts it would take one year for planning and two to three years for construction and commissioning for the plants to become operational.
	**Dish concentrators** Parabolic mirrors are placed into a dish and track the sun, forcing sunlight onto a receiver, creating intense heat that can be used to create steam. 6MW installed at 2011	**Planned:** Wizard Power is building a 40MW-capacity plant at Whyalla, South Australia using 300 of its 'Big Dish' concentrators.[111] The plant will provide peaking power in the day and early evening when electricity is most in demand.

106 http://spectrum.ieee.org/energy/environment/largest-solar-thermal-storage-plant-to-start-up
107 http://www.nrel.gov/csp/solarpaces/project_detail.cfm/projectID=4
108 http://ivanpahsolar.com/about
109 www.NextEraEnergyResources.com
110 http://www.solarmillennium.de/press/press-releases/2010_11_16-news.html
111 Wizard Power, 2011. http://www.wizardpower.com.au

"It's estimated that all electricity demand on the SWIS could be supplied by just 200 sq km (14 km x 14km) of solar thermal collectors in sunny, clear sky areas".

Sustainable Energy Now, 2011 p5

Sustainable Energy Now has calculated that the entire demand on WA's main electricity grid, the South-West Interconnected System (SWIS), could be met by building just 200sq km (14km by 14km) of CSP collectors with storage, situated in sunny, clear-sky areas.[112] This is backed by a report by Next Energy which 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.[113]

SunLab, a US Department of Energy partnership between Sandia Laboratories and the US National Renewable Energy Laboratory, has completed publicly reviewed engineering designs and costings for 13.5, 50, 100, 200 and 220MW power towers with 17 hours molten storage.[114] This research, along with projects in planning or construction phases by Torresol Energy and Solar Reserve, provided the basis for Beyond Zero Emissions' study.

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.

In order to provide output with the kind of reliability expected of baseload plants, the BZE study proposes to install biomass co-firing units at some of the of the CST power blocks. These would only be used to augment output on rare occasions of 2-3 day simultaneous solar and wind 'droughts' across the whole extent of the grid.

"To completely ensure energy security under the plan, a system of biomass co-firing of the CST plants is incorporated, utilising only waste biomass. The proposed system is to incorporate a biomass thermal heater alongside the molten salt tanks at the actual CST sites. Biomass is burnt, and the energy used to heat the molten salt reservoirs, so that the existing steam power cycle, turbine and transmission can be utilised. This means the only extra expenditure is for the biomass heater, minimising the extra cost of the backup system."[115]

112 Sustainable Energy Now (2011) Renewable Energy Scenarios for Western Australia – A discussion paper. At www.sen.asn.au. They note this has the caveat that it would be based on a mix of renewable energy sources to cover for cloud cover over numerous days, windless days, and so on.

113 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

114 Beyond Zero Emissions, 2010. Zero Carbon Australia Stationary Energy Plan P46-47 http://beyondzeroemissions.org/zero-carbon-australia-2020

115 "Zero Carbon Australia Stationary Energy Plan" The University of Melbourne Energy Research Institute Beyond Zero Emissions P68 http://media.beyondzeroemissions.org/ZCA2020_Stationary_Energy_Report_v1.pdf

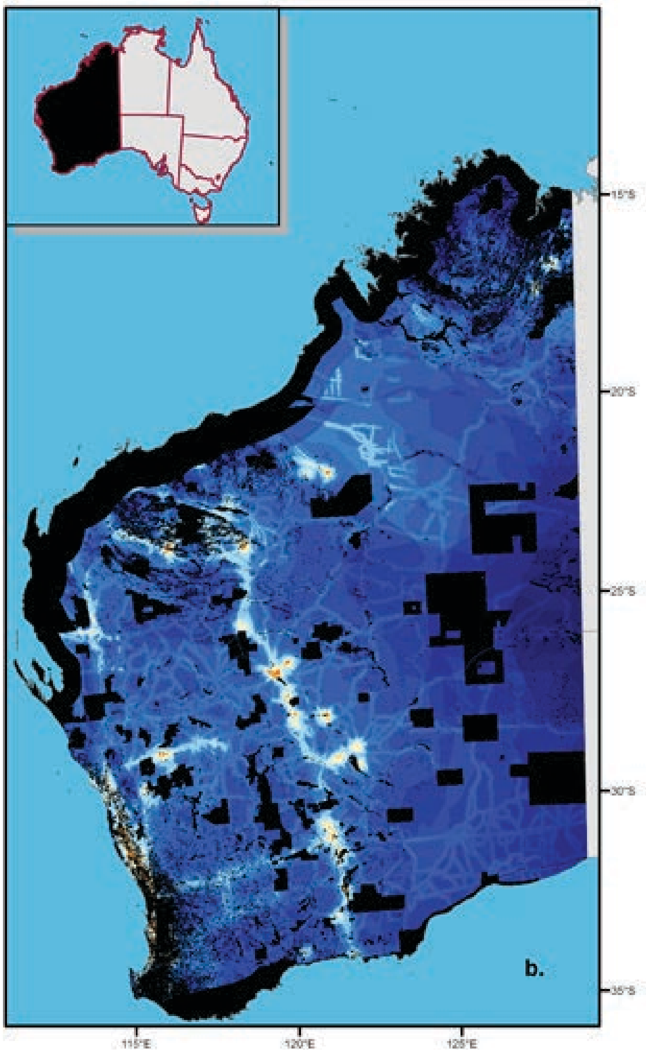
Where would we build it?

A 2012 study[116] into the potential for CST plants in Western Australia provides valuable guidance as to the most prospective areas for large-scale solar thermal installations, while giving order-of-magnitude estimates of technical production potential.

The study considered seven climate and terrain variables in a subtractive model and identified that 1.78 million km^2 of Western Australia is "technically suitable" for CST – or a full 70% of the land mass of WA.

In calculating 'technical suitability', the study's authors had regard to the following criteria:

- **Direct normal irradiation (DNI values) ≥2000 kW h/m^2/year;**
- **Ground slope ≤2.1%;**
- **Located on land free from all conservation management and geo-heritage protection measures;**
- **Not located in high wind load risk zones;**
- **Not classed as water bodies or wetlands, regardless of ephemerality;**
- **Not located in built-up residential/commercial/industrial areas; and**
- **Not classified as land use type associated with potentially high socio-economic opportunity cost.**



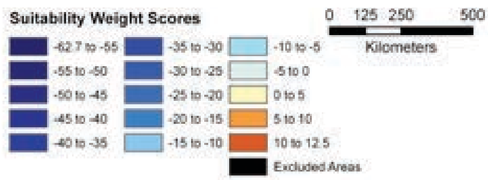


Figure 12 Strategic site suitability for CST in WA, with areas shown in yellow and orange considered suitable for the current and near term. Dawson and Schlyter, Energy Policy 47, 2012.

Image source: Dawson, L and Schlyter, P. (2012) "Less is more: Strategic scale site suitability for concentrated solar thermal power in Western Australia Energy Policy". Energy Policy. Volume 47, August 2012, Pages 91–101. At http://www.sciencedirect.com/science/article/pii/S0301421512003254

116 Lucas Dawson and Peter Schlyter 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

If put into production under utility-scale parabolic trough CST plants, the theoretical output of 908,000 tW h/year would be fifty times greater than that required to power the entire industrialised world.

Such abstractions make great headlines but are not of great practical use. The study then goes on to overlay existing grid infrastructure and off-grid load, proximity to backup fuels an roads, as well as a number of other variables, to arrive at a more modest estimate of 'actual site suitability'.

The study finds:

"The total area showing medium to very high suitability within the near-term is only 11,273 km^2, or around 0.6% of the area identified as technically suitable..."

Even this greatly reduced land area (see figure 12) if dedicated to CST electricity production would be capable of powering one third of the planet's electricity demand.

The study however is not arguing 11,000km^2 should be covered in reflective glass, rather it demonstrates both the extraordinary potential of the technology and points in the direction of the most prospective regions. It appears the study did not take into account Aboriginal heritage sites which are extremely poorly documented under state and federal heritage 'protection' legislation, so the maps should be considered indicative only.

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 competitive bid for funding under the Federal Government's Solar Flagships program. Unfortunately, no Solar Flagships money was allocated to WA, but the area remains under study. In October 2012 Solastor, in consortium with Carbon Reduction Ventures, announced the development of a 1.5MW grid-connected concentrated thermal power station near Morawa, east of Geraldton. The project 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.

Greens Proposed Goldfields CST solar field (model by Scott Ludlam)

Kalgoorlie

The Beyond Zero Emissions study identified Kalgoorlie, which is connected to the SWIS and receives abundant sunshine, as a possible location for major concentrated solar power generation hubs.[117] In Kalgoorlie, the Goldfields Renewable Energy Lobby has strong local industry, business and government support and is working hard towards this outcome.

The Pilbara

In 2008, Australia's biggest engineering firm, WorleyParsons, backed by firms such as Woodside Petroleum Ltd and Fortescue Metals Group Ltd, proposed construction of up to 34, 250MW CSP plants in the Pilbara and elsewhere in Australia. While insufficient investment interest prevented the project from proceeding, the fact that WorleyParsons considered it feasible confirms that the obstacles are political and economic rather than technical.

The Coastal Pilbara, Kimberley and Gascoyne Regions are largely excluded from consideration due to the frequency of cyclones.

The conclusions of the 2012 study into CST prospectivity in Western Australia could not be more relevant to the central Pilbara, where proposals for grid

117 Beyond Zero Emissions, 2011. Zero Carbon Australia Stationary Energy Plan. P46 http://beyondzeroemissions.org/zero-carbon-australia-2020

extensions have been hamstrung for years through the fragmented nature of infrastructure provision by competing iron ore companies:

"The availability of infrastructure is critical to site suitability and the introduction of new major loads and infrastructure in currently under-developed regions is likely to open up further areas with medium to very high suitability"

How much does CST Cost?

Enough historical operational data now exists to offer confident estimates of the present-day construction and operating costs of large-scale CST plants with thermal storage, and to provide a direct comparison with revenues likely to be achievable on the SWIS.

Less can be said with precision about the future costs of this technology, which are subject to unavoidable chicken-and-egg scenarios in that costs will fall rapidly if global deployment continues at the present rapid pace, but that pace itself depends in part on the speed with which costs fall. Added to this mix will be the inevitable backlash by existing energy incumbents as they seek to protect their investments from being swiftly out-competed by large-scale solar plants with effectively zero fuel costs.

The evidence leans strongly toward the capital costs of CST falling by 50% within a decade if present annual growth rates of 40% are maintained. As costs fall, the other key variable of prevailing energy prices comes into play. Energy prices are rising rapidly in Western Australia as the State Government attempts to compensate for more than a decade in which electricity was sold at far below the cost of generation. Western Australia is also uniquely vulnerable to rising gas prices, as we have a far higher proportion of gas generation on the grid than the eastern states and are now effectively at the mercy of world gas prices.

The point at which the costs and revenue trends converge will represent a watershed moment in Western Australian energy policy. 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.

In 2012 the Australian Solar Institute (ASI) conducted a detailed study of the economics of CST technology in an Australian context. The study uses the metric 'Levelised Cost of Energy' to offer a comparison between different technologies and potential revenues:

The best comparative metric is the Levelised Cost of Energy (LCOE), which amortises the construction, operation and other costs across the plant's lifetime. A baseline LCOE of $252 per MWh represents the most conservative, least technical-risk CSP technology built at a 'most favourable' site in Australia. However, that baseline is strongly sensitive to capital cost variables (notably system size, storage, and relative power block size), the cost of capital, and the amount of energy generated annually[118].

The ASI study clearly demonstrates the present magnitude of the cost-revenue gap:

The revenues available to a potential Australian CSP plant in 2011 fall far short of the cost of building and running it. The indicative baseline LCOE of $252 per MWh for a typical 64 MWe trough CSP plant compares to potential earnings of around $120 per MWh in today's grid-connected markets.

The study is clear in outlining that a hypothetical plant of this type built in 2011 will lose $132 for every MWh dispatched, which explains why in Western Australia's partially deregulated electricity market, investors have not been lining up to construct such plants. The study offers a variety of cost/revenue gap estimates under different conditions, including on the SWIS where the existence of a Capacity Credit mechanism recognising the value of immediately dispatchable energy would be available to CST plants with sufficient thermal storage:

In the WA SWIS, capacity value is recognised explicitly, with payments of around $180,000 per MW per year for available capacity. If a high-capacity CSP system could earn 90% of that rate it would equate to an extra $20 per MWh income. A CSP system that could retain a few hours of energy in storage would qualify for such payments.

118 http://www.australiansolarinstitute.com.au/SiteFiles/australiansolarinstitutecomau/CSP_AUST_Final_May2012.pdf

For this reason (among others) the estimated cost/revenue gap is lower under Western Australian market conditions at around $100/MWh, and much lower under off-grid / mini grid conditions where the current cost of providing gas or distillate to remote locations make small CST systems a much more attractive proposition (Table 4).

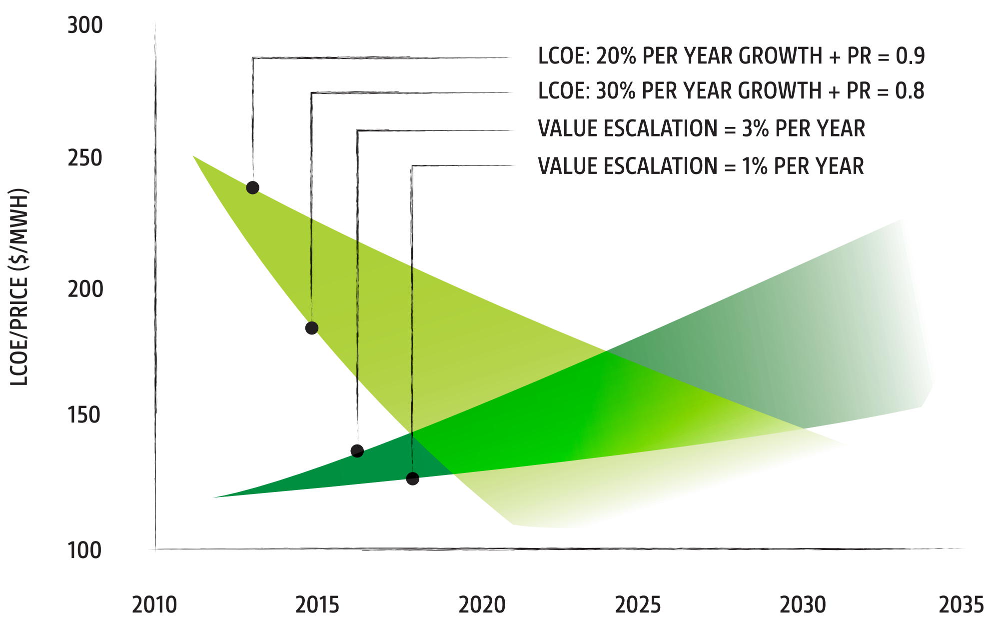
Table 4 Estimated 2012 Australian LCOE and market value of CSP systems for various market segments

	CSP WITH NO STORAGE			CSP WITH SIGNIFICANT (5+ HOURS) STORAGE		
	LCOE ($/MWh)	**VALUE ($/MWh)**	**GAP ($/MWh)**	**LCOE ($/MWh)**	**VALUE ($/MWh)**	**GAP ($/MWh)**
Large Systems on NEM	220 to 300	100 to 106	115+	250 to 360	125 to 138	110+
Small Systems on NEM	350 to 550	102 to 110	240+	370 to 500	132 to 148	220+
Large Systems on SWIS	250 to 300	98 to 102	150+	260 to 360	154 to 162	100+
Off-grid/mini grid	400 to 550	290 to 390	10+	500 to 650	340 to 450	50+

The remarkable convergence of predicted costs and revenues is graphically illustrated below (Figure 13), with different estimates of LCOE (light green) falling to meet rising energy prices (dark green) sometime between 2018 and 2030. The ASI study describes it as follows:

However, rising energy prices and falling CSP capital costs should close this gap between 2018 and 2030. On the revenue side, real energy values are likely to rise at between 1% and 3% per year through to 2030. Meanwhile, capital costs are expected to fall by 20% to 50% by 2020, depending on the eventual growth rate and progress ratio.

Figure 13 Possible progression of indicative CSP LCOE and market value in Australia (2011 real AUD) for 2 combinations of growth rate and progress ratio.



Abengoa's Planta Solar 20 plant, Sanluca la Mayor, Spain
(Image: Scott Ludlam)

It cannot be emphasised strongly enough that the speed with which the costs of CST fall are strongly sensitive to the pace at which expanded deployment brings economies of scale to bear, and in this endeavour it is essential that Australia play its part.

The key question – and main premise of the ASI report – remains the speed at which policymakers and engineering companies are able to close the cost-revenue gap. Before examining the answers advanced by various researchers, it is worth considering how Western Australian energy policy makers would have answered this question in decades past.

If energy planners in the early 20th century had waited for market forces to make the East Perth Power Station economic, Perth would probably still be burning horse manure and firewood for energy. Similarly, if policymakers in the 1970s and 1980s had waited until price signals made the Dampier to Bunbury Natural Gas pipeline a purely commercial proposition, we would still be waiting for a reticulated gas service. In both of these cases, a self-evident public interest argument was advanced that substantial up-front state investment was required in order to bridge cost-revenue gaps of at least the same order of magnitude as faced by utility-scale CST plants today.

It is a fundamental challenge of our age to break the present political gridlock which benefits incumbent energy generators at the expense of everyone else, in order to unlock investments of far greater urgency for the common good.

The establishment of the Clean Energy Finance Corporation with an investment budget of A$2 billion per year could play a crucial role in closing this gap. Key complimentary measures such as the Mandatory Renewable Energy Target (MRET) for large generators should be immediately expanded as its effectiveness is now well established.

In terms of closing the cost-revenue gap, the ASI study is unequivocal:

"Unless the gap is bridged, there will be no significant CSP deployment in Australia in the near term.

"The benefits identified in this study would be maximised by early deployment. Rather than simply subsidising CSP, technology-neutral market-based measures should target the dispatchable clean energy characteristics and strong correlation of generation to real time demand that CSP provides and Australia needs. Rewards linked to competitive market time of day pricing or equivalent firm capacity contributions should be considered. Public sector loan guarantees to mitigate construction risk have been used successfully in other countries, in parallel with other risk-mitigation measures.

Facilitated finance, such as through the Clean Energy Finance Corporation, will only be defensible if revenue and capital depreciation settings are in place for both public or private loans to be repaid on their respective terms. Financial products such as infrastructure bonds, developed for large capital assets in the energy and infrastructure sectors to offer long-term low-risk returns, may be adapted to CSP projects to meet their large upfront capital cost."

The groundbreaking Zero Carbon Australia Stationary Energy Plan by Beyond Zero Emissions and the University of Melbourne offers estimates of cost reductions for large-scale CST plants based on a rapid deployment schedule of 42.46GW of capacity installed within a decade. Their cost estimates draw from the construction costs of the 100MW Tonopah Project married with a key US study by Sargent & Lundy, in which future costs decrease roughly in line with the scenarios presented in the ASI study; that is, capital cost reductions of 50% within a decade[119]:

- **The first 1,000 MW is priced at similar price to SolarReserve's existing Crescent Dunes Tonopah project — $AU10.5 million per MW;**
- **The next 1,600 MW is priced slightly cheaper at $AU9.0 million per MW;**
- **The next 2,400 MW is priced at Sargent & Lundy' conservative mid-term estimate for the Solar 100 module which is $AU6.5 million per MW; and**
- **The next 3,700 MW is priced at Sargent & Lundy Solar 200 module price of $AU5.3 million per MW.**

The Tonopah Project is a 110MW plant of the same type as the 19MW Torresol facility in Andalucia, Spain. The project is due for startup in late 2013 and incorporates molten salt storage for up to 10 hours of operation without sunlight.

The prospect of utility-scale, better-than-baseload solar power stations on this scale has yet to take hold in Australia. With a world-class solar resource identified and many of the pre-requisites for a large-scale rollout to occur (including a large investment pool through the CEFC), it may be that Australia can take its place as a global leader in solar energy.

119 Sargent & Lundy LLC Consulting Group, 2003, "Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts", Chicago, Illinois.

4.2 Solar PV

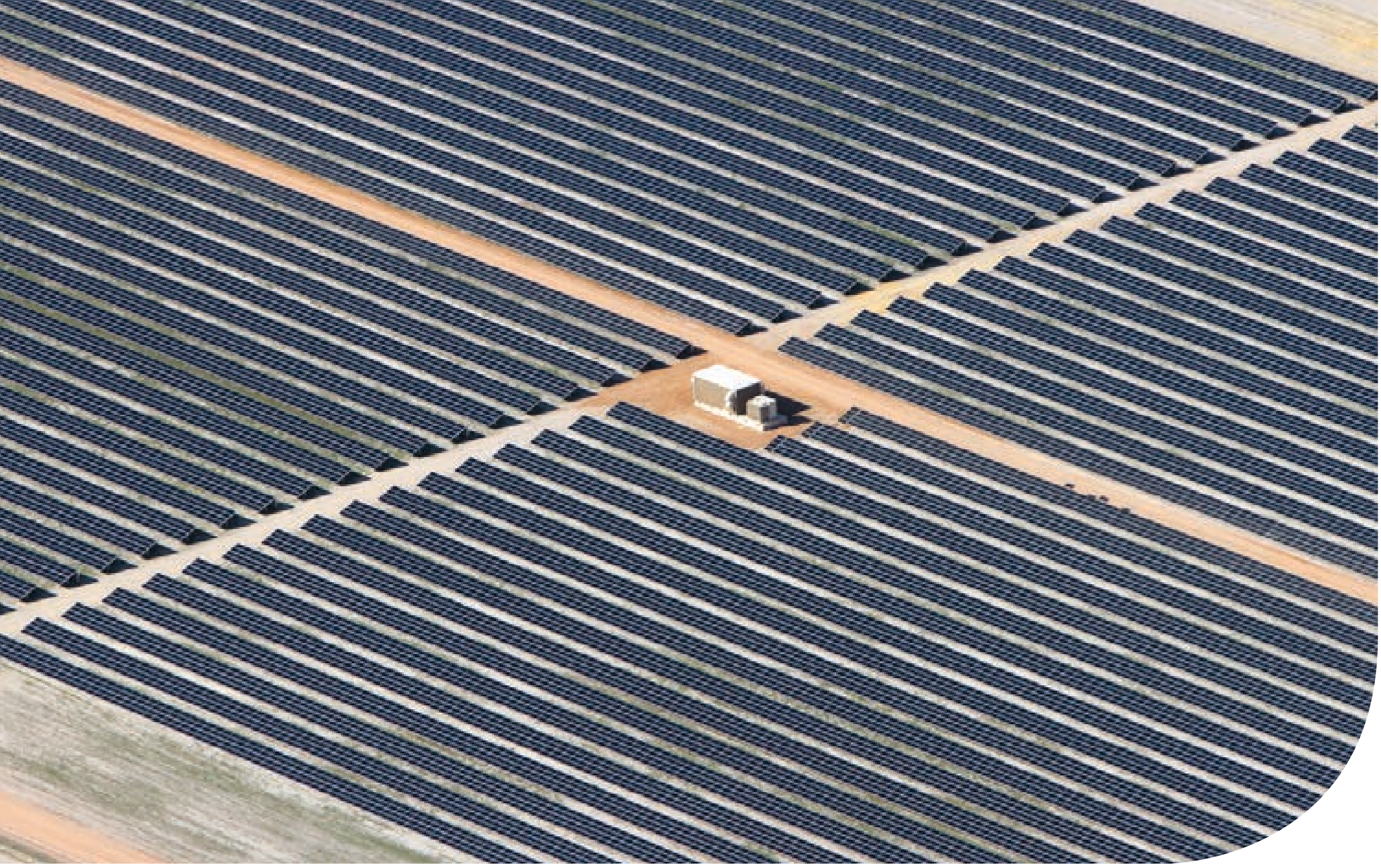
Solar Photovoltaic (PV) cells convert solar radiation directly into electrical current. PV panels can be used both for small-scale household and large-scale commercial plants. The benefit of solar PV is that it corresponds well with higher daytime electricity demands and is embedded directly into the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

The cost of solar PV is rapidly decreasing due to increasing installation and economies of scale worldwide. The global growth rate has been more than 25% a year; in Australia the annual growth rate was 200% per year between 2004-2008[120]. Germany leads the world in total PV installations with around 10GW capacity -which would be enough to cover all of WA's peak electricity needs.

Perth currently has about 218MW of rooftop grid-connected solar PV[121]. There are more than 900,000 homes in WA, providing scope for plenty of PV installation. If 1.5 kW solar panels were installed on just a quarter of the WA homes currently supplied by Synergy, 230 MW of peak electricity capacity would be created – comparable to the amount produced by a typical WA coal-fired power station. At current rates of growth, it's expected 10% of Perth rooftops will have PV by 2020[122].

> **"If 1.5kW solar panels were installed on one quarter of the WA homes currently supplied by Synergy, 230MW of electricity would be created – comparable to one of the larger WA coal-fired power generating turbines".**
>
> Sustainable Energy Now (2011) Renewable Energy Scenarios for Western Australia p7

120 Clean Energy Council of Australia at www.cleanenergyaustraliareport.com.au/technologis/solar, cited in SEN (2011) Renewable Energy Scenarios for Western Australia – A discussion paper.
121 http://reneweconomy.com.au/2012/australia-keeps-adding-solar-as-rooftop-installs-head-to-one-million-46665.
122 Sustainable Energy Now Inc, 2011. www.sen.asn.au



Images top and right: Greenough River Solar Farm

Photo credit: First Solar/Greenough River Solar Farm. Appearing in "Australia's first utility-scale solar farm officially opened in WA", Renew Economy 10 October 2012 at http://reneweconomy.com.au/2012/australias-first-utility-scale-solar-farm-officially-opened-in-wa-70785

The vast rooftop expanses of commercial buildings could provide an even greater proportion of WA's electricity.

In January 2013, WA Greens proposed a $68 million social housing plan to fund 1.5kW solar PV systems on all 30,000 of WA's public and social housing. This would save each household $500 a year, reduce carbon emissions by 74,000 tonnes annually and collectively reduce demand for another centralised power station equivalent to 45 MW (see *Solar Powered Social Housing Initiative* at wa.greens.org.au).

Utility-scale solar PV plants are now being installed. In 'fresnel lens' systems, flat plastic PV lenses are mounted in arrays to track the sun, with the solar radiation focusing on high efficiency PV cells.

The world's largest operational plant is Sarnia solar farm in Canada, which has 80MW capacity[123] while the Desert Sunlight Solar Farm currently being developed in California will have a capacity of 550MW.[124] First Solar has a contract to install a 2GW system in Inner Mongolia.

In Western Australia, the 10MW Greenough River Solar Farm, 50km south-east of Geraldton was completed and 'switched on' in October 2012, with potential to expand it to 40MW.[125] Much smaller solar PV farms at Carnarvon (15kW) and Kalbarri (20kW) already exist.

Solar installations of this size, with battery and wind backup are appropriate for remote applications such as mining camps, pastoral stations, Aboriginal communities and remote tourism locations. The use of absorption chiller technology in these installations would also avoid large energy loads for air conditioning at night.

Utility scale PV plants are at medium maturity, with 15MWe installed at 2011[126] across Australia.

The ***Australian Energy Technology Assessment*** Report (2012) prepared by the usually conservative Bureau of Resource Economics and Energy said solar PV would be unequivocally the cheapest form of new-build generation by 2030, and even in 2012 when its report was released, said the best sites might be cheaper than coal or gas[127]. This is likely to be a substantial underestimate, with solar PV already achieving grid parity in a number of markets.

The International Energy Agency – in its 2011 ***Solar Energy Perspectives*** report said solar could form the backbone of the world's electricity market, and that solar PV could account for 20 per cent of global capacity by 2050 – or about 12 million MW (12,000GW). That compares to around 40GW now[128].

123 See http://www.solaripedia.com/13/303/3431/sarnia_solar_farm_photovoltaics.html
124 See http://www.blm.gov/ca/st/en/fo/palmsprings/Solar_Projects/Desert_Sunlight.html
125 See http://smartmidwest.com/Portals/0/Science/2010Summit/5-Mark%20Rayner-%20Greenough%20River%20Solar%20Farm.pdf
126 Australian Solar Institute (2012) Realising the Potential of Concentrating Solar Power in Australia – Summary for Stakeholders. P7
127 Australian Government Bureau of Resources and Energy Economics (2012) The Australian Energy Technology Assessment 2012; at http://bree.gov.au/documents/publications/aeta/Australian_Energy_Technology_Assessment.pdf
128 International Energy Agency (2011) Renewable Energy Technologies: Solar Energy Perspectives at http://iea.org/publications/freepublications/publication/Solar_Energy_Perspectives2011.pdf

In light of these forecasts, the Australian Government's *Energy White Paper 2012: Australia's Energy Transformation* predicted only a 16% role for large scale solar and 13 per cent for household solar photovotaics by 2050, with fossil-fuel-fired generation with carbon capture and storage (CCS) contributing 29%.[129]

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). That would require some 20,000 to 30,000MW of solar PV installed across the country over the next few decades. ***First Solar*** estimates there could be 3,000MW to 5,000MW of utility-scale solar by 2020 for example.[130]

Table 5 Setting the myths about solar straight

MYTH	FACT
Solar is too expensive	Solar is getting cheaper and the cost of solar is falling fast. Since 1980 the cost per watt of solar cells has fallen 7% per year[131].
Solar is raising costs for consumers	Utilities charge a premium rate during hours of peak electricity demand. As more solar is added, wholesale prices fall during peak hours.
Solar needs more energy to manufacture than it produces	Although true in the 1970s when solar technology was in its infancy, a large installation now 'pays back' its energy debt in 1.5 to 2.5 years and generates 10 to 20 times this amount of energy in its lifetime[132].
Solar doesn't work on cloudy days	On a cloudy day a solar system will still produce about half of what it does on a sunny day[133], and some solar systems are actually more efficient in low light conditions[134]. Many countries with cloud cover such as Germany, China and Canada are embracing solar.
Solar cannot compete with fossil fuels on price.	In 2010 the price of solar fell below that of nuclear energy, and is clearly on track to fall below fossil fuels too[135]. Coal is already more expensive than solar when the health and environmental costs are factored in[136].

129 http://www.ret.gov.au/energy/facts/white_paper/Pages/energy_white_paper.aspx p88

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

131 DOE NREL Solar Technologies Market Report, Jan 2010

132 Progress in Photovoltaics: Research and Applications, Vol 16, Issue 1, pp17-30, Jan 2008

133 www.yourturn.ca/solarfour-system/how-much-power-can-it-produce/

134 TUV Rheinland and Solarpraxis AG, PV+Test, May 2012

135 Blackburn and Cunningham, Solar and Nuclear Costs – the historic crossover. Duke University.

136 Epstein et al, Full cost accounting for the life cycle of coal, Harvard University. All of the above cited in www.pv-magazine.com "Setting the solar story straight" fact sheet.

CHAPTER 5

Wind Power

Wind power is one of the cheapest and most commercially advanced renewable energy technologies and is used as a major power source in more than 70 countries.

At February 2013 wind is now cheaper than fossil fuels in producing electricity in Australia. A new wind farm can supply electricity at a cost of $80/MWh compared with 143 or 116 from a new coal or gas fired station (Bloomberg). Wind power has grown even faster than the booming solar industry. In 2008 installed wind power capacity rose by 30%.[137] Globally, wind is the fastest growing type of new electricity generation, with the capacity to generate electricity from wind growing by around 28% annually.[138]

Germany had installed a total capacity of 23,903MW of wind power in 2008, and that year the 20,301 wind turbines in the country generated 40.4 terawatt-hours (tWh) of wind power, equivalent to 7.5% of Germany's power consumption. The figure was 5.7% only two years earlier. At the end of 2007, 90,000 people were employed in the German wind power sector[139].

China, with its 15% renewable energy target by 2020, installed 13 gigawatts (GW) of wind capacity in 2009 alone, bringing it more than halfway to its target of 20GW by 2020, and making it the global wind leader for that year[140].

The UK plans to install 30,000 MW of offshore wind farms by 2020 – equivalent to seven times the peak demand on the SWIS[141].

Wind power has grown in Australia by over 40% each year since 2004[142]. The cost has fallen by 10% since 2011.

Western Australia has abundant wind resources, including the South and West coasts and in many inland areas. While wind currently makes up only about 2% of electricity generated in Western Australia, several new major wind farms are already operating or under construction (Table 6).[143]

Western Australia had installed capacity of 424 megawatts of wind generation as at the end of 2011/12, with most of this connected to the SWIS. Wind power accounts for 75% of renewable energy produced on the SWIS. Most of Western Australia's wind-generated electricity currently comes from three large wind farms:

- **Collgar, Merrdin (206 megawatts)**
- **Walkaway, Geraldton (90 megawatts)**
- **Emu Downs, Badgingara (80 megawatts)**

Turbine being lowered for maintenance at Coral Bay wind farm
Photo Credit: Brendan Ryan at http://ramblingsdc.net/Australia/WindWA.html#Wind_power_generation_in_WA

Denmark community wind farm under construction (2012)
Photo credit: www.skyfarming.com.au/normal.dcw.htmurbineinstall/turbineinstall_4.htm

137 Renewables Global Status Report 2009 p9
138 http://www.energy.wa.gov.au/2/3699/64/wind.pm
139 Seifried and Witzel 2010 p11
140 Neue Energie, March 2010, p94
141 Sustainable Energy Now Inc, 2011. www.sen.asn.au
142 Sustainable Energy Now Inc, 2011. www.sen.asn.au
143 http://www.energy.wa.gov.au/cproot/1684/2/Renewable%20Energy%20Fact%20Sheet%20January%202010.pdf

The Albany wind farm constructed in 2001 and expanded in 2012 supplies around 80% of Albany's electricity, and has a capacity of 35MW.

Table 6 Current and developing wind farms in WA

REGION	WIND FARM	STATUS	MW	COMPLETION	COST ($M)
Far north	Coral Bay Carnarvon (Horizon power) Denham, Shark Bay	Operating Proposed Operating	0.8 5 1		$4
North coast	Geraldton (Walkaway) Emu Downs, Badgingara Kalbarri Mumbida Dandaragan Nilgen (north Lancelin) Warradarge	Operating Operating Operating Construction Proposed Proposed Proposed	89.1 79.2 1.6 55 513 132.5 250	2006 Late 2013 TBC 	$210 $280 $600
Inland	Collgar, Merredin Flat Rocks, Kojonup	Operating Proposed	206.5 150	2011 TBC	$750
Perth metro	Fremantle	Proposed	6.4	TBC	$16-18
Islands	Rottnest	Operating	0.6	2006	
South Coast	Albany Grasmere (Albany) Bremer Bay Denmark Community Wind Farm Esperance: Nine Mile Beach Ten Mile Lagoon Mt Barker Community Windfarm Hopetoun Milyeannup (near Augusta) (Verve)	Operating Operating Construction Operating Operating Proposed	21.6 13.8 1.6 3.6 2.025 2.4 1.2 55	2001 2012 2013 2003 1993 2011 2009 	$45 $8.5
		Total installed	**424***		

Source: Data compiled from http://ramblingsdc.net/Australia/WindWA.html#Wind_power_generation_in_WA with Total installed MW figure from Office of Energy at January 29 2013 http://www.finance.wa.gov.au/cms/content.aspx?id=15114

Three large wind farms are currently planned for construction:

- **The 55 MW Mumbida wind farm in the Mid West is currently under construction, due to be completed early 2013 (Office of Energy);**
- **The Warradarge Wind Farm – a 250MW wind farm with up to 100 turbines, to be built by Verve energy between 2014-2020 at a cost of $600m; and**
- **Dandaragan Wind Farm will be the largest wind farm in Australia, with 151 turbines, planning approval received December 2011.[144]**

While much smaller in scale, wind generation is also located in isolated and 'fringe of grid' power systems at Esperance, Hopetoun, Bremer Bay, Rottnest Island, Kalbarri, Denham and Coral Bay. In these areas, wind contributes a high relatively high proportion of electricity supply requirements, displacing diesel and improving reliability[145].

144 http://dandaraganwindfarm.com.au/

145 Office of Energy (2012) Wind Energy – Current use in Western Australia. At http://www.finance.wa.gov.au/cms/content.aspx?id=15114

Before sunrise, Albany Wind Farm.
(Photo: David Clarke. Source: www.ramblingsdc.net/Australia/WindWA.html)

Size counts

Large, modern wind turbines provide cheaper electricity per kilowatt hour than smaller turbines because taller turbines tap into the stronger and more consistent wind speeds that exist higher above the ground. In addition, a few, large turbines instead of many smaller ones means fewer moving parts to maintain.

The biggest wind turbines operating in Western Australia are around 2MW each at the Collgar Wind Farm near Merredin. However, 5MW and 7.5MW turbines are already being built elsewhere in the world and are becoming more common (a 10MW offshore turbine is also being developed). The 7.5MW Enercon E126 wind turbine, designed for onshore use and installed at Emden in Belgium, has a hub height of 138 metres and a blade length of more than 60 metres.[146] This compares to the 1800kW Enercon E66 turbines installed at Albany Wind Farm in 2001, which have a hub height of 65 metres and 30 metre blades.[147]

146 P6, http://www.enercon.de/p/downloads/WB-0407-en.pdf
147 http://www.verveenergy.com.au/mainContent/sustainableEnergy/OurPortfolio/Albany_Wind_Farm.html

What happens when the wind drops?

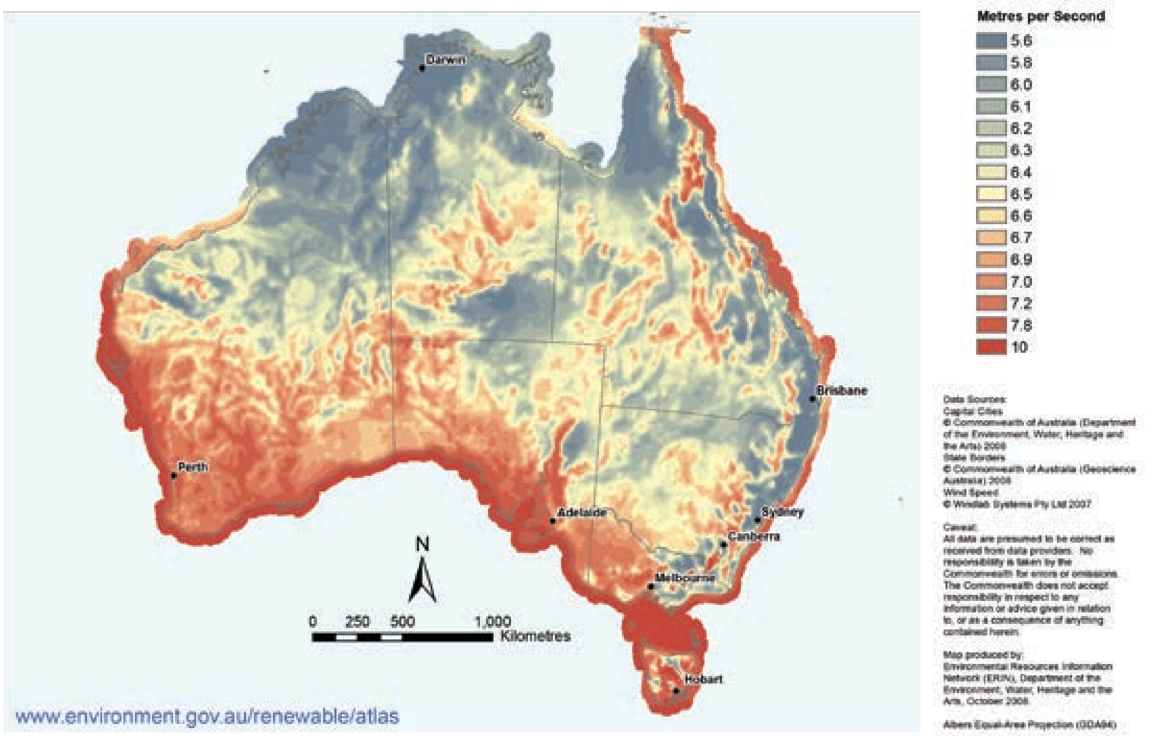
While we can't rely on wind to meet all of our energy needs wind can nonetheless accommodate a surprisingly large fraction of our energy needs wind.

Western Australia has relatively strong and consistent winds, which means that wind farms here have a capacity factor of 40% or more, compared to 30–35% for wind farms elsewhere in Australia, or 20% capacity in other parts of the world. The Western Australian town of Hopetoun already meets more than 45% of its electrical demand with wind turbines.[148]

Capacity factor refers to a power plant's actual production over time compared to the amount of power the plant would have produced if it ran at full capacity all the time. Conventional electricity generators such as coal-fired power stations have a capacity factor of 40–80%, due in part to deliberate shutdowns because the electricity they produce is not continuously required and in part due to forced shutdowns for maintenance.[149]

Wind turbines, which have relatively few parts and therefore require little maintenance or repairs are available to operate 98% of the time.[150] Therefore, wind turbines, while reliant on an intermittent energy source, are in one way more reliable than comparatively complex, fossil fuel-based power systems.

Figure 14 Renewable Energy Atlas of Australia: Mean wind speed at 80m above ground level



Source: Environmental Resources Information Network (ERIN), Australian Government Department of the Environment, Water, Heritage and the Arts (2008). At http://www.energy.wa.gov.au/cproot/2469/2/mean-wind-speed.pdf

148 P13; Renewable Energy Handbook Western Australia (Government of Western Australia, 2010

149 P46, Renewable Energy Handbook Western Australia (Government of Western Australia, 2010

150 Ibid.

How to make the most of wind power

The demand for electricity in Western Australia varies greatly over a single day and seasonally. Even with conventional fossil fuel-generated electricity, operators have a difficult job ensuring they supply the right amount of electricity to meet demand at all times.

While gas-fired power plants are relatively easy to start up and vary their output in response to variation in demand, coal-fired power stations have large, difficult to manage boilers and cannot be quickly started up or respond to demand. This is why some energy operators complain that adding wind energy to WA's electricity grid has makes it difficult for existing, inflexible coal-fired power stations.

In contrast to coal, concentrated solar thermal technology (CST) backed with thermal storage, is a dispatchable electricity source, able to be highly responsive to demand. This makes CST a good match for wind. Electricity generated by wind during the day displaces the need for daytime solar electricity generation, allowing CST plants to store surplus thermal energy during the day.[151]

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. Analysts say that this makes a strong argument for co-locating solar and wind generation in this region, with solar providing electricity during the day and wind taking over as the power source as the day draws to a close.

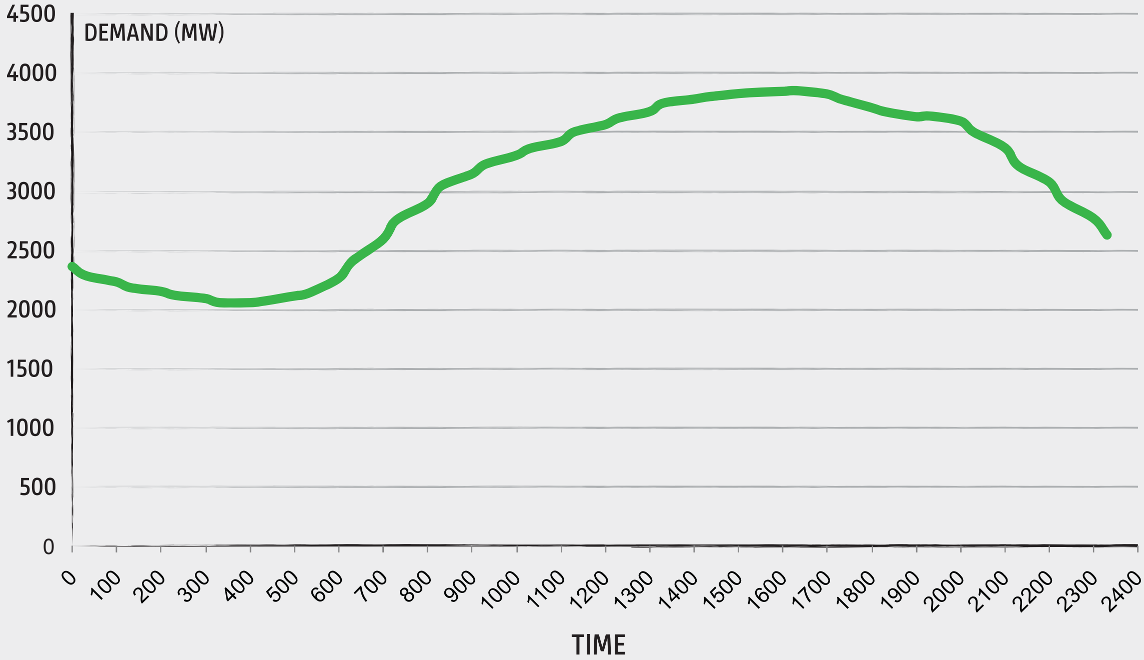
> **"In WA's South-West there is about 500,000 sq km with average wind speeds above 6m/second at a height of sixty metres. Just 50km x 50km of this area (2500 sq km) would produce energy equivalent to the peak demand on the SWIS"**
>
> Sustainable Energy Now. 2011 p5

On a large interconnected national grid as proposed by Beyond Zero Emissions, local wind variation can be partially overcome by situating wind farms in geographically diverse locations to exploit the fact that over the entire continent, areas with little wind can be compensated by plants operating in windy areas.[152] Detailed meteorological modeling must be used to choose sites that will complement each other.

151 P65, Zero Carbon Australia Stationary Energy Plan (Beyond Zero Emissions, 2010)

152 P63, Zero Carbon Australia Stationary Energy Plan (Beyond Zero Emissions, 2010)

Figure 15 Demand curve for peak demand day (25/01/2012)



Source: Independent Market Operator "Statement of Opportunities" (June 2012) p25 http://www.imowa.com.au/f176,2338348/2012_SOO_rev0.pdf

How much wind power is right for WA?

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

Beyond Zero Emissions' ***Zero Carbon Australia*** stationary energy plan recommends that 40% of Australia's electricity could be met with wind power, and given Western Australia's particularly consistent wind resources and suitable locations for wind farms close to population centres, the 40% figure seems feasible as a source of Western Australia's future electricity generation.

CHAPTER 6

Wave, hydro and tidal energy

Wave power is not currently as commercially developed as wind and solar power, yet it has massive potential as an electricity source for Western Australia.

Regular storms and steady circumpolar winds in the Southern Ocean deliver consistent swells to our shoreline, making our wave energy highly predictable and reliable. Near-shore wave energy could meet four times Australia's current electricity needs.[153]

Most of the southern half of Australia receives two-metre swells for at least 90 per cent of the year. Carnegie Wave Energy estimates that the coastline between Geraldton and Bremer Bay could produce more than five times the peak power demand on the electricity grid supplying south-western Western Australia in continuous equivalent energy[154].

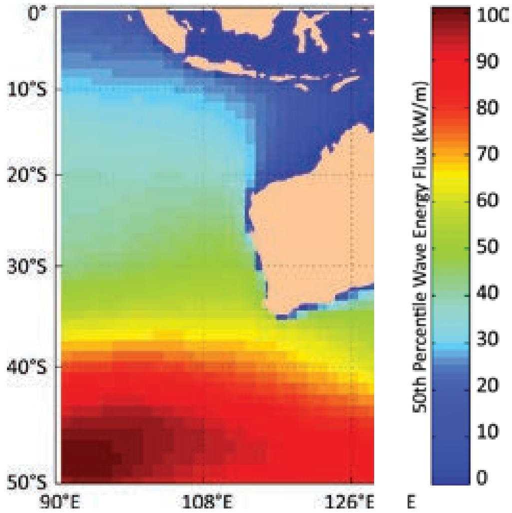


Figure 16: WA's wave power potential

Wave resources on WA's coastline, with south-west WA one of the best sites on the map. Source: CSIRO (2012) at http://www.csiro.au/~/Media/CSIROau/Portals/Media%20Releases/2012/OceanRenewableEnergyReport/High_Resolution.jpg

Wave energy around 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.

CETO technology

Fremantle-based company, Carnegie Wave Energy (www.carnegiewave.com) has developed the 'CETO' wave energy system which requires waves in excess of only one metre to produce reliable electricity.

Carnegie Wave Energy's CETO system differs from most other wave technologies because it operates below the sea surface and is anchored to the ocean floor. An array of submerged buoys is tethered to seabed pump units. The buoys move with the passing waves, driving the pumps which in turn pressurise water delivered to the shore via a pipeline. The high-pressure water drives hydroelectric turbines, generating zero-emission electricity. The pressurised water can also be directly used in a reverse osmosis desalination plant, replacing fossil-fired desalination options heavily favoured by successive state Governments.

Carnegie is currently building a 5MW commercial wave project west of Garden Island, WA. The system began producing electricity in April 2011 and is currently being developed to feed into the electricity grid. Carnegie is also developing commercial scale demonstration projects off Reunion Island and Ireland with help from the French and Irish governments.

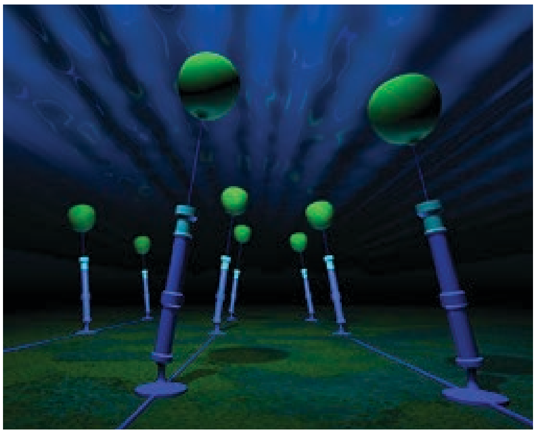


Figure 17 Carnegie Power Schematic diagram

(Image: Scott Ludlam)

153 P51 of the OoE Renewable Energy Handbook 2010; See also Carnegie Wave Energy website at http://www.carnegiewave.com/index.php?url=/ceto/what-is-ceto

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

CHAPTER 7

Hydro and tidal energy

Two hydro-electric plants exist in Western Australia – the 30MW Ord River plant and 2MW Wellington Dam plant (currently out of use). While hydroelectricity supplies more than 90% of Tasmania's electricity, Western Australia's flat and dry environment means it has relatively low potential for further development of this type of power.

The vast tidal ranges off Western Australia's Kimberley coast have long been the subject of debate and proposals for tidal power. There are serious environmental and cultural concerns about damming estuarine environments for tidal power. The potential for in-stream tidal plants remains untapped in Western Australia and could ultimately provide a large fraction of energy in the Kimberley, but proposals to date have only assessed large-scale flooding of tidal mudflats which ultimately proved non-viable.

Pumped-storage hydroelectricity

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 (that has been pumped from a lower elevation reservoir) 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[155]. The technique is currently the most cost-effective means of storing large amounts of electrical energy on an operating basis, but capital costs and the presence of appropriate geography are critical decision factors.

At March 2012 pumped storage is the largest-capacity form of grid energy storage available and accounted for more than 99% of bulk storage capacity worldwide, representing around 127,000 MW[156].

Verve Energy is currently investigating the use of Pumped hydro for energy storage, using some of Perth's existing dams.

155 http://www.electricitystorage.org/about/welcome

156 "Energy storage – Packing some power" The Economist. 2011-03-03. At http://www.economist.com/node/21548495?frsc=dg%7Ca

CHAPTER 8

Geothermal energy

Geothermal energy has great potential to meet Western Australia's energy needs, either in the form of geothermal electricity or through a variety of 'direct use' applications, where heat from the Earth is used to replace other energy sources.

While relatively undeveloped in Australia, geothermal energy is widely used around the world. 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.[157]

"Geoscience Australia estimates that the geothermal energy resource in Australia from rocks hotter than 150 degrees Celsius and shallower than 5km would provide about 26,000 times Australia's 2005 primary power energy usage"

Sustainable Energy Now. 2011 p6

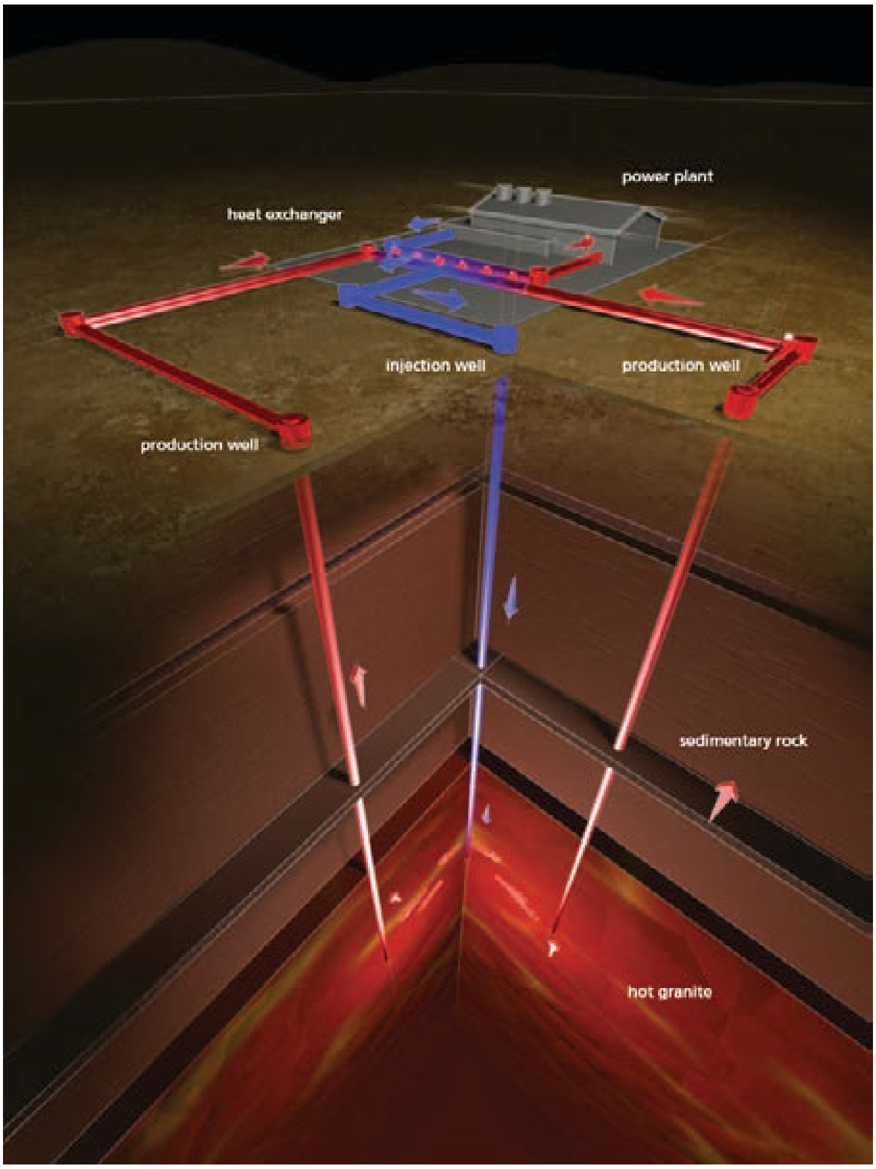


Figure 18 Diagrammatic representation of Hot Dry Rock (HDR) Geothermal plant

(Image by Scott Ludlam)

157 P53 OoE Renewable Energy Handbook 2010

Direct use geothermal

Direct use geothermal refers to using heat extracted from the Earth as an energy source without converting it to electricity first.

Applications range from heating and cooling large offices, businesses or industrial premises using heat from wells drilled to 1km or deeper to household applications that draw on the Earth's temperature at much shallower depths.

Applied in Western Australia, direct use geothermal has great potential to replace both direct use gas and electricity use.

Household-scale applications: ground source heat pumps

Geothermal or 'ground source' heat pumps, while still relatively unknown in Western Australia, are catching on in Victoria and already popular in the USA, China and Sweden and Germany, with global use doubling since 2005.

They are central heating or cooling systems that use the relatively stable temperatures of the upper metres of the Earth's crust as either a heat source in winter or a heat sink in summer.

Heat pumps can transfer heat from a cool space to a warm space, against the natural direction of flow (to help cool a building), or they can enhance the natural flow of heat from a warm area to a cool one, using a loop of either water or refrigerant pumped through a vapour-compression refrigeration cycle that moves heat. A reverse cycle air conditioner is a form of air-sourced heat pump. In contrast, a ground source heat pump exchanges heat with the stable temperatures of the ground and is therefore more energy-efficient.

Closed loop systems are likely to have the greatest application in Western Australia and while an expensive option now for all but very large households, they are likely to rapidly fall in price in coming years, due to their rapidly growing global popularity.

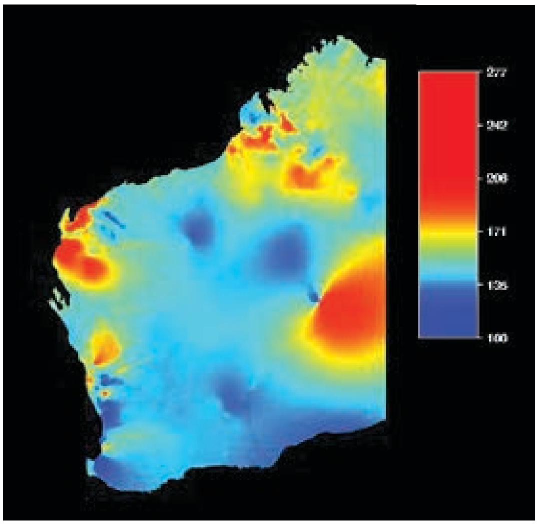
Medium to large applications: hot sedimentary aquifers

Perth is blessed by being built over sedimentary aquifers. These aquifers can be drilled into at depth of 1km or more to extract hot aquifer water. Deeper wells yield higher temperatures.

Thermal energy is extracted by running the aquifer water, at pressure, to the surface where its heat is extracted via a simple heat exchanger before the aquifer water is re-injected into the ground.

The heat can be used in a wide range of ways (see Table B), including cooling using absorption chillers[158]. For greatest efficiency, multiple uses are made of the thermal energy with it used first for higher-temperature applications and then for applications that require less high temperatures in a cascade effect. Doing this would spread the initial high upfront cost of installing a deep well and its associated surface infrastructure, known as a doublet, over several users.

Figure 19 Crustal temperature image
http://www.dmp.wa.gov.au/11591.aspx



158 Combining an adsorbent with a refrigerant, adsorption chillers use heat to provide a cooling effect. The adsorption chamber of the chiller is filled with a solid material (for example silica gel), which when heated releases refrigerant vapour which subsequently is cooled and liquefied.

Table 7 Direct uses of geothermal applications

MEDIUM-SIZED DIRECT USE GEOTHERMAL APPLICATIONS USING HOT SEDIMENTARY AQUIFERS	
Swimming pools	Five Perth swimming pools, including Challenge Stadium, are already using geothermal energy to heat pool water. Hot water at around 50 degrees centigrade is extracted from drill holes about 1km deep and used to heat the pool water via a simple heat exchanger. The cold aquifer water leaving the heat exchanger is reinjected back underground and continually circulated. Given there are many other pools in Perth that require between 10,000 and 20,000 GJ to heat, geothermal energy offers an excellent proven alternative to gas that is usually used.
Large buildings and campuses	Buildings can also be heated or cooled using hot sedimentary aquifer water. At least 100MW of air-conditioner use in Perth could be offset using this energy source.[159] Amongst other geothermal projects underway in Perth, 3km-deep holes are being drilled to extract hot sedimentary aquifer water to provide heating and cooling to buildings on the University of Western Australia campus, using absorption chillers.
Industrial uses	Industrial uses such as desalination, water heating, mining processes, and textile and agricultural drying.

Large-scale applications: geothermal electricity

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 and Indonesia.[160]

With many new projects under development, especially in Africa, the USA and Europe, global installed capacity in geothermal electricity is projected to reach 18.5GW by 2015.[161]

Australia currently only has one small (120kW) operating geothermal electricity project at Birdsville, Queensland but Geodynamics aims to develop a 25MW demonstration project in the Cooper Basin in South Australia by 2015. The project will involve drilling to up to 4km, where temperatures are at 250-300 degrees centigrade[162].

Western Australia's geothermal resource

In Western Australia, several companies are exploring opportunities for geothermal electricity development.

The **Jurien-Woodada** project, owned by New World Energy Limited, is one of the most advanced geothermal projects in Western Australia for electricity production. The project is adjacent to transmission infrastructure and large resource-driven energy markets in the mid-west region. The project area has the potential to contain both hot sedimentary aquifer and Engineered Geothermal System (EGS) styles and is being assessed for delivery of electricity into Western Australia's South West Interconnected System[163]. The **Green Rock Energy** project[164], also a partnership with New World Energy is the most advanced geothermal project in WA at 2013.

159 http://www.energy.wa.gov.au/3/3713/64/wa_geothermal_centre_of_excellence.pm
160 P53 OoE Renewable Energy Handbook and p20 Renewables 2010 Global Status Report: http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf .
161 P20 Renewables 2010 Global Status Report: http://www.ren21.net/Portals/97/documents/GSR/REN21_GSR_2010_full_revised%20Sept2010.pdf
162 Temperatures of at least 150C or higher are generally needed to generate electricity.
163 http://newworldenergy.com.au/index.php/projects/perth-basin/
164 http://www.greenrock.com.au/index.php

CHAPTER 9

Bioenergy

Bioenergy, derived from plant and organic matter (or 'biomass') is a proven renewable energy used in all countries of the world.

What is bioenergy?

Biomass provides heating for homes and units in a way that genuinely competes with oil and gas heaters by using renewably sourced wood (to form wood pellets) or energy crops such as plantations of rapeseed, along with biogas digesters.

The number of homes using this technology just for heating their homes has increased tenfold in just three years[165]. In some European countries with a carbon trading scheme, it contributes 5–20% of electricity needs.

In Australia it currently produces less than 2% of our electricity and in WA less than 1%.[166] 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 in the world.

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 ('syngas'), liquid fuel ('bio-oil'), 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. The charcoal can be burned to produce electricity in steam thermal power stations.

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,

- **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; and**
- **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.

165 Seifried and Witzel 2010 p11
166 Ibid and P50, OoE Renewable Energy Handbook 2010

Back-up for solar thermal plants

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 (see chapter 4.1, CST.)

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 (sawmill and plantation residues).

Oilseeds can also be used to produce biodiesel and low grade grains can be fermented for ethanol, but as these are important food commodities and the energy input: output ratios are at best 50% of those achievable by cellulosic feedstocks. Energy 2029 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 and the scenarios prepared by SEN specifically exclude waste incineration which may reduce air quality, and burning of native forestry 'residues' which would incentivise further logging in native forests.

Oil mallees to produce renewable fuels and generate electricity

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.[167] 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, while woody biomass prices would be stable and input costs low. In addition, the plantation belts provide other benefits such as income from carbon credits, shelter for stock, reduction of soil erosion and lowering of saline water tables.

This proposal avoids the problem of biofuels displacing food production, as only 10% of dryland agricultural land would be used for biomass crops. The land used to grow oil mallees would also benefit from directly lower saline groundwater tables, soil conservation, create windbreaks and new wildlife habitats, and sequester carbon sequestration.

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

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-scale biomass

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.[168]

Biomass in the energy mix

There are several ways in which cellulosic biomass can be integrated in the energy mix:

Trigeneration

It comprises an engine which runs on natural or renewable gases and produces low-carbon electricity,

heating and air-conditioning. Gas-fuelled trigeneration is already making an impact in other parts of the world. In the Borough of Woking near London, the council achieved an 80 per cent reduction in carbon emissions using cogeneration, trigeneration, energy efficiency and renewable energy over 14 years. A retrofitted network of trigeneration plants has transformed the Borough of Woking in the UK, reducing emissions by around 80% from 1990 levels[169].

The City of Sydney in partnership with Origin Energy will introduce a citywide tri-generation grid that will supply 70 per cent of the area's electricity needs, and will make reductions in greenhouse gas emissions for CBD buildings of between 40 and 60 per cent on 2006 levels. It's also estimated CBD energy users could save up to $1.5 billion in spending on electricity upgrades and new power stations by 2030.

Trigeneration is a key part of the Sustainable Sydney 2030 goal to reduce greenhouse emissions by 70 per cent by 2030[170]. The first plants will be implemented in 2013.

Trigeneration systems produce local low-carbon electricity and zero-carbon heating and cooling for buildings which also further displaces existing electricity for air conditioning and some heating supplied from remote coal fired power stations.

Australia uses relatively little cogeneration or trigeneration technology, with 5 per cent of total energy production in 2006 compared to 40 per cent in the Netherlands and 55 per cent in Denmark. In Asia, Japan has 17 per cent, China 11 per cent and India 12 per cent. Australia ranked 34th out of 40 countries surveyed for decentralised energy generation.[171]

"Plans to install 360 megawatts of localised power generation in the Sydney CBD could avoid the need for up to $1.5 billion investment in new power stations and electricity network infrastructure by 2030"

UTS Institute for Sustainable Futures (ISF) Report

168 http://www.refgas-uk.com
169 http://www.sydney2030.com.au/development-in-2030/city-wide-projects/powering-sydney-allan-jones
170 http://newsroom.uts.edu.au/news/2010/12/sydney-trigeneration-plan-could-do-a-power-of-good.
171 http://www.cityofsydney.nsw.gov.au/environment/documents/TrigenerationTheInternationalPerspective.pdf

PART 3
The Roadmap

CHAPTER 10

Meeting the target: 100% Renewable Energy on the SWIS to 2029

In 2012 Senator Scott Ludlam commissioned Sustainable Energy Now to undertake a scenario modeling study for different pathways to a 100% renewable energy electricity network by 2029.

The following is an extract of this study: ***SEN WA 100% Renewable Energy on the SWIS 2029 – Full Report (2013)*** which is available in full online at greenswa.net.au/energy2029

Background, Objectives And Caveats

Sustainable Energy Now Inc. (SEN) was commissioned to provide scenarios which demonstrate the potential for WA's SWIS electricity grid energy demand to be fully met by a combination of renewable energy generation, energy efficiency, storage and demand-side management.

There are various combinations of renewable energy and complementary technologies which could meet this objective, and SEN was asked to provide one which is high in concentrated solar thermal (CST) generation, with other possible scenarios as options. This report has used the SEN Renewable Energy Simulation to assist in modelling the scenarios, however, this software has limited capabilities and has not been independently checked and is therefore only intended as an illustration to aid in visualisation.

While the aim of 100% renewable energy generation may be achievable, SEN recognises that there are practical limits with diminishing returns, to achieving this by a certain time, and that some forms of fossil generation may linger for various reasons, and/or be converted to use renewable fuels as feedstock.

The option of a high voltage DC interconnector to the NEM grid in the Eastern States has not been considered in this project. This means instead that biomass-fuelled generation and storage for backup is unavoidable at times of low solar irradiance and low wind speeds.

It should also be noted that 'fully renewable" does not mean 'zero carbon' as even the technologies here have embodied emissions factors, albeit low (<0.06 kg CO2e / kWh) compared to coal fired electricity emission factors (> 1.0 kg CO2e / kWh).

This study is a considered a preliminary investigation of the options for a 100% renewably powered electricity grid (the SWIS). Levelised costs of electricity and other parameters have been estimated by rationing capacity factors of the various technologies against rated (maximum) capacity factors from references, and are shown in Tables 8, 9 and 10. Due to the number of assumptions and projections both in this study and referenced studies, the information presented should be considered only approximate, for visioning and discussion purposes.

Executive Summary And Principles

1. WA has among the best solar, wind and wave resources in the world and the potential to generate renewable energy from these resources is enormous.
2. A number of SWIS grid scenarios were investigated for this report, summarised as:
   - **Scenario 1: Solar thermal dominant with backup biomass at solar CST plants;**
   - **Scenario 2: A diverse mix with wind and solar PV dominant; and**
   - **Scenario 3: Business as Usual (BAU) without Carbon Capture and Storage or efficiency/waste reduction gains.**

   Costs for generation, storage and transmission are summarised in Tables 8 – 10.

   If the existing fossil fuelled grid is retained in a BAU case (Scenario 3), capital investment excludes the cost of any form of Carbon Capture and Storage (CCS), should it ever become viable. An additional gas pipeline will also be needed to deliver gas to generators near Perth. This would add many billons of dollars to the cost of the BAU scenaro. Rising coal and gas prices, and to a lesser extent the price on carbon, will make fossil generation more expensive.

   While renewable scenarios will require more capital expenditure than adapting the existing fossil fuelled grid, it will ultimately provide energy at less cost because technology costs of renewables are decreasing and there are no fuel costs, except for biomass. For example the AETA has forecast the Levelized Cost of Electricity (LCOE) from new wind, biomass and solar PV power plants is lower than generation from new coal fired plants even without being equipped with CCS while the cost of solar concentrated thermal with storage is likely to be only slightly more.[172]

   In our Scenarios the determined capacity factor is less than that used in the BREE report which means that the LCOE for total renewable generation is roughly equivalent to that of business as usual.
3. The absence of interconnection with the NEM grid and the need for rotating generators that can control network voltages and frequency results in the requirement for a small amount of biomass-fuelled backup generation combined with pumped-hydro storage during times of low solar irradiance and wind velocity.
4. SEN scenarios outlined in the tables below utilise LCOE and capital costs adapted largely from BREE Australian Energy Technology Assessment (AETA) 2012[173] and the Melbourne Energy Institute Renewable Energy Technology Cost Review (2011).
5. Significant 'over-build' of wind, solar and biomass generation is included so that the proposed scenarios should provide sufficient dispatchable backup and storage for up to 3 consecutive days 4 times per year of coinciding minimal solar and wind conditions throughout the SWIS area. However, more widespread, detailed analysis of wind and solar records is required to confirm this assumption.

172 Australian Bureau of Resource and Energy Economics (BREE) "Australian Energy Technology Assessment

173 http://www.bree.gov.au/publications/aeta.html

Electricity Demand In 2029

Assumptions:

- The WA ***Strategic Energy Initiative 2031 Directions Paper*** (May 2011) projects electrical energy growth of 2.3%/yr. (Derived from electricity growth of 57% over 20 years).
- For the renewable energy scenarios, it is assumed that efficiency gains, waste reduction and displacement of electricity by direct solar water and space heating and geothermal 'Hot Sedimentary Aquifer' (HSA), reduces the rate of energy growth by 30%, resulting in a 1.6%/yr actual growth. Therefore it is assumed that demand reaches 23,000GWhr/yr (23 TWh/yr) in 2029. (An overall increase of 31%).
- For the non-renewable energy scenario 3a (BAU) it is assumed that no gains in efficiency or waste reduction occur, resulting in a 2.3%/yr electricity growth, reaching 26,000 GWh (26 TWh) in 2029. (An overall increase of 47%).
- Plug-in Hybrid Electric Vehicles (PHEV) and Electric Vehicles (EV) increase demand negligibly by 800 GWhr/yr (0.8 TWh/yr).
- Electric Metro/light rail increases demand negligibly by 0.075 TWhr/yr.

Figure 20 shows our current energy mix.

Figure 20 Current energy mix

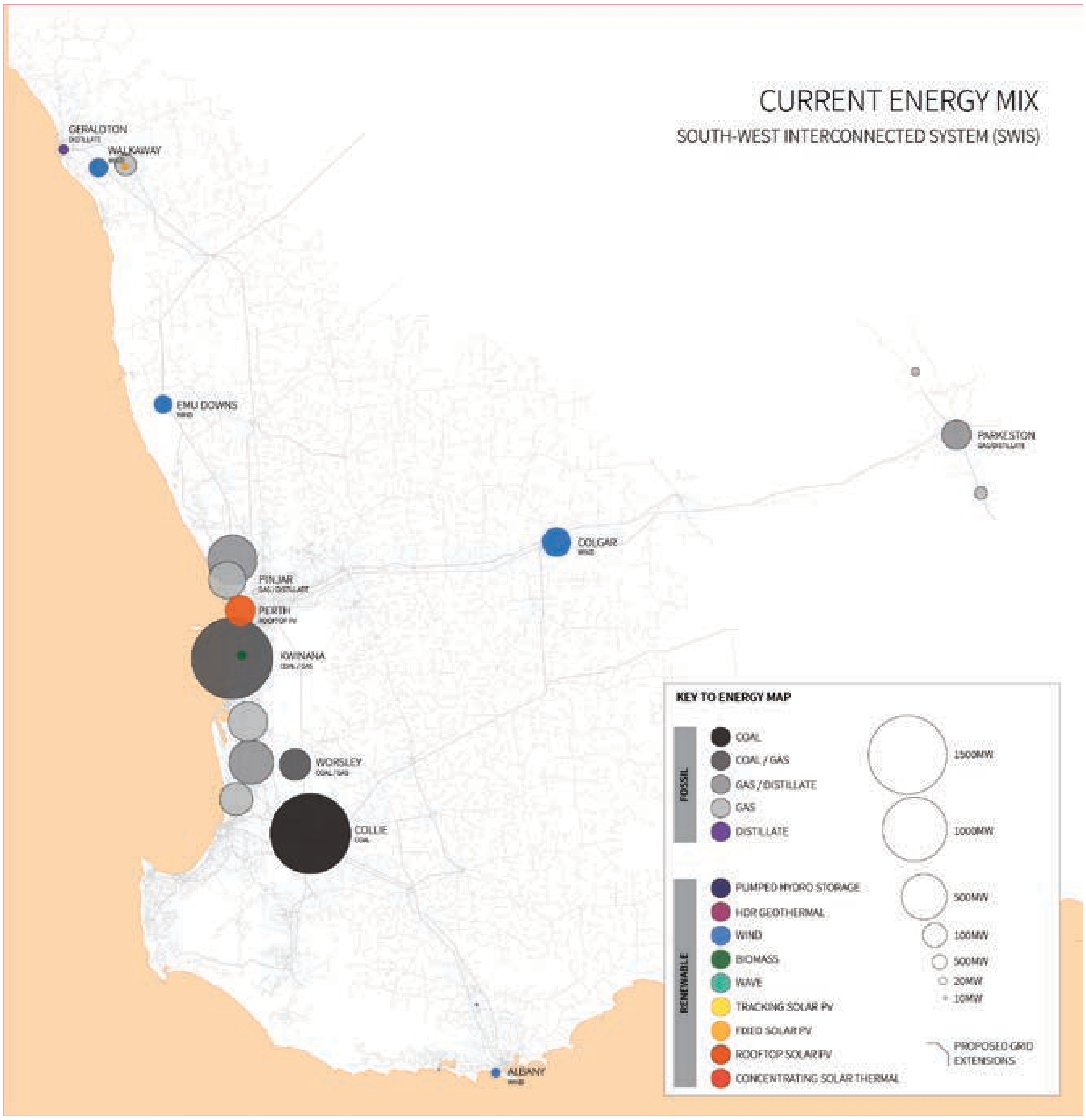


Image: Scott Ludlam and David Robertson

This map describes the total capacity for all power generators on the SWIS as of 2012.

The size of the circle represents the maximum output capacity for that generator in MW, and is not intended to be representative of the actual output of power stations at any given time. Only grid-connected generators are represented on this map, and cumulative capacity from grid-connected rooftop PV systems has been calculated for Perth only. Small-scale installations including landfill gas proposals have been excluded.

Renewable Energy Scenarios For The Swis Grid

Numerous scenarios which meet the requirements for a reliable adequate SWIS energy supply are possible, but the two scenarios presented are based on:

1. **Concentrated solar-thermal (CST) based, central receiver technology; and**
2. **Diverse technology configuration – more wind and solar photovoltaic (PV).**

In both scenarios, the aim is to:

- **Diversify the mix of renewables;**
- **Disperse renewables geographically;**
- **Balance best renewable resources with proximity to existing grid and load centre (Perth);**
- **Minimise peak power required by maximising demand-side management load-levelling/ shifting capacity; and**
- **Ensure sufficient energy & power backup supply to cover for short and extended (several days) low-solar & wind weather events. Solar CST storage (with biomass backup), biomass, pumped-hydro, wave (derated) and geothermal are suitable.**

Table 8 Scenario 1: Solar CST dominant

TECHNOLOGY	POWER CAPACITY, MW 2029	EST. ENERGY GWH / YR	CAP. COST $/kW' (BREE, 2012 & ZCA 2010)	NEW PLANT CAP. COST $B	MAXIMUM (RATED) CAPACITY FACTOR (CF)	LCOE $/ MWH AT RATED CF	EST. (CF) FOR SCENARIO ***	LCOE AT SCENARIO CF
Wind	2500	6,242	$2,530	$6.3	0.38	$91	0.29	$121
Solar CST + storage	3500	9,658	$8,308	$29.1	0.42	$187	0.32	$249
Solar PV large tracking + rooftop	1300	2,050	$3,860	$5.0	0.24	$147	0.18	$196
Biomass backup (Solar CST co-firing + Collie/Kwinana)****	2800	2,453	$500	$1.4	0.80	$89	0.10	$299
Wave	500	1,150	$5,900	$3.0	0.35	$222	0.26	$296
Geothermal (hot sedimentary aquifer)	300	1,636	$7,000	$2.1	0.83	$156	0.62	$208
TOTAL & Weighted Average Levelized Cost of Energy $/ MWh	**10900**	**23,188**		**$46.9**		**$147**		**215**
Pumped storage hydropower* (Assume servicing 50% of wind energy)	500	3,121	2500	$1.3	0.80	$86	0.80	$86
Total Generation + Pumped Hydro				$48.1				
Weighted Average Levelized Cost of Energy (incl Pumped Hydro) $/MWh**						**$151**		**$221**
Storage solar CST	3500	n/a	n/a	n/a				

* Note: Pumped hydro ref for Capital Cost & LCOE: NREL, 7% discount rate. Cost of lower pond is minor factor.

** LCOE increased by the ratio of: total capital with pumped hydro / capital without pumped hydro.

*** LCOE's for this scenario are based on CF which is 75% of the CF at rated LCOE (excluding biomass which is the minimum considered necessary for backup/reserve).

**** Capital portion of LOCE assumed as 50% of full biomass plant. Therefore LCOE = (fuel cost+ratio of CFs x (capital component of LCOE-fuel component of LCOE). Fuel component is $ 59/MWh.

SCENARIO 1: **Concentrated Solar Thermal dominant**

This scenario seeks to achieve a large part of generation by CST (3500 MW).

In addition to this there are 2500 MW of wind farms and 1300 MW of solar PV which are 'non-dispatchable' resources, relying on the intensity of wind and solar radiation. Backup (dispatchable) generation is also required for several 2-3 day periods through the year, and this is mainly provided by 2800 MW of biomass generation co-fired at the CST plants (by biomass delivered from the wheatbelt on existing rail lines), pumped ocean storage with 300 MW capacity, 300 MW of geothermal and a derated amount of wave energy.

Due to the substantial 'over-build' (10,900 MW , for 5,500 MW maximum demand) required to cover periods of low wind and sun and the high cost of solar CST, this scenario is relatively expensive - $46.9 billion for new power plants. An additional $13.9b is required for new 330 kV substations and HVAC transmission lines connecting to the dispersed solar and wind farms. Pumped hydro storage using new storage dams to pump back up into existing dams near Perth, would cost about $1.3b.

Figure 21 Locations of proposed renewable energy generation for Scenario 1

Image: Angus King (SEN)

Figure 22 Relative capacity for Scenario 1

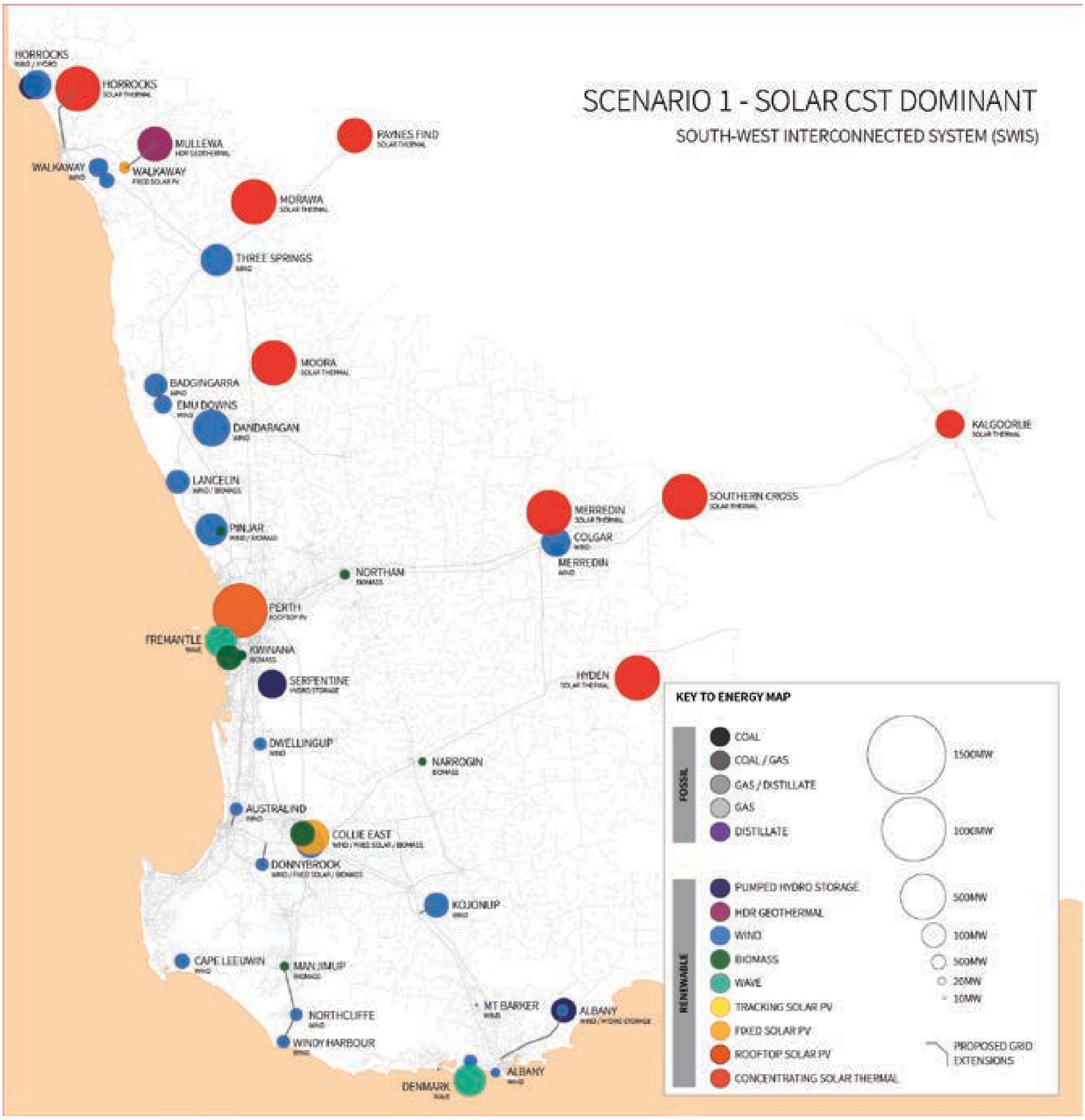


Image: Scott Ludlam and David Robertson

This map describes the total capacity for all power generators envisaged under Scenario 1.

The size of the circle represents the maximum output capacity for that generator in MW, and is not intended to be representative of the actual output of power stations at any given time. Only grid-connected generators are represented on this map, and cumulative capacity from grid-connected rooftop PV systems has been calculated for Perth only. Small-scale installations including landfill gas proposals have been excluded.

SCENARIO 2: **Diverse mix**

The strategy for proportioning the various renewable generation other technologies is to maximise the use of the lowest-cost renewables, using a combination of biomass and pumped-hydro for backup. This scenario utilizes:

- **Wind** (increased to 3000 MW)
- **Solar CST**(reduced to 1500 MW)
- **Solar PV** (increased to 3000 MW) with large tracking solar farms
- **Pumped Hydro** increased to 2000MW
- **Biomass configuration:** at 2500 MW, slightly lower than Scenario 1
- **Wave Energy configuration:** as per Scenario 1
- **Geothermal HDR/EGS configuration:** as per Scenario 1

New transmission connections are as per Scenario 1 with minor differences in connectors.

This scenario still entails 'over-build' of wind, solar CST and biomass with a total of 10,800 MW of generation to provide for a maximum peak of 5,500 MW. The total cost for this is estimated at $42.9bn for new generation, slightly less than Scenario 1.

More pumped hydro storage with total power capacity of approximately 2,000 MW is needed and would cost about $5b. Nominally 500 MW would be located at dams near Perth as for Scenario 1, and used for primarily for load balancing purposes. The remainder is two large cliff-top ponds located north of Geraldton and east of Albany.

Table 9 Scenario 2: Diverse mix, Wind and PV heavy

TECHNOLOGY	POWER MW CAPACITY 2029	EST. ENERGY GWH / YR	CAPITAL COST $/kW (BREE, 2012)	NEW PLANT CAP. COST $B	RATED CAPACITY FACTOR (CF)	LCOE $/ MWH AT RATED CF	EST. CF FOR SCENARIO ***	LCOE AT SCENARIO CF
Wind	3000	7789	$2,530	$7.6	0.38	$91	0.30	$117
Solar CST + storage	1500	4305	$8,308	$12.5	0.42	$187	0.33	$240
Solar PV large tracking + rooftop	3000	4920	$3,860	$11.6	0.24	$147	0.19	$188
Biomass backup (Co-firing)******	2500	3285	$500	$1.3	0.80	$89	0.15	$219
Wave	500	1196	$5,900	$3.0	0.35	$222	0.27	$285
Geothermal	300	1701	$7,000	$2.1	0.83	$156	0.65	$200
TOTAL GENERATION	**10800**	**23196**		**$37.9**		**$132**		**184**
Pumped storage hydropower*	2000	3,895	2500	$5.0	0.80	$86	0.80	$86
Total Generation + Pumped Hydro				$42.9				
Weighted Average Levelized Cost of Energy $/ MWh**						**$149**		**$208**
Storage solar CST	1500	n/a	n/a	n/a				

* Note: Pumped hydro ref for Capital Cost & LCOE: NREL, 7% discount rate. Cost of lower pond is minor factor.

** LCOE increased by the ratio of: total capital with pumped hydro / capital without pumped hydro.

*** LCOE's for this scenario are based on CF which is 78% of the CF at rated LCOE (excluding biomass which is the minimum considered necessary for backup/reserve).

**** Capital portion of LOCE assumed as 50% of full biomass plant. Therefore LCOE = (fuel cost+ratio of CFs x (capital component of LCOE-fuel component of LCOE). Fuel component is $ 59/MWh.

Figure23 Locations of proposed renewable energy generation for Scenario 2

Image: Angus King (SEN)

Figure 24 Relative capacity – Scenario 2

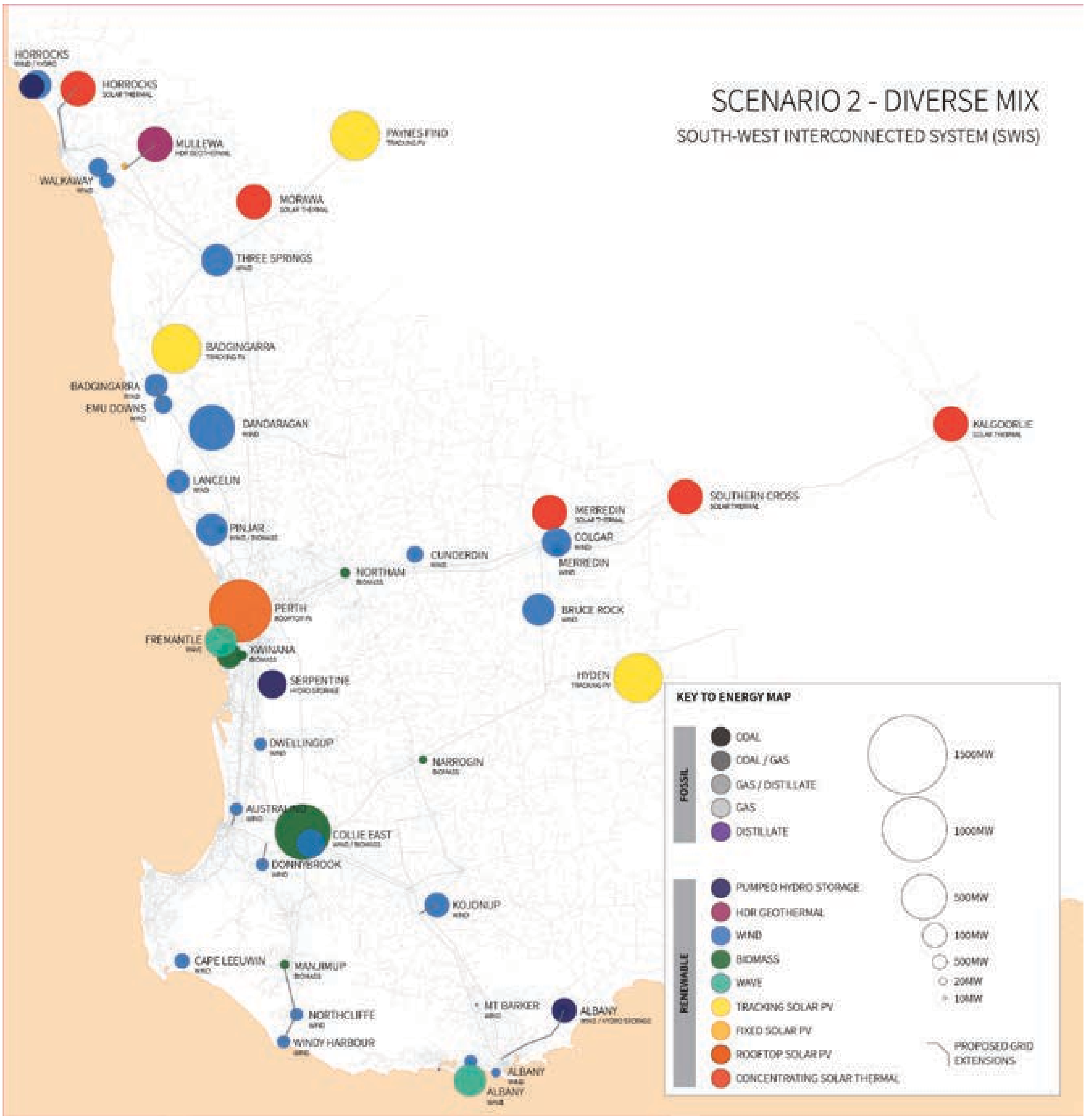


Image: Scott Ludlam and David Robertson

This map describes the total capacity for all power generators envisaged under Scenario 2.

The size of the circle represents the maximum output capacity for that generator in MW, and is not intended to be representative of the actual output of power stations at any given time. Only grid-connected generators are represented on this map, and cumulative capacity from grid-connected rooftop PV systems has been calculated for Perth only. Small-scale installations including landfill gas proposals have been excluded.

SCENARIO 3: **Business as usual (BAU)**

The BAU scenario assumes the same mix of fossil fuel generation concentrated at Collie and Kwinana with a minor amount of wind, and that SWIS demand is scaled up account for growth to 2029 without gains in efficiency or waste reduction, resulting in a 47% increase in demand plus a 15% spinning reserve for peak demand.

This scenario assumes that the power stations are all replaced at a cost of $16.7bn, but without being CCS equipped. Cost of implementing this, if viable would add significantly to both capital costs and LCOE. $3.9bn would be required to replace some transmission infrastructure or increase its capacity, but there would be no pumped storage required.

In addition, the increased demand will require an increased gas supply to SWIS generators, in the form of a new pipeline or other form, but this has not been costed.

Table 10 'Business as usual' per SEI2031 SWIS (Replace and expand existing fossil plant)

REPLACEMENT TECHNOLOGY	POWER CAPACITY 2012, MW	POWER CAPACITY EST. 2029 (1.47* 2012*1.15), MW	EST. ENERGY GWH / YR 2029	CAPITAL COST $/kW (BREE AETA)	REPLACEMENT PLANT COST ($B)	RATED CAPACITY FACTOR (BREE AETA)	LCOE $/MWH AT RATED CF* (BREE AETA)	EST. CF FOR SCENARIO	EST. LCOE $/MWH, SCENARIO CF***
Coal supercritical (No CCS)	2,317	3,916	20,879	$3,381	$13.2	0.83	**$166**	0.70	197
Combined cycle gas (No CCS)	274	463	2,116	$1,111	$0.5	0.83	**$137**	0.60	190
Open cycle gas (No CCS)	2,399	4,054	3,088	$723	$2.9	0.1	**$253**	0.10	253
**Other - IC (est costs scaled up from CCG) ** **	2	3	16	$800	$0.0	0.83	**$137**	0.80	142
TOTAL	4,992	8,436	26,101		$16.7				
Weighted average levelized cost of energy (LCOE)									**$203**

* Note : All LCOE (levelized cost of energy) figures assume a carbon price
** Capital cost estimated.
*** Proportional to ratio of Rated and Estimated CFs. "Variable costs" difference is small because CFs are similar.

Meeting the demand – How much space would 100% renewable energy take?

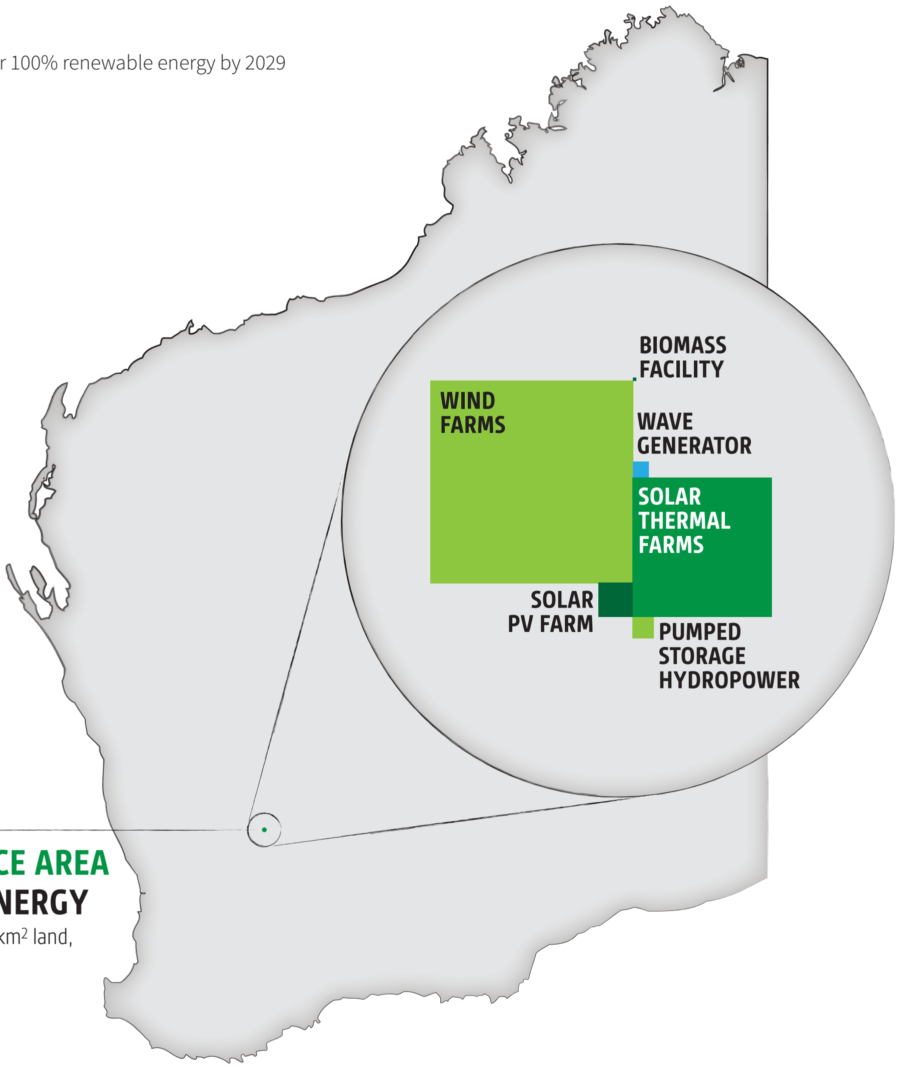
The diagram below (Figure 25) shows the relatively small amount of land needed to provide the energy demand in 2029 on WA's main electricity grid, the SWIS by a combination of the following renewable energies:

- **Solar thermal farm:** 18 x 18 km
- **Solar PV farm:** 4.4 x 4.4 km
- **Wind farm:** 26.5 x 26.5 km
- **Wave generation:** 1.5 x 1.5km
- **Biomass facility:** 0.7 x 0.7km
- **Pumped storage hydropower:** 2.6 x 2.6km

The total surface area of 32.7 x 32.7 km (1072.4km^2) represents just 0.04% of the total land surface area of Western Australia of 2,5000,000 km^2.

The total area for wave generation represents 0.017% of our total coastline of 12,889 km^2 [174].

Figure 25 Total land area required for 100% renewable energy by 2029



174 Note: WA total land surface area is 2,500,000 km2, WA total coastline is 12,889 km2. Source: http://www.landgate.wa.gov.au/corporate.nsf/web/Interesting+Facts+About+Western+Australia

CHAPTER 11

Jobs in WA under a 100% renewable future

Background

At 2010 more than 8,000 people were working in the Australian renewable energy industry full-time, including in construction, installation and operations and maintenance, mainly of biomass, wind and solar PV energy.[175]

This figure does not include people employed in sales, administration, management and other staff associated with the ongoing running of renewable energy businesses - which is likely to number in many thousands. Neither does this figure include around 3,000 part-time solar PV installers nationally, who alternate between solar installations and mainstream electrical contracting.

The Clean Energy Council calculated that by 2020, the total number of full-time workers directly involved in renewable energy construction, installation and operations and maintenance will grow 6-fold to 55,000 nationally, including 8,790 jobs in Western Australia.[176]

Jobs under our plan

Depending on the scenario, an estimated total of **22,267 to 26,861** new net jobs are created[177].

Table 12 summarizes the number of jobs (in construction only) estimated to be created in each technology under Scenario 1.

Table 12 Number of new net jobs created under Scenario 1: Solar heavy mix

TYPE	SIZE (MW)	% OF MIX	ESTIMATED JOBS
Roof-top PV	960	11	2060
Solar Thermal Farm	3500	40	18758
Fixed Solar PV Farm	340	3.9	931
Wind Farm	2500	29	718
Geothermal Station	300	3.4	716
Wave Generator	500	5.7	483
Biomass Facility	400	4.6	656
Storage	5000		2500
Energy Efficiency	232	2.7	39
			26,861

175 Clean Energy Council, 2010. http://cleanenergyaustraliareport.com.au/money-talk/renewable-energy-jobs/

176 Ibid.

177 Job figures sourced from Greenpeace (2008) 'Energy Revolution, A Sustainable Australia Energy Outlook', www.energyblueprint.info/australia.0.html (Accessed 26-Aug-2009). pg 34 table 9, which cites: http://www.energyblueprint.info/fileadmin/media/documents/national/australia_report.pdf

A 100% renewable energy future provides at least three times more new jobs than are employed currently in coal, oil and gas in WA. Figure 26 below illustrates the relative size of the workforce that would be employed just in the construction phase, compared with current industries in WA.

Figure 26 Jobs in Western Australia in 2010 – compared to potential jobs under a 100% Renewable Energy future: A snapshot across industries[178]

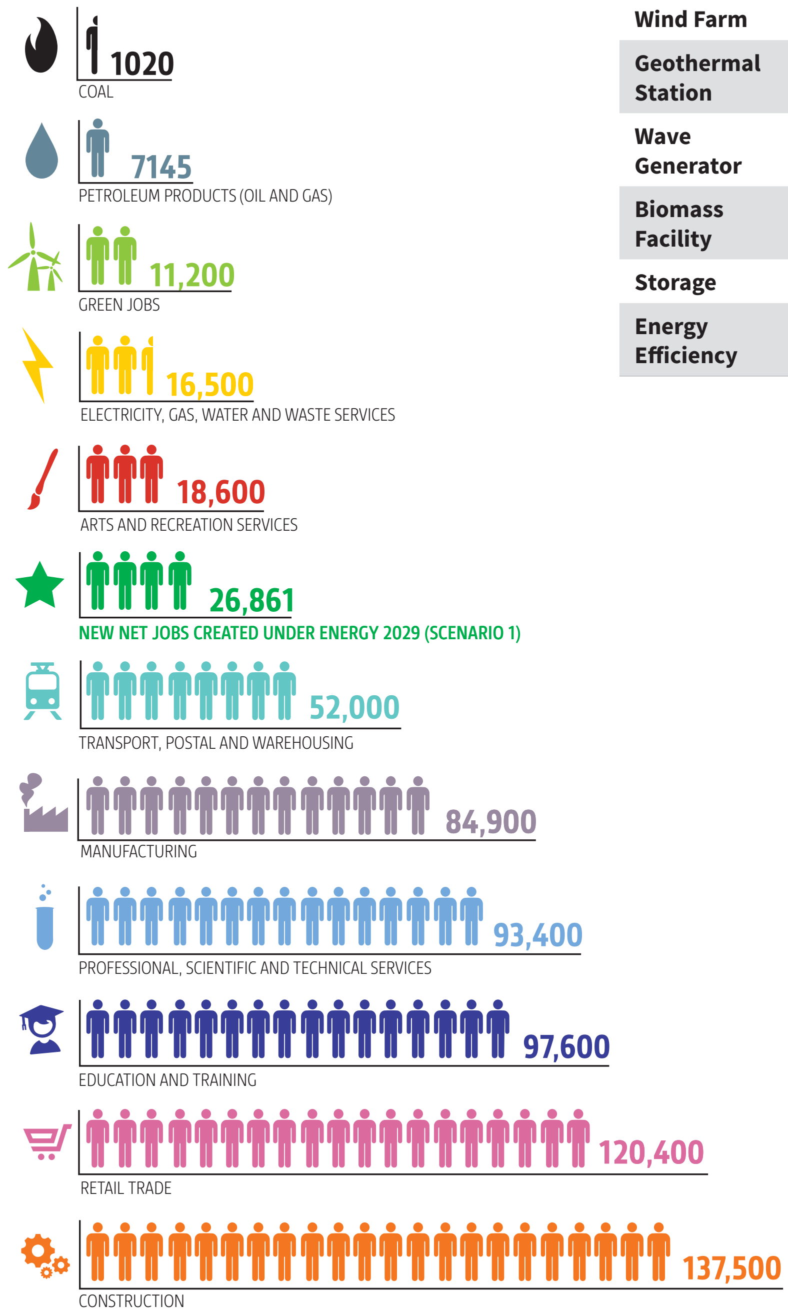


Table 13 Number of new net jobs created under Scenario 2: Diverse mix

TYPE	SIZE (MW)	% OF MIX	ESTIMATED JOBS
Roof-top PV	1190	12	2709
Solar Thermal Farm	1500	16	8104
Fixed Solar PV Farm	10	0.1	0
Tracking Solar PV Farm	1800	19	5080
Wind Farm	3000	31	890
Geothermal Station	300	3.1	716
Wave Generator	500	5.2	483
Biomass Facility	1000	10	1746
Storage	5000		2500
Energy Efficiency	232	2.4	39
			22,267

178 Not a full list of all industries in WA. Mining figures from Employment in Western Australia at November 2010 May 2011 Report from DMP: http://www.dmp.wa.gov.au/documents/StatsDigest2010a.pdf Remaining figures from ABS Statistical snapshot of WA at http://www.abs.gov.au/ausstats/abs@.nsf/Products/788845E95CEACAC1CA25781D000D69AA?opendocument and ACF and ACTU (2008) cited in Thomas, Sandri and Hegarty (2010) Green Jobs in Australia: A Status Report. Sustainability 2010, 2, 3792-3811. Figures are pro rata for the Australian total of 112,000.

CHAPTER 12

What will it cost?

The costs of the 3 scenarios described in Chapter 10 are summarised in Table 14.

Table 14

	AVG. LCOE, $/MWH	GENERATION CAPITAL COST, $BN	OTHER CAPITAL COST, $BN	TRANSMISSION CAPITAL COST, $BN
Scenario 1 100% Renewable Energy CST dominant	221	46.9	1.3	14
Scenario 2 100% Renewable Energy Diverse mix, wind dominant	208	37.9	5	14
Scenario 3 Business As Usual Replace/expand fossil generation, no energy efficiency.	203	16.7	Note: Not included but significant. Will include gas supply system to SWIS generators (pipeline) for example.	3.9

The Business as Usual scenario does not include a number of significant costs. Just two of these costs include ongoing maintenance and upgrades to existing plant, which as previously identified in this report (Appendix Table 17) would be in the vicinity of up to $1 billion every four years. The Dampier to Bunbury gas pipeline will also reach capacity before 2029 requiring a duplicate pipeline laid – another significant cost.

Implementation Rate

To reach the necessary installed capacity of each of the Scenarios to 2029 the rates of deployment are as follows (Table 15 and 16).

Compared to installation timeframes of existing renewable generators, these are achievable, provided forward planning and coordination is done. Examples of forward planning for renewable energy generation are in practice in California, Texas and Queensland, known as "Renewable Energy Zones"[179].

Table 15 Implementation rates by 2029 – Scenario 1

	TOTAL INSTALLED CAPACITY, MW IN 2029 SCENARIO 2	APPROX. AVG. IMPLEMENTATION RATE, MW/YR
Wind	2500	145
Solar PV (utility, commercial, residential)	1300	75
Concentrated Solar Thermal w/storage	3500	205
Pumped-hydro storage	500	30
Biomass	2800	165
DSM (demand side management)	800	45
Wave	500	30
Geothermal	300	15

Table 16 Implementation rates by 2029 – Scenario 2

	TOT. INSTALLED CAPACITY, MW IN 2029 SCENARIO 2A	APPROX. AVG. IMPLEMENTATION RATE, MW/YR
Wind	3000	180
Solar PV (utility, commercial, residential)	3000	180
STC w/storage	1500	90
Pumped-hydro storage	2000	120
Biomass	2500	150
DSM (demand side management)	800	50
Wave	500	30
Geothermal	300	20

179 http://www.westgov.org/rtep/219
http://rti.cabinet.qld.gov.au/documents/2009/jun/qld%20renewable%20energy%20plan/Attachments/Qld%20Renewable%20Energy%20Plan.pdf

Recommendations

State Government

1. Immediately commission the Independent Market Operator (IMO) to undertake a 100% renewable energy study for WA, consistent with the national study being undertaken by the AEMO;
2. Immediately revise the Strategic Energy Initiative 2031, with the revision to acknowledge the existence of climate change and fossil fuel depletion;
3. Appoint a state Minister for Climate Change with cabinet level portfolio responsibility;
4. Establish the Office of Renewable Energy and Innovation to replace the function and priorities of the Department of State Development, with an operational and project budget funded from a transfer of current state mining and fossil fuel subsides (worth approximately $200 million across forward estimates) into the Climate Change portfolio; and
5. Reform the Western Australian electricity market to enable the greatest possible deployment of energy efficiency and renewable energy.

Federal Government

1. Introduce a low greenhouse trigger in the Environment Protection Biodiversity Conservation Act (EPBC), ensuring Federal oversight of developments which are liable to have a significant impact on domestic or global greenhouse emissions;
2. A national system of energy efficiency targets and stringent Minimum Energy Performance Standards (MEPS) for products, buildings and infrastructure;
3. Increase the renewable energy target (RET) and additional measures such as feed-in tariffs and regulations to support a range of prospective new renewable energy technologies;
4. Exclude from the RET new large-scale hydroelectric and native forest fuelled power stations; and
5. Reform electricity markets to remove the bias towards centralised fossil fuel-based generation and encourage demand management and the development of distributed generation and renewable energy.

Glossary

Terminology

Bioenergy	Energy derived from organic matter or biomass - is a term that covers a wide range of energy resources and methods of extracting that energy. Traditional bioenergy, that is burning biomass for heating and cooking, still makes up 13% of global final energy consumption. Modern bioenergy technologies range from direct combustion, pyrolysis, and gasification to anaerobic digestion (breakdown of organic materials by microbes in an oxygen-free environment, producing methane), fermentation of starches or sugars to produce alcohol biofuels and conversion of vegetable oils to biodiesel by chemical reaction (transesterification).
Capacity factor	Ratio of likely actual output of a power plant over a period of time versus its maximum (installed) capacity, taking into account the type of energy used, its availability and plant design. See also installed capacity.
Carbon capture and storage (CCS)	Storage of carbon dioxide in underground rock strata, also referred to as carbon geo-sequestration.
Conventional gas	Natural gas (methane) sourced from onshore and offshore fields using conventional drilling and extraction technology
Dispatchable power	Electricity that may be dispatched at the request of power grid operators; that is, it can be turned on or off upon demand.
Heavy rail	Train/rail transit system that operates within a rail reserve, as opposed to sharing roads with other traffic, such as Perth's existing train lines
Installed/Rated capacity	The maximum amount of electrical power which a power station or other generator can produce at any given point in time. This is different from the total amount of electricity (energy) produced over a period of time. A wind farm with an installed capacity of 100MW may only produce electricity at maximum capacity for 40% of the time, meaning that over a year, its actual electricity produced will be an equivalent of only 40% - as much as if it could generate (i.e. 24 hours x 365 days) x 100MW x 40% = 350,400MWh, or 350.4GWh. Few, if any, power stations, including those run on fossil fuels, are able to operate at 100% installed capacity for 100% of the time due to the need for shut-downs and maintenance.
Life cycle analysis	A technique to assess environmental impacts, such as greenhouse gas emissions, associated with all stages of a product's life including raw material extraction through processing, distribution and use. This is a mixture of lifecycle analysis (i.e. costs over the entire life) and TBL analysis including externalities.
Light rail	A modern tram system with carriages running along tracks within the road reserve, generally powered by electricity.
South West Interconnected System (SWIS)	Electricity grid supplying southern Western Australia (Perth, Geraldton, Kalgoorlie and Albany and areas in between)
Stationary energy	Refers to all non-transport uses of energy including in electricity generation and in manufacturing and industrial processes , as well as heating and cooking in homes and commercial buildings.
Unconventional gas	Natural gas (methane) extracted from onshore gas fields traditionally viewed as too difficult to exploit. Includes coal seam, shale and 'tight' gas, which often require innovative drilling and extraction techniques including horizontal well drilling and hydraulic fracturing, or 'fracking'.

Units

General

Millions of tonnes per annum **(mtpa)**	Commonly used in relation to annual greenhouse gas emissions as well as annual production in the resources industry

Energy

Joule **(J)**	A unit of energy
Terajoule **(TJ)**	One trillion joules (equivalent to one million million joules) = 10^{12} joules
Petajoule **(PJ)**	Equivalent to one thousand terajoules = 10^{15} joules

Electricity

Watt **(W)**	A unit of electrical power equivalent to one joule per second. A 100W appliance will use 100 joules per second of energy.
Kilowatt **(kW)**	One thousand watts = 10^3 watts
Megawatt **(MW)**	One million watts = 10^6 watts
Gigawatt **(GW)**	One billion watts (equivalent to one thousand million watts) = 10^9 watts
Terawatt **(TW)**	One trillion watts (equivalent to one million million watts) = 10^{12} watts
Watt hours **(Wh)**	The amount of power used or produced over one hour. For example, a 100W appliance run continuously will use 100Wh over one hour, or 2400Wh (2.4kWh) over a day.
Kilowatt hours **(kWh)**	One thousand watt hours = 10^3 wH
Watt thermal **(WTh)**	Refers to a unit of thermal energy instead of electricity
Megawatt electric **(MWe)**	Refers to the electric power measured in megawatts

What's with these watts?

One watt: Roughly the energy expended by a candle.
14 watts: Compact fluorescent globe
60-100 watts: Old-school incandescent globe
One thousand watts (one kilowatt, kW)
Roughly equal to 1.34 horsepower
Single bar heater : 1 kW
Car air conditioner: 4 kW
Residential reverse cycle air conditioner: 6 kW
Small community-scale wind turbine: 10 kW
Tesla Roadster electric car: 185 kW
One million watts (one megawatt, MW)
Albany wind turbine: 1.8 MW maximum output
Muja power station stages C and D: 854 MW

Acronyms

ABARE	Australian Bureau of Agricultural and Resource Economics
CO2e	Carbon dioxide equivalent (refers to a measurement of all greenhouse gases emitted from a source. Since the intensity of various gases that contribute to the Greenhouse Effect vary, they can be measured in terms of their equivalent weight in carbon dioxide)
CSG	Coal seam gas
CSP	Concentrated solar power – generally refers to concentrated solar thermal power (CST) which is more specific to themal plants rather than concentrated solar PV.
GDP	Gross domestic product
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
mtpa	millions of tonnes per annum
PV	Photovoltaic
SWIS	South-West Interconnected System (see glossary)

Appendices

Table 17 WA Government budgeted and estimated forward spending via the Office of Energy 2010-2011 to 2013-2014

AGENCY	ITEM	TOTAL FUNDING ALLOCATED IN 2010/11 BUDGET AND OVER FORWARD ESTIMATES TO 2013/14
Western Power	**Total spending on asset investment, including:**	**$2.7B**
	Transmission works, including customer-driven works ($100M) and new capacity, asset replacement etc. ($741M)	$841M
	Distribution works, including customer-driven works ($294M - mainly to be spent expanding the SWIS to meet new land residential, commercial and industrial land divisions) and new capacity and asset replacement ($1.3B – mainly new feeder lines, replacing poles and meeting new regulatory requirements)	$1.6B
	Mobile plant, replacement IT and motor vehicles	$239M
Verve Energy	**Total spending on asset investment, including:**	**$391M**
	Construction of two 100MW high efficiency gas turbines, to be commissioned in 2011-2012	$177M
	Various works at Muja coal-fired power station	$83M
	Strategic 'spares' for Cockburn and Pinjar gas turbines & other plant modifications	$70M
	Various works at Kwinana gas, coal and oil-fired power station	$25M
	Total spending on fossil fuel assets	$355M
	Wind-diesel operations off the SWIS	$2.6M
	Total spending on renewable energy assets	$2.6M

AGENCY	ITEM	TOTAL FUNDING ALLOCATED IN 2010/11 BUDGET AND OVER FORWARD ESTIMATES TO 2013/14
Horizon Power	**Total spending on asset investment, including:**	**$378M**
	Pilbara Underground power Project to increase protection from cyclones	$119M
	Regularising electricity supplies to Aboriginal communities	$26M
	Distribution network enhancements	$121M
	Other works	$44M
	Improve reliability in Carnarvon	$68M
North Country Reinforcement (A 200km, 330kV transmission line from Pinjar to Eneabba and a 132/330kV terminal at Three Springs, enabling connection of Karara Mining Ltd iron ore mine site with the Eneabba and Three Springs terminals)	**Total asset investment**	**$319M**
Synergy	**Total asset investment** (mainly enhancement of IT and improvements in services to 900,000 customers)	**$31M**
Independent market operator	Upgrade and enhance operations of the wholesale electricity market system	$5M
TOTAL PROPOSED CAPITAL INVESTMENT OVER BUDGET & FORWARD INVESTMENT PERIOD 2010/11- 2013/14		**$3.8B**

Source: Office of Energy Budget Paper, 2010-2011 at http://www.dtf.wa.gov.au/cms/uploadedFiles/State_Budget/Budget_2010_11/00_part_11_0_energy.pdf

Table 18 WA Government budgeted and estimated forward spending on fossil fuels via the departments of State Development and Mines and Petroleum, 2010-2011 to 2013-2014[180]

AGENCY	ITEM	TOTAL MONEY ALLOCATED IN 2010-2011 BUDGET AND OVER FORWARD ESTIMATES TO 2013-2014
Office of State Development	Ashburton North and Anketell strategic industrial areas	$4.5M
	Browse Basin liquid natural gas precinct	$101M
Total allocated to developing infrastructure for LNG		**$105.5M**

Table 19 WA Government budgeted and estimated forward spending on fossil fuels via the departments of Department of Mines and Petroleum, 2010-2011 to 2013-2014[181]

AGENCY	ITEM	TOTAL MONEY ALLOCATED IN 2010-2011 BUDGET AND OVER FORWARD ESTIMATES TO 2013-2014
Dept of Mines & Petroleum	Petroleum systems and process improvements	$6M
	Regulating the Gorgon gas project	$5M
	Regulating the introduction of uranium mining	$3M
	Exploration Incentive Scheme (EIS)	$80m (allocated 2009-10 budget over 5 years)
Total allocated to providing services to petroleum and uranium industry		**$94M**

Table 20 Energy Consumption in Western Australia by Industry and Fuel type 2008–2009[182]

FUEL TYPE	AGRIC	MINING*	INDUSTRIAL PROCESSES**	ELECTRICITY, GAS, WATER & WASTE SERVICES	CONSTRUCTION	COMMERCIAL SERVICES	RESIDENTIAL	TRANSPORT & STORAGE	SOLVENTS, LUBRICANTS, BITUMEN	TOTAL	% OF TOTAL
Natural gas	-	162	157	155	-	3	10	13	-	500	**53**
Petroleum products* **	16	42	26	10	5	7	2	190	7	305	**32**
Black coal	-	5	28	86	-	-	-	-	-	119	**13**
Renewables ****	-	-	5	1	-	-	12	-	-	18	**2**
TOTAL	16	209	216	252	5	10	24	203	7	942	**100**
(% of total)	**1.7**	**22.2**	**23**	**27**	**0.53**	**1.1**	**2.5**	**21.5**	**0.7**		

* Includes coalmining, oil and gas extraction, metal and non-metallic mineral mining, exploration and support services.
** Includes petroleum and coal product manufacturing, metal and non-metallic mineral product manufacturing.
*** Includes aviation fuels, automotive and industrial diesel, fuel oil, refinery fuel, solvents, lubricants, etc.
**** Wind and solar production data sourced from Energy Supply Association of Australia (ESAA).

180 Source: 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
181 Government of Western Australia 2011-11Budget 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
182 Source: Adapted from ABARE data, Australian Parliamentary library brief "Energy use in WA" and Pers.Comm with Greg Baker.

Table19 Concentrating Solar Power Projects – Operational, under construction, and under development at December 2012

Concentrating Solar Power Projects - Operational Plants

There are 61 Concentrating solar power (CSP) projects with working power plants currently operating at December 2012. These are listed below alphabetically by project name.

	PROJECT	LOCATION	LAT/LONG LOCATION	TECHNOLOGY	TURBINE CAPACITY (GROSS)	STORAGE	JOBS CONSTRUCTION (JOB-YEARS)	JOBS ANNUAL O&M
1	Andasol-1 (AS-1)	Granada, Spain	37°13′ 50.83″ North, 3°4′ 14.08″ West	Parabolic trough	50MW	7.5hrs	600	40
2	Andasol-2 (AS-2)	Granada, Spain	37°13′ 50.83″ North, 3°4′ 14.08″ West	Parabolic trough	50MW	7.5hrs	600	40
3	Andasol-3 (AS-3)	Granada, Spain	37°13′ 42.7″ North, 3°4′ 6.73″ West	Parabolic trough	50MW	7.5hrs		
4	Archimede	Sicily, Italy	37°8′ 3.12″ North, 15°13′ 0.15″ East	Parabolic trough	5MW	8 hrs		
5	Arcosol 50 (Valle 1)	Cadiz, Spain	36°39′ 40.0″ North, 5°50′ 0.0″ West	Parabolic trough	49.9MW	7.5hrs		
6	Aste 1A	Ciudad Real, Spain	39°10′ 34.0″ North, 3°14′ 4.0″ West	Parabolic trough	50MW	8hrs	500	50
7	Aste 1B	Ciudad Real, Spain	39°10′ 34.0″ North, 3°14′ 4.0″	Parabolic trough	50MW	8hrs	500	50
8	Astexol II	Badajoz, Spain	38°48′ 36.0″ North, 7°3′ 9.0″ West	Parabolic	50MW	8hrs	500	50
9	Augustin Fresnel 1	Pyreneans, France	42°30′ 4.0″ North, 1°58′ 20.0″ East	Linear Fresnel reflector	250kW	0.25hrs	10	3
10	Beijing Badaling Solar Tower	Beijing, China	40°40′ North, 115°90′ East	Power tower	1.5MW	1 hr		
11	Colorado Integrated Solar Project (Cameo)	Colorado, USA	39°8′ 54.96″ North, 108°19′ 5.1234″ West	Parabolic trough	2MW	NA		
12	Extresol-1 (EX-1)	Badajoz, Spain	38°39′ North, 6°44′ West	Parabolic trough	50MW	7.5hrs	600	40
13	Extresol-2 (EX-2)	Badajoz, Spain	38°39′ North, 6°44′ West	Parabolic trough	49.9MW	7.5hrs	600	40

	PROJECT	LOCATION	LAT/LONG LOCATION	TECHNOLOGY	TURBINE CAPACITY (GROSS)	STORAGE	JOBS CONSTRUCTION (JOB-YEARS)	JOBS ANNUAL O&M
14	Gemasolar Thermosolar Plant (Gemasolar) Cost: 230m Euro	Sevilla, Spain	37°33′ 44.95″ North, 5°19′ 49.39″ West	Power tower	19.9MW	15hrs	800	45
15	Helioenergy 1	Sevilla, Spain	37°34′ 55.0″ North, 5°6′ 57.0″ West	Parabolic trough	50MW	-	600	60
16	Helioenergy 2	Sevilla, Spain	37°34′ 55.0″ North, 5°6′ 57.0″ West	Parabolic trough	50MW	-	600	60
17	Helios I (Helios I)	Ciudad Real, Spain	39°14′ 24.0″ North, 3°28′ 12.0″ West	Parabolic trough	50MW	-	600	40
18	Holaniku at Keahole Point	Hawaii, USA	19°43′ North, 156°2′ West	Parabolic trough	2MW	2hrs	NA	NA
29	Ibersol Ciudad Real (Puertollano)	Castilla-La Mancha, Spain	38°38′ 36.19″ North, 3°58′ 29.6″ West	Parabolic trough	50MW	-	NA	60
20	ISCC Hassi R'mel (ISCC Hassi R'mel)	Hassi R'mel, Algeria	33°7′ 0.0″ North, 3°21′ 0.0″ West	Parabolic trough	25MW	-	NA	NA
21	ISCC Kuraymat (ISCC Kuraymat)	Kuraymat, Egypt	29°16′ 0.0″ North, 31°15′ 0.0″ East	Parabolic trough	20MW	-	NA	NA
22	ISCC Morocco (ISCC Morocco)	Ain Beni Mathar, Morocco	34°3′ 50.0″ North, 2°6′ 0.0″ West	Parabolic trough	20MW	-	NA	NA
23	Jülich Solar Tower	Rhineland, Germany	NA	Power tower	1.5MW	1.5hrs	NA	NA
24	Kimberlina Solar Thermal Power Plant (Kimberlina)	Kern, California	35°34′ 0.0″ North, 119°11′ 39.1″ West	Linear fresnel reflector	5MW	-	NA	NA
25	La Africana	Cordoba, Spain	37°44′ 52.0″ North, 5°6′ 56.0″ West	Parabolic trough	50MW	7.5hrs	300	40
26	La Dehesa	Badajoz, Spain	38°57′ 6.14″ North, 6°27′ 48.36″ West	Parabolic trough	49.9MW	7.5hrs	950	45
27	La Florida	Badajoz, Spain	38°49′ 1.11″ North, 6°49′ 45.49″ West	Parabolic trough	50MW	7.5hrs	950	45

	PROJECT	LOCATION	LAT/LONG LOCATION	TECHNOLOGY	TURBINE CAPACITY (GROSS)	STORAGE	JOBS CONSTRUCTION (JOB-YEARS)	JOBS ANNUAL O&M
28	La Risca (Alvarado I)	Badajoz, Spain	38°49′ 37.0″ North, 6°49′ 34.0″ West	Parabolic trough	50MW	-	350	31
29	Lebrija 1 (LE-1)	Sevilla, Spain	37°0′ 10.8″ North, 6°2′ 52.0″ West	Parabolic trough	50MW	-	500	-
30	Majadas I	Caceras, Spain	39°58′ 5.0″ North, 5°44′ 32.0″ West	Parabolic trough	50MW	-	350	31
31	Manchasol-1 (MS-1)	Ciudad Real, Spain	39°11′ 17.08″ North, 3°18′ 33.71″ West	Parabolic trough	49.9MW	7.5hrs	600	40
32	Manchasol-2 (MS-2)	Ciudad Real, Spain	39°10′ 55.5″ North, 3°18′ 48.96″ West	Parabolic trough	50MW	7.5hrs	600	40
33	Maricopa Solar Project (Maricopa)	Arizona, USA	33°33′ 31.0″ North, 112°13′ 7.0″ West	Dish/Engine	1.5MW	-	50	5
34	Martin Next Generation Solar Energy Center (MNGSEC)	South Florida, USA	27°3′ 13.0″ North, 80°33′ 46.0″ West	Parabolic trough	75MW			
35	Morón	Seville, Spain	37°8′ 23.0″ North, 5°28′ 16.0″ West	Parabolic trough	50MW	-	600	40
36	Nevada Solar One (NSO) Cost US$266m	Nevada, USA	35°48′ North, 114°59′ West	Parabolic trough	75MW	0.5hrs	350	30
37	Palma del Río I	Cordoba, Spain	37°38′ 42.0″ North, 5°15′ 29.0″ West	Parabolic trough	50MW	-	350	31
38	Palma del Río II	Cordoba, Spain	37°38′ 42.0″ North, 5°15′ 29.0″ West	Parabolic trough	50MW	-	350	31
39	Planta Solar 10 (PS10)	Sevilla, Spain	37°26′ 30.97″ North, 6°14′ 59.98″ West	Power tower	11.02MW	1hr		
40	Planta Solar 20 (PS20)	Sevilla, Spain	37°26′ 30.97″ North, 6°14′ 59.98″ West	Power tower	20MW	1hr		
41	Puerto Errado 1 Thermosolar Power Plant (PE1)	Murcia, Spain	38°16′ 42.28″ North, 1°36′ 1.01″ West	Linear Fresnel reflector	1.4MW			

	PROJECT	LOCATION	LAT/LONG LOCATION	TECHNOLOGY	TURBINE CAPACITY (GROSS)	STORAGE	JOBS CONSTRUCTION (JOB-YEARS)	JOBS ANNUAL O&M
42	Puerto Errado 2 Thermosolar Power Plant (PE2)	Murcia, Spain	38°16′ 42.28″ North, 1°36′ 1.01″ West	Linear Fresnel reflector	30MW	0.5hrs		
43	Saguaro Power Plant	Red Rock, Arizona	32°57′ 36.0″ North, 111°32′ 30.0″ West	Parabolic trough	1.16MW			
44	Sierra SunTower (Sierra)	Lancaster, California	34°46′ North, 118°8′ West	Power tower	5MW	-	130	12
45	Solaben 3	Caceres, Spain	39°13′ 29.0″ North, 5°23′ 26.0″ West	Parabolic trough	50MW	-	700	85
46	Solacor 1	Cordoba, Spain	37°54′ 54.0″ North, 4°30′ 9.0″ West	Parabolic trough	50MW	-	450	40
47	Solacor 2	Cordoba, Spain	37°54′ 54.0″ North, 4°30′ 9.0″ West	Parabolic trough	50MW	-	450	40
48	Solar Electric Generating Station I (SEGS I)	Mojave Desert, California	34°51′ 47.0″ North, 116°49′ 37.0″ West	Parabolic trough	13.8MW	3 hrs		
49	Solar Electric Generating Station II (SEGS II)	Mojave Desert, California	34°51′ 47.0″ North, 116°49′ 37.0″ West	Parabolic trough	30MW	-		
50	Solar Electric Generating Station III (SEGS III)	Mojave Desert, California	35°0′ 51.0″ North, 117°33′ 32.0″ West	Parabolic trough	30MW			
51	Solar Electric Generating Station IV (SEGS IV)	Mojave Desert, California	35°0′ 51.0″ North, 117°33′ 32.0″ West	Parabolic trough	30MW			
52	Solar Electric Generating Station V (SEGS V)	Mojave Desert, California	35°0′ 51.0″ North, 117°33′ 32.0″ West	Parabolic trough	30MW			
53	Solar Electric Generating Station VI (SEGS VI)	Mojave Desert, California	35°0′ 51.0″ North, 117°33′ 32.0″ West	Parabolic trough	30MW			
54	Solar Electric Generating Station VII (SEGS VII)	Mojave Desert, California	35°0′ 51.0″ North, 117°33′ 32.0″ West	Parabolic trough	30MW			

	PROJECT	LOCATION	LAT/LONG LOCATION	TECHNOLOGY	TURBINE CAPACITY (GROSS)	STORAGE	JOBS CONSTRUCTION (JOB-YEARS)	JOBS ANNUAL O&M
55	Solar Electric Generating Station VIII (SEGS VIII)	Mojave Desert, California	35°1′ 54.0″ North, 117°20′ 53.0″ West	Parabolic trough	89MW			
56	Solar Electric Generating Station IX (SEGS IX)	Mojave Desert, California	35°1′ 54.0″ North, 117°20′ 53.0″ West	Parabolic trough	89MW			
57	Solnova 1	Sevilla, Spain	37°26′ 30.97″ North, 6°14′ 59.98″ West	Parabolic trough	50MW	-		
58	Solnova 3	Sevilla, Spain	37°26′ 30.97″ North, 6°14′ 59.98″ West	Parabolic trough	50MW			
59	Solnova 4	Sevilla, Spain	37°26′ 30.97″ North, 6°14′ 59.98″ West	Parabolic trough	50MW	-		
60	Termesol 50 (Valle 2)	Caidz, Spain	36°39′ 40.0″ North, 5°50′ 50.0″ West	Parabolic trough	49.9MW	7.5hrs	900	45
61	Thai Solar Energy 1 (TSE1)	Kanchanaburi Province, Thailand	14°19′ 34.0″ North, 99°39′ 52.0″ East	Parabolic trough	5MW	-	120	10

Source: http://www.nrel.gov/csp/solarpaces/operational.cfm

Concentrating Solar Power Projects - Under Construction

At December 2012 there were 22 Concentrating Solar Plants under construction

	PROJECT	LOCATION	LAT/LONG LOCATION	TECHNOLOGY	TURBINE CAPACITY (GROSS)	JOBS CONSTRUCTION (JOB-YEARS)	JOBS ANNUAL O&M
1	Abengoa Mojave Solar Project	Harper Dry Lake, California	35°1′ North, 117°20′ West	Parabolic trough	250 MW	1200	80
2	Agua Prieta II	Sonora State, Mexico	31°19′ 33.0″ North, 109°32′ 56.0″ West	Parabolic trough	14 MW	NA	NA
3	Arenales	Sevilla, Spain	N/A	Parabolic trough	50MW	NA	NA
4	Borges Termosolar	Lledia, Spain	N/A	Parabolic trough hybrid CSP biomass plant	25MW	NA	NA
5	Casablanca	Badajoz, Spain	N/A	Parabolic trough	50MW	NA	NA
6	Enerstar (Villena)	Alicante, Spain	38°44′ 33.0″ North, 0°54′ 27.0″ West	Parabolic trough	50 MW	NA	NA
7	Extresol-3 (EX-3)	Badajoz, Spain	38°39′ North, 6°44′ West	Parabolic trough	50MW	600	40

	PROJECT	LOCATION	LAT/LONG LOCATION	TECHNOLOGY	TURBINE CAPACITY (GROSS)	JOBS CONSTRUCTION (JOB-YEARS)	JOBS ANNUAL O&M
8	Godawari Solar Project	Rajhasta, India	N/A	Parabolic trough	50MW	NA	NA
9	Guzmán	Cordoba, Spain	37°9′ 7.0″ North, 5°16′ 16.0″ West	Parabolic trough	50MW	NA	NA
10	Helios II (Helios II)	Ciudad Real, Spain	39°14′ 24.0″ North, 3°28′ 12.0″ West	Parabolic trouch	50MW	600	40
11	Ivanpah Solar Electric Generating Station (ISEGS)	San Bernadino, California	35°33′ 8.5″ North, 115°27′ 30.97″ West	Power tower	370MW	NA	NA
12	Kogan Creek Solar Boost Kogan Creek)	Chinchilla, Queensland	NA	Linear Fresnel reflector	44MW	NA	NA
13	Olivenza 1	Badajoz, Spain	38°48′ 37.0″ North, 7°3′ 32.0″ West	Parabolic trough	50MW	600	45
14	Orellana	Badajoz, Spain	38°59′ 31.0″ North, 5°32′ 56.0″ West	Parabolic trough	50MW	NA	NA
15	Shams 1 (Shams 1)	Madinat Zayed, United Arab Emirates	NA	Parabolic trough	100MW	NA	NA
16	Solaben 1	Caceres, Spain	39°13′ 29.0″ North, 5°23′ 26.0″ West	Parabolic trough	50MW	700	85
17	Solaben 2	Caceres, Spain	39°13′ 29.0″ North, 5°23′ 26.0″ West	Paraobolic trough	50MW	700	85
18	Solaben 6	Caceres, Spain	39°13′ 29.0″ North, 5°23′ 26.0″ West	Parabolic trough	50MW	700	85
29	Solana Generating Station (Solana)	Phoenix, Arizona	32°55′ 0.0″ North, 112°58′ 0.0″ West	Parabolic trough	280MW	1500	85
20	Supcon Solar Project	Qinghai, China	NA	Power tower	50MW	NA	NA
21	Termosol 1	Badajoz, Spain	NA	Parabolic trough	50MW	NA	NA
22	Termosol 2	Badajoz, Spain	NA	Parabolic trough	50MW	NA	NA

Source: http://www.nrel.gov/csp/solarpaces/under_construction.cfm

Concentrating Solar Power Projects - Under Development

At December 2012 there were 16 Concentrating solar power (CSP) projects under development are listed below—alphabetically by project name. These projects have signed agreements, but actual construction is still pending.

	PROJECT	LOCATION	LAT/LONG LOCATION	TECHNOLOGY	TURBINE CAPACITY (GROSS)	JOBS CONSTRUCTION (JOB-YEARS)	JOBS ANNUAL O&M
1	BrightSource Coyote Springs 1 (PG&E 3) (Coyote Springs 1)	Nevada, USA	NA	Power Tower	200MW		
2	BrightSource Coyote Springs 2 (PG&E 4) (Coyote Springs 2)	Nevada, USA	NA	Power tower	200MW		
3	BrightSource PG&E 5	TBC, California	NA	Power tower	200MW		
4	BrightSource PG&E 6	TBC, California	NA	Power tower	200MW		
5	BrightSource PG&E 7	TBC, California	NA	Power tower	200MW		
6	Crescent Dunes Solar Energy Project (Tonopah)	Nevada, USA	38°14′ North, 117°22′ West	Power tower	110MW		
7	Gaskell Sun Tower (Gaskell)	Lancaster, California	NA	Power tower	245MW		
8	Genesis Solar Energy Project	Riverside, California	33°40′ North, 114°59′ West	Parabolic trough	250MW		
9	KaXu Solar One	Northern Cape, South Africa	29°7′ 46.0″ South, 19°23′ 37.0″ East	Parabolic trough	100MW		
10	Khi Solar One	Northern Cape, South Africa	28°28′ 34.0″ South, 21°14′ 18.0″ East	Power tower	50MW		
11	NextEra Beacon Solar Energy Project (Beacon)	Kern, California	35°16′ North, 118°0′ 30.0″ West	Parabolic trough	250MW		
12	Palen Solar Power Project	Riverside, California	33°50′ 56.0″ North, 115°14′ 22.0″ West	Parabolic trough	500MW		
13	Palmdale Hybrid Power Plant (PHPP)	Victorville, California	NA	Parabolic trough	50MW		
14	Pedro de Valdivia	Antofagasta, Chile	NA	Parabolic trough	360MW		
15	Rice Solar Energy Project (RSEP)	Mojave Desert, California	34°4′ North, 114°49′ West	Power tower	150MW	450	445
16	Victorville 2 Hybrid Power Plant	Victorville, California	NA	Parabolic trough	50MW		

Source: http://www.nrel.gov/csp/solarpaces/being_developed.cfm greenswa.net.au/energy2029

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