RENEWABLE NARRABRI SHIRE:
Solar and Wind versus Gas
In North-West New South Wales

UTS Institute for Sustainable Futures

2018

ABOUT THE AUTHORS

The Institute for Sustainable Futures (ISF) was established by the University of Technology Sydney in 1996 to work with industry, government and the community to develop sustainable futures through research and consultancy. Our mission is to create change toward sustainable futures that protect and enhance the environment, human well-being and social equity. We seek to adopt an inter-disciplinary approach to our work and engage our partner organisations in a collaborative process that emphasises strategic decision-making.
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COOPERATION PARTNER

The report has been commissioned by Lock the Gate and all information related to the Narrabri Gas Project has been taken from public websites. ISF did not undertake any direct interviews with company representatives from Santos. The contract focus for ISF was the development of RENEWABLE energy scenarios.

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All conclusions and any errors that remain are the authors own.

DISCLAIMER

The authors have used all due care and skill to ensure the material is accurate as at the date of this report. UTS and the authors do not accept any responsibility for any loss that may arise by anyone relying upon its contents.

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Research structure

This research is divided in four parts:

1. Mapping of solar and wind resources for the Narrabri Shire
2. Development of a pathway for new installed capacity of solar and wind power generation in the Narrabri region for 2020 and 2030
3. Calculation of possible generation output from new capacities of renewable energy (RE) as an alternation to gas exports from the Narrabri Shire to New South Wales
4. Compare RE parameters with planned gas developments (based on publicly available Santos information)

EXECUTIVE SUMMARY

The Shire must however balance any negative impacts from renewable energy development against the continued need to sustain its agricultural base. The NSW Government has commited to utilise energy production from renewable sources (wind, solar, biofuel, geothermal) to 20% of all production by 2020. Narrabri Shire's part of the "New England Renewable Energy Precinct" established by the State Government in February 2010 to attract investment in renewable energy prospects".[1]

Narrabri Shire Economic Social Plan 2000-2015

In September 2013, the NSW Government released the NSW Renewable Energy Action Plan to guide NSW's renewable energy development and to support the former national target of 20% renewable energy by 2020. According to this plan, the NSW Government's vision for a secure, reliable, affordable and clean energy future is estimated to create 6,000 new jobs in regional NSW. The strategy is to work closely with NSW communities and the renewable energy industry to increase renewable energy generation in NSW[2]. This action plan is in line with the RENEWABLE exports scenario(s) outlined in this report.

This report has been commissioned by Lock the Gate in order to analyse solar and wind resources for the Narrabri Shire and to develop pathways for solar and wind power generation in the Narrabri Shire for 2020 and 2030. The Narrabri Shire covers an area of around 13,000 square kilometres. It is located in the heart of the Namoi Valley in the North West slopes and plains of New South Wales. Based on the potential electricity generation from new renewable energy (RE) power plants, ISF developed two different renewable export scenarios to provide an alternative to gas exports from the Narrabri Shire to New South Wales.

In both Renewable Energy Export scenarios, the Narrabri Shire plays an important part in New South Wales' energy transformation – producing significantly more electricity than is required locally, resulting in more and longer lasting jobs for the Shire than the Narrabri gas field would generate, and affecting a much smaller area of land. The scenarios outlined in this report are aligned with the NSW Renewable Energy Action Plan.

In the **RENEWABLE ADVANCE EXPORT (RE-ADV-X)** scenario, significant land area in the Narrabri Shire is dedicated to solar and wind generation. Though with 38 km^2 of solar photovoltaic and 120 km^2 of wind power, the total land area needed to fulfil this ambitious scenario is only 17% of the area proposed to be occupied by the Santos gas field. This scenario would lead to a capacity of 3,800 MW of solar photovoltaic and 600 MW of wind installed by 2030 turning Narrabri Shire into an energy powerhouse.

While the Narrabri Shire currently has an average load of 9 MW – with a peak just under 20 MW - the RE-AD-X would deliver a maximum solar and wind production of 1,450 MW in 2020 and up to 3,900 MW in 2030. This scenario requires addition power lines as well as a significant enforcement of the existing 132 kV transmission line in order to export this capacity to the Australian National Electricity Market (NEM) grid[3]. The actual required grid concept is not within the scope of this analysis

A second, more conservative scenario – the **RENEWABLE EXPORT (RE-X)** scenario – will require a total land area of 41 km^2 in the Narrabri Shire; 6 km^2 for solar photovoltaic and 35 km^2 of wind power. The total land area needed to fulfil this scenario is only 4% of the area proposed to be occupied by Narrabri Gas Project. Under the RE-X 622 MW of solar photovoltaic and 175 MW of wind would be installed in the Shire by 2030 and supply at all times 100% of Narrabri Shire's power demand and export the remaining power to the NEM grid. Table 1 shows the average projected demand, supply and export quantities for 2020 and 2030 under the RE-X scenario. The maximum export capacity will be limited to 240 MW in 2020 and 640 MW by 2030, however the average

[1] Narrabri Shire Economic Social Plan, 2000-2015 (N-ESP 2015), http://www.narrabri.nsw.gov.au/files/uploaded/file/Economic%20Development/Narrabri%20Shire%20Economic%20Social%20Plan_Public%20Exhibition%20Final(1).pdf
[2] NSW Renewable Energy Action Plan; https://www.resourcesandenergy.nsw.gov.au/energy-consumers/sustainable-energy/renewable-energy-action-plan
[3] Australian Energy and Market Operator (AEMO): The National Electricity Market (NEM) incorporates around 40,000 km of transmission lines and cables; supplies about 200 terawatt hours of electricity to businesses and households each year and serves around 9 million customers. It has a total electricity generating capacity of almost 54,421 MW (as at December 2017). https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM

export capacity in 2030 is around 154 MW. The existing power line might still need an upgrade, however the required additional power transmission capacity is significantly lower than that for the advanced case.

Table 1: RE-X: Narrabri Shire electricity production and export to NSW 2020 and 2030

		Load	
	Total [MWh/a]	MAX [MW]	AVERAGE [MW]
Electricity Production Narrabri Shire 2020	548,840	240	63
Demand Narrabri Shire 2020	74,511	17	9
Export Narrabri Shire to NSW 2020	474,330	231	54
Electricity Production Narrabri Shire 2030	1,432,332	641	164
Demand Narrabri Shire 2030	81,962	19	9
Export Narrabri Shire to NSW 2030	1,350,370	632	154

In order to install the suggested solar and wind capacity for the ADVANCED case (RE-ADV-X), a total investment of approximately $6.5 billion is required. The amount can be lower, if solar photovoltaic and wind turbine equipment and installation costs continue to fall as they have over the past decade due to economies of scale. The RE-X case requires less than one sixth of the overall investment volume - $ 1 billion - compared to the advanced case. The majority of the investment will be in solar photovoltaic, while the investments for wind are moderate and in the typical range of a community lead project.

Table 2: Key results – Narrabri Shire RENEWABLES Export (RE-X)

Narrabri Shire: RENEWABLES EXPORT - Key Results -	2015 [MW]	2020 [MW]	2025 [MW]	2030 [MW]
Installed Capacity	**50**	**298**	**550**	**797**
- Wind (Onshore)	0	72	104	175
- PV (utility scale + roof top)	50	226	446	622
Total Investment Cost 2015 - 2030	**2015-2020**		**2021-2030**	
- Wind (Onshore)	$ 43 mio.		$ 55 mio	
- PV (utility scale + roof top)	$ 303 mio.		$ 602 mio.	

Employment effects

The RE-ADV-X would create at the peak of the construction period up to 3,600 jobs. Government policy to support apprenticeships and skills development would significantly impact the proportion of jobs that could be taken up by Narrabri Shire residents, compared to those taken by the existing labour force of the wider Australian solar and wind industry.

Unlike construction and installation jobs, the operation and maintenance jobs will have to be done by the local workforce, as they need to be close to the power plants. A specific training and education program is required to build up a skilled workforce to operate and maintain solar photovoltaic and wind power plants in the Narrabri Shire. By 2030, around 2,500 solar and 180 wind workers will be required in the Narrabri Shire. Thus, in comparison with the existing workforce of around 6,000 people in the region, the solar and wind industry can become as important as the current largest employer in the Narrabri Shire - the agriculture sector.

The RE-X still leads up to 500 jobs during the peak construction time and – in addition – between 200 to 500 jobs in operation and maintenance in 2020 - 2030 respectively. This translates to around 430 solar and 50 wind workers in the Narrabri Shire by 2030.

Conclusion: COMPARING NARRABRI RENEWABLE EXPORT CASES TO NARRABRI GAS PROJECT

According to Narrabri Gas Project information, the 950 km^2 production field is projected to produce gas with an energy content of around 74 PJ per year or approximately 8 TWh/a electricity (assumptions see 5.2.1). If this entire area were used for solar photovoltaics, the output would be just over 100 TWh/a – higher than the expected output of the gas field – for as long as solar power plants would operate in that region, while the gas field will only provide energy for a limited period of time.

The RENEWABLES scenarios in this analysis however have adopted a much more conservative approach and estimated potential based on current and projected future demand in the Narrabri Shire. Under the RE-ADV-X case, 2.98 TWh will be exported, while the RE-X case would lead to an export of 0.474 TWh annually. Thus, income from exported electricity from Narrabri Shire to the rest of NSW will benefit the community as long as the power plants are in operation, while the gas field will be exhausted after a limited period. Furthermore, employees who operate and maintain solar and wind power plants as well as the regional power grid will have sustainable long-term jobs.

The RE-ADV-X case would require an investment of $ 6.5 billion for the power generation capacity, double the planned investment for the gas field, but would create at least 15 times more employees for operation and maintenance on around 17% of the area the gas field would take up.

The RE-X case requires one third of the planned gas field investment, but would create around 3 times more long-term jobs in operation and maintenance than the Narrabri Shire Gas Project. Furthermore, it would only require 41 km^2 i.e. 4% of the proposed gas field area.

The authors suggest developing a detailed regional project development plan and supporting policies in order to encourage apprenticeships and skills development in the solar and wind technologies for the Narrabri Shire.

1 NARRABRI SHIRE: REGIONAL INFORMATION AND SCENARIO ASSUMPTIONS

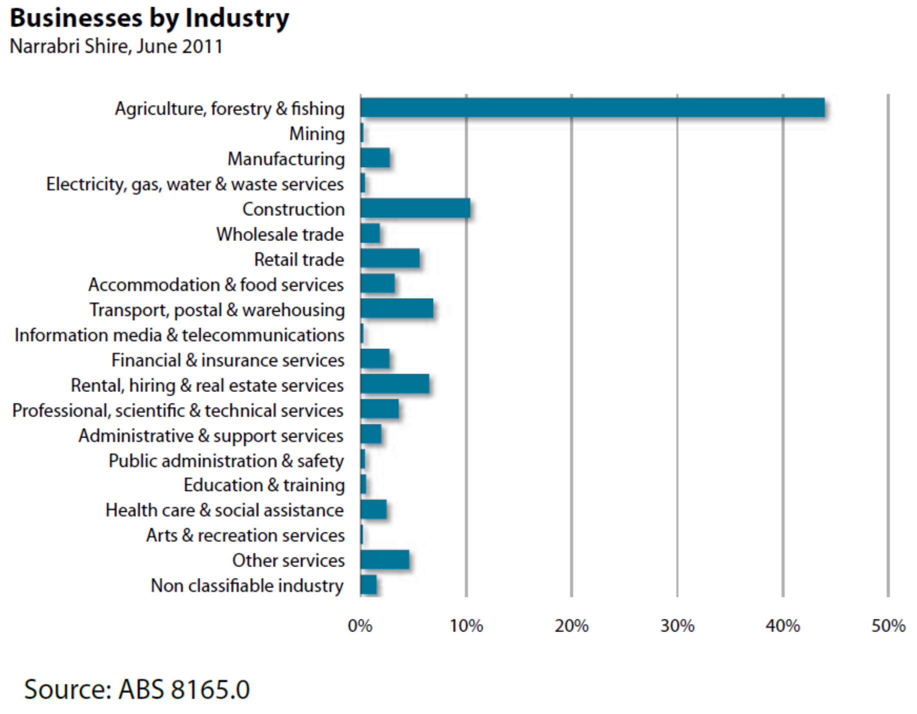
1.1 NARRABRI SHIRE OVERVIEW

The Narrabri Shire covers an area of around 13,000 square kilometres. It is located in the heart of the Namoi Valley in the North West slopes and plains of New South Wales. Set against the backdrop of the Nandewar Ranges and on the banks of the Namoi River, the town of Narrabri is the administrative centre of the Shire[4]. Narrabri is a transport hub on the crossroads of the Newell and Kamilaroi Highways, and operates freight services to major cities and ports by rail, road and air. An existing inland port supports local distribution, transportation and logistics industries. The climate is mild with average summer temperatures between 20-39 °C, while the winter temperatures range from 0-20 °C; the average annual rainfall is approximately 657 mm per year.

1.2 NARRABRI SHIRE: ECONOMIC SITUATION AND WORKFORCE

The Narrabri Shire has a stable population of around 13,000 persons[5] with minor growth rates. However, the annual population growth in the Narrabri Shire was higher than the average for the New England and North West region (0.6%) and slightly lower than the level for New South Wales (1.1%). The most recent ABS Australian Business Register indicated there were an estimated 1,463 local businesses (i.e. registered for GST and actively trading) in Narrabri Shire in June 2011[6], which represented an annual increase of 0.1%[7]. Agriculture, Forestry & Fishing is the largest industry in terms of business numbers in Narrabri Shire, accounting for 44.0% of the total number of businesses, followed by the Construction (10.4%), Transport, Postal & Warehousing (6.9%) and Rental, Hiring & Real Estate Services (6.5%) sectors. As of January 2018, there is no more recent information about the Narrabri industry situation available.

Figure 1: Narrabri Shire – Industry Shares



[4] http://www.narrabri.nsw.gov.au/introduction-to-narrabri-shire-1167.html
[5] In 2016, the Narrabri Shire had 13,084 persons
[6] The Narrabri Shire did not undertake any further employment inventory survey after 2011.
[7] Narrabri Economic Profile; http://www.narrabri.nsw.gov.au/files/uploaded/file/Economic%20Development/Narrabri_Shire_Economic_Profile.pdf

EMPLOYMENT IN THE NARRABRI SHIRE

There were 6,013 people who reported being in the labour force in the week before the 2016 Census night in Narrabri. Of these 60.6% were employed full time, 27.4% were employed part-time and 6.0% or 359 people were unemployed[8]. There is a decline in employment numbers from the previous recorded number of 7,463 people in 2012. The overall population also shows a small decline over this period. However the unemployment rate in Narrabri Shire was 5.2% in the December Quarter 2012. Unemployment in Narrabri Shire has remained below 6% or around 450 people since the December Quarter 2004[7].

Table 3 shows the employment by industry in the Narrabri Shire and – for comparison – in New South Wales. Agriculture is the single largest employment provider with around 20% pf the total population engaged with the sector, followed by retail & trade and healthcare & social assistance with close to 10% each. The remaining 60% of the Shire's working population is distributed across 17 other sectors and therefore diversified, which is an economic strength of this region. In 2016, the mining sector employed 266 persons, or 4.8% of Narrabri Shire's work force [8], a slight increase since 2011.

Table 3: Employment by Industry

Industry	Narrabri Shire		New South Wales	
	Total 2011	% of total	Total 2011	% of total
Agriculture, forestry & fishing	1,248	20.7	69,014	2.2
Mining	257	4.3	30,809	1.0
Manufacturing	296	4.9	264,406	8.4
Electricity, gas, water and waste services	71	1.2	34,159	1.1
Construction	403	6.7	228,893	7.3
Wholesale Trade	220	3.6	138,300	4.4
Retail Trade	572	9.5	324,314	10.4
Accommodation & food services	360	6.0	210,185	6.7
Transport, postal & warehousing	373	6.2	154,449	4.9
Information media & telecommunications	33	0.5	72,320	2.3
Financial & insurance services	81	1.3	158,175	5.1
Rental, hiring & real estate services	53	0.9	51,511	1.6
Professional scientific & technical services	287	4.8	246,198	7.9
Administrative & support services	123	2.0	102,121	3.3
Public administration & safety	276	4.6	192,426	6.1
Education & training	367	6.1	248,635	7.9
Health care & social assistance	565	9.4	363,406	11.6
Arts & recreation services	37	0.6	46,299	1.5
Other services	247	4.1	117,499	3.8
Not stated	169	2.8	77,100	2.5
Total	**6,038**	**100.0**	**3,130,219**	**100.0**
Source: Narrabri Economic Profile, ABS 2011 Census				

[8] 2016 Census, Australian Bureau of Statistics http://www.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/LGA15750

Future Perspectives

The Narrabri Shire Economic Social Plan, 2000-2015 (N-ESP 2015), published in 2010, states that there is 'potential for a growing green economy' and highlights the following sectors:

- Building Retrofitting
- Mass Transit/Freight Rail
- Smart Grid
- Wind Power
- Solar Power
- Advanced Biofuels

Furthermore, the N-ESP 2015 states that "collectively, these six industries could be generating $US243 billion in investment for Australia and employing 847,000 workers by 2030[9]. In a similar vein, CSIRO has calculated that 560,000 new jobs will be created in high environmental impact industries (like manufacturing and heavy industry) by 2025 if Australia sets course to become carbon neutral by 2050. With respect to individual sectors, the job potential is:

- Renewable energy: up to 500,000
- Energy efficiency: 75,000
- Sustainable water systems: 75,000
- Biomaterials: 33,000
- Green buildings: 230,000
- Waste and recycling: 50,000 (14,000 direct 36,000 indirect)

The Shire must however balance any possible impacts from renewable energy development against the continued need to sustain its agricultural base. The NSW Government has committed to 20% of all production energy production to be from renewable sources (wind, solar, biofuel, geothermal) by 2020. Further, Narrabri Shire is part of the "New England Renewable Energy Precinct" established by the State Government in February 2010 to attract investment in renewable energy prospects".[10]

In September 2013, the NSW Government released the NSW Renewable Energy Action Plan to guide NSW's renewable energy development and to support the former national target of 20% renewable energy by 2020. According to this plan, the NSW Government's vision for a secure, reliable, affordable and clean energy future is estimated to create 6,000 new jobs in regional NSW. The strategy is to work closely with NSW communities and the renewable energy industry to increase renewable energy generation in NSW[11]. This action plan is in line with the RENEWABLE exports scenario(s) outlined in this report.

Alongside the sector growth in renewables for energy production, the Narrabri Shire is host to an application for the biggest coal seam gas production field in NSW, the Narrabri Gas Project.

[9] Australian Conservation Foundation (ACF) and Australian Conservation Foundation (ACTU), Green Gold Rush – How ambitious environmental policy can make Australia a leader in the global race for green jobs, 2008

[10] Narrabri Shire Economic Social Plan, 2000-2015 (N-ESP 2015), http://www.narrabri.nsw.gov.au/files/uploaded/file/Economic%20Development/Narrabri%20Shire%20Economic%20Social%20Plan_Public%20Exhibition%20Final(1).pdf

[11] NSW Renewable Energy Action Plan; https://www.resourcesandenergy.nsw.gov.au/energy-consumers/sustainable-energy/renewable-energy-action-plan

1.3 POWER DEMAND

The load curves in megawatt per hour used for this work for New South Wales and the Narrabri Shire are taken from the Australian Renewable Energy Mapping Infrastructure (AREMI) website. AREMI is a spatial data platform for the Australian energy industry and aims to support developers, financiers, and policy makers in evaluating spatial renewable energy information. AREMI is funded by the Australian Renewable Energy Agency and developed by Data61 in partnership with Geoscience Australia and the Clean Energy Council[12]. By the end of 2015, 1,904 small scale solar photovoltaic roof-top system have been installed in the Narrabri Shire[13].

The annual electricity demand projections for 2020 and 2030 are calculated with an annual increase of 1%. This assumption is based on a 100% renewable energy scenario for Australia that was developed by the University of Technology Sydney, Institute for Sustainable Futures (UTS/ISF) in 2016[14]. This scenario assumes an increased deployment of electric vehicles, while consumer and industrial electricity consumption decreases due to energy efficiency measures.

1.3.1 COST PROJECTIONS FOR INVESTMENT, OPERATION AND MAINTENANCE COSTS

Assumptions for the specific investment and operation costs of coal, gas, brown coal and oil power plants have been made according to the World Energy Outlook (WEO) *2014 Special Report on Investments*[15]. Because these resources are at an advanced stage in terms of both technology and market development, the potential for cost reduction is limited. On the other hand, different renewable energy technologies have different costs, levels of technical maturity and development potential. While hydropower has been widely used for decades, other technologies – such as the gasification of biomass or concentrated solar power plants – have yet to reach market maturity. Thus, some renewable technologies being employed today are at a relatively early stage in market development, while others have already developed mature markets. It is expected, however, that for renewable technologies, large cost reductions will come from technical advances, manufacturing improvements and large-scale production, unlike conventional technologies. The dynamic trend of cost developments over time plays a crucial role in identifying economically sensible expansion strategies for scenarios spanning several decades.

By their very nature, some renewable sources, including wind and solar power, provide a variable supply, requiring a revised coordination with the grid network. However, although in many cases renewable energy technologies are 'distributed' – their output being generated and delivered locally to the consumer – they also have large-scale applications like utility scale wind parks, photovoltaic power plants or concentrated solar power stations.

To identify long-term cost developments, learning curves have been applied to the model calculations, to reflect how the cost of a particular technology changes in relation to cumulative production volumes. The learning factor (or progress ratio) sits between 0.75 for less mature systems and 0.95 and higher for well-established technologies. A learning factor of 0.9 means that costs are expected to fall by 10% every time the cumulative output from the technology doubles. Empirical data shows, for example, that the learning factor for PV solar modules has been fairly constant at 0.8 over 30 years, whilst that for wind energy varies from 0.75 in the UK to 0.94 in the German market.

ISF's research partner, the German Aerospace Centre (DLR) Institute for Technical Thermodynamics, Technology and System-Analysis, has developed cost projections for renewable energy technologies. Assumptions on future costs for renewable electricity technologies were derived from a review of learning curve studies by Lena Neij[16], the analysis of technology foresight and road mapping studies, including the European

[12] AREMI, https://nationalmap.gov.au/renewables/#share=s-xbJhVq8tzR2U8PJi
[13] Australian Bureau of Statistics (ABS):
(http://stat.abs.gov.au/itt/r.jsp?RegionSummary&region=15750&dataset=ABS_REGIONAL_LGA2016&geoconcept=LGA_2016&maplayerid=LGA2016&measure=MEASURE&datasetASGS=ABS_REGIONAL_ASGS2016&datasetLGA=ABS_REGIONAL_LGA2016&regionLGA=LGA_2016&regionASGS=ASGS_2016
[14] Teske, S., Dominish, E., Ison, N. and Maras, K. (2016) 100% Renewable Energy for Australia – Decarbonising Australia's Energy Sector within one Generation. Report prepared by ISF for GetUp! and Solar Citizens, March 2016.
[15] IEA 2014: *Power Generation in the New Policies and 450 Scenarios - Assumed investment costs, operation and maintenance costs and efficiencies in the IEA World Energy Investment Outlook 2014*, data file download: http://www.worldenergyoutlook.org/investment/
[16] Neij, L, 'Cost development of future technologies for power generation - a study based on experience curves and complementary bottom-up assessments', *Energy Policy* 36 (2008), 2200-2211

Commission funded NEEDS project (New Energy Externalities Developments for Sustainability)[17], the IEA Energy Technology Perspectives 2008, projections by the European Renewable Energy Council published in April 2010 ("Re-Thinking 2050") and discussions with experts from different sectors of the renewable energy industry.

In 2014 and 2015, DLR updated and revised cost projections for the Greenpeace International Energy [R]evolution research[18]. Due to significant cost decreases between 2014 and 2016, recent market developments have been taken into account leading to a further reduction in assumed costs, particularly for photovoltaics and solar thermal power plants (including heat storage). However, to increase consistency in the modelling, cost assumptions from WEO 2014 are adopted for biomass power plants, hydro and wind power.

These cost assumptions – especially for the base years – have been adapted to current Australian costs based on the Australian Power Generation Technology Report[19]. Future cost projections have been compared with several other projections including the International Renewable Energy Agency (IRENA) Renewable Power Generation Costs in 2014[20].

Numerous cost projections, particularly for renewable power generation technologies – have been published in recent years. In August 2017, the US-based National Renewable Energy Laboratory (NREL) published a comprehensive survey – the 2017 Annual Technology Baseline (ATB)[21]. All publications show that renewable power generation continues to reduce costs, though costs vary significantly by region. In this research, a conservative cost reduction rate has been chosen due to the relatively small size of Australia's current renewable energy market. Even with high growth rates, the market is likely to remain small in comparison to global standards; therefore, the cost reductions assumed in this analysis are conservative and may be larger, further increasing the economic benefits of the RENEWABLES cases.

[17] www.needs-project.org
[18] This research has been undertaken for more than 10 years and resulted in more than 100 country analyses
[19] CO2CRC Limited, 2015, *Australian Power Generation Technology Report*:, Australia, www.co2crc.com.au
[20] IRENA, *Renewable Power Generation Costs in 2014*, January 2014, Abu Dhabi, www.IRENA.org
[21] National Renewable Energy Laboratory (NREL), Annual Technology Baseline (ATB) August 2017, https://www.nrel.gov/news/press/2017/nrel-updates-baseline-cost-and-performance-data-for-electricity-generation-technologies.html

2 NARRABRI SHIRE MAPPING

2.1 MAPPING METHODOLOGY – PROCESS & ASSUMPTIONS

The Global Information System (GIS) mapping exercise aims to ascertain the renewable energy resources (primarily solar and wind) available in the Narrabri Shire. It also helps to develop an understanding of the existing geographic and demographic profile of the region. Mapping the available electricity infrastructure highlights opportunities that could be leveraged in developing the renewable energy scenarios.

Open source data and maps from various sources were used to visualize the region. Further demographic data related to population as well as infrastructure in terms of centralized transmission network and power plants was also plotted on to the map. Raster images were converted to vector maps to enable analysis using the Conversion tool in QGIS. Geo-processing tools were used to understand the potential of wind and solar resources at the local level.

The wind atlas used in the spatial modelling was generated using the DNV GL Wind Mapping System (WMS). The WMS is a dynamical downscaling system developed to generate high-resolution mesoscale wind maps for any part of the world. For this analysis wind speed at a height of 100 meters was used to determine the electricity generation potential. Similarly, Bureau of Meteorology Australian Hourly Solar Irradiance Gridded Data was used to estimate the solar power generation potential. The average yearly DNI (Direct Normal Insolation/ Irradiation) values in the region range from 900-1050 W/m^2/year. The values are usually highest in cloud-free conditions in the middle of the day.

In order to isolate potential sites for wind and solar power generation, it was important to avoid conflict with competing uses of land. Hence, areas of national parks and nature reserves, forestry and environmental management were not included in the analysis. The selected sites are located in areas earmarked as primary production. Areas mapped by the Government as Biophysical Strategic Agricultural Land (BSAL) have been excluded from consideration given their importance for agriculture and any placement of renewable energy generation facilities in other parts of the Shire would have to be assessed for its compatibility with agricultural land uses.

The area of both land available for potential solar and wind power generation was calculated using the *Field Calculator*. This input feeds into the GIS Model as described below.

Table 4: Data sources for GIS mapping Narrabri Shire

Data	Source
Land use / Land cover	NSW Department of Planning and Environment, NSW Department of Planning and Infrastructure
Boundaries	NSW Department of Planning and Environment
Population Demographics	National Exposure Information System (NEXIS)
Power plants & Transmission lines	Australian Renewable Energy Mapping Infrastructure (AREMI)
Solar Irradiance	Bureau of Meteorology
Wind Speed	DNV GL
Terrain / Topography	Google Satellite / Earth

2.2 ELECTRICITY INFRASTRUCTURE IN NSW

Figure 2 represents the existing electricity infrastructure in New South Wales. The diamonds show the positions of major power plants; black diamonds represent non-renewable and green diamonds, renewable power generation plants. The red dotted outline at the centre of the map marks the position of the Narrabri Shire relative to the state.

Figure 2: Electricity infrastructure in New South Wales

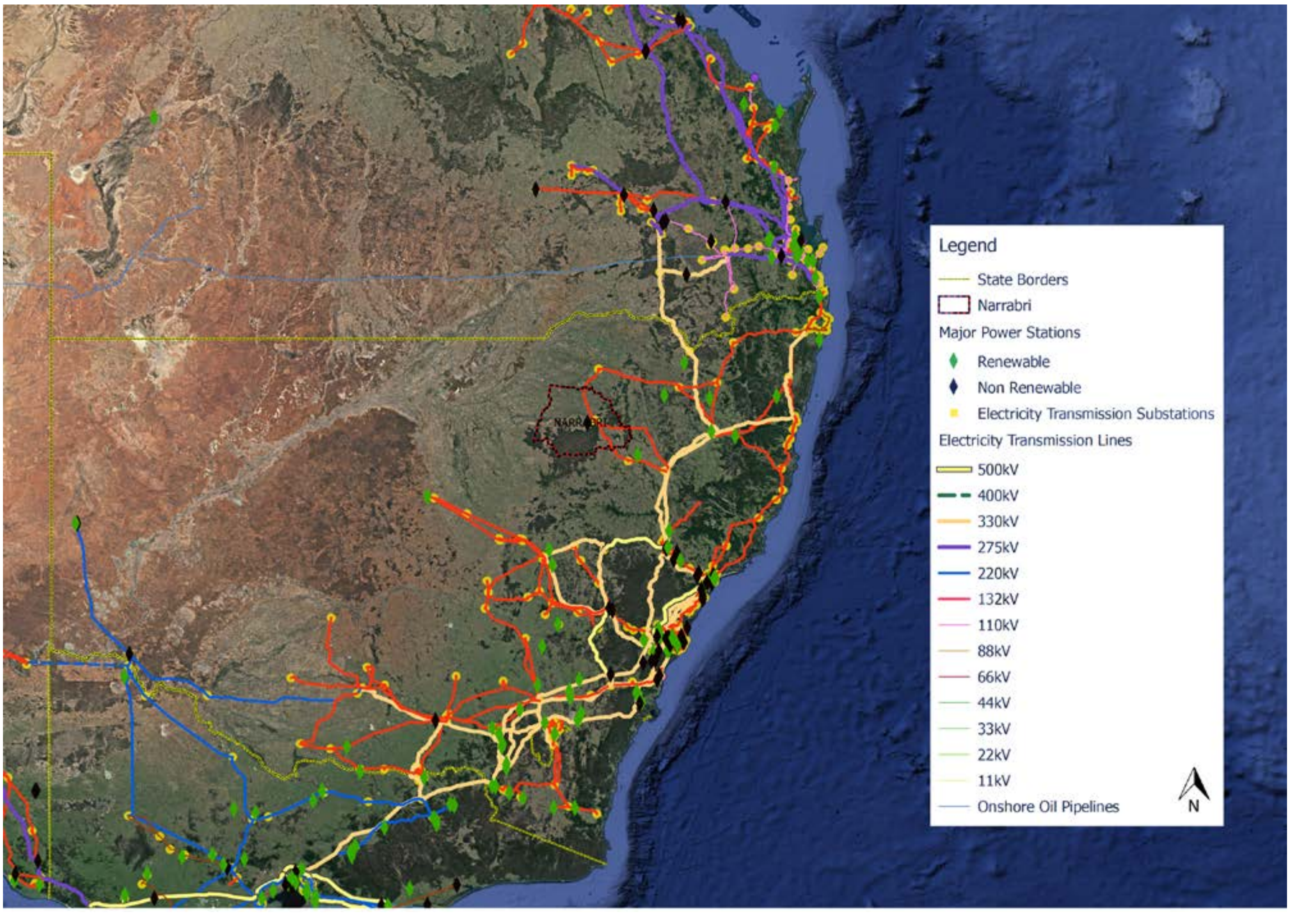
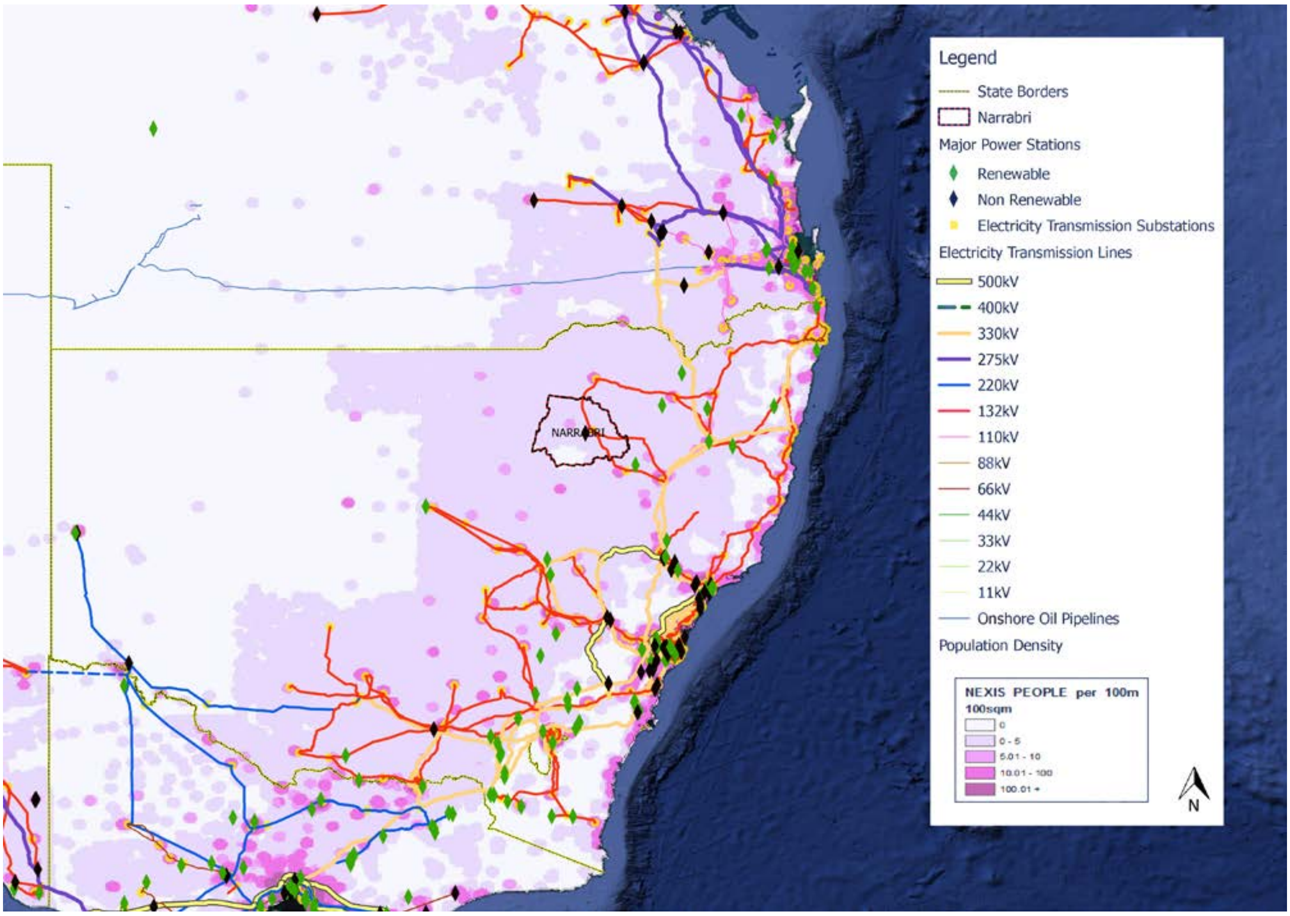


Figure 3 overlays the population density over the electricity infrastructure. The darker areas signify higher population densities and coincide with where the transmission network is most dense. The onshore oil pipeline is visible in Southern Queensland, just above the NSW/QLD border.

Figure 3: Population Density and electricity infrastructure in New South Wales



Zooming into Narrabri Shire (Figure 4), we can see the existing Wilga Park Gas Power Station (black diamond). The closest green diamond is the Lake Keepit Hydro Power Station.

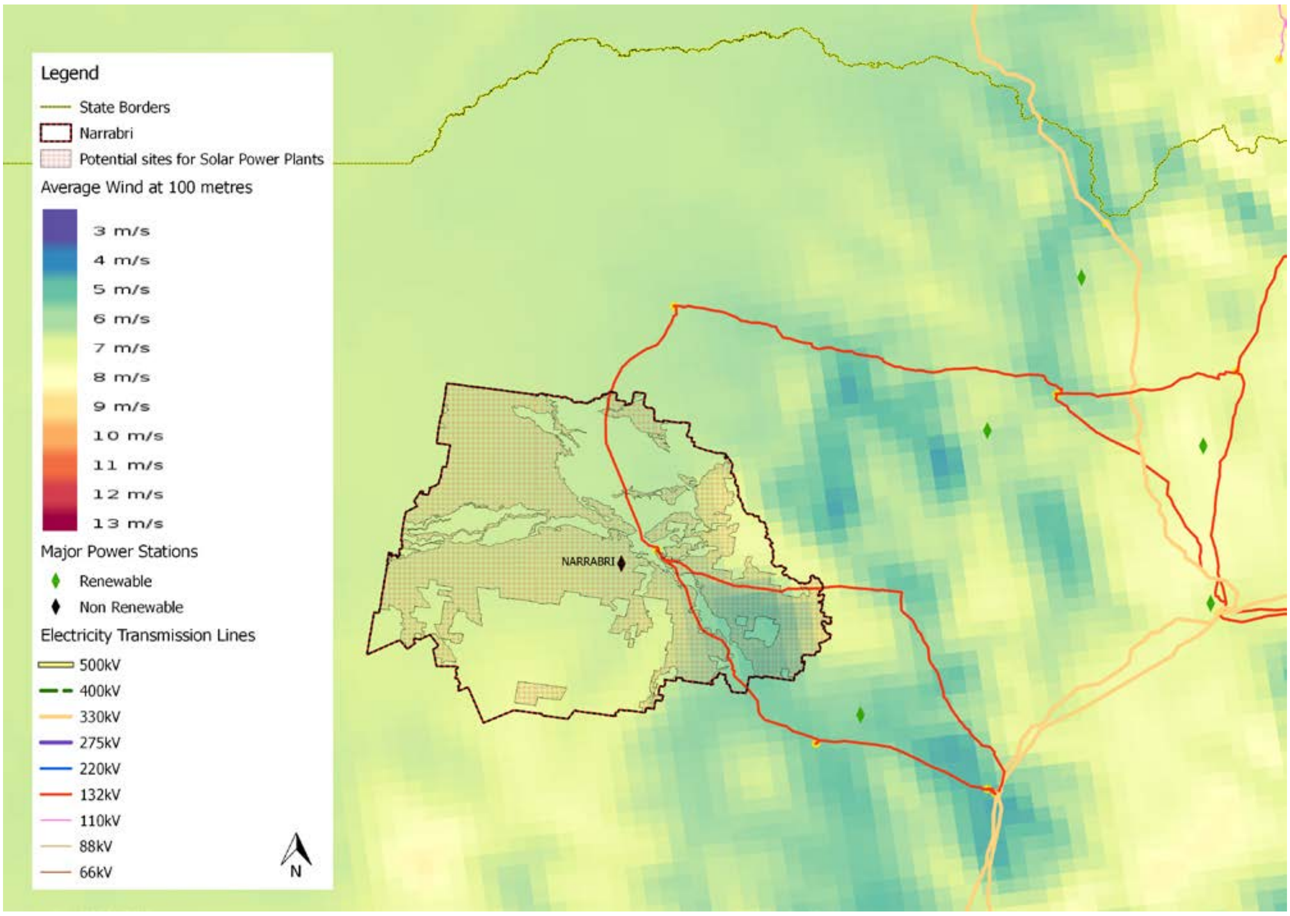
2.3 WIND ENERGY POTENTIAL IN NSW AND THE NARRABRI SHIRE

Figure 4 shows the wind energy potential of the region. In order to operate wind farms economically, the average annual wind speed should not be below 6 m/s. The map shows the range of wind speeds prevalent in the region with the blue areas at the lower end of 5 – 6 m/s and the yellow areas with 7 – 8 m/s. As seen in the map, the south and a small part of the northeast Narrabri Shire show the best potential for wind generation. However, this area falls under National Parks and Nature Reserves. The potential land area available eliminates conflicting uses and focuses on land available for primary production (excluding the land earmarked by the government as Strategic Agricultural land). Except the southeast corner of the Narrabri Shire, the region has a medium to good wind potential. The overall area with an average annual wind speed of over 6m/s covers 5684 km^2 which is 43% of the Shire's area.

The maximum wind turbine density is calculated with 5 MW per square kilometre, meaning that 1 large or 2 medium size wind turbines, in either cases with a hub height not under 100m can be installed per square kilometre. The actual space requirement for one turbine is around 25 X 25 m for the fundament of the tower and grid connection equipment; the distance in-between wind turbines should be 6 to 7 times the rotor diameter (of around 100 – 130 m) in order to achieve a good wind farm efficiency. The land in between the turbines of a wind farm can of cause be used as agricultural land as usually done in wind farms of Europe, the Americas and Asia.

With these assumptions, 44% of the Narrabri Shire is suitable to host wind farms which adds up to a technical potential of over 28 GW of installed wind capacity. This is obviously only a mathematical figure, in practice only a fraction of these areas should be opened for wind farm development.

Figure 4: Wind potential in New South Wales and the Narrabri Shire



Comparison with international experiences: Case study North Germany

The federal government of Germany directed all communities to identify 1% to 2% of their land that is suitable of wind farm development between 1997 and 1998. There are over 12,000 communities in Germany and at the end of 2017 - 20 years later - around 28,000 wind turbines have been installed with a total capacity of 46,000 MW. Those wind turbines supply 13% of Germany's total electricity demand and have created a market with over 120,000 jobs.

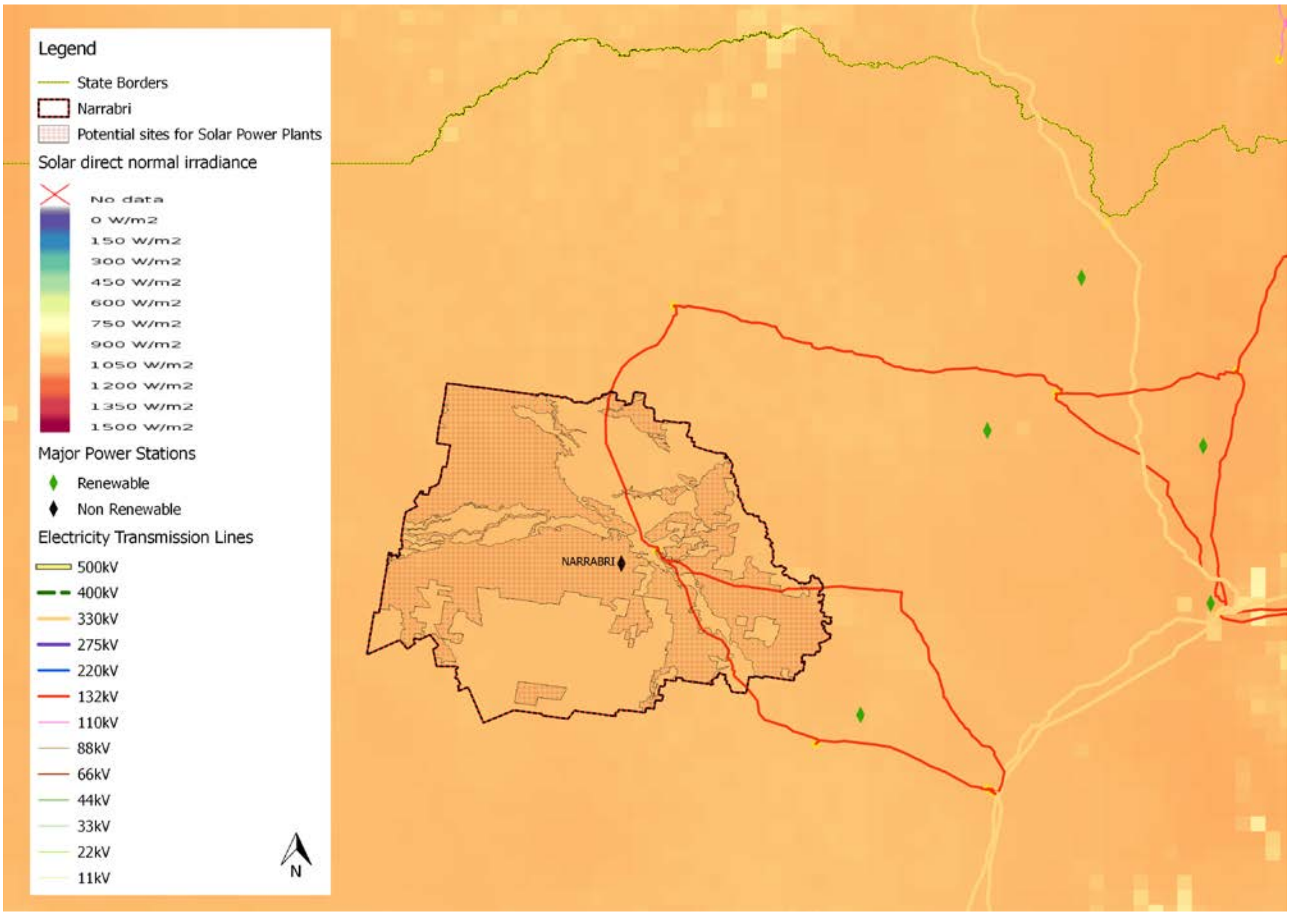
Germany covers a total area of 357.385 km², compared to the area of NSW with 809.444 km². The northern most state of Germany, Schleswig-Holstein that has a border with Denmark in the north, had a total installed wind capacity of 5,700 MW[22] at the end of 2017. This state covers an area of 15.799 km² with a total population of 2.8 million, in comparison; the Narrabri Shire covers 13,434 km² and with a population of 14,000. The average wind speed of Schleswig Holstein is around 5m/s inland and 6m/s to 7.5m/s[23] in coastal regions, thus the wind resource of Narrabri Shire is comparable to Schleswig-Holstein. For this analysis, we assume a possible installed capacity of around 600 MW, which requires 2% of the area suitable for wind farms.

[22] https://www.schleswig-holstein.de/DE/Themen/W/windenergie.html
[23] http://www.norddeutscher-klimamonitor.de/klima/1981-2010/jahr/mittlere-windgeschwindigkeit/schleswig-holstein-hamburg/coastdat-2.html

2.4 SOLAR ENERGY POTENTIAL IN NSW AND THE NARRABRI SHIRE

The solar resource of the Narrabri Shire is quite encouraging. For the solar energy potential assessment, the same land constraints are used as documented in section 2.1. The range of annual solar irradiation in the region is between 900 – 1050 W/m². The technical potential for the suitable land area (Figure 5) would add up to over 173 GW of solar power in the Narrabri Shire. The proposed Narrabri Gas Project covers 950 km² (see 5.2) or 7% of Narrabri's total land area. An area of approximately 31 km by 31 km, could host a 95,000 MW utility scale solar photovoltaic power plant in case the entire surface would be used. The average annual generation of a solar plant of this size would lead to 105 TWh/a with the Narrabri Shire's solar resource, enough to supply 75% of NSW electricity demand. Again, this is a theoretical output and only calculated to demonstrate the region's significant solar potential.

Figure 5: Solar potential in New South Wales and the Narrabri Shire



For the Narrabri Shire under the Advanced Renewable (RE-ADV-X) Scenario, the authors suggest a deployment of a solar farm in an area equal to 4% (38 km²) of the Narrabri Gas Project surface i.e. with an expanse of just 6.2 km by 6.2 km. This solar power plant would generate around 4.5 TWh electricity per year, enough to supply 3% of New South Wales 2016 electricity demand of around 140 TWh. A more conservative scenario (RE-X) requires only an equivalent of 6 km² or 0.6% of the Santos gas field area.

Figure 6 shows the potential area available for wind and solar power plants in the Narrabri Shire and compares the area proposed for the Narrabri Gas Project to the area of land that would be occupied by renewable energy in the two scenarios featured in this report[24]. The red area shows the potential sites for renewable energy generation within the LGA. Only a fraction of the area of land to be occupied by the proposed gas field would be necessary to generate the renewable energy and ongoing jobs represented by our two scenarios. The green

[24] Scenarios described in Section 4

boxes demonstrate to scale the total area of land in the shire needed for solar and wind generation in the two scenarios. These could be located in any suitable part of the Narrabri Shire. Windfarms can be co-located with agricultural production, but solar energy is a more intensive land use. Figure 7 shows a comparison of the land required for each of the scenarios as compared to the proposed Santos gas field.

Figure 6: Potential renewable wind and solar energy sites in Narrabri Shire, comparing land area with the proposed Narrabri Gas Project.

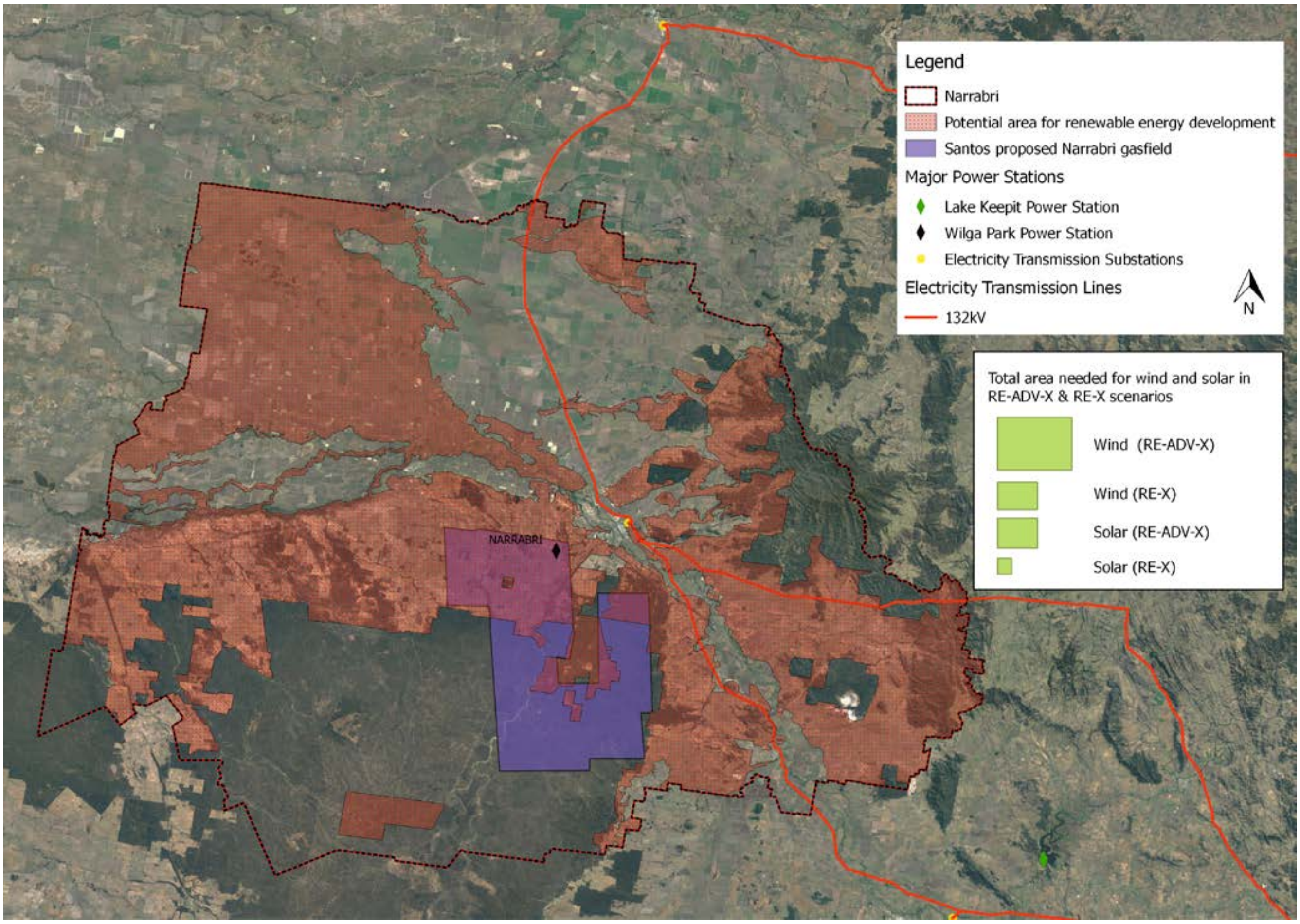
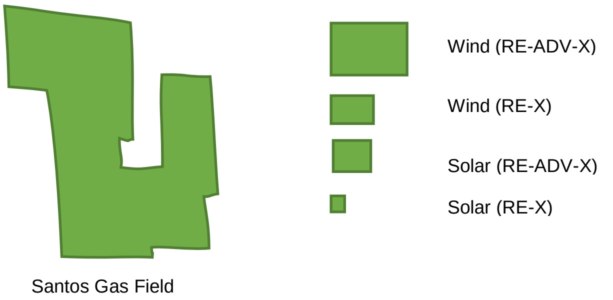


Figure 7: Comparison of land area required for the different scenarios



3 METHODOLOGY EMPLOYMENT

The Institute for Sustainable Futures at the University of Technology Sydney modelled the effects of the employment for the global, regional and national energy sector between 2009 and 2015 for the Energy [R]evolution (E[R]) science project[25]. The chapter is based on this work and has adopted most parameters and assumptions from the E[R] analysis for the Narrabri Shire analysis. However, the employment factors for the base year have been controlled and updated as required. This section provides a simplified overview of how the calculations were performed. A detailed methodology is also available[26]. Chapters 2 and 4 contain the data and input parameters used to develop the scenarios.

For the **RENEWABLES** scenario, the main inputs to the calculations are:

- The amount of electrical capacity that will be installed each year for each technology
- The primary energy demand for gas and biomass fuels in the electricity sector
- The amount of electricity generated per year from each source

Employment:

- 'Employment factors', or the number of jobs per unit of capacity, were separated into manufacturing, construction, operation and maintenance, and per unit of primary energy for fuel supply.
- For the 2020, 2025, and 2030 calculations, there is a 'decline factor' for each technology that reduces the employment factors by a certain percentage per year. This reflects the fact that employment per unit falls as technology efficiencies improve.

Regional factor:

- The percentage of local (Narrabri Shire) manufacturing in relation to domestic (Australian) fuel production, in order to calculate the proportion of manufacturing and fuel production jobs which occur in the Narrabri Shire.
- A "regional job multiplier", which indicates how labour-intensive economic activity is in Australia compared to other world regions. This is used to adjust Australian employment factors where local data is not available and international factors were used. For Australia, it is assumed that average OECD employment factor will apply.
- The electrical capacity increase and energy use figures from each scenario were multiplied by the employment factors for each of the technologies, and then adjusted for regional labour intensity and the proportion of fuel or manufacturing which occurs locally.

A range of data sources are used for the model inputs, including the International Energy Agency, US Energy Information Administration, BP Statistical Review of World Energy, US National Renewable Energy Laboratory, International Labour Organisation, World Bank, industry associations, national statistics, company reports, academic literature, and ISF's own research.

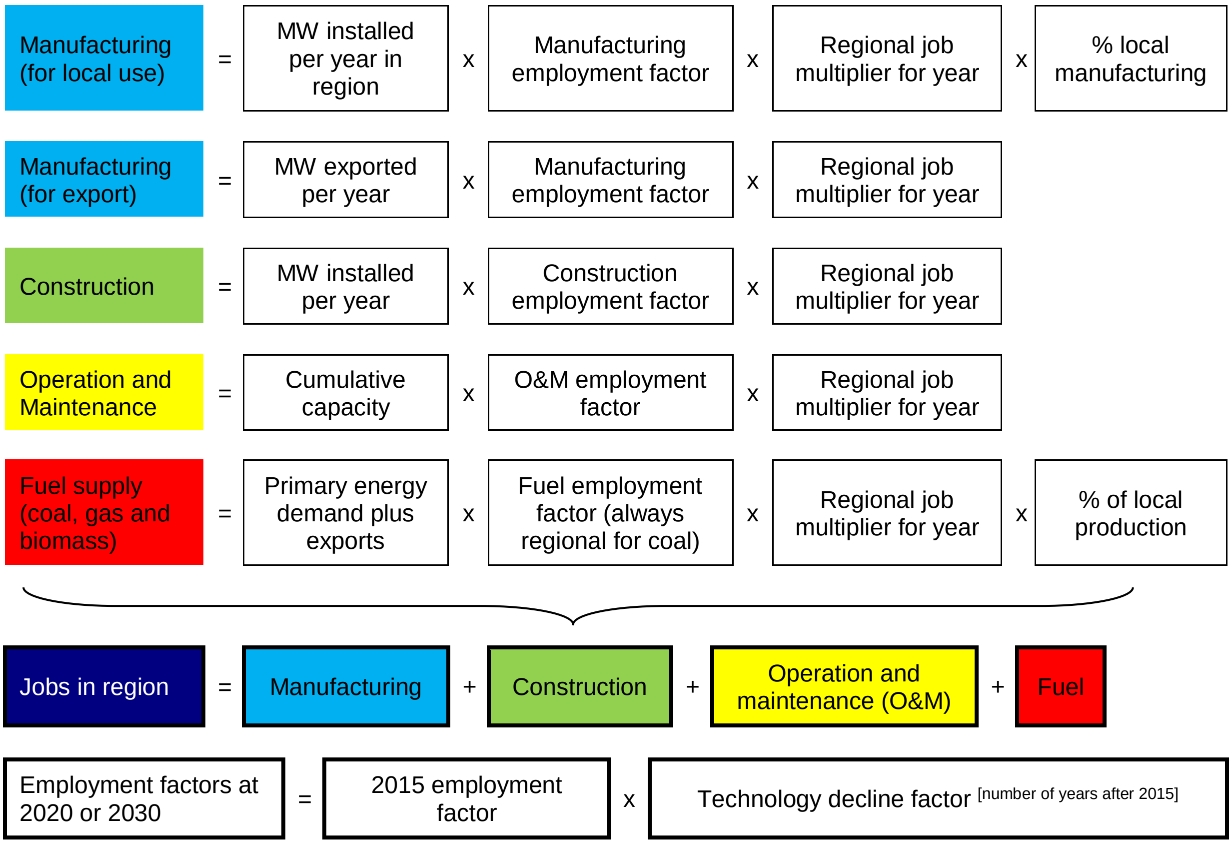
These calculations only take into account direct employment, for example the construction team needed to build a new wind farm. They do not cover indirect employment, for example the extra services provided in a town to accommodate the construction team. The calculations do not include jobs in energy efficiency, although these are likely to be substantial.

[25] The Energy [R]evolution series has been financed and developed by Greenpeace International between 2004 and 2015 and has been acknowledged as the most accurate renewable energy forecasts worldwide by numerous scientific publications. The E[R] scenario series served as benchmark scenarios for the International Panel on Climate Chanhe (IPCC) of the United Nations

[26] Rutovitz, J., Dominish, E. and Downes, J. 2015. Calculating global energy sector jobs: 2015 methodology update. Prepared for Greenpeace International by the Institute for Sustainable Futures, University of Technology Sydney.

The large number of assumptions required for these calculations mean that employment numbers are indicative only, especially for regions where little data exists. However, within the limits of data availability, the figures presented are representative of employment levels under the two scenarios.

Figure 8: Methodology overview



The authors assumed that manufacturing of wind, solar power plants will most likely not take place in the Narrabri Shire, and therefore, employment effects from manufacturing are not calculated.

3.1 EMPLOYMENT FACTORS

"Employment factors" are used to calculate how many jobs are required per unit of electrical capacity, or per unit of fuel are required. They take into account jobs in manufacturing, construction, operation and maintenance, and fuel. Table 5 lists the employment factors used in the calculations. These factors are usually from OECD countries, as this is where most data is available. For job calculations for the Narrabri Shire, the OECD (= Australia) regional factor has been used.

Table 5: Summary of employment factors for power generation technologies

	Construction/ installation REGIONAL	Manufacturing (INTER) NATIONAL	Operations & maintenance REGIONAL	Total	Fuel – PRIMARY energy demand
	Job years/ MW	Job years/ MW	Jobs/MW	Jobs years/MW	
Coal	11.2	5.4	0.14	**16.74**	*OECD Factor*
Gas	1.3	0.9	0.14	**2.34**	*OECD Factor*
Biomass	14.0	2.9	1.5	**18.4**	29.9 Jobs/PJ
Hydro-large	7.4	3.5	0.2	**11.1**	
Hydro-small	15.7	5.8	5.8	**27.3**	
Wind onshore	3.2	4.7	0.3	**8.2**	
Solar PV	13.0	6.7	0.7	**20.4**	
Geothermal	6.8	3.9	0.4	**11.1**	

Note: For details of sources and derivation of factors see Rutovitz et al, 2015[27]

[27] Rutovitz et al, 2015, https://opus.lib.uts.edu.au/bitstream/10453/43718/1/Rutovitzetal2015Calculatingglobalenergysectorjobsmethodology.pdf

4 THE NARRABRI SHIRE: RENEWABLE EXPORT SCENARIO

In this section, two different renewable export scenarios are developed. In both Renewable Energy Export scenarios, the Narrabri Shire plays an important part in New South Wales' energy transformation – producing significantly more electricity than is required locally, resulting in more and longer lasting jobs for the Shire than the Narrabri Gas Project would generate, and affecting a much smaller area of land.

In the RENEWABLE ADVANCE EXPORT (RE-ADV-X) scenario, significant land area in Narrabri Shire is dedicated to solar and wind generation, though with 38 km^2 of solar photovoltaic and 120 km^2 of wind power, the total land area needed to fulfil this ambitious scenario is only 17% of the area proposed to be occupied by Santos gas field. This scenario would see 3,800 MW of solar photovoltaic and 600 MW of wind installed by 2030 turning Narrabri Shire into an energy powerhouse.

A second more conservative scenario – the RENEWABLE EXPORT (RE-X) scenario – will require significantly less space and would limit the renewable power export to around 200 MW to 250 MW. This which would still require an upgrade of the existing 132 kV power line, but may not require an entirely new high voltage line. However, the required power system analysis was not part of this analysis.

The RE-X case would require a total land area of 41 km^2 in the Narrabri Shire: 6 km^2 for solar photovoltaic and 35 km^2 of wind power. The total land area needed to fulfil this scenario is only 4% of the area proposed to be occupied by Narrabri Gas Project. This scenario would see 622 MW of solar photovoltaic and 175 MW of wind installed in the Shire by 2030 expected to supply at all times 100% of Narrabri Shire's power demand and export the remaining power generation to the NEM power grid.

4.1 ASSUMPTIONS FOR THE RENEWABLES EXPORT SCENARIO

The RENEWABLES EXPORT (RE-X) and the RENEWABLE ADVANCED EXPORT (RE-ADV-X) scenarios are built on a framework of energy policy targets and assumptions that strongly influence the development of solar photovoltaic and wind power and structural support (grid connection, technology support, education) for each technology. The main assumptions considered for both scenario-building processes are as follows:

- **Renewable industry growth:** Dynamic growth in new capacities for solar photovoltaic and wind power generation is assumed based on current knowledge about potential, costs and recent trends in renewable energy deployment (see energy potentials discussed in Chapter 2). Communities in New England / Narrabri Shire will play a significant role in the expansion of this renewable capacity, particularly concerning site-specific project development, inclusion of local population and operation of regional and/or community owned renewable power projects.
- **Gas project phase-out**: It is assumed that the proposed Narrabri Gas Project will not go ahead. Instead, part of the site that is not excluded for nature conservation will be available for potential utility scale solar photovoltaic and wind projects.
- **Future power supply:** The new solar and wind capacity increases are relatively stable over the entire scenario period, while the demand of the Narrabri Shire is assumed almost stable over the entire modelling period. The surplus electricity will be exported to the NSW power grid and used to support supply in NSW and the NEM.

This chapter provides an overview to the results for the calculated RENEWABLE scenarios for Narrabri Shire. The development of power generation capacity for Australia, NSW and the Narrabri Shire are based on the ADVANCED RENEWABLES scenario that has been developed from UTS/ISF published in March 2016.[28].

[28] Teske, S., Dominish, E., Ison, N. and Maras, K. (2016) 100% Renewable Energy for Australia – Decarbonising Australia's Energy Sector within one Generation. Report prepared by ISF for GetUp! and Solar Citizens, March 2016

4.2 ELECTRICITY GENERATION CAPACITY DEVELOPMENT

Figure 9 shows the development of total installed power plant capacity for Australia in case a 100% renewable energy pathway will be implemented until 2050. The main technologies in the scenario are solar photovoltaic, onshore wind and concentrated solar power, with dispatchable power plants, like bio energy, hydro and geothermal. In addition, a combination of demand side management and storage technologies such as pumped hydro, batteries and hydrogen/synthetic fuels are included to guarantee year round reliable and secure power supply.

Figure 9: Installed capacity development for Australia for the Advanced Renewables scenario until 2030

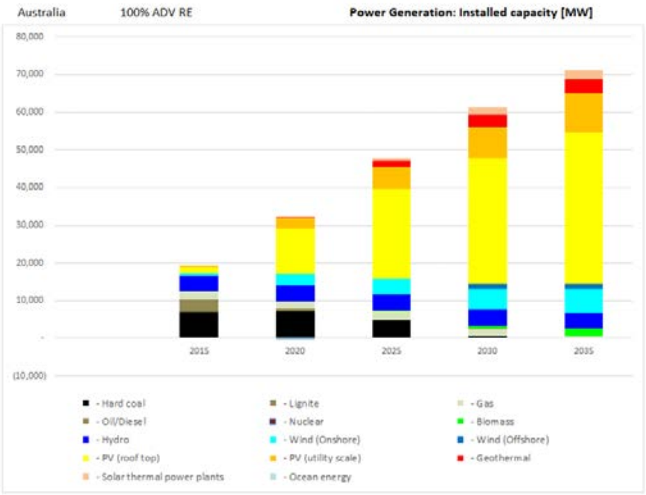
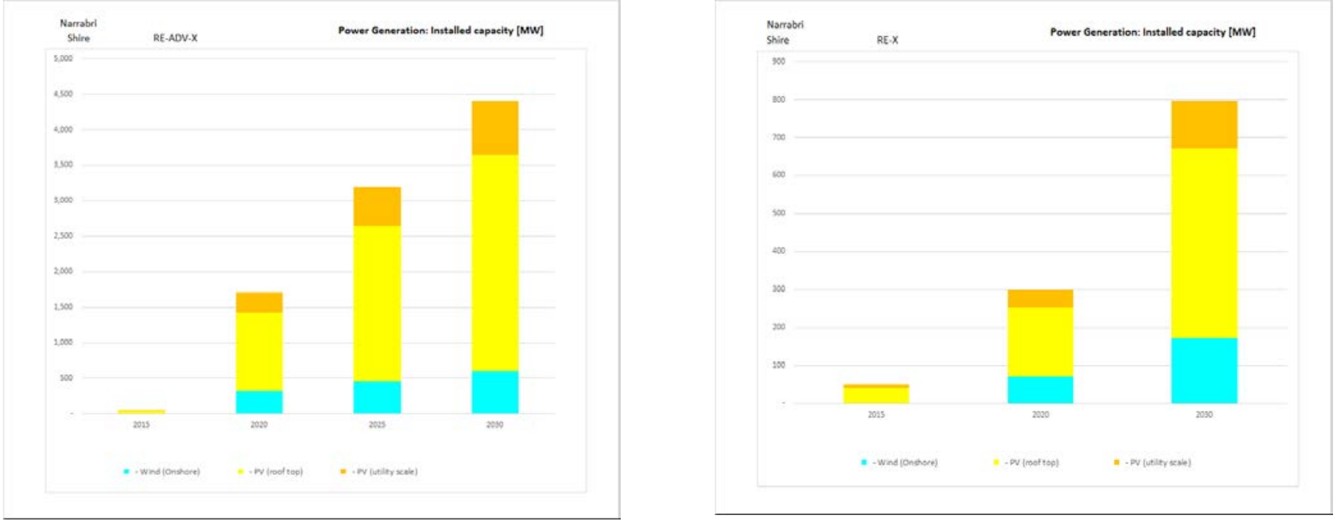


Figure 10: Assumed installed capacities under the RE-ADV-X and RE-X case for the Narrabri Shire until 2030



As part of the Narrabri Shire energy export concept, the region will produce significantly more electricity than required locally. Electricity will therefore be the new export product of the Narrabri Shire. Under the RE-ADV-X case, 2.98 TWh will be exported, while the RE-X case would lead to an export of 0.474 TWh annually.

4.3 ELECTRICITY GENERATION FOR NSW AND THE NARRABRI SHIRE

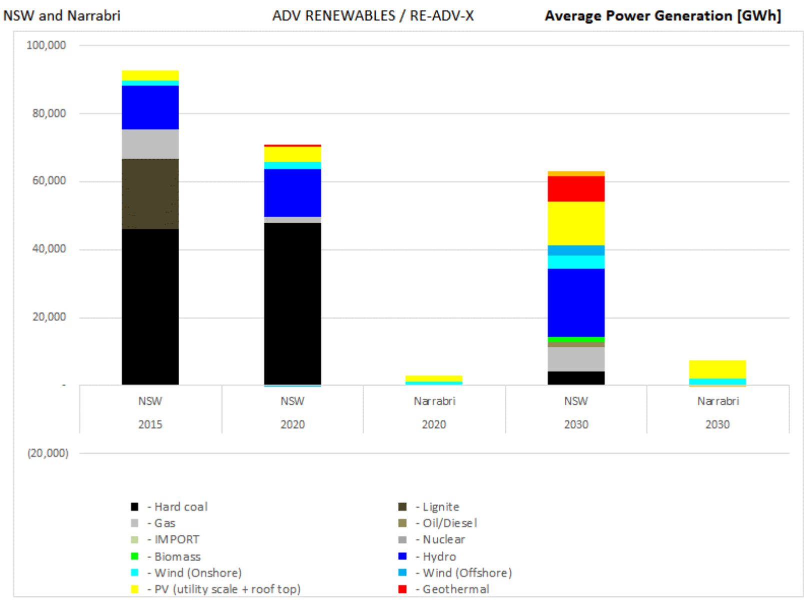
Table 6 and Figure 11 show the average annual power generation for NSW and the Narrabri Shire between 2015 and 2030 for the ADVANCE RENEWABLE EXPORT (RE-ADV-X) case and Table 7 shows the RE-X case with significantly lower solar and wind capacities. While NSW uses a whole range of (renewable) power generation technologies, Narrabri Shire only generates electricity from solar photovoltaic and wind power. The electricity will be exported via (new) power transmission lines to the main NSW power grid that is part of the NEM. The RE-ADV-X would require a significant expansion of the power grid capacity in order to enable to export enough electricity from the Narrabri Shire to the NEM power grid.

Table 6: RE-ADV-X: Average annual power generation in NSW and the Narrabri Shire 2015 – 2030

Average Power Generation [GWh]
Region NSW and Narrabri
Scenario: ADV RENEWABLES / RE-ADV-X

	2015	2020	2020	2030	2030
	NSW	NSW	Narrabri	NSW	Narrabri
Power plants	**92,688**	**70,879**	**3,062**	**63,196**	**7,508**
- Hard coal	45,948	47,707	0	4,198	0
- Lignite	20,617	235	0	0	0
- Gas	8,722	1,698	0	7,295	0
- Oil/Diesel	66	85	0	1,369	0
- IMPORT		0	0	0	0
- Nuclear					
- Biomass	46	68	0	1,486	0
- Hydro	12,750	13,948	0	19,973	0
- Wind (Onshore)	1,637	2,016	1,095	3,860	2,096
- Wind (Offshore)	16	0	0	3,216	0
- PV (utility scale + roof top)	2,886	4,619	1,967	12,707	5,412
- Geothermal	0	502	0	7,649	0
- Solar thermal power plants	0	0	0	1,444	0
- Ocean energy	0	0	0	0	0
Variable RES (PV, Wind, Ocean)	4,540	6,636	3,062	19,782	7,508
Share of variable RES	5%	9%	100%	31%	100%
RES share (domestic generation)	**19%**	**30%**	**100%**	**80%**	**100%**

Figure 11: RE-ADV-X: Average annual power generation in NSW and the Narrabri Shire 2015 – 2030



The RE-X case assumes an ambitious but slower expansion of the solar photovoltaic and wind capacities over the next 15 years as compared to the advanced case. By 2030, 10 to 15 utility scale solar photovoltaic and wind farms will be operating within the Narrabri Shire.

Table 7: RE-X: Average annual power generation in NSW and the Narrabri Shire 2015 – 2030

Average Power Generation [GWh]
Region NSW and Narrabri
Scenario: ADV RENEWABLES / RE-X

	2015 NSW	2020 NSW	2020 Narrabri	2030 NSW	2030 Narrabri
Power plants	**92,688**	**70,879**	**549**	**63,196**	**1,426**
- Hard coal	45,948	47,707	0	4,198	0
- Lignite	20,617	235	0	0	0
- Gas	8,722	1,698	0	7,295	0
- Oil/Diesel	66	85	0	1,369	0
- IMPORT		0	0	0	0
- Nuclear					
- Biomass	46	68	0	1,486	0
- Hydro	12,750	13,948	0	19,973	0
- Wind (Onshore)	1,637	2,016	245	3,860	597
- Wind (Offshore)	16	0	0	3,216	0
- PV (utility scale + roof top)	2,886	4,619	304	12,707	837
- Geothermal	0	502	0	7,649	0
- Solar thermal power plants	0	0	0	1,444	0
- Ocean energy	0	0	0	0	0
Variable RES (PV, Wind, Ocean)	4,540	6,636	549	19,782	1,429
Share of variable RES	5%	9%	100%	31%	100%
RES share (domestic generation)	**19%**	**30%**	**100%**	**80%**	**100%**

4.4 RE-ADV-X: ELECTRICITY EXPORT FOR THE NARRABRI SHIRE

Table 8 shows the average projected demand, supply and export quantities for 2020 and 2030. While the Narrabri Shire only has an average load of 9 MW – with a peak just under 20 MW - the maximum solar and wind production can add up to over 1,450 MW in 2020 and up to 3,900 MW in 2030. This scenario requires addition power lines as well as a significant enforcement of the existing 132 kV transmission line in order to export this capacity to the NEM grid. The actual required grid concept is not within the scope of this analysis.

Table 8: RE-ADV-X: Narrabri Shire electricity production and export to NSW 2020 and 2030

	Total [MWh/a]	Load MAX [MW]	Load AVERAGE [MW]
Electricity Production Narrabri Shire 2020	3,062,469	1,451	350
Demand Narrabri Shire 2020	74,511	17	9
Export Narrabri Shire to NSW 2020	2,987,959	1,438	341
Electricity Production Narrabri Shire 2030	7,511,454	3,878	857
Demand Narrabri Shire 2030	81,962	19	9
Export Narrabri Shire to NSW 2030	7,429,493	3,864	848

Figure 12 and Figure 13 show the projected solar and wind generation for one day in December (2020) and one day in September (2030). Those projections are based on actual wind, solar and demand data of the 19th December respectively the 28th September[29] for the Narrabri Shire. This hourly simulation has been done in order to assess the maximum and average export capacity and the possible annual generation for solar and wind power plants in this region. On annual average, the combination of wind and solar photovoltaic electricity supply was more than sufficient to supply the Narrabri Shire with reliable power; the average generation capacity was at 63 MW in the 2020 simulation, while the average load was only at around 9 MW. Storage technologies can increase security of supply further and enable the operator of solar and wind farms to trade electricity to the NEM with more independent from the actual time of generation.

Figure 12: RE-ADV-X - Possible generation and electricity export curve 2020

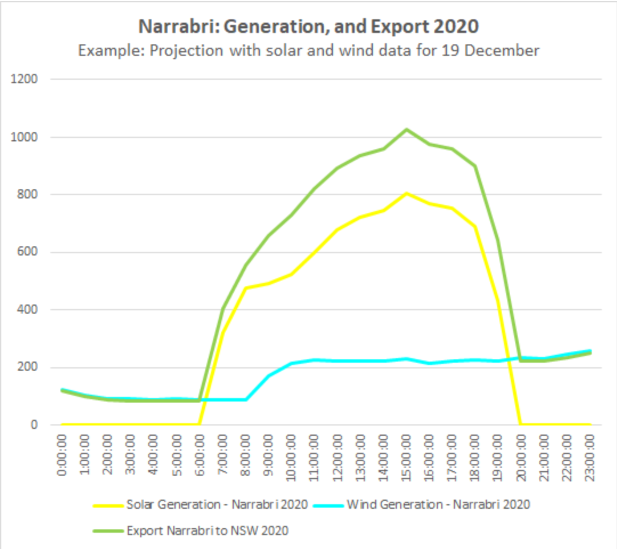
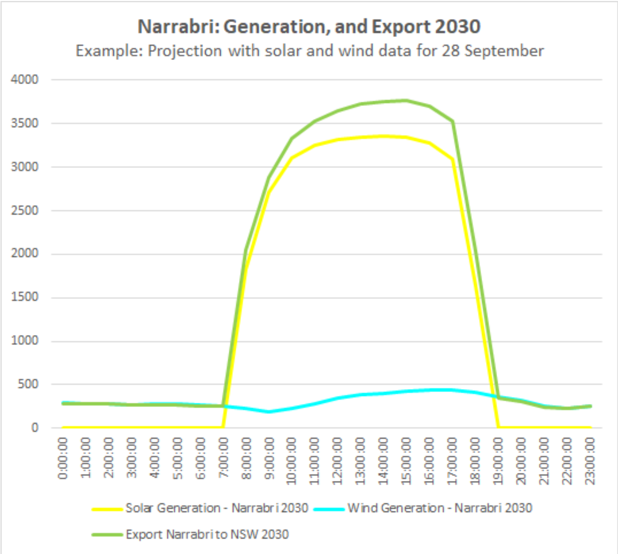


Figure 13: RE-ADV-X - Possible generation and electricity export curve 2030



4.5 RE-X: ELECTRICITY EXPORT FOR THE NARRABRI SHIRE

Table 9 shows the average projected demand, supply and export quantities for 2020 and 2030 under the RE-X scenario. The maximum export capacity will be limited to 240 MW in 2020 and 640 MW by 2030, however the average export capacity in 2030 is around 154 MW. The existing power line might still need an upgrade, however the required additional power transmission capacity is significantly lower than that for the advanced case.

Table 9: RE-X: Narrabri electricity production and export to NSW 2020 and 2030

	Total [MWh/a]	Load MAX [MW]	Load AVERAGE [MW]
Electricity Production Narrabri Shire 2020	548,840	240	63
Demand Narrabri Shire 2020	74,511	17	9
Export Narrabri Shire to NSW 2020	474,330	231	54
Electricity Production Narrabri Shire 2030	1,432,332	641	164
Demand Narrabri Shire 2030	81,962	19	9
Export Narrabri Shire to NSW 2030	1,350,370	632	154

[29] Solar data from 28th September and 19th December 2012, wind data from 28th September and 19th December 2010 and load from 19th December 2016 with an assumed increase of 1% per year until 2020 and 2030 respectively

Figure 14 and Figure 15 show projected solar and wind generation for the same days as shown for the advanced case, the overall export capacities are significantly lower. A storage management might further limit the required grid upgrade. However, the system optimisation required exceeded the scope of this analysis.

Figure 14: RE-X - Possible generation and electricity export curve 2020

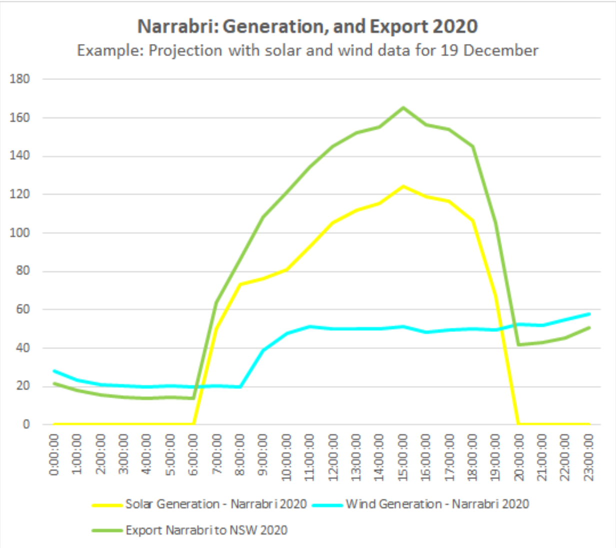
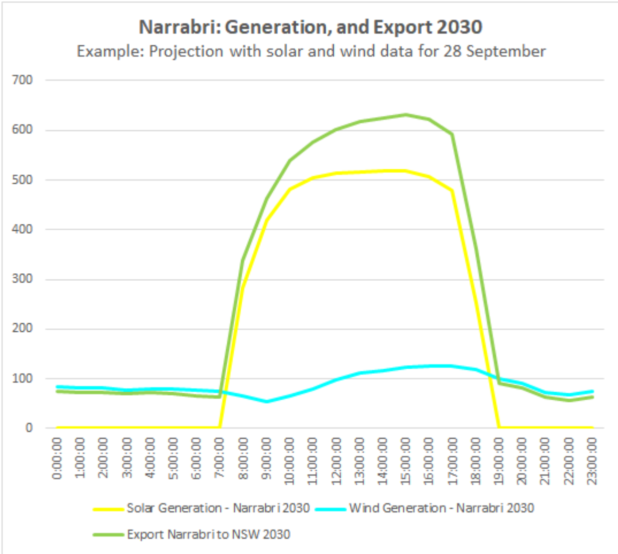


Figure 15: RE-X -Possible generation and electricity export curve 2030



4.6 INVESTMENT REQUIREMENTS

In order to install the suggested solar and wind capacity for the advanced case (RE-ADV-X), a total investment of approximately $6.5 billion is required. The amount can be lower, in case solar photovoltaic and wind turbine equipment and installation costs will continue to fall as they have over the past decade due to economies of scale. Table 10and Table 11 provide an overview of the key results of the investment calculations. Additional investments in the power grid infrastructure are required in order to transport the generated electricity to the NEM power network, which was not within the scope of this analysis. The RE-X case requires less than one sixth of the overall investment volume - $ 1 billion – compared to the advanced case. The majority of the investment will go in solar photovoltaic, while the investments for wind are moderate and in the typical range of a community lead project.

Table 10: Key results – Narrabri Shire:

RENEWABLES ADVANCED Export (RE-ADV-X)

Narrabri Shire: RENEWABLES EXPORT - Key Results -	2015 [MW]	2020 [MW]	2025 [MW]	2030 [MW]
Installed Capacity	**50**	**1,703**	**3,186**	**4,403**
- Wind (Onshore)	0	320	461	598
- PV (utility scale + roof top)	50	1383	2,725	3,805
Total Investment Cost 2015 - 2030	**2015-2020**		**2021-2030**	
- Wind (Onshore)	$ 320 mio.		$ 251 mio	
- PV (utility scale + roof top)	$ 2,293 mio.		$ 3,681 mio.	

Table 11: Key results – Narrabri Shire:

RENEWABLES Export (RE-X)

Narrabri Shire: RENEWABLES EXPORT - Key Results -	2015 [MW]	2020 [MW]	2025 [MW]	2030 [MW]
Installed Capacity	**50**	**298**	**550**	**797**
- Wind (Onshore)	0	72	104	175
- PV (utility scale + roof top)	50	226	446	622
Total Investment Cost 2015 - 2030	**2015-2020**		**2021-2030**	
- Wind (Onshore)	$ 43 mio.		$ 55 mio	
- PV (utility scale + roof top)	$ 303 mio.		$ 602 mio.	

4.7 EMPLOYMENT EFFECTS

Based on the methodology documented in Chapter 3, the employment effects have calculated for the first period until 2020 and the second one between 2021 and 2030 for both scenarios.

The RE-ADV-X would create at the peak of the construction period up to 3,600 jobs. Government policy to support apprenticeships and skills development would significantly alter the proportion of jobs that would be taken up by Narrabri Shire locals, to the existing labour force of the wider Australian solar and wind industry.

Contrary to construction and installation jobs, the operation and maintenance jobs will have to be done by Narrabri residents, as the workforce needs to be close to the power plants. A specific training and education program is required to build up a skilled workforce to operate and maintain solar photovoltaic and wind power plants in Narrabri. By 2030, around 2,500 solar and 180 wind workers will be required in the Narrabri Region. In comparison with the existing workforce of around 6,000 people in the region, the solar and wind industry can become as important as the current largest employer in the Narrabri Shire - the agriculture sector.

The RE-X still leads up to 500 jobs during the peak construction time and – in addition – between 200 to 500 jobs in operation and maintenance in 2020 - 2030 respectively. The RE-X requires around 430 solar and 50 wind workers in the Narrabri Region by 2030.

Table 12: Employment effects– Narrabri RENEWABLES ADVANCED Export (RE-ADV-X)

	Scenario Parameter						Employment			
	New Installed Capacity		Annual Generation		Annual Investment		Construction and installation		Operation and maintenance	
	[MW/a]		[GWh/a]		[Million $ / a]		[Jobs]		[Jobs / a]	
	2015-2020	2021-2030	2020	2030	2015-2020	2021-2030	2015-2020	2021-2030	2020	2030
Solar Photovoltaic	267	134	1,967	5,412	$ 459	$ 368	3,466	1,745	968	2,663
Wind power	64	14	1,095	2,096	$ 64	$ 25	205	45	96	179
Total	331	148	3,062	7,508	523	393	3,671	1,790	1,064	2,843

Table 13: Employment effects– Narrabri RENEWABLES Export (RE-X)

	Scenario Parameter						Employment			
	New Installed Capacity		Annual Generation		Annual Investment		Construction and installation		Operation and maintenance	
	[MW/a]		[GWh/a]		[Million $ / a]		[Jobs]		[Jobs / a]	
	2015-2020	2021-2030	2020	2030	2015-2020	2021-2030	2015-2020	2021-2030	2020	2030
Solar Photovoltaic	35	22	304	837	$ 61	$ 60	458	285	158	436
Wind power	14	3	245	597	$ 9	$ 6	46	10	22	52
Total	50	25	549	1,435	69	66	504	296	180	488

4.8 COMPARING NARRABRI RENEWABLE EXPORT CASES TO NARRABRI GAS PROJECT

According to Narrabri Gas Project information, the 950 km^2 production field is projected to produce gas with an energy content of around 74 PJ per year or approximately 8 TWh/a electricity (assumptions see 5.2.1). In case the entire area would have been used for solar photovoltaics, the output would be just over 100 TWh/a – higher than the expected output of the gas field – for as long as solar power plants would operate in that region, while the gas field will only provide energy for a limited period of time[30]. The RENEWABLES scenarios in this analysis however have adopted a much more conservative approach and estimated potential based on current and projected future demand in the Narrabri region. Under the RE-ADV-X case, 2.98 TWh will be exported, while the RE-X case would lead to an export of 0.474 TWh annually.

Thus, income from exported electricity from Narrabri Shire to the rest of NSW will benefit the community as long as the power plants are in operation, while the gas field will be exhausted after a limited period. Furthermore, employees who operate and maintain solar and wind power plants as well as the regional power grid will have sustainable long-term jobs.

The RE-ADV-X case would require an investment of $ 6.5 billion for the power generation capacity – just over twice as the planned investment for the gas field, but would create at least 15 times more employees for operation and maintenance on around 17% of the area the gas field would take up.

The RE-X case requires one third of the planned gas field investment, but would create around 3 times more long-term jobs in operation and maintenance than the Santos project. Furthermore, it would only require 41 km^2 i.e. 4% of the proposed gas field area.

[30] According to Santos project information, the gas field might have a possible production time of up to 25 years

5 REGIONAL ENERGY CONTEXT

5.1 POWER PLANTS IN NSW

Utility scale power plant capacities in NSW are based on coal (53%), hydro (22%) and gas (11%). The remaining 14% are solar photovoltaic, cogeneration and bio energy generators. In total, NSW has 17,055 MW of installed electricity generation capacity plus 1557 MW of solar photovoltaics; mainly small rooftop systems under 10 kW [31] and 700 MW of wind power.

Figure 17: Installed Capacities of NSW power generation 2017

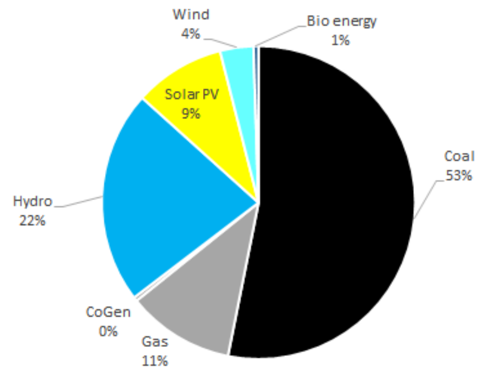
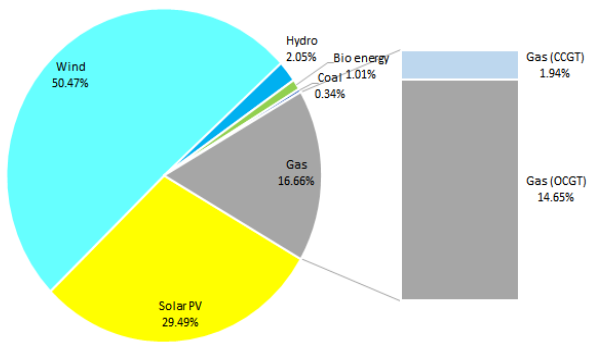


Figure 16: Proposed new power plants for the NEM area (May 2017)



5.1.1 NEW ENERGY PROJECTS IN NSW

The National Electricity Market (NEM) includes Queensland, NSW, ACT, Victoria and South Australia. Across the NEM there are new power plants with a total proposed capacity of over 23,000 MW, most of them are wind farms (12,000 MW) and solar photovoltaic plants (7,000 MW). A list of new generation projects is also available on the AEMO website[32]. In NSW, proposals to build power stations fall under the Environmental Planning and Assessment Act 7979[33], which states that new power stations shall be subject to a transparent and public assessment process to ensure protection of the environment and the health and amenity of local communities.

The environmental assessment process for electricity generation projects is the same as that for any other major project. This process requires a full environmental assessment by the Secretary of the Department of Planning and Environment with particular emphasis given to ensuring approved proposals proceed in an environmentally appropriate and sustainable manner. Furthermore, a National Transmission Network Development Plan[34] is prepared annually and provides an outlook of estimated future generation requirements over the next 20 years. Details of proposed generation plants are available at the *Department of Planning's Major Projects Register*[35].

As of 2017 there are two utility scale solar photovoltaic power plants in the planning phase; 60 MW *Narrabri South* and 55 MW *Wee Waa* projects.

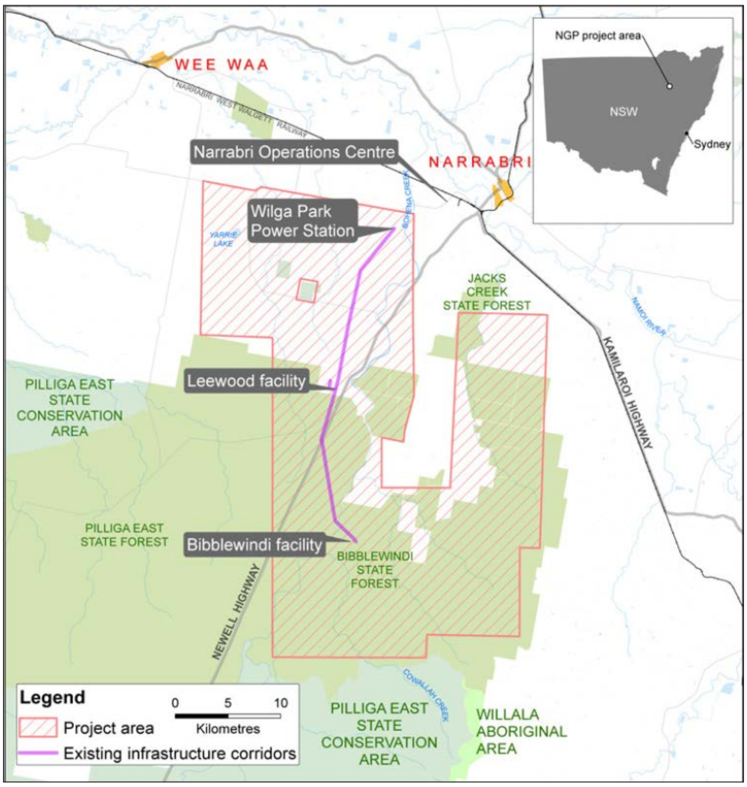
5.2 THE PROPOSED NARRABRI GAS PROJECT

Santos is one of Australia's largest domestic gas producers and increasingly a significant gas exporter. The company is seeking approval to develop a coal-seam gas project near Narrabri. The project requires drilling up to 850 wells on 425 sites in the project area in and around the Pilliga (Figure 18). According to Santos' Environmental Impact Statement (EIS), published in February 2017, "around 60% of the project area is located

[31] Australian Solar PV Institute, Status November 2017, http://pv-map.apvi.org.au/historical#4/-26.67/134.12
[32] http://www.aemo.com.au/Electricity/Planning/Related-Information/Generation-Information
[33] http://www legjslatjon nsw goy au/yjewtop/jnforce/act+203+J979+FIRST+0+N/2
[34] http://www.aemo.com.au/ElectricitvlPlanning/National-Transmission-Network-Development-Plan
[35] http://majorprojects.planning.nsw.gov.au/page/project-sectors/transport--communications--energy---water/generation-of-electricity-or-heat-or-co-generation/)

on state land in a section of the Pilliga set aside by the NSW Government for uses including logging and extractive industries and does not include National Parks or Nature Reserves". Furthermore, Santos states that they "will only drill on private land when the landholder agrees to host our activities. The operational facilities would be located on about 1000 hectares or around 1% of the 95,000-hectare (950 km^2) project area". However the impact of the operations might extend far beyond this 1%.

Figure 18: Map of the Narrabri Gas Project



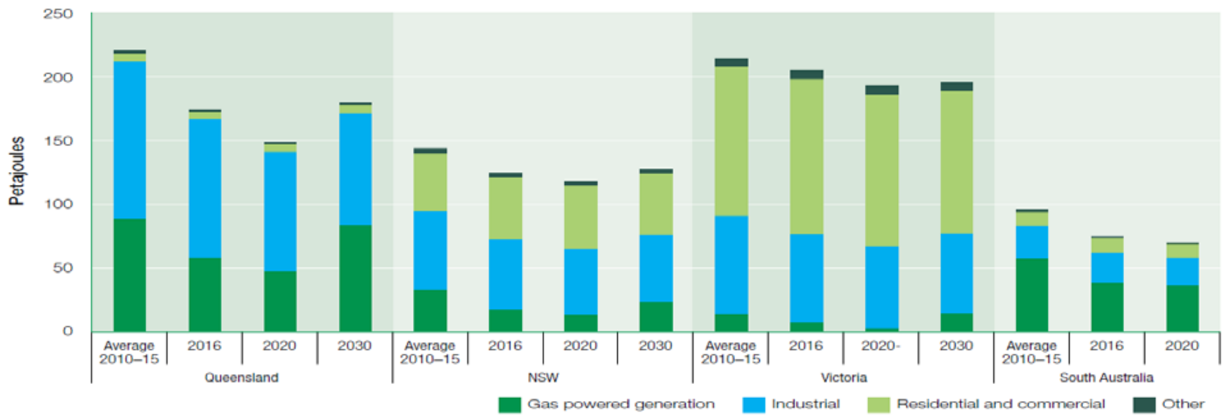
Source: Santos, Environmental Impact Statement (EIS)

5.2.1 SANTOS ESTIMATION: GAS PRODUCTION

Santos quantified the estimated total gas volume for this project "up to half of NSW annual gas demand" or 200 TJ per day. According to the Australian Energy Regulator, the average annual gas consumption of New South Wales between 2010 - 2015 was close to 150 PJ/a[36] (Figure 19). Thus the Santo gas field project might supply around 74 PJ of gas per year.

[36] Australian Energy Regulator, State of the Energy Market May 2017, https://www.aer.gov.au/system/files/AER%20State%20of%20the%20energy%20market%202017%20-%20A4.pdf

Figure 19: Domestic gas consumption in Eastern Australia



Source: AEMO, *National gas forecasting report*, 2016.

There are several options for how the produced gas can be used:

- Gas supply for household cooking and warm water supply
- Industry use e.g. process heat production
- In gas power plant to generate electricity for the NEM
- For export

By the time of the final editing of this report, it was still unclear how the gas will be used. In case this gas will be used in gas power plants with an average efficiency of 40%[37] this would lead to a generation of 8 TWh electricity. In order to compare the energy content of the gas field project with the alternative renewable energy project, the energy measured in $TWh_{electric}$ will be used.

5.2.2 SANTOS ESTIMATION: ECONOMIC AND EMPLOYMENT

According to the Environmental Impact Statement for the gas field, the employment at peak construction that will be sourced from Narrabri Shire or the surrounding shires will be 390 people (30% of the total estimated construction workforce of 1,300). However, during the operations phase 120 local people from the Narrabri Shire and surrounding shires will be employed (60% of 200 strong operations workforce).[38]

The cost of gas field includes a construction nominal capital investment of $3.6 billion, or around $3 billion in real terms, with a net present value of $2 billion. This is including operational costs over 25 years. [39]

[37] Average efficiency gas power plant up to 39%, CCGT power plants achieve up to 58%, source: EFFICIENCY IN ELECTRICITY GENERATION, EURELECTRIC in collaboration with VGB July 2003

[38] Narrabri Gas Project, Environmental Impact Statement, Appendix U2 Economic Assessment https://majorprojects.accelo.com/public/486343c7aeff880520e893fc8f392450/Appendix%20U2%20Economic%20assessment%20_macroeconomic%20analysis_.pdf

[39] Narrabri Gas Project, Environmental Impact Statement, Executive Summary https://majorprojects.accelo.com/public/599b13c8378739ff1fd1451067c2ab38/00c%20Executive%20summary.pdf

APPENDIX

The following tables set out the costs for power generation for the range of technologies used in the modelling. These are based on up-to-date data and current market developments, as described in Chapter 3. The specific investment costs in $/kW are detailed in Table 14 and ongoing operation and maintenance costs in $/kW/year are shown in Table 15.

Table 14: Specific investment costs for power generation

in $/kW		2015	2020	2030	2040	2050
Power plants	Biomass and waste power plant	3,145	2,969	2,867	2,750	2,691
	Coal power plant	1,411	1,390	1,356	1,321	1,287
	Diesel generator	907	907	907	907	907
	Gas power plant	769	751	715	679	644
	Geothermal power plant	12,579	9,507	6,509	5,409	4,652
	Hydro large	3,466	3,573	3,734	3,869	3,987
	Hydro small	3,466	3,573	3,734	3,869	3,987
	Lignite power plant	1,645	1,609	1,575	1,540	1,507
	Nuclear power plant	6,615	6,615	6,615	6,615	6,615
	Ocean energy power plant	4,710	3,364	2,340	1,943	1,730
	Oil power plant	967	948	910	872	834
	PV power plant	1,817	1,682	1,305	1,059	1,079
	Solar thermal power plant	5,787	4,705	3,799	3,595	3,479
	Wind turbine offshore	5,631	3,876	3,072	2,775	2,386
	Wind turbine onshore	1,519	1,316	1,305	1,312	1,371
CHP for Power Generation and Industry	CHP Biomass and waste	5,150	4,505	3,934	3,626	3,445
	CHP Coal	1,950	1,919	1,872	1,824	1,777
	CHP Fuel cell	1,726	1,346	1,214	1,155	1,141
	CHP Gas	1,038	995	974	954	933
	CHP Geothermal	13,456	11,409	9,068	7,606	6,582
	CHP Lignite	1,950	1,919	1,872	1,824	1,777
	CHP Oil	1,340	1,312	1,259	1,205	1,153
Buildings / Other Small Scale	CHP Biomass and waste	2,545	2,486	2,443	2,418	2,391
	CHP Coal	1,949	1,919	1,872	1,824	1,777
	CHP Fuel cell	1,726	1,346	1,214	1,155	1,141
	CHP Gas	965	911	804	790	775
	CHP Geothermal	13,456	11,409	9,068	7,606	6,582
	CHP Lignite	1,950	1,919	1,872	1,824	1,777
	CHP Oil	1,339	1,312	1,259	1,205	1,153

Table 15: Operation and maintenance costs for power generation technologies

in $/kW/a		2015	2020	2030	2040	2050
Power plants	Biomass and waste power plant	189.1	178.3	172.0	165.5	162.2
	Coal power plant	30.8	29.7	29.7	29.7	29.7
	Diesel generator	112.6	112.6	112.6	112.6	112.6
	Gas power plant	23.7	22.1	20.6	18.6	17.8
	Geothermal power plant	548.6	426.6	324.4	302.9	286.7
	Hydro large	139.0	143.3	149.2	155.0	159.4
	Hydro small	139.0	143.3	149.2	155.0	159.4
	Lignite power plant	27.1	26.5	25.9	25.4	24.9
	Nuclear power plant	162.0	162.0	162.0	162.0	162.0
	Ocean energy power plant	188.7	134.7	93.0	78.2	69.0
	Oil power plant	22.4	21.7	20.3	18.8	17.4
	PV power plant	38.7	21.9	15.4	14.7	15.4
	Solar thermal power plant	350.9	270.0	233.8	215.0	196.4
	Wind turbine offshore	209.5	164.5	133.6	126.6	108.9
	Wind turbine onshore	56.5	55.9	56.8	59.8	62.6
CHP for Power Generation	CHP Biomass and waste	361.3	315.9	275.0	254.5	241.3
	CHP Coal	68.7	67.3	65.8	64.4	62.9
	CHP Gas	42.4	39.5	39.5	38.0	38.0
	CHP Geothermal	487.1	409.5	342.3	298.4	272.1
	CHP Lignite	81.9	80.4	77.5	76.1	73.1
	CHP Oil	48.3	46.8	43.9	42.4	41.0
CHP for Industry	CHP Biomass and waste	93.6	83.4	74.6	68.7	62.9
	CHP Coal	68.7	67.3	65.8	64.4	62.9
	CHP Fuel cell	86.3	67.3	61.4	58.5	57.0
	CHP Gas	42.4	39.5	39.5	38.0	38.0
	CHP Geothermal	239.9	231.1	222.3	220.9	219.4
	CHP Lignite	81.9	80.4	77.5	76.1	73.1
	CHP Oil	48.3	46.8	43.9	42.4	41.0
CHP for Buildings / Other Small Scale	CHP Biomass and waste	101.7	99.5	98.0	96.5	95.1
	CHP Coal	68.0	67.3	65.8	64.4	62.9
	CHP Fuel cell	86.3	67.3	61.4	58.5	57.0
	CHP Gas	38.8	36.6	32.2	32.2	30.7
	CHP Geothermal	239.9	231.1	222.3	220.9	219.4

	CHP Lignite	81.9	80.4	77.5	76.1	73.1

Table 16 provides a list of major existing, under construction and proposed NSW power stations larger than 30 MW of installed capacity. A full list of current NSW generators registered with the Australian Energy Market Operator (AEMO) are available at the AEMO website[40].

Table 16: New South Wales power plants

PowerPlants in New South Wales/ Australia			
Power station	Max. Capacity [MW]	Technology	Fuel
Moree Solar Farm, Moree, NSW	56	Photovoltaic	solar
Royalla Solar Farm, Royalla NSW	20	Photovoltaic	solar
Nyngan Solar Plant, Nyngan, NSW	102	Photovoltaic	solar
Broken Hill Solar Plant, Broken Hill, NSW	53	Photovoltaic	solar
Mugga Lane Solar Park, Canberra, ACT	13	Photovoltaic	solar
Gullen Range Solar Farm, Crookwell, NSW	10	Photovoltaic	solar
Power station	Max. Capacity	Technology	Fuel
Bayswater	2,640	Coal Power	bituminous
Eraring	2,880	Coal Power	bituminous
Liddell	2,000	Coal Power	bituminous
Mt Piper	1,400	Coal Power	bituminous
Vales Point B	1,320	Coal Power	bituminous
Power station	Max. Capacity	Technology	Fuel
Colongra	667	Gas Power Plant	natural gas
Liddell	50	Gas Power Plant	fuel oil
Tallawarra	435	Gas Power Plant	natural gas
Smithfield	176	Gas Power Plant	natural gas
Uranquinty	641	Gas Power Plant	natural gas
Power station	Max. Capacity	Technology	Fuel
Appin Mine	55.6	Gas Power Plant	coalbed methane+natural gas
Belrose	4	Gas Power Plant	landfill gas
Earthpower Camellia	3.9	Gas Power Plant	biogas
Jacks Gully	2.3	Gas Power Plant	landfill gas
Lucas Heights I	5.4	Gas Power Plant	landfill gas
Lucas Heights II	17.3	Gas Power Plant	landfill gas
Sydney Water, Malabar	3	Gas Power Plant	sewage gas
Shoalhaven Landfill Gas Project	1	Gas Power Plant	landfill gas
Tahmoor [1]	7	Gas Power Plant	coalbed methane
Teralba	8	Gas Power Plant	coalbed methane
Tower Mine	41.2	Gas Power Plant	coalbed methane+natural gas
Wilga	11	Gas Power Plant	natural gas
Woodlawn	4	Gas Power Plant	landfill gas
Kincumber Landfill Gas Abatement [1]	1	Gas Power Plant	landfill gas
Woy Woy Landfill Gas Abatement [2]	1	Gas Power Plant	landfill gas
Power station	Max. Capacity	Technology	Fuel
Bendeela (Shoalhaven)	80	Hydro Power Plant	water
Blowering	80	Hydro Power Plant	water
Brown Mountain	4.95	Hydro Power Plant	water
Burrendong	14.5	Hydro Power Plant	water
Burrinjuck	27	Hydro Power Plant	water
Copeton	24	Hydro Power Plant	water
Glenbawn	5.8	Hydro Power Plant	water
Guthega	60	Hydro Power Plant	water
Hume	58	Hydro Power Plant	water
Kangaroo Valley (Shoalhaven)	160	Hydro Power Plant	water
Keepit	7.2	Hydro Power Plant	water
Kembla Grange	6.8	Hydro Power Plant	water
Murray 1	950	Hydro Power Plant	water
Murray 2	550	Hydro Power Plant	water
Nymboida	5	Hydro Power Plant	water
Oaky River	12	Hydro Power Plant	water
Pindari	5.6	Hydro Power Plant	water
The Drop, Mulwala Canal	2.5	Hydro Power Plant	water
Tumut 1	330	Hydro Power Plant	water
Tumut 2	287	Hydro Power Plant	water
Tumut 3	1500	Hydro Power Plant	water
Warragamba	50	Hydro Power Plant	water
Williams River Dam (private)	7	Hydro Power Plant	water
Wyangala	22.5	Hydro Power Plant	water
Power station	Max. Capacity	Technology	Fuel
Broadwater Sugar Mill	10	Bio energy Power Plant	bagasse
Broadwater Biomass Co-Gen	30	Bio energy Power Plant	bagasse/wood waste
Condong Sugar Mill	3	Bio energy Power Plant	bagasse
Condong Biomass Co-Gen	30	Bio energy Power Plant	bagasse/wood waste
Harwood Sugar Mill	4.5	Bio energy Power Plant	bagasse
Visy Paper, Tumut	21	Bio energy Power Plant	black liquor
Power station	Max. Capacity	Technology	Fuel
Amcor, Bomaderry	6	CoGen	
BlueScope Steel, Port Kembla	62	CoGen	
Macquarie University	1.5	CoGen	
Stadium Australia	1	CoGen	
University of Western Sydney	1	CoGen	
Visy Paper, Smithfield	6	CoGen	
Decommissioned Power station	Max. Capacity	Technology	Fuel
Munmorah	1,400		bituminous
Redbank	150		bituminous (tailings)
Wallerawang	1,240		bituminous
Total Capacity	**17,055**		

[40] http://www.aemo.com.au/About-the-Industry/Registration/Current-Registration-and-Exemption-Lists

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