REPOWERING OUR REGIONS

TECHNICAL REPORT

Nature Conservation Council

#REPOWER NSW

REPOWERING OUR REGIONS TECHNICAL REPORT NOVEMBER 2017

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1. INTRODUCTION

Academic studies have modelled scenarios for reaching 100% clean electricity in Australia, and a selection are cited in the main report. This report translates those results into the impacts and benefits that NSW regions will see if the state transitions to generating 100% of its energy from clean sources.

Repowering our Regions especially builds on the scenarios developed in the Homegrown Power Plan and UTS Institute for Sustainable Futures' *100% renewable energy for Australia* modelling [1], as well as renewable energy studies by Beyond Zero Emissions [2] and ANU [3].

This document serves as an appendix to the *Repowering our Regions* report, providing the references, assumptions, methods and input data that underpin the results in the main report.

2. THE TECHNOLOGY MIX

Studies have modelled different combinations of technologies to optimise for reliability and lowest cost. A wide variety of combinations of PV, wind, pumped hydro storage, solar-thermal and transmission capacity in a variety of locations can all meet the NEM reliability standard with similar cost. Given this, it is not necessary or possible to predict the future technology mix precisely.

There are two main pieces to the transition: generating sufficient clean energy (around 76,000 GWh per year) to meet NSW consumption and having sufficient reliable capacity (over 14 GW) to meet peaks in demand whenever they occur.

While the exact mix of generation technologies will depend on policy settings and technological and economic developments, *Repowering our Regions* looks at previous modelling of least-cost pathways, and combines this with assessments of available solar and wind resources in NSW to create a roadmap of a likely pathway to a 100% clean energy electricity supply, as summarised in Figure 1.

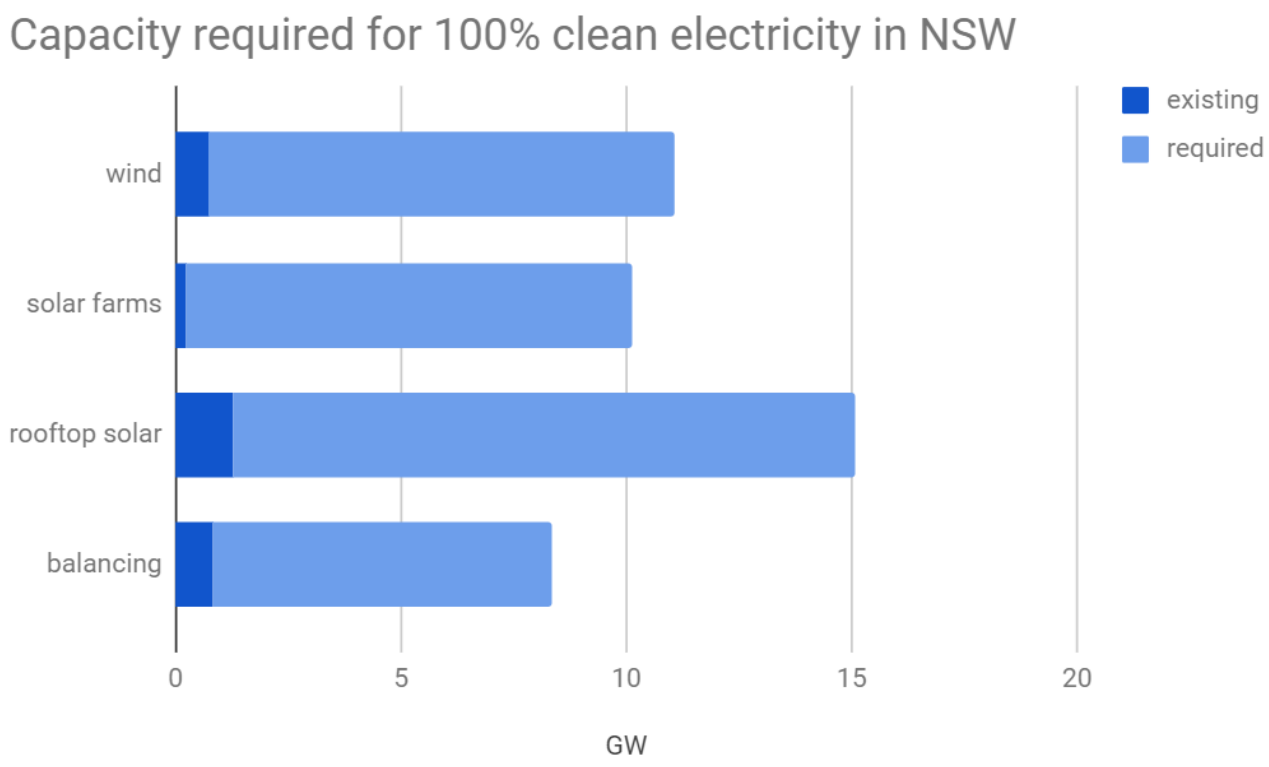


Figure 1: generation required for NSW to source all electricity from clean sources

2.1. MEETING NSW ELECTRICITY CONSUMPTION

Under the ISF advanced renewables scenario, 100% of the stationary electricity powering our households, businesses and industry comes from clean renewable sources. While electricity consumption is likely to increase as transport and heat are electrified, our 100% scenario does not include this increase, due to uncertainty in the timing and the extent that it will be offset by improving energy productivity.

We therefore estimate that NSW consumption will increase by 10% from 69 TWh in 2017 to 77 TWh by 2030 to account for spillage and storage losses associated with balancing a 100% renewable energy grid.

A key result identified in the CSIRO and Energy Networks Australia modelling is that rooftop solar will boom, owing to the large price difference between grid-sourced electricity and so called “behind the meter” generation [1]. High grid electricity prices and falling solar installation costs are already driving increased installation, with 26% more capacity installed in the first six months of 2017 compared with the same period in 2016.

By considering estimates of available roof space, we find that rooftop solar for both residential and commercial buildings could saturate at around 14 GW of capacity, under conservative assumptions. The vast bulk of this is residential rooftops, with commercial and industrial only providing 1.2 GW. This rooftop solar will provide 19 TWh of energy per year, up from 1.5 TWh in 2017. This represents 25% of NSW consumption in 2030, up from the 2.2% it currently provides in 2017.

With hydro and biomass continuing to provide 5% of the State’s needs, the remaining 70% of generation will need to come from a mix of large-scale clean sources, with the make-up determined by a range of factors including resource availability, transmission capacity, matching generation with the demand profile and cost.

Wind has dominated large-scale renewable generation in Australia as a lower-cost, more mature technology than solar PV. But falling prices of solar PV, large areas of sunny land and the complimentary generation profile mean that solar is taking an ever-larger share. As at September 2017, there are 219 MW of solar projects and 920 MW of wind farms under construction in NSW, while the total development pipeline is 5,100 MW of wind and 2,100 MW of solar. Prices for both wind and solar to continue to reduce, and we expect solar to continue to make up a larger share of installations due to cost reductions and the complementary nature of diverse sources.

For the sake of jobs and industry growth projections, we assume that the 20 GW required large-scale renewable energy generation capacity will include approximately 10 GW of solar and 10 GW of wind, backed up by 7.5 GW of flexible, dispatchable capacity such as demand management, solar-thermal, batteries and pumped-hydro.

A comparison of the required wind and solar farms and rooftop solar required to meet 100% of electricity demand with the available resources in NSW is shown in Table 1.

Table 1: Required capacity for a 100% clean energy grid vs wind and solar resources available in NSW

	Required for 100% clean energy scenario	Build capacity in NSW and ACT region	Fraction of resource required
Wind	10 GW	287 GW	1 in 20 sites (5%)
Solar	10 GW	4,220 GW of PV or 5,582 GW of CSP	1 in 400 sites (0.2%)
Rooftop solar	14 GW	20 GW	3 in 4 suitable houses
Balancing	7.5 GW/100 GWh	2,000 GW / 30,000 GWh PHES 5,582 GW / 55,000 GWh CSP 4 GW DM	1 in 200 PHES sites or 1 in 550 CSP sites

Notes: PHES = pumped-hydro energy storage, CSP = concentrating solar power, DM = demand management. Economic build capacity limits for large scale wind and solar calculated by ROAM and are a conservative estimate [2]. Wind estimates only include sites with capacity factors ≥ 35%. Capacity limit for rooftop solar is based on 7.5 kW average installation size and 75% uptake as detailed in Section 2.2.2. Solar farm capacity is based on ROAM's most conservative scenario of 20 MW/km^2 DC. PHES estimates from [3].

The resulting technology mix in 2030 is shown in Figure 2.

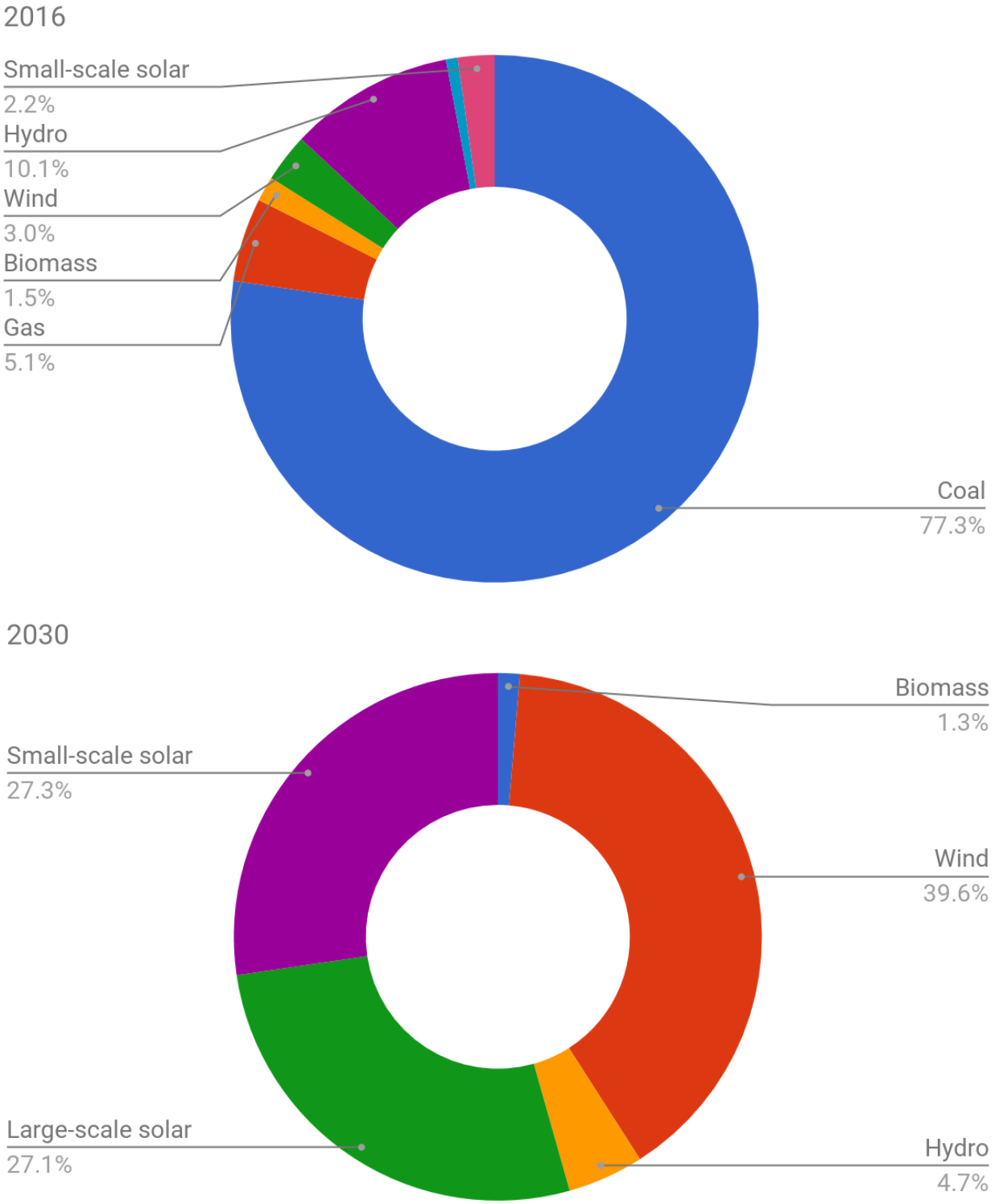


Figure 2: Current and 100% renewable technology mixes for electricity generation in NSW. Note, storage and balancing capacity such as Snowy 2.0 is not shown as it is not a net energy generator.

We estimate hydro generation as the average generation for 2008 – 2014 of 3.7 TWh, and biomass to be equal to 2016 generation. We note that even with pumped hydro expansions like Snowy 2.0, net hydro generation from the Snowy catchment is limited by rainfall and will not increase. While some clean energy scenarios forecast a greater role for biomass, concerns with burning of native forests, displacement of food production and pollution means that we are unwilling to suggest a greater role for biomass than current generation.

The current and 100% clean energy generation mix for NSW is shown in Table 2.

Table 2: Technology mix of NSW electricity generation in 2030 and 2016. Note, storage and balancing capacity such as Snowy 2.0 is not shown in this table as it is not a net energy generator.

	2016		2030	
	TWh	%	TWh	%
Rooftop solar	1.6	2%	19.1	25%
Solar farm	0.5	1%	21.8	28%
Wind farm	2.1	3%	31.8	41%
Hydro	7.1	10%	3.7	5%
Biomass	1.1	2%	1.1	1%
Total clean energy	12.3	18%	77.3	100%

Comparison of the required energy generation with existing and proposed projects is shown in Figure 3.

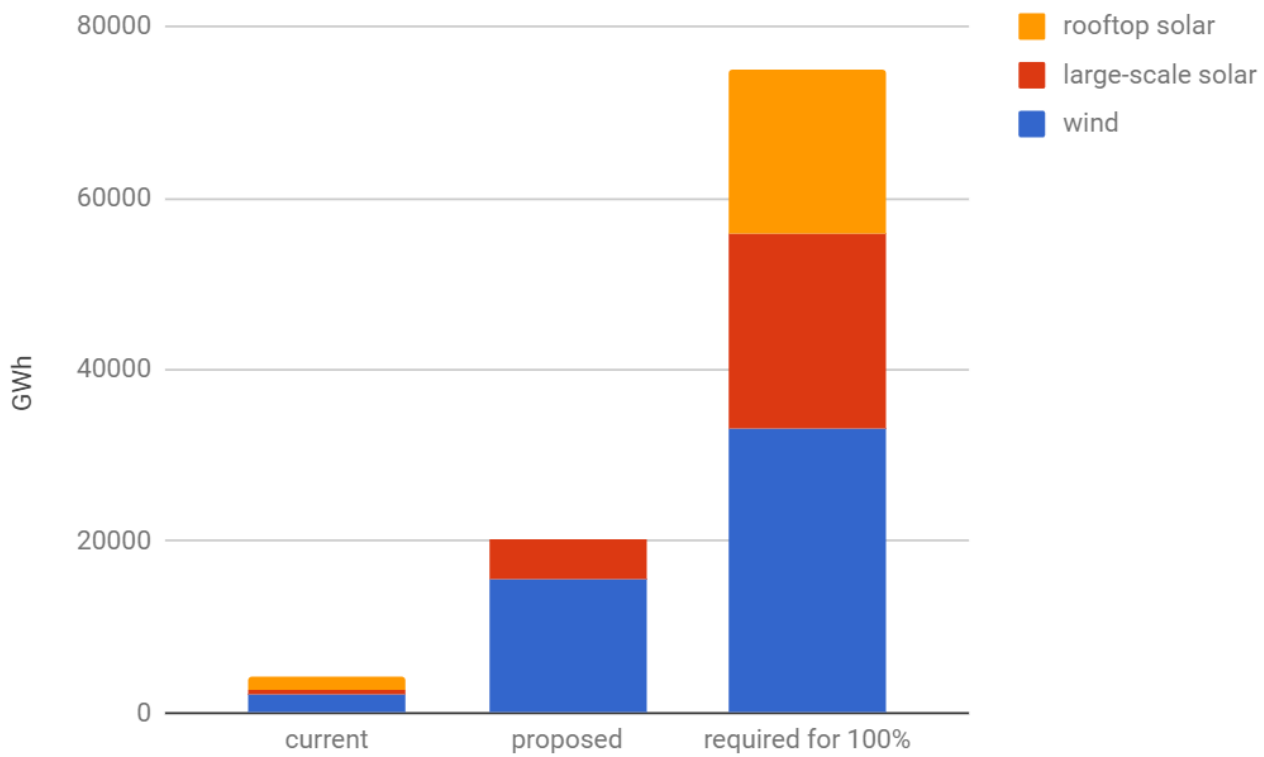


Figure 3: While proposed wind and solar projects in NSW dwarf current generation, not only do these projects need to reach construction, but significant additional projects are required to meet 100% of our energy needs from clean sources.

2.2. THE ROOFTOP REVOLUTION

Household rooftop solar is booming in some parts of Australia, with NSW having a great opportunity to source more energy from our rooftops. The cost of grid electricity has been increasing, while the cost of powering our lives from our rooftops has fallen to the point that it is several times cheaper, for households and businesses who have a suitable roof.

NSW is lagging in terms of rooftop solar at just 16% of suitable homes, compared to the Australian average of 21%.

CSIRO and Energy Networks Australia have estimated that by 2050, 30 to 45% of energy will be generated on our rooftops. This will be driven by more households and businesses going solar and rooftop systems increasing in size. In 2010 the average solar installation was 2 kW in size. By 2017, it is already 5.2 kW, and CSIRO expects this trend to continue, assuming a maximum PV size of 10 kW will be taken up by up to 90% of detached households. NSW network companies currently limit the maximum size of PV inverters to 5 kW for most houses, however there are several technological changes that would allow larger systems. Examples include home batteries, EV charging, grid export limited inverters, and three-phase connections. Indeed, the Queensland distributor has already relaxed solar system limit on one phase to allow 10 kW systems, so long as grid exports are limited to 5 kW [4].

Our estimate of a 10-fold increase in rooftop solar considers the growing number of households in NSW, the growing average size of solar installations, household batteries and electric vehicles becoming more common, solar agreements between renters and landlords becoming commonplace and more businesses going solar.

2.2.1. THE FINANCIAL DRIVER – CUTTING BILLS

High electricity prices and plummeting costs of solar panels means that the only guaranteed way for households and businesses to take control of their electricity bills is to install solar. Carbon and Energy Markets estimate that solar electricity is approximately 5 times cheaper than grid-sourced electricity for NSW households, as shown in Figure 4.

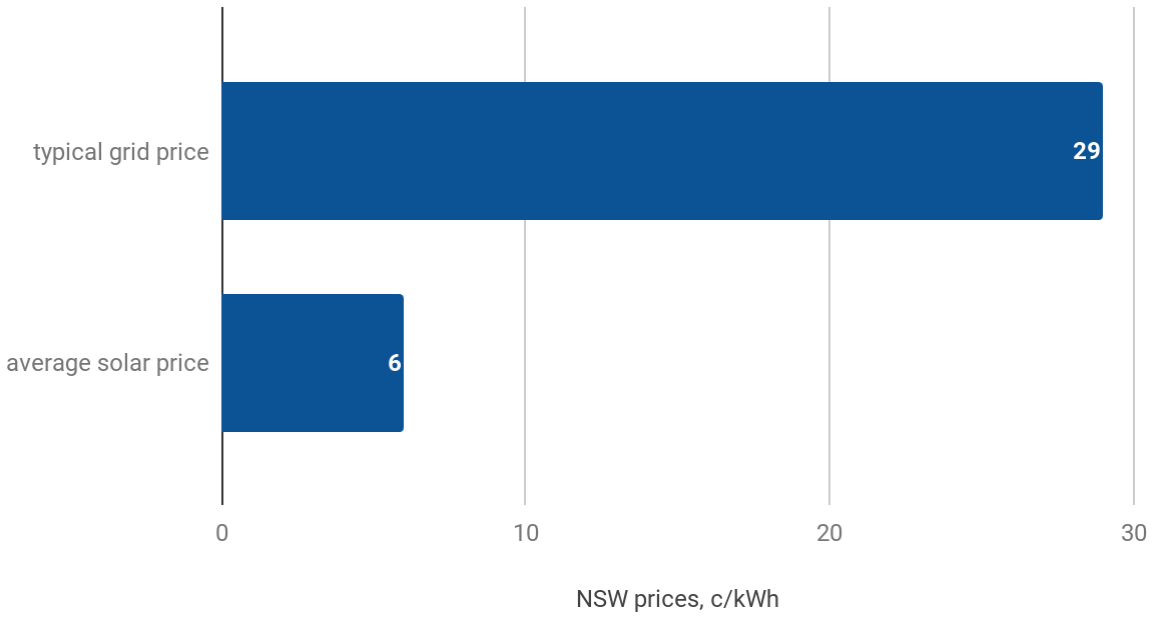


Figure 4 Average cost of rooftop solar electricity for NSW households vs grid electricity. Data: Bruce Mountain, CEM [5]

For businesses despite lower grid tariffs per kWh the cost imperative is still strong with recent high electricity prices.

NSW rooftop solar installs in the first half of 2017 increased by 23% compared to the same period in 2016.

The benefits of this more distributed electricity generation model are not limited to solar households and businesses if it is managed well. Already there is evidence of rooftop solar cutting generation prices in NSW by up to $3.3 bn in the twelve months to April 2017 [6].

Furthermore, the cost of building and maintaining electricity poles and wires currently makes up around 50% of electricity bills. The rooftop revolution offers an opportunity to drastically reduce this. CSIRO and Energy Networks Australia calculate that households will save $414 per year by transitioning to a 100% renewable energy grid that makes efficient use of rooftop solar and household batteries [1].

The rooftop revolution must be well managed to ensure that households are not left to pay for an underutilized network that duplicates the services that household solar and battery systems can provide more cheaply.

2.2.2. LIMITS TO ROOFTOP PV GROWTH

The 16% of NSW houses that have rooftop solar currently generate 2% of NSW's total electricity needs, or 1.6 TWh. But by 2030, rooftop solar can generate at least twelve-times more, producing 25% of NSW's electricity needs, or 19 TWh.

We consider suitable rooftop space to be the main limit to rooftop PV uptake.

For the residential sector, there are several estimates of available roof area. Beyond Zero Emissions estimate that NSW residential capacity is 10 GW [7]. Meanwhile, at the upper end, Energeia modelling predicts total

rooftop PV uptake in the NEM to be 65 GW to 78 GW (commercial and residential) by 2050, and 90 GWh of battery storage [8]. For NSW the total is 25 GW solar and 25 GWh batteries [9].

Our result of 12.6 GW of household solar falls between previous estimates. It is slightly higher than the BZE estimate for several reasons. Firstly, BZE's estimate was intentionally a "worst-case" conservative estimate and did not consider expected growth in household roof-space. Secondly, BZE used the worst-case usable roof area of 15% of building footprint, while the best-case they cited was 36.5%. Our estimate falls between the two cases. The CSIRO/Energeia study is far more ambitious. As well as longer timeframe, CSIRO discusses the integration of solar panels into roof tiles and walls, which substantially increases the available roof area. Indeed, several suppliers already offer solar roof tiles. However, our estimates rely only on traditional solar panels.

Still, our estimate is a 12-fold increase in rooftop generation and would create 16,000 full-time jobs in NSW over the thirteen-year period from now to 2030. On a household level, 12.6 GW will be achieved if 75% of all detached and semi-detached houses to install solar, and the average installation size to rises from 3.4 kW to 7.5 kW. The average size of rooftop solar system installations has been steadily rising and in the first six months of 2017 in NSW was 5.2 kW.

2.2.3. GROWTH IN NUMBER OF HOUSEHOLDS

We use a growth in the number of households in the regional NSW of 10% over the 14 years between the 2016 census and 2030, except for Western NSW, where we assume no growth. The ABS estimates the number of households will grow at slightly higher than the population growth rate, due to declining number of persons per dwelling. Our growth rate in the number of houses is based on regional population growth being 40% lower than the statewide rate, in line with other estimates [10] [11].

2.2.4. COMMERCIAL ROOFTOP SOLAR

For the commercial sector, Weiss estimates the potential for the NEM of around 10 GW by 2030 [12]. ACIL Allen, based on the work of Beyond Zero Emissions estimate that commercial capacity in NSW is 1.1 GW in 2011, out of 3.5 GW total across the NEM [13]. We use the ACIL Allen/BZE estimate for this roadmap.

2.3. SOLAR FARM LAND USE

The land area used by solar farms is estimated at 20 MW/km^2 for single-axis tracking arrays to 40 MW/km^2 for fixed arrays with efficient panels. For reference, the Broken Hill solar farm produces 53 MW from a 140 Ha area, or 38 MW/km^2.

The 10GW of solar farms in this plan will require 500 km^2 (50,000 Hectares) compared to NSW's total land area of 800,000 km^2.

Land used for solar farms can also be simultaneously be used for conventional agriculture, a process known as agrivoltaics. Grazing sheep amongst solar arrays is common practice globally. While photosynthetic active radiation is reduced by the solar panels, shade-resistant species can be used to minimize the impact on productivity. Total rainfall is undisturbed by solar panels, and evaporation is reduced [14]. Research indicates that soil carbon is unchanged under solar panels or in gaps between rows and more work can be done to establish best-practice solar farm development and agricultural methods to maximise productivity and the coexistence of the two land-uses in Australian contexts [14].

2.4. DISPATCHABLE BALANCING CAPACITY

When weather conditions in an area mean that not enough wind and solar energy can be generated locally, energy will have to be sourced either by transmission lines from another region, or from flexible, dispatchable resources like solar thermal, batteries, pumped hydro or demand management.

By 2030, NSW will require 7.5 GW of flexible capacity to balance supply and demand in a 100% renewable energy system, according to NSW's share of the NEM and ANU modelling [3]. It will also require up to 115 GWh of energy storage to cover extended periods of still, cloudy weather.

ANU estimates that this level of storage, as well as some spillage of unused renewable energy and increased transmission of power from renewable energy zones would add 2.4 to 3.6c/kWh to the wholesale cost of 100% renewable electricity. This results in total prices of 7.4 to 8.6 c/kWh, which is significantly below the current NSW wholesale price, which was 11.7c/kWh for the first six months of 2017.

2.5. TRANSMISSION

Transgrid have received connection interest from 4.5 GW of projects where transmission capacity is available. In addition, they have received 1.7 GW of connection interest in excess of current grid capacity and identified a total of 21 GW solar and 5 GW wind precincts that could be unlocked up with additional transmission infrastructure as shown in Table 3.

Australia's transmission network was built to connect our cities and industrial areas with coal fields and snowy hydro. To shift from a coal-based system and enable the regions of NSW to become exporters of clean energy, new transmission will be needed.

> *"The existing transmission network outside the Sydney – Wollongong – Newcastle – Hunter Valley area will reach its existing capacity to connect renewable generation by 2020."*
>
> Transgrid Annual Planning Report 2017

Table 3: Transgrid identify 26 GW of large-scale renewable transmission connection opportunities around the state.

Western NSW	11 GW solar, 3 GW wind
New England	5 GW solar
Central West	5 GW solar
Southern Tablelands	2 GW wind
Total	26 GW

Transgrid's plan to provide transmission infrastructure to unlock renewable energy precincts and improve interconnection and reliability would cost around $15 per year for average households and $3/MWh for large industrial users. Early modelling indicates that this cost would be completely offset by the wholesale price reductions driven by access to more low-cost renewable energy [15].

3. JOBS AND INVESTMENT

We estimate up to 22,000 jobs created by rooftop solar, solar farms and wind farms. Jobs from constructing and operating balancing technologies, transmission, energy efficiency and manufacturing are not considered, hence these are conservative estimates. Jobs created could be significantly higher with appropriate policies to establish clean energy manufacturing in NSW.

Jobs and investment estimates are based on previously published work and on averages of reported jobs and investment for projects in NSW's development pipeline.

3.1. JOBS

The most recent ABS figures show that there were 2,900 jobs in renewable energy in NSW in 2015-16, with rooftop solar making up 50% of all renewable energy jobs nationally [16].

Jobs figures included in this report are direct, sustained jobs in renewable energy.

Ongoing jobs are tallied for the total capacity installed, while construction and installation jobs are averaged over the 13-year study period.

ROAM consulting in 2014 published jobs-per-megawatt factors for operations and maintenance and construction and installation of solar farms, wind farms and rooftop solar [17]. These were based on a survey of 22 wind farms and 4 solar farms in Australia.

Our own analysis of 52 projects at various stages of the development process in NSW resulted in slightly lower jobs estimates, especially for construction of wind farms. This possibly reflects more efficient construction processes and higher capacity turbines since ROAM's study. As per ROAM's assumptions, we assume a 24 month construction period for wind farms and 12 months for solar farms. The estimate of jobs requirement per MW of wind and solar are shown in Table 4.

Table 4: Jobs requirements for renewable energy projects per MW

	ROAM estimate		NCC estimate	
	Construction (job-years/MW)	Operations and maintenance (ongoing jobs)	Construction (job-years/MW)	Operations and maintenance (ongoing jobs)
Wind farms	4.4	0.1	1.8	0.08
Solar farms	2.4	0.13	1.8	0.06
Rooftop solar	15			

A rooftop solar industry of the scale required to generate 25% of NSW's energy by 2030 would create 14,000 direct full-time jobs across the 13 years from 2017 to 2030. The large-scale solar and wind industries would create 3000 solar and 4200 wind full-time jobs across the study period, as shown in Table 5.

Table 5: Total jobs created in 100% clean energy roadmap, by technology and job type

	Construction jobs, averaged over study period	Operations and maintenance jobs	Total

Solar farms	1791	1261	3052
Wind farms	3283	970	4253
Rooftop solar	14487	0	14487
Total full-time jobs for 13-year study period			21792

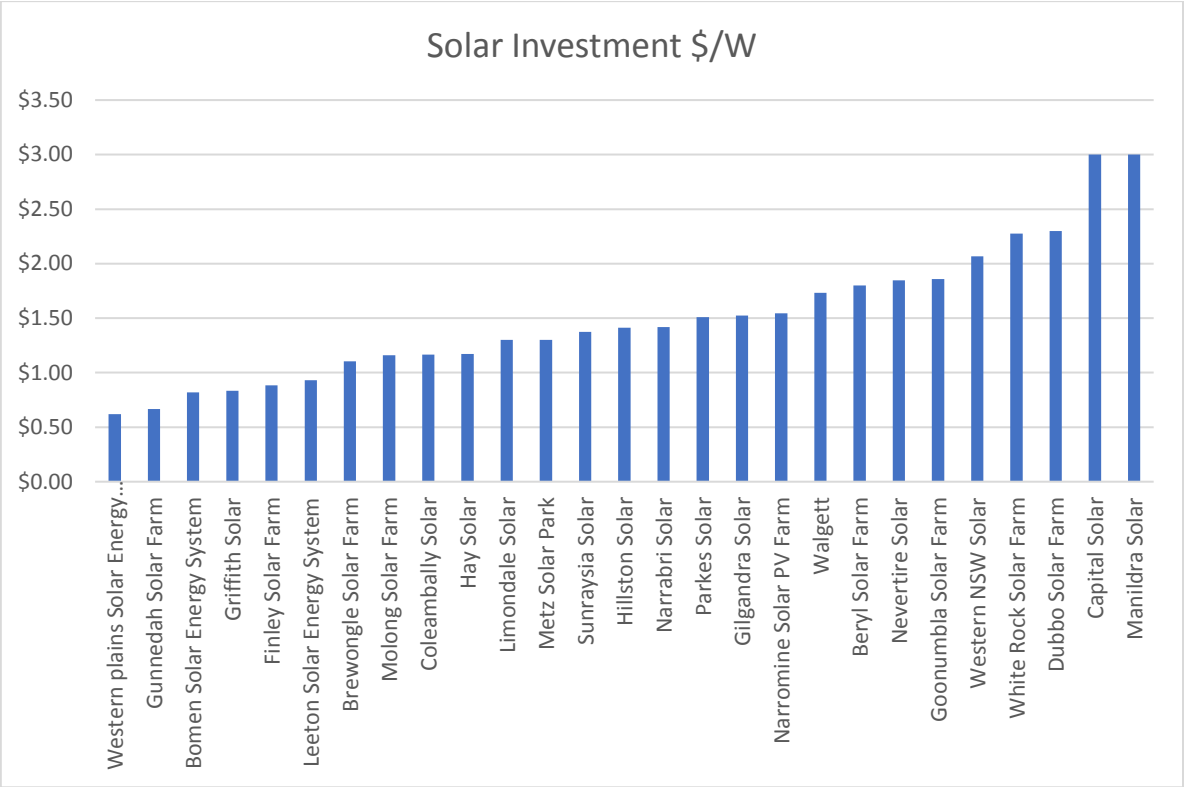
3.2. INVESTMENT

Investment required per MW of solar and wind farms were based on a study of the solar farms and wind farms in development in NSW. Costs of already operational projects were not considered, as solar and wind farm costs have fallen in recent years.

3.2.1. SOLAR INVESTMENT

To arrive at solar farm investment estimates, 29 solar farms were considered, with capacity and investment estimates drawn from project application documentation or company statements if more recent.

The average investment was $1.87m per MW. For our investment projections we used a more conservative figure of $1.2m per MW, to account for falling costs and the likelihood that more expensive projects are less likely to proceed to construction.



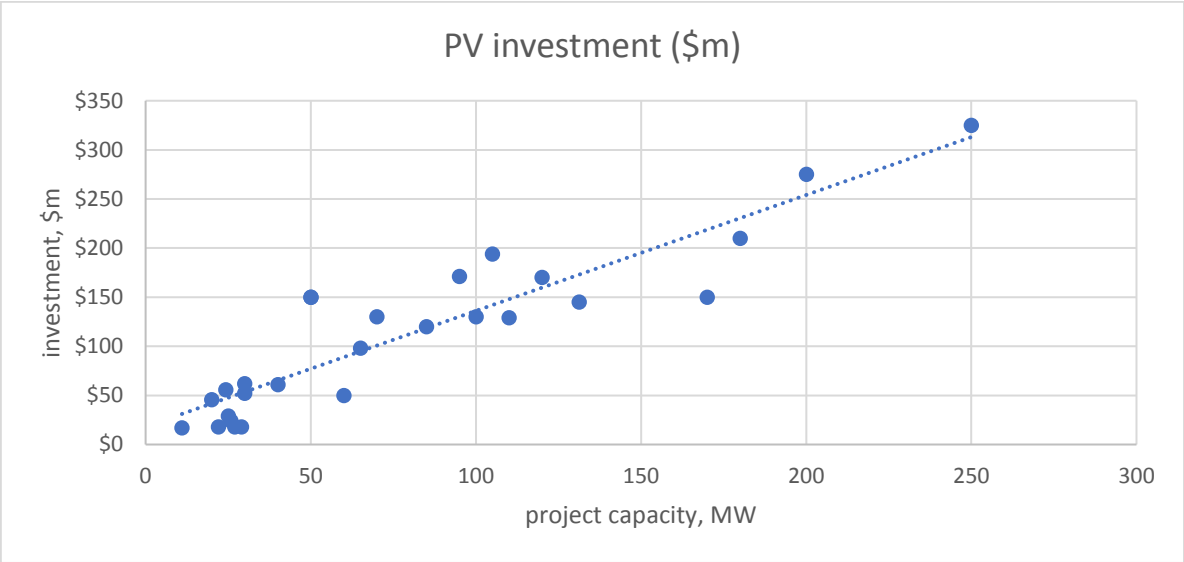
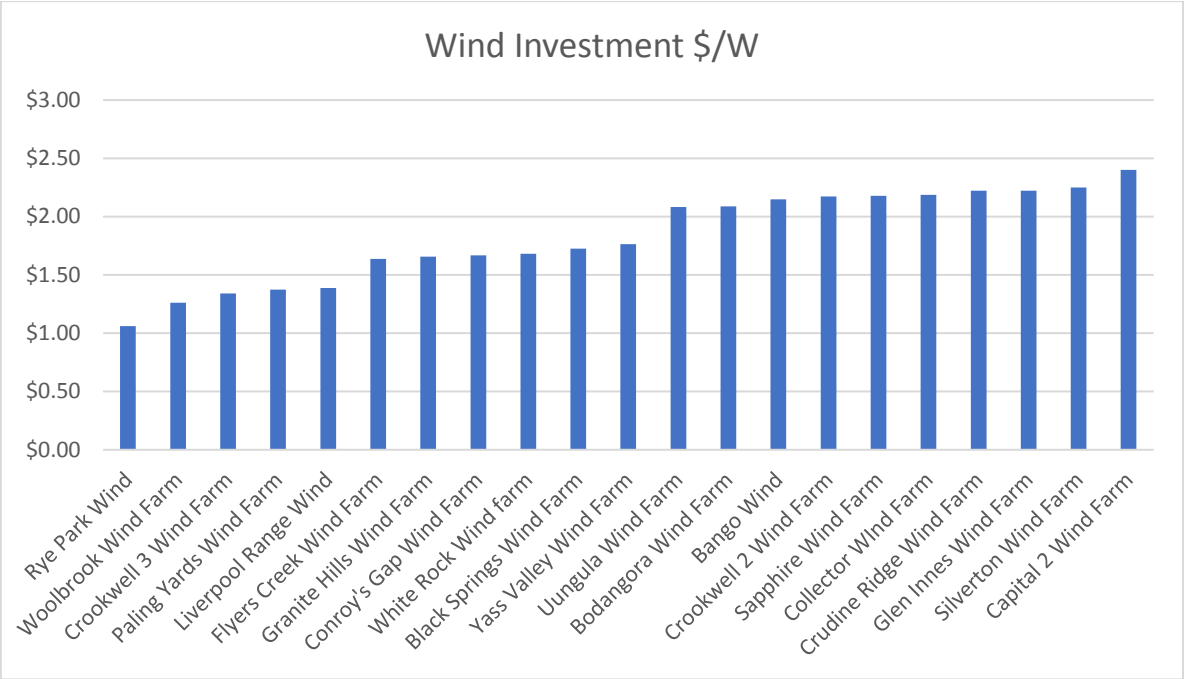


Figure 5: Investment value for the 29 solar farms in development in NSW is, on average, $1.86m per megawatt. The trendline in the bottom figure is $1.2m/MW plus $17.6m in fixed costs.

3.2.2. WIND INVESTMENT

To estimate investment in wind farms, 23 projects were considered, with capacity and investment estimates drawn from project application documentation or company statements if more recent.

The average investment was $1.82m per MW. For our investment projections we used a more conservative figure of $1.4m per MW, to account for falling costs and the likelihood that more expensive projects are less likely to proceed to construction.



3.3. GROWTH-RATE OF THE CLEAN ENERGY INDUSTRY

Our scenario sees 13 GW of rooftop solar and 10 GW of utility-scale solar installed in 13 years, or 1.8 GW per year. This means the NSW rooftop solar industry would grow around five times, from 214 MW of estimated installs in 2017 to an average of 1080 MW per year, and the large-scale solar industry would grow by 3.5 times from approximately 219 MW under construction in 2017 to 770 MW per year. The scale of the wind industry would remain steady at around 800 MW per year, which is similar to current construction rates.

4.PROJECTS AND POTENTIAL BY REGION

Table 6 provides summary of the renewable energy generation required per region.

Table 6: Summary of jobs, investment and renewable energy capacity per region.

	Jobs (lower est.)	Jobs (upper est.)	Investment ($bn)	Solar farms (GW)	Wind farms (GW)	Rooftop solar (GW)	Number of wind turbines	Solar farm area (hectares)	Total capacity (GW)
Western NSW	1824	2824	$8.0	3.5	2.7	0.6	750	17,500	6.80
Central West	1931	2720	$6.4	3.0	2.0	0.9	556	15,000	5.91
New England	1163	1776	$5.3	3.0	1.2	0.3	333	15,000	4.51
South East	1443	2126	$4.5	0.2	3.0	0.7	833	1,000	3.94
Rest of State	12171	12347	$1.2	0	0.8	10.4	222	0	11.20
Total	18532	21792	$25.4	9.7	9.7	13.0	2,694	48,500	32

4.1. WESTERN NSW

Transgrid have identified transmission upgrades for western NSW which would enable 11,000 MW of solar farms and 3000 MW of wind, seven times more than already proposed.

The 3.5 GW of solar farms proposed would utilise 175 km^2 (17,500 hectares), which is 0.04% of the total land area (450,000 km^2). Land used for solar farms can also be simultaneously be used for conventional agriculture, such as grazing sheep.

Large-scale renewable energy projects in operation or development in Western NSW are shown in Table 7.

Table 7: Renewable energy projects in Western NSW, as at September 2017

Project Name	Status	Type	Capacity (MW)	Employment (Construction)	Employment (Operation)	Investment ($m)
Bomen Solar Energy System	Approved	Solar	22			$18
Limondale Solar	Approved	Solar	250	200	5	$325
Sunraysia Solar	Approved	Solar	200	150	10	$275
Walgett	Approved	Solar	30	42	1	$52
Western NSW Solar	Approved	Solar	30	100	3	$62
Conroy's Gap Wind Farm	Approved	Wind	30	50	5	$50
Yass Valley Wind Farm	Approved	Wind	482	167	34	$850
Broken Hill Solar	Operational	Solar	53	197	4	$200
Finley Solar Farm	Proposed	Solar	170	130	6	$150
Leeton Solar Energy System	Proposed	Solar	26			$24
Coleambally Solar	Proposed	Solar	180	225	7	$210
Hay Solar	Proposed	Solar	110	100	5	$129
Hillston Solar	Proposed	Solar	85	100	5	$120
Gidginbung Solar Farm	Proposed	Solar	15	30		
Griffith Solar	Under Construction	Solar	60	90	2	$50
Silverton Wind Farm	Under Construction	Wind	200	150	20	$450
Total			1,943	1731	107	$2,965

4.2. NEW ENGLAND

The 3 GW of solar farms proposed for New England would require 150 km^2 (15,000 hectares), which is 0.16% of the total land area (92,000 km^2). Land used for solar farms can also be simultaneously be used for conventional agriculture, such as grazing sheep.

Large-scale renewable energy projects in operation or development in New England are shown in Table 8.

Table 8: Renewable energy projects in the New England region, as at September 2017

Project Name	Status	Type	Capacity (MW)	Employment (Construction)	Employment (Operation)	Investment ($m)
Gunnedah Solar Farm	Approved	Solar	27			$18
Metz Solar Park	Approved	Solar	100	110	10	$130
Glen Innes Wind Farm	Approved	Wind	67.5	40	3	$150
Moree Solar	Operational	Solar	56	130	11	$101
Narrabri Solar	Proposed	Solar	120	280	12	$170
Woolbrook Wind Farm	Proposed	Wind	80	88	8	$101
White Rock Solar Farm	Under Construction	Solar	20	50	2	$46
White Rock Wind farm	Under Construction	Wind	238	70	7	$400
Sapphire Wind Farm	Under Construction	Wind	270	100	8	$588
Total			979	868	61	$1,704

4.3. CENTRAL WEST

The 3 GW of solar farms proposed for the Central West would require 150 km^2 (15,000 hectares), which is 0.15% of the total land area (100,000 km^2). Land used for solar farms can also be simultaneously be used for conventional agriculture, such as grazing sheep.

Large-scale renewable energy projects in operation or development in the Central West are shown in Table 9.

Table 9: Renewable energy projects in the Central West region, as at September 2017

Project Name	Status	Type	Capacity (MW)	Employment (Construction)	Employment (Operation)	Investment ($m)
Western Plains Solar, Brocklehurst	Approved	Solar	29			$18
Molong Solar Farm	Approved	Solar	25	50	4	$29
Gilgandra Solar	Approved	Solar	40	110	2	$61
Narromine Solar PV Farm	Approved	Solar	11			$17
Nevertire Solar	Approved	Solar	105	150	2	$194
Goonumbla Solar Farm	Approved	Solar	70	75	1	$130
Flyers Creek Wind Farm	Approved	Wind	110	50	3	$180
Black Springs Wind Farm	Approved	Wind	18.9	32	1	$33
Crudine Ridge Wind Farm	Approved	Wind	135	75	15	$300
Bogan River Solar (formerly Nyngan)	Operational	Solar	102	50	5	$300
Blayney Wind Farm	Operational	Wind	10			$18
Brewongle Solar Farm	Proposed	Solar	131	100	10	$145
Beryl Solar Farm	Proposed	Solar	95	150	3	$171
Jemalong Solar	Proposed	Solar Thermal	30	375	12	$100
Paling Yards Wind Farm	Proposed	Wind	200	65	11	$275
Uungula Wind Farm	Proposed	Wind	300	250	20	$625
Parkes Solar	Under Construction	Solar	65	100	0.5	$98
Dubbo Solar Farm	Under Construction	Solar	24	35	1	$56
Manildra Solar	Under Construction	Solar	50	50	5	$150
Bodangora Wind Farm	Under Construction	Wind	113	120	7	$236
Total			1,664	1,837	103	$3,135

4.4. SOUTH EAST

The 0.2 GW of solar farms proposed for the Central West would require 10 km^2 (1000 hectares), which is 0.03% of the total land area (36,000 km^2). Land used for solar farms can also be simultaneously be used for conventional agriculture, such as grazing sheep.

Large-scale renewable energy projects in operation or development in the South East region are shown in Table 10.

Table 10: Renewable energy projects in the South East region, as at September 2017

Project Name	Status	Type	Capacity (MW)	Employment (Construction)	Employment (Operation)	Investment ($m)
Capital Solar	Approved	Solar	50	50	5	$150
Collector Wind Farm	Approved	Wind	160	100	10	$350
Capital 2 Wind Farm	Approved	Wind	100	100	5	$240
Biala Wind	Approved	Wind	77.5	74	7	$200
Shoalhaven Pumped Hydro Storage Scheme	Operational	Hydro	240			
Snowy Hydro: Tumut 3, Upper Tumut, Blowering, Guthega	Operational	Hydro	2,564			
Hume Hydro	Operational	Hydro	58		5	
Gullen Solar Farm	Operational	Solar	13.3	70		$25
Boco Rock Wind Farm	Operational	Wind	113	100	15	$361
Capital Wind Farm	Operational	Wind	140	100	8	$220
Cullerin Wind Farm	Operational	Wind	30	50	5	$50
Gullen Range Wind	Operational	Wind	165.5	80	5	$250
Gunning Wind Farm	Operational	Wind	46.5	100	8	$147
Tarago Wind Farm	Operational	Wind	48	80	5	$96
Taralga Wind Fram	Operational	Wind	107		6	$280
Woodlawn Wind Farm	Operational	Wind	48	150		$115
Jupiter Wind Farm	Proposed	Wind	350	300	30	$300
Rye Park Wind	Proposed	Wind	283	363	34	$300
Crookwell 3 Wind Farm	Proposed	Wind	76	40	6	$102
Granite Hills Wind Farm	Proposed	Wind	120.75	100	10	$200
Bango Wind	Proposed	Wind	326	120	12	$700
Crookwell 2 Wind Farm	Under Construction	Wind	92	80	14	$200
Total			5,209	2057	190	$4,286

5.INPUT DATA AND ASSUMPTIONS

Table 11: Input Data and Assumptions

2017 NSW PV Generation	1579	GWh
2017 NSW total consumption (estimate)	69400	GWh
2030 NSW total consumption (forecast)	77311	GWh
annual consumption per NSW household	5.25	MWh
GHG intensity of non-renewable NSW generation	0.86	t CO2e/MWh
GHG emissions from one NSW car	2.578	tonnes p.a. CO2e
NSW PV 2017 percentage	2.30%	
Snowy Hydro average generation	3722.3	GWh
existing wind farm generation (2016)	2078.0	GWh
existing solar farm generation (2016)	501.2	GWh
existing biomass generation (2016)	1100.0	GWh
solar farm average capacity factor	0.25	
wind farm average capacity factor	0.35	
rooftop solar average capacity factor	0.16	

6.REFERENCES

[1] CSIRO and Energy Networks Australia, "Electricity Network Transformation Roadmap: Final Report," 2017.

[2] ROAM Consulting, "ROAM Report on Wind and Solar Modelling for AEMO 100% Renewables Project," 2012.

[3] A. Blakers, B. Lu and M. Stocks, "100% renewable electricity in Australia," *Energy,* vol. 133, pp. 471-482, 2017.

[4] Ergon Energy and Energex, "Connection Standard: Micro Embedded Generating Units, v4.0 section 5.4," 2017.

[5] G. Parkinson, "Rooftop Solar and Storage - Cheaper than Subsidising Old Coal," RenewEconomy, 18 September 2017. [Online]. Available: http://reneweconomy.com.au/rooftop-solar-storage-cheaper-subsidising-old-coal-33294/. [Accessed 18 September 2017].

[6] Energy Synapse, "Impact of small solar PV on the NSW wholesale electricity market," 2017.

[7] Beyond Zero Emissions, "Zero Carbon Australia Buildings Plan," 2013.

[8] Energeia, "Electricity Network Transformation Roadmap: Work Package 5 – Pricing and Behavioural Enablers Network Pricing and Incentives Reform," 2016.

[9] Energeia, "DER Simulation Platform Technical Report," 2016.

[10] National Aged Care Data Clearing House, "Population growth projections for NSW – New England and North West," Australian Government Department of Infrastructure and Regional Development, [Online]. Available: http://regional.gov.au/regional/data/Home/Indicator?regionId=6ae3311a-874c-e511-8d47-001dd8b71caf&indicatorId=b2bebf9b-223f-e511-8743-001dd8b71caf. [Accessed 26 10 2017].

[11] Australian Bureau of Statistics, "3218, regional population growth 2006-2016," 28 July 2017. [Online]. Available: http://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/3218.0Main%20Features202016.

[12] CSIRO, "Future Grid Forum, Refresh Technical Report," 2015.

[13] ACIL Allen Consulting, "Small-Scale Technology Certificates: Projections 2016 - 2018," 2016.

[14] A. Armstrong, N. Ostle and J. Whitaker, "Solar park microclimate and vegetation management effects on grassland carbon cycling," *Environmental Research Letters,* vol. 11, p. 074016, 2016.

[15] Transgrid, NSW Transmission Annual Planning Report, 2017.

[16] Australian Bureau of Statistics, "4631.0 - Employment in Renewable Energy Activities, Australia, 2015-16," 2017.

[17] ROAM Consulting, "RET Policy Analysis," 2014.

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

[19] M. Wright and P. Hearps, "Zero Carbon Australia Stationary Energy Plan," Beyond Zero Emissions and The University of Melbourne Energy Research Institute, 2010.

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