SEN Jobs Report 2020

90% Renewable Energy
9,000 Jobs
on the SWIS by 2030

Sustainable Energy Now
2020

Alastair Leith
Dr Rob Phillips

SEN Jobs Report 2020

Sustainable Energy Now 2020

Alastair Leith
Dr Rob Phillips

Publication and Authors

Lead Author: Alastair Leith

Author: Dr Rob Phillips

Publication Design & Layout: Useful Design

Photography:

Cover image: Yandin Wind Farm, Jason Thomas, courtesy of Alinta and RATCH Australia.

Damian Kelly: Damian Kelly Photography, www.damiankellyphotography.com.au

Jason Thomas: Yandin Wind Farm, courtesy of Alinta and RATCH Australia

Other photographs indentified in photo credits beside images.

Disclaimer

Intellectual Property

Sustainable Energy Now

SEN was formed over ten years ago to promote the widespread use of Sustainable Energy in Western Australia; and to raise awareness of the economic and environmental benefits of Sustainable Energy. Our purpose is to minimise the impact of energy generation on the global environment by encouraging the transition from fossil fuels to renewable energy sources that minimise pollution and emissions of greenhouse gases to the atmosphere.

This report is in line with SEN's mission to promote the phasing out of fossil fuel use for energy generation by modelling energy systems and demonstrating the efficacy of renewables in their place.

This Report, and the energy modelling used in it, were produced by consultants associated with SEN.

The energy modelling was performed utilising three interrelated software packages, two of them available under open source licenses:

- SIREN: developed by Angus King
- Powerbalance: developed by Ben Rose, Len Bunn and Steve Gates
- PowerMatch developed by Angus King

The Jobs Model 2020 was developed by Alastair Leith

Acknowledgements

We acknowledge that the body of this work was produced on the land of the Wurundjeri, the Dja Dja Wurrung and the Nyoongar people. We pay respect to their Elders – past, present and future – and acknowledge the important role all Aboriginal and Torres Strait Islander people continue to play in advancing a more sustainable Australia.

This report was commissioned by Clean State. ***Clean State*** advocates for action on climate change in Western Australia. ***Clean State*** promotes solutions to address WA's biggest polluters in ways that create thousands of jobs and exciting opportunities for communities and businesses across the state.

The Jobs Model 2020 was informed by prior work of Manish Ram, Arman Aghahosseini and Christian Breyer, Lappeenranta – Lahti University of Technology (LUT) (see Bibliography). Thanks goes to Nikki Potter and Dr Anita Talberg at Clean Energy Council Australia for early access to new employment research and to Dr Jay Rutovitz and Dr Chris Briggs at Institute for Sustainable Futures, UTS for their assistance in interpreting this new work. Any accidental misrepresentations of that work would be ours alone.

Several SEN committee members were involved in the preparation of this report and the authors thank them for that work. Particular thanks to Len Bunn and Angus King for their valuable work in verifying the model calculations and methodology, and assistance in writing this report.

Glossary

Acronym	Explanation
AEMO	Australian Energy Market Operator
ANU	Australian National University
BZE	Beyond Zero Emissions
C&I	Construction and Installation
CAPEX	Capital Expenditure
CCGT	Combined Cycle Gas Turbine
CEC	Clean Energy Council
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DERR	Distributed Energy Resources Roadmap
DF	Decline Factor
DSM	Demand-side Management
EV	Electric Vehicle
FIFO	Fly-in, Fly-out
FTE	Full-time Equivalent
GHG	Greenhouse Gas
GIS	Geographical Information System
GW	Gigawatt – one gigawatt equals 1,000 MW
GWh	Gigawatt hour — one GWh equals 1,000 MWh
HRSG	Heat Recovery Steam Generator
kW	Kilowatt – 1,000 kilowatts equals one megawatt
kWh	Kilowatt hour — 1,000 kWh equals one megawatt hour
LCOE	Levelised Cost of Energy (Electricity). An amortised cost of electricity production: a combination of costs of capital expenditure, operations and maintenance and fuel, over the lifetime of a generation source.

Acronym	Explanation
LNG	Liquefied Natural Gas
LUT	Lappeenranta-Lahti University of Technology, Finland
MERRA	Modern-Era Retrospective Analysis Re-run Research and Applications
MW	Megawatt
MWh	Megawatt hour
NASA	National Aeronautics and Space Administration
NEM	National Electricity Market
O&M	Operations and Maintenance
OCGT	Open Cycle Gas Turbines
OPEX	Operational Expenditure
PHES/ PHS	Pumped Hydro Energy Storage
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable Energy
RET	Renewable Energy Target
SAM	System Advisor Model
SAT	Single Axis Tracking PV panels
SEN	Sustainable Energy Now
SIREN	SEN Integrated Renewable Energy Network Toolkit
SWIS	South West Interconnected System
WoSP	Whole of System Plan

Contents

List of Tables

Lists of Figures

Executive Summary

This analysis and report focusses on new jobs resulting from the transition to Renewable Energy (RE) within the South West Interconnected System (SWIS) system. The vision presented in this report is premised on reaching 90% of electricity provided by clean energy in the SWIS in 2030 (including rooftop energy behind the meter). Key findings from this report are presented here.

Our modelled transition to 90% RE by 2030 determined the following direct jobs:

- 55,100 job-years (2020-30) with an average of 5,000 jobs per annum.
- 8,600 FTE jobs in 2030 of which approximately 2,700 would be ongoing operations and maintenance jobs.
- Approximately 50-60% of the jobs created can be in regional areas.

Analysis of independent industry information on jobs created from the installation of new RE in Australia shows two major RE job categories will be created:

- Repeat construction work for anything up to 24 months per project, followed by
- Ongoing long-term operations and maintenance work.

There will also be jobs created from the closure and rehabilitation of existing carbon-based energy systems such as the Muja power plants.

Resources developments in WA have shown that the construction work for new projects has become an industry in itself. This analysis indicates that something as significant as the transition to high levels of RE will create a sustainable RE construction industry.

In the creation of this new industry, the WA Government has the choice of a hands off "industry will decide approach" which is likely to involve significant delay followed by problematic booms and busts in RE construction employment, or a managed approach. We have assumed a more rational managed approach where there is a steady flow of new jobs through an informed and well directed government policy. The WA Government Energy Transformation Taskforce is key to providing the strong guidance needed.

The majority of jobs considered in this report are related to new wind and solar energy as well as pumped hydro and storage. All of them create significant new jobs:

- Wind energy construction jobs of 280 FTE per new 100 MW.
- Wind energy operations and maintenance jobs of 22 FTE per new 100 MW.
- Solar rooftop PV construction jobs of 580 FTE per new 100 MW.
- Solar rooftop PV operations and maintenance jobs of 16 FTE per new 100 MW.
- Solar utility PV construction jobs of 230 FTE per new 100 MW.
- Solar utility PV operations and maintenance jobs of 11 FTE per new 100 MW.

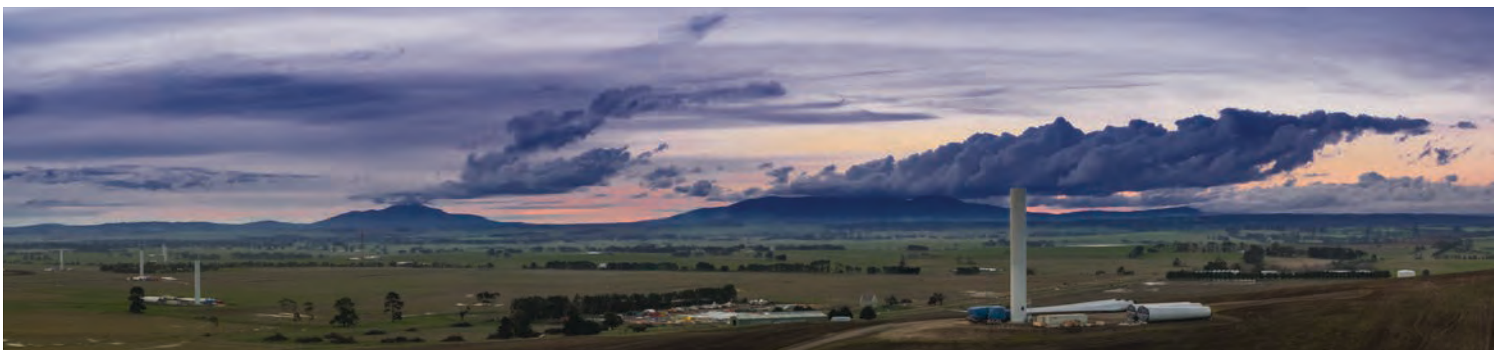
Our energy modelling was developed using SEN's published and open source system modelling tools using a cost optimised blend of clean energy RE and storage technologies, with limited utilisation of fossil gas.

Should the transition be slower as a result of ineffective policies or a delayed response, then a similar level of new jobs will still be created, but over a longer timeframe.

The jobs referred to in this report are direct jobs only. New jobs create indirect and induced jobs through multiplier effects, but these have not been taken into account in this report. The resources industry tends to assume the creation of indirect and induced jobs in its reporting so this important factor needs to be considered when making comparisons with other jobs reporting.

The scenario we consider in this report excludes the significant upsurge in energy demand expected to flow from a substantial transition to electric vehicles and fuel switching from gas to electricity in domestic, commercial and industrial applications. These factors are expected to significantly increase electricity demand and therefore RE jobs over those presented in this report.

The transition of an electricity system to high levels of RE results in clean energy. There is an increasing demand for clean energy in existing and new industries. This has also not been directly taken account of in the figures in this report and provides considerable additional upside.



Section 1

Introduction

Image courtesy of Damian Kelly Photography

The forthcoming recovery from the Coronavirus pandemic provides an opportunity to build forward-looking industries, in particular to address climate change and reduce Greenhouse Gas (GHG) emissions.

This work sets out to demonstrate how the Western Australian government can start to meet its share of the 2030 commitments under the Paris 1.5 °C global warming target, and its aspiration of net zero emissions by 2050. The WA Government has acknowledged an in-principle commitment to Paris, but is yet to formally engage in the task of decarbonising the WA economy. Currently, one of the least disruptive and most economic ways to reduce Greenhouse Gas (GHG) emissions is through Renewable Energy (RE), in order to displace current and projected coal and fossil gas consumption.

Significant employment can arise from an ambitious, but technically and economically achievable roll-out of Renewable Energy (RE) across the South West Interconnected System (SWIS). There are two key aspects to this work; modelling of electricity demand and supply in the SWIS; and jobs modelling based on published figures of the number of different types of jobs associated with each type of installed generation capacity. Relatively conservative cost assumptions have been made in the energy model to derive a cost optimised mix of technologies using historical Australian technology prices.

1.1 Background

In 2016, SEN conducted extensive modelling of the renewable electricity opportunities in the South West Interconnected System (SWIS). This work demonstrated that the SWIS can transition to renewable energy in a planned, orderly and secure series of steps (Sustainable Energy Now, 2016, 2017b).

SEN followed this work by analysing the total employment opportunities arising from a roll-out of renewables in the Collie region (Sustainable Energy Now, 2017a), concluding that the transition to renewables would result in 2,000 ongoing Operations and Maintenance jobs – 1,350 more than the 650 jobs in coal-fired electricity power station operations jobs in 2016. Work was carried out by the lead author in 2017 to map the jobs created across a 15 year transition to 85% renewables, and shared in SEN briefings to Government but never published. Here we consolidate that study with pre-publication access to new employment data from the Clean Energy Council

(CEC) (Clean Energy Council, 2020), and make detailed jobs projections for the 2020 to 2030 period.

This work complements the numerous technical studies completed at the state and national level, showing it is technically possible to reach 85-100% renewables by 2030, including Australian Energy Market Operator (2013); Beyond Zero Emissions (2010); A. Blakers, Lu, and Stocks (2017); Clean Energy Council (2016b); Parkinson (2019); Teske, Dominish, Ison, and Maras (2016).

1.2 Technical, Economic and Regulatory Context

The rapid growth of unconstrained solar PV is raising concerns that an unplanned transition to RE on the SWIS will cause stability problems, and the State Government's Energy Transformation Strategy (Government of Western Australia, 2019b) is investigating this issue through three work streams:

- Distributed Energy Resources Roadmap (DERR), so that Rooftop PV growth can continue without compromising the required levels of grid security (Government of Western Australia, 2019a).
- Whole of System Planning (WoSP) based on modelling to show preferred locations for renewable generation in each region (Government of Western Australia, 2019c) (due mid-year 2020).
- Redevelopment of Regulatory Frameworks, starting with a revision of the Networks Access Code.

The DERR is an essential first step to provide grid security during the phase out of fossil-fuelled generation, and is an integral part of the WoSP, supported by new regulatory frameworks. We await further developments from the Western Australian Renewable Hydrogen Strategy (Department of Primary Industries and Regional Development, 2019).

The Government Issues Paper "**Climate Change in Western Australia**" released in September 2019 (Department of Water and Environmental Regulation, 2019) mentions the state's interest in industry innovation to address climate change:

> *Harnessing our world-class renewable resources to break the link between energy and emissions can put Western Australia's energy intensive businesses at the forefront of cleaner production trends and provide a competitive advantage in a low-carbon world.*

While the issues paper covers renewables, the state still lacks decisive policy or regulatory mechanisms to promote innovation or rapid RE rollout. While a climate policy will be a useful step, WA is behind other states in terms of the policy settings they have in place, such as a Renewable Energy Target (RET). This report provides a pathway to decouple energy and GHG emissions in a secure and economically responsible way. It's predicated on a determined decade of energy policy reform by the WA government. Current and recent market changes proposed by the Government will not, on their own, achieve these ambitious outcomes. This report seeks to outline the benefits to Western Australians of a more climate-centric set of policies around grid and off-grid energy use.

1.3 Modelling Overview

The outcomes of modelling depend on the assumptions made and inputs chosen, which are detailed below. Other than the somewhat ambitious goal of 90% RE by 2030, generally conservative cost and employment assumptions were made, and these are justified in ***Appendix*** A.

1.3.1 Energy Model

This work is predicated on these arguments:

- An abundance of RE can be rolled out across the SWIS.
- Wind and Solar Photovoltaic (PV) power is currently the cheapest form of new generation, and prices will continue to fall in the next decade at least.
- A similar trend has emerged in clean energy storage technologies.
- Coal-fired generation will be phased out by 2030, beginning with a scheduled closure of Muja C/D, and Combined Cycle Gas Turbine (CCGT) generation will be phased out by 2027.

We have based our employment figures on a scenario of a 90% RE generation mix by 2030, with nominal, annual transition steps along the way. The scenario we used included battery storage (both utility-scale and 'behind the meter') and Pumped Hydro Energy Storage (PHES) to provide grid stability and backup power when variable renewable sources need 'firming' to match demand. Open Cycle Gas Turbines (OCGT) are also used in the scenario to provide fuelled backup when required – the 10% of generation mix in our energy model that is non-renewable.

Based on the projected demand for energy in 2030, we modelled a scenario where 90% of the required energy was provided by RE generation as an average across the whole year. At times, 100% of energy demand would be supplied by RE and at other times, less. As a general principle, the wind and solar generation complement each other well, with solar generating during the day and wind generating during the night. The storage and gas fired generation cover the short periods when neither is generating, or not generating enough.

The energy scenario projects a consistent RE build from 2021 through to 2030 on the basis that it enables a stable and low risk growth of the RE sector, and consistent long-term jobs. It is important to avoid the boom/bust inefficiencies seen in RE initiatives in the other jurisdictions and the resource industries, because this will enable long term planning, ability to commit to substantial investment, and retention of a growing skill and experience base.

We understand that project commencement in 2021 at the levels required will be difficult without immediate policy prescription and a pipeline of well advanced projects in development, but the figures can be scaled across different time-horizons. Short delays can be made up if the commercial fundamentals are attractive to project developers.

The energy model is described in detail in ***Appendix*** A.

1.3.2 Employment Model

The employment model describes and quantifies the new jobs created under a transition to 90% renewables by 2030. Existing jobs in maintaining the fossil fuel energy system are not included in the model — for the sake of a presenting a comparative analysis to BAU, however, decommissioning jobs for coal and CCGT units are included, as are a small number of new-build OCGT jobs.

The construction and ongoing operations of generation and storage technologies can be broken down into roles in the engineering design, planning, manufacturing, warehousing, transport, construction, installation, operations maintenance and decommissioning. These roles can be categorised as (Ram, Aghahosseini, & Breyer, 2020; Rutovitz, Dominish, & Downes, 2015):

- Manufacturing (Manuf.)
- Construction and Installation (C&I)
- Operations and Maintenance (O&M)
- Decommissioning and site remediation jobs (Decomm.)
- Transmission (Grid)

The employment model is adapted from work by Ram et al., (2019), derived from Rutovitz et al. (2015). The jobs model has three major components (an energy model, an employment model which relates jobs to technologies, and decline factors), as indicated in ***Figure 1.1***. Specific aspects of the model are discussed in detail in ***Appendix B***.

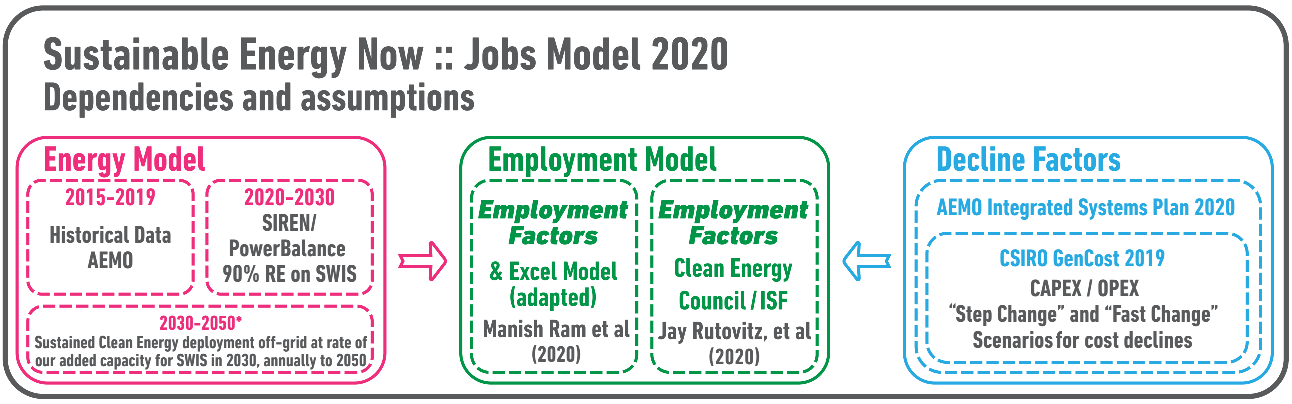


Figure 1.1 Schematic diagram of data assumptions and modelling components in SEN Jobs Model 2020.

For each employment category and for each technology, the jobs are a function of the Installed Capacity (MW) from the energy model, multiplied by an Employment Factor from the employment model, and a Decline Factor. The Employment Factor (***Appendix*** B.2) is a number representing the jobs per MW installed for each technology for each job category.

The Decline Factor (***Appendix*** B.3) is a reduction in cost over time (and therefore jobs) due to the productivity gains specific to each technology. That is, over time, engineers have developed techniques to manufacture and install technologies for declining capital expense per unit of energy generation or storage.

Manufacturing jobs have a further component, which is the percentage of local manufacture (***Appendix*** B.4). For example, wind turbines and solar panels are almost exclusively manufactured in other countries. In this context, Local Content refers to the proportion of manufacturing in WA, for example, solar panel frames.

This report uses conservative assumptions for the number of jobs that would be created from a 90% target by 2030:

- All of the figures are for direct employment only; no indirect jobs are counted and no employment multipliers for 'induced jobs' were applied.
- Employment factors are at the low end of the published scale, derived from the most recent and comprehensive industry research, namely the Clean Energy Council's research findings published in their "Clean Energy at Work" (Clean Energy Council, 2020) and "Renewable Energy Employment in Australia: Methodology" (Rutovitz, Briggs, Dominish, & Nagrath, 2020) reports.
- Decline factors are derived from the most recent official Australian capital expenditure predictions from the Australian Energy Market Operator (AEMO) (Graham, Hayward, Foster, & Havas, 2019). Decline Factors will progressively reduce the employment per Megawatt (MW) installed over time, as a result of productivity gains in the technology and labour efficiencies realised. We have used their "Step Change" and "Fast Change" scenarios, meaning that more jobs are discounted from the model than if their slower scenarios were used.
- Local content factors are based on the current Australian context. WA manufacturing components are currently likely to be less than the current Australian average.

An important point to clarify is that the employment model did not model Operations and Maintenance jobs from existing fossil-fuel generators.

1.4 The Policy Environment

This work assumes that, to meet the State's aspiration for net zero emissions by 2050, the government will make progress towards meeting its proportion of the Nationally-determined Contribution under the Paris Agreement – an emissions cut of 26-28% over 2005 levels by 2030 at an absolute minimum. This will entail deep cuts in WA emissions in the stationary energy sector, and decarbonisation of other sectors via fuel switching away from fossil fuels to electrification. Abundant renewable energy resources are the key to emissions reductions in other energy sectors, and meeting state targets:

- To transition the transport sector to electric vehicles
- To replace fossil fuels for industrial process heat
- To create green hydrogen, which can replace other fuels and be used to produce green metals
- To build new desalination plants to combat a drying climate

The foreshadowed level of deployment of renewables is premised on strong WA Government policy, recognising the innovation and employment opportunities that this report demonstrates. We believe this is both appropriate and achievable, and SEN have been maintaining a watching brief of initial Government efforts through Energy Policy WA.

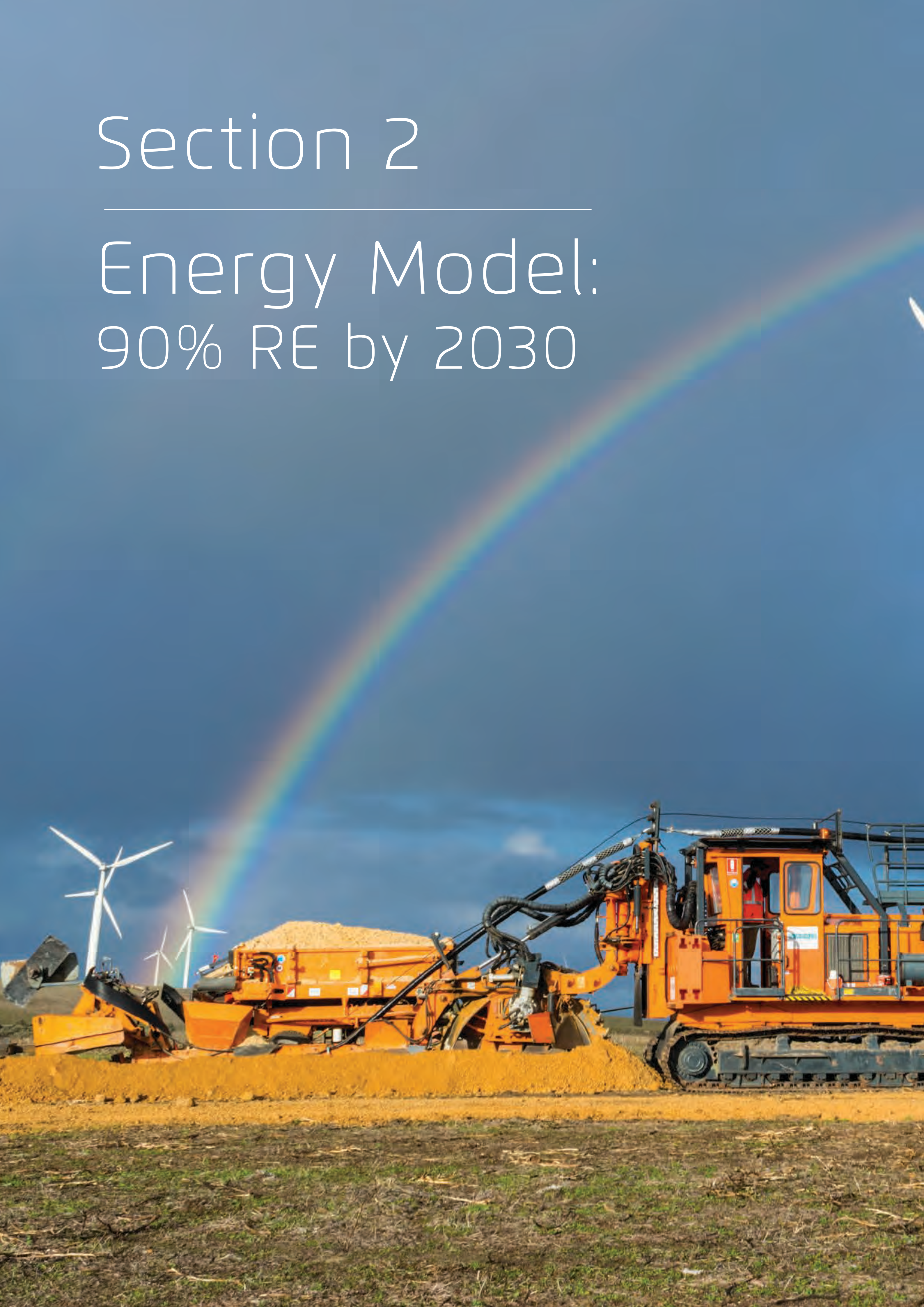
To achieve 90% RE by 2030, we have assumed a steady pipeline of work, rather the feast and famine cycles that characterised the large scale Australian RE sector. We assert that the Government must mandate and/or facilitate stimulation for a rapid renewable energy roll-out. Renewable Energy Targets (for industry transparency and regulatory authority goal alignment) and Power Purchase Agreement (PPA) reverse auctions with a 'strike price' as under Victoria's VRET legislation (for optimal cost, quality and regional employment outcomes) would enable commercial enterprises to invest in appropriate and sufficient manufacturing capacity.

While this report addresses immediate policy implications, it does not specifically address the broader policy context.

Photographer: Jason Thomas Image courtesy of Alinta and RATCH Australia.

Section 2

Energy Model:
90% RE by 2030



SEN's SIREN – PowerBalance software was used for the energy modelling which our jobs modelling is predicated on (as shown in diagram form, ***Figure 1.1***). Specific details of the energy scenario and the technologies used are given in ***Appendix A.***

An optimized scenario was developed with a mixture of wind and rooftop and utility solar photovoltaic (PV) generation. Coal-fired generation will be phased out by 2030, beginning with a scheduled closure of Muja C/D, and Combined Cycle Gas Turbine (CCGT) generation will be phased out by 2027. However, fuelled Open Cycle Gas Turbines (OCGT) are retained for backup generation. The scenario also includes significant amounts of battery and Pumped Hydro Energy Storage (PHES).

The 90% energy model was assumed to apply to 2030, but to calculate jobs for each intervening year, we interpolated an amount each year from 2015. For the years 2015-19, historical data from the Australian Energy Market Operator (2019) and the Australian PV Institute (2019) were used. 2020 values were estimated from known wind projects being commissioned and 2019 values. Various appropriate growth rates were applied to each technology to achieve an optimal transition to the modelled results of the 90% RE scenario for 2030, as described in ***Appendix A.***

Table 2.1 provides a summary of the historical (2015), expected (2020) and modelled (2030) technology capacity, while ***Figure 2.1*** shows the annual capacity additions and decommissions of thermal generation. As indicated in ***Table 2.1*** fossil-fuelled generation capacity changed little from 2015 to 2019. There is a small reduction in coal capacity due to the closure of the Muja A/B plant, and gas generation remains constant. There has, however, been a doubling of wind capacity and a tripling of rooftop PV to 2020.

From 2020 to 2030, the scenario models:

- A 4-fold, staged expansion of wind capacity to 5.0 GW. Wind power spread across the grid is an important factor for power reliability and reducing demand for fossil-fuelled generation.
- A large expansion of rooftop and utility PV to 6.7 GW, with the majority being on rooftops. The growth in rooftop PV modelled is less than the recent historical trend might suggest will go in.

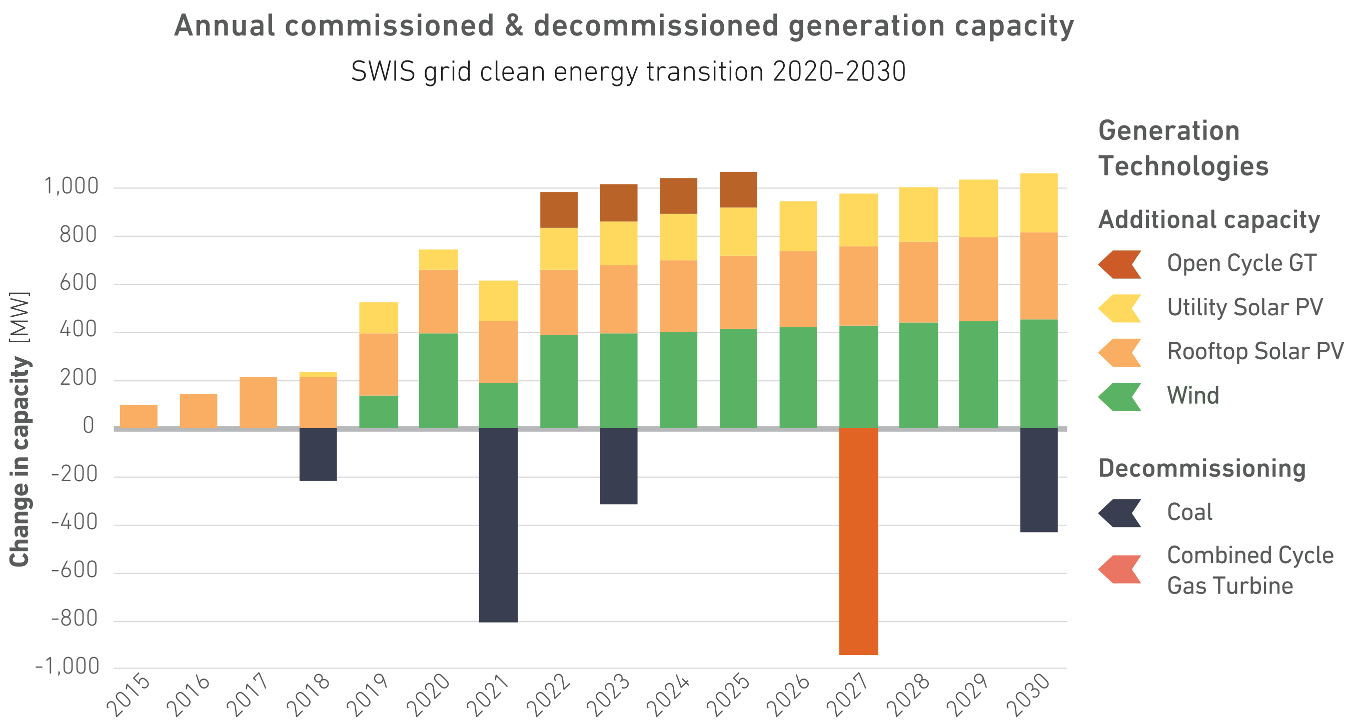


Figure 2.1 Annual change in generation capacity from 2015 to 2030 by technology. (2015-2019 is historical, 2020 is expected and 2021-2030 illustrates the SEN Jobs Model 2020 energy model projection)

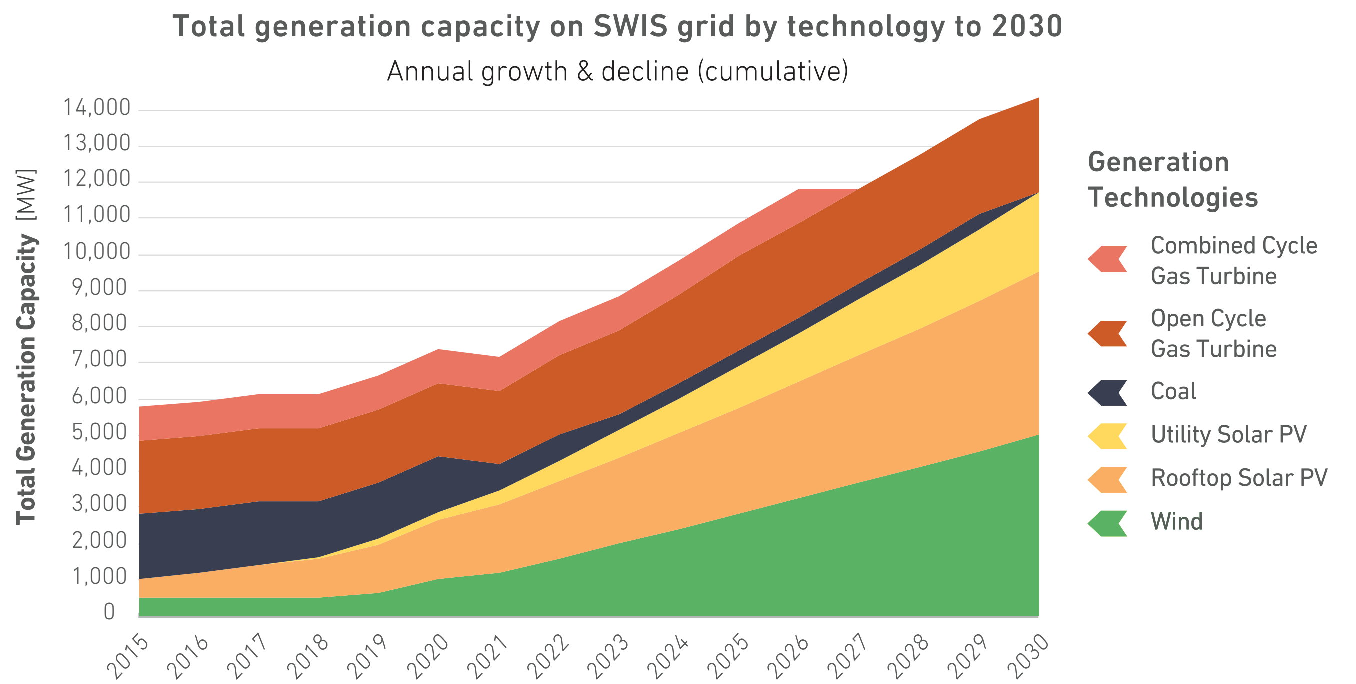


Figure 2.2 Transition towards clean sourced generation from 2015 to 2030. (2015-2019 is historical, 2020 is expected and 2021-2030 illustrates the SEN Jobs Model 2020 energy model projection).

Figure 2.1 shows the annual deployment of RE and decommissioning of thermal generation technologies modelled to achieve 90% renewable by 2030. *Figure 2.2* illustrates the cumulative growth in generation capacity year by year to 2030. We see a steady increase in the annual deployment rates each year for wind, rooftop PV and utility PV generation. It also shows:

- A phasing out of coal fired generation by 2030.
- A small expansion of OCGT generation capacity from 2022 to 2024 to balance the retirement of other fossil generation while the new build of wind and solar occurs. While maintaining and slightly increasing the capacity of OCGT, the capacity factor

Table 2.1 Generation and storage capacities 2015–30

Generation technologies	2015 (actual)	2020 (estimated)	2030 (modelled)
Wind (MW)	481	1,015	5,000
Rooftop PV (MW)	653	1,784	4,500
Utility PV (MW)	0	263	2,200
OCGT (MW)	2019	2019	2,600
Coal (MW)	1,778	1,558	0
CCGT (MW)	945	945	0
Storage technologies	**2015 (actual)**	**2020 (estimated)**	**2030 (modelled)**
PHES Power (MW)	0	0	800
PHES Energy (MWh)	0	0	8,000
Utility batteries (MW)	0	0	600
Utility batteries (MWh)	0	0	1,620
Prosumer batteries (MW)	0	-*	600
Prosumer batteries (MWh)	0	-*	1,620

* Current level of prosumer battery low but unconfirmed..

(amount of use) of these units will drop over the decade as they will only be used in a 'gap-filling' role to balance clean energy generation and storage, that is, for its dispatchable capacity and flexibility. The bulk (90%) of energy comes from renewables, firmed with some storage at the higher levels of RE.

- A phasing out of CCGT generation by 2027.

Table 2.1 also shows the amount of storage (by power rating) over the 2030 transition. This includes 800 MW of PHES (with 10 hours of full load discharge providing 8.0 GWh of capacity) and 1,200 MW of battery storage (with 2.7 hours of discharge, 3.24 GWh), for a total of 11.24 GWh of storage, with growth across the decade shown in ***Figure 2.3***.

Figure 2.3 illustrates that:

- Utility scale batteries are installed at similar annual rate across the decade starting with 52 MW in 2021, increasing stepwise to 68 MW in 2030. 52 MW is around half the size of the first utility scale 'big battery' in South Australia, the (Tesla) Hornsdale Power Reserve, originally installed at 100 MW and now 150 MW (Parkinson, 2018).
- Very strong growth in Prosumer batteries beginning with 10 MW/27 MWh in 2020 and leading to 110 MW/300 MWh in 2030.
- Installation of Pumped Hydro Energy Storage totalling 800 MW/8 GWh, beginning formal planning permit processes in 2023/24 with construction from 2025/26 to 2030.

This scenario is just one example of how a 90% RE generation mix could look in 2030. There are many valid scenarios and associated pathways to achieve 90% RE, some of which may result in either higher or lower jobs numbers. For example, a higher PHES component and less battery storage creates more local jobs, because PHES is more construction-intensive. On the other hand, a low storage and high wind and PV scenario also creates more jobs since an overcapacity of generation for the 90% RE target is realised. Validation of the modelling with 10 different scenarios (Appendix 4.4) shows that the model we have used for the basis of jobs modelling is towards the lower (conservative) end of the job numbers range. This gives us confidence that there will be this order of magnitude of jobs for a range of 90% RE scenarios.

2.1 Pumped Hydro Energy Storage

This study examined various combinations and combined levels of storage using batteries and Pumped Hydro Energy Storage (PHES). The deployment of PHES is important in reducing the spilled energy from curtailment (non-usage) of wind and PV generation to be used days or weeks later, thereby reducing overall wholesale energy costs. The scenario assumes a construction time of five years, commencing in 2026.

Under the (relatively superficial) Levelised Cost of Energy (LCOE) generation cost assumptions in our model, PHES is approximately 20 to 30 thirty times less expensive than current battery costs per MWh of energy stored than batteries at this scale of storage (8 GWh).

Three brownfield sites have been identified for this report by Prof. Andrew Blakers (2020) at viable locations in the South West of WA, close to an existing 330 kV transmission line. Details of these sites are discussed in ***Appendix E.***

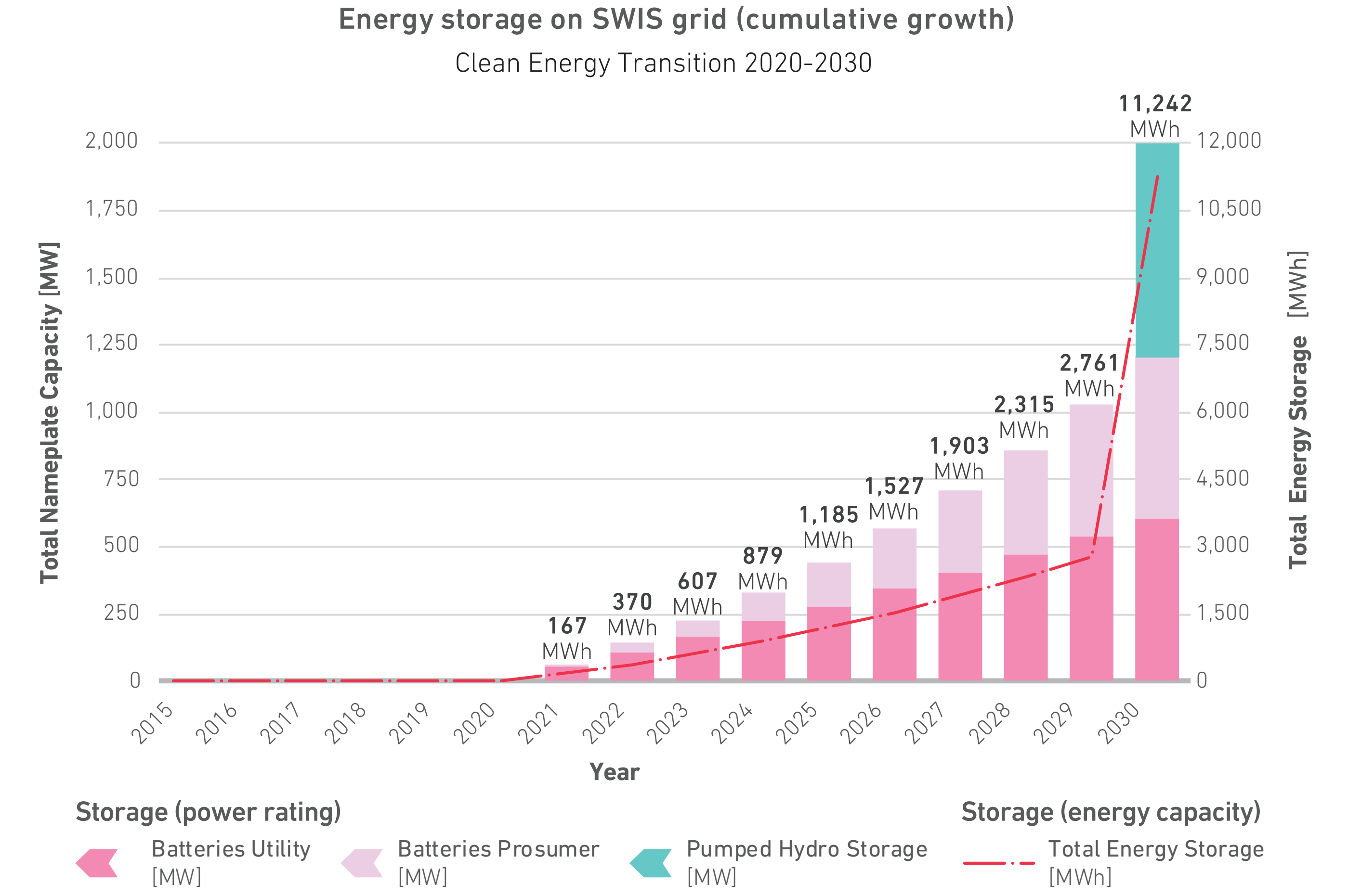


Figure 2.3 **Historical and projected growth in storage, 2015–30.**
Stacked columns show year-on-year cumlative total power values (MW) and the dashed red line shows year-on-year cumulative storage energy capacity (MWh)

2.2 Progressing to 100% RE

Achieving a 100% renewable energy supply on the SWIS is technically feasible employing a broad range of technology mixes. However, a 100% renewable grid is currently more difficult to achieve assuming today's RE and storage technology costs. SEN's 2016 modelling showed that including enough storage to meet all (100%) of the bulk wholesale energy needs on the SWIS would cost 1.5 times as much as the 2016 85% RE model (Sustainable Energy Now, 2016).

Achieving the final 10% after 2030 will be influenced by available technologies and technology costs as clean energy costs decline over the transition period. Market trends and political leadership will influence both the timing of the move from 90% to 100%+ RE — and the technology choices to achieve it.

In this context, rather than focussing on the last 10% of emissions in electricity production, it is more productive — in 2020 — to look to GHG abatement in other sectors, where there is a potential for bigger reductions at lower cost – for example, mitigating LNG related emissions. Other abatement examples (similar to those currently being considered by the Australian Government (Department of Industry Science Energy and Resources, 2021, Figure 6.) are:

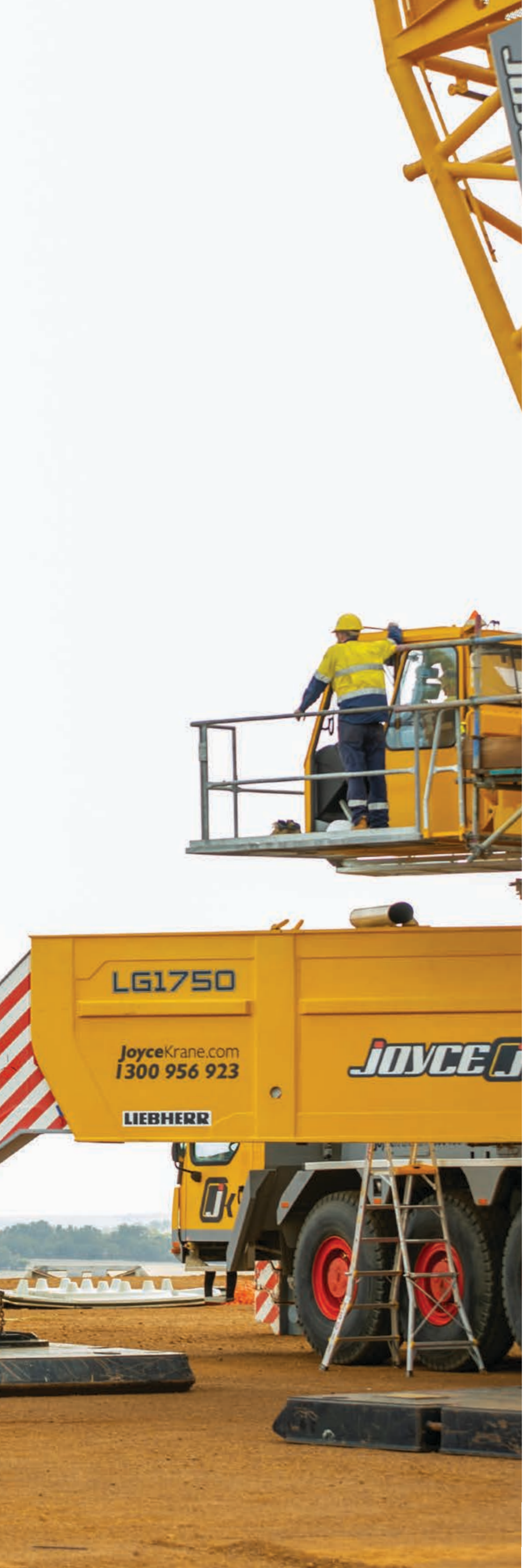
- off grid electricity supply and fossil fuel burning in industry for process heat;
- fuel switching to renewable energy supply and more efficient electrical heating applications;
- electrification of transport;
- energy efficiency in the built environment;
- emissions from cement production;
- moving into regenerative agricultural practices to build soil carbon and
- curbing methane emissions from livestock production using herd reduction and on farm revegetation as offsets.

Photographer: Jason Thomas Image courtesy of Alinta and RATCH Australia.

Section 3

Employment Model:

Jobs to 2030



Photographer: Jason Thomas Image courtesy of Alinta and RATCH Australia.

This section discusses the results of the jobs modelling from 2015 to 2030, both in terms of the technology typology, and the employment category (i.e. broad job descriptions relating to the phase the project is in).

The SEN Jobs Model 2020 for 90% RE by 2030 projects 8,618 direct jobs in the year 2030.

The jobs modelling was validated by running it across ten energy models with various technology mixes to achieve 90% RE (***Appendix A4.9***). Across all models, the distribution of jobs ranges from 8,101 to 11,386 (indicatively a -500/+2,800 variance from the energy model used for figures generated in this report). These figures demonstrate that our model is appropriate, and no matter what the technology mix for 90% RE in 2030, there can be this order of total jobs delivered with various 90% RE clean energy mix.

3.1 Job Creation by Technology

Jobs created from 2015 to 2030 are shown in ***Figure 3.1***, for each technology. These are calculated by multiplying annual additional capacities in the energy model (described in ***Section 2; Figures 2.1 & 2.2***) by the relevant Employment Factors for each technology and job role. These include all jobs classifications including operations and maintenance, for which additional capacity is cumulative in terms of ongoing employment. The following description addresses each technology in turn, starting from the bottom of ***Figure 3.1***.

The SEN Jobs Model 2020 projects that:

- **Onshore wind jobs** increase sharply from 2018 and continues to increase towards 2030.

  (Reflecting on ***Figure 2.1***, the number of jobs increases from 2018, while the capacity does not increase until 2020. This is because there is currently a substantial amount of wind generation under construction, which will come online from 2020.)
- **Rooftop PV jobs** are fairly constant from 2020 to 2030, as households and businesses continue to install systems under the low growth scenario we have modelled.
- Jobs associated with a roll out of **Utility PV**, has commenced, and is slowly increasing. As more capacity is added, there will ongoing construction & installation and operations employment.
- Jobs associated with **decommissioning coal plants** and site remediation correspond to the closure of the Muja C/D and Collie plants. The shutdown of the Bluewaters plant is forecast to commence

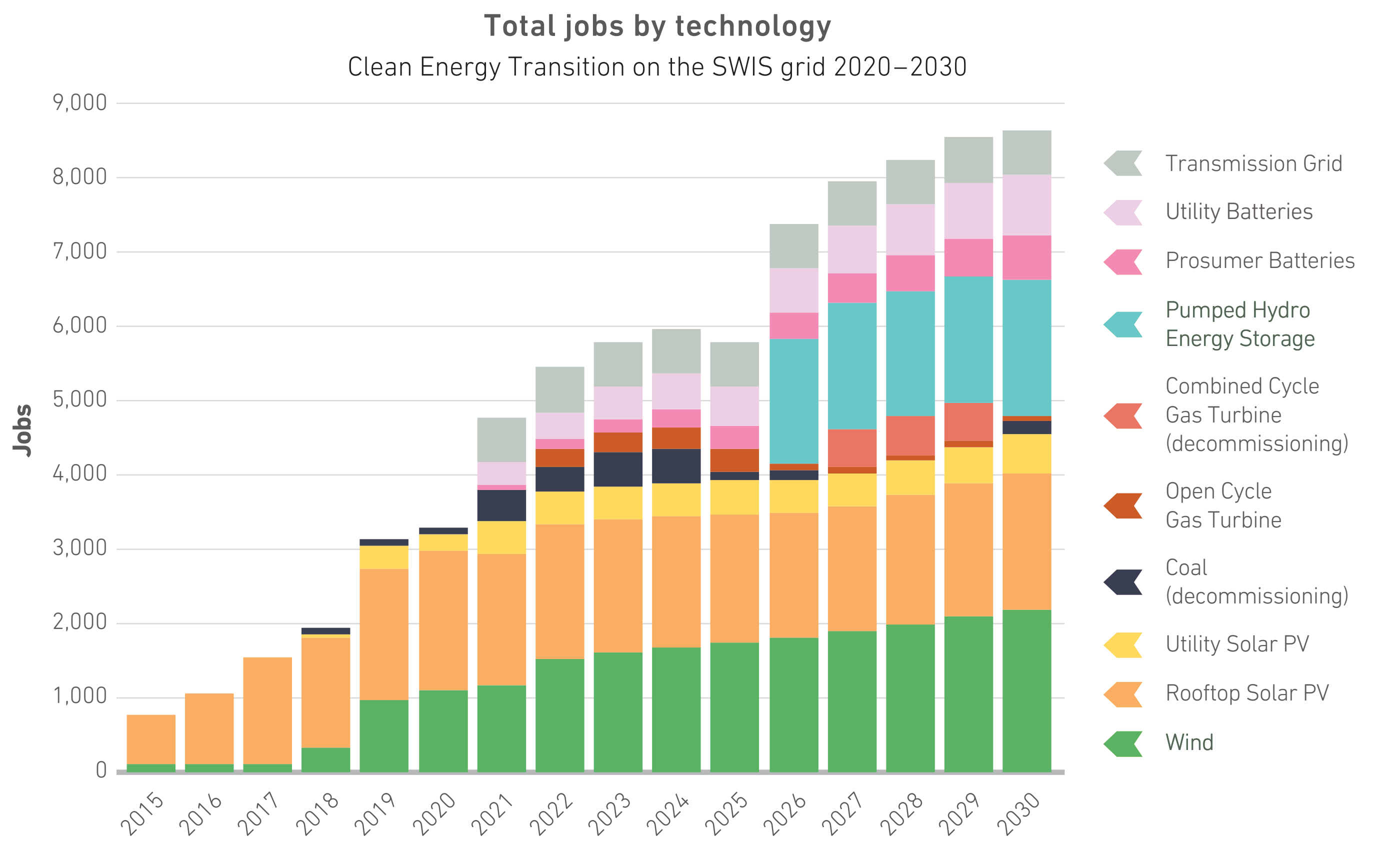


Figure 3.1 **FTE jobs to 2030 classified by generation technology.**

in 2029 but market conditions may influence its closure prior to that, given the apparent need for its units to run at very high Capacity Factors.

- A number of jobs are also shown with the **decommissioning of CCGT** generation capacity in 2027-2028 and construction of new peaking gas capacity required for grid stability commences.
- Construction of **pumped hydro storage** occurs in the last half of the decade. The C&I employment factor for this technology is approximately three times larger than wind and 1.5 times that of utility PV, per MW, hence the increase in employment. Notably, the job skills required for this technology are closely related to the skills of coal miners and turbine operators offering an employment opportunity to workers who wish to stay in the local area rather than retrain into other industries or locations.
- Construction and installation (C&I) jobs for batteries see many more **utility batteries** being installed in the early years of the transition, and these are surpassed by **prosumer battery** C&I jobs in the latter half of the decade. Operations and Maintenance jobs are much higher in **utility batteries** and grow to six times the number of **prosumer battery** O&M jobs by 2030.
- Jobs in building **transmission lines** are constant over the decade. New **transmission infrastructure** preparedness is critical for allowing large quantities of new wind and solar capacity.

3.1.1 Total jobs created

Our modelling shows there are 8,618 direct jobs in 2030. This includes approximately 1,100 five-year construction jobs and 550 five-year local manufacturing jobs from 2026 to 2030 as the pumped hydro storage capacity is built. Assuming the pipeline of renewable energy work continues after 2030, total jobs would actually decrease markedly in 2031, because the large scale PHES construction work will be complete. On the other hand, the commissioning of more PHES to enable 100% RE may be considered appropriate at that time.

An alternative representation of modelled employment between 2015 and 2030 is shown in ***Table 3.1*** as five year averages. Wind, and battery storage are modelled with steady growth, and this is seen in ***Table 3.1***. Construction of transmission lines is constant from 2021-2030. However, jobs from the other technologies are variable. For example, coal decommissioning varies by time period, with the majority of decommissioning occurring in 2021-2025. CCGT decommissioning, on the other hand, only occurs from 2026 to 2030. The same is the case for the construction of the Pumped

Table 3.1 Summary of average FTE jobs by generation technology*

Technologies	Total jobs as the average job number over 5 year periods		
	2016-20	2021-25	2026-30
Wind	523	1,537	1,988
Rooftop PV	1,494	1,773	1,743
Utility PV	120	443	471
Biomass	0	0	0
CST/CSP	0	0	0
Coal (Decommissioning)	54	363	62
OCGT (new build only)	0	219	83
CCGT (Decommissioning)	0	0	312
Pumped Hydro Storage	0	0	1,717
Batteries Prosumer	0	182	466
Batteries Utility	0	423	696
Grid (Transmission)	0	598	598
Total	*2,192*	*5,537*	*8,136*

* Note that the five-year averages are all lower than the number of total jobs in 2030 (as indicated in Figure 3.1). The 2030 figure is the peak number of annual FTE jobs in our projected employment for the decade.

Hydro storage. For these reasons, the average of jobs over five years is less than the total jobs in 2030.

Finally, the new build of OCGT involved an average of 219 jobs during 2021-2025. From 2026, there was an average of 83 O&M jobs for the new build of 500 MW of OCGT.

Yet another measure of the employment amounts is expressed in job-years. Over the transition from 2020 to 2030, a total employment quantum of 55,548 job-years is projected on the SWIS grid. That is, there is an average 5,555 jobs for each year of the decade.

3.2 Jobs Growth by Employment Category

An additional view of employment is by employment category. Typically this is expressed in five areas: manufacturing, construction and installation, operations and maintenance, grid, and decommissioning. These are illustrated in *Figure 3.2* and summarised in *Table 3.2*.

The SEN Jobs Model 2020 projections find:

Manufacturing jobs: 782 jobs created by 2030. Job numbers are relatively low, in part because local content factors are low, as outlined earlier. Potential for increasing the local content proportion will be discussed in Sections 3.3 and 7.2.4.

Construction and Installation activities are the major employment category, with 4,459 FTE jobs in 2030. There is ongoing growth to 2022, as RE development ramps up; then a steady phase as projects smoothly follow each other; then a jump corresponding to the start of Pumped Hydro development.

Operations and Maintenance job numbers continually grow as installed RE capacity and storage increases across the grid. Many of the 2,819 O&M jobs are potentially locally-based, permanent positions conducive to family life. O&M jobs potentially strengthen regions with secure, permanent, well paid, skilled jobs.

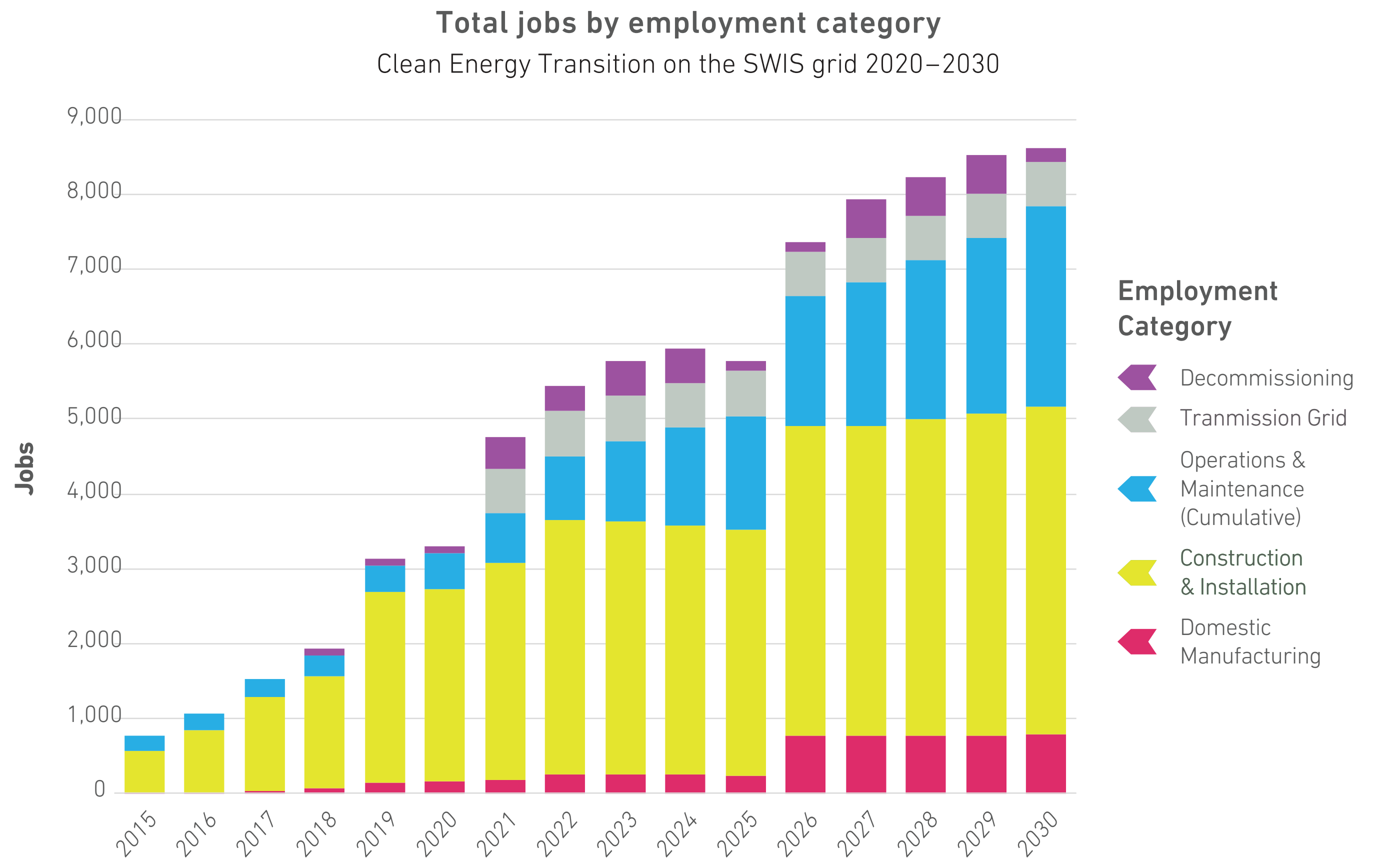


Figure 3.2 FTE jobs to 2030 classified by employment category.

On the other hand, mobile work-sites are more likely in the construction phase, as skilled workers travel within regions, and to different regions to construct generation and storage assets.

Finally, 598 jobs are seen to be created over the ten years in grid expansion. Additionally, in 2030 there are 179 jobs in decommissioning fossil fuel plants.

Table 3.2 displays the categories of jobs as five year averages from 2016 to 2030. It is apparent here how the

Table 3.2 Summary of average FTE jobs by employment category*

Technologies	Total jobs as the average job number over 5 year periods*		
	2016-20	2021-25	2026-30
Domestic Manufacturing	85	233	773
Construction & Installation	1,735	3,257	4,235
Operations & Maintenance (ongoing)	317	1,086	2,156
Grid	0	598	598
Decommissioning	54	363	374
Total	*2,192*	*5,537*	*8,136*

* Note the five-year averages are all lower than the number of total jobs in 2030 (see Figure 3.1). The 2030 figure is the peak number of annual FTE jobs in our projected employment for the decade.

Operations and Maintenance jobs continue to increase with the amount of new capacity add to the network.

A feature of SEN Jobs Model is that no jobs are shown for existing fossil-fuelled generators – jobs are only modelled for new generators. This is unproblematic for coal and CCGT, because they will be retired by 2030. In 2016, we estimated that the number of coal O&M jobs was 672 (Sustainable Energy Now, 2017a). Information is not available for CCGT.

On the other hand, the model does not account for the ~2,000 MW of OCGT capacity which will be required in 2030. It does, however, account for the 500 MW of new OCGT capacity added from 2022 to 2025, and ***Table 3.1*** indicates that there are 83 ongoing O&M jobs from 2026. Using the same Employment Factor for older OCGT units we estimated O&M jobs associated with the ~2,000 MW of existing OCGT capacity to be 332. Total modelled and unmodeled FTE jobs in 2030 in generation and storage will therefore be of the order of 8,950.

3.2.1 Employment per Project

Table 3.2 demonstrates that the major employment categories are Construction and Installation, and Operations and Maintenance. This section breaks those down in terms of the fast-growing RE technologies used in our modelling, that is Wind and Solar PV. For comparison, we calculated the employment numbers for each technology in terms of an indicative 100 MW generation capacity. ***Table 3.3*** shows the results for the three major technologies, for both C&I and O&M. It is apparent that the highest C&I employment comes from Rooftop PV. C&I employment is similar for Wind and Utility PV, while Wind generation has the highest O&M employment.

These figures provide a metric for estimating the major employment related to a particular new generation project, whether there is a steady rollout of RE as assumed, or not.

3.3 Local Content and Manufacturing Potential

The modelling reported above was based on the Australian average Local Content Factors provided by Clean Energy Council (2020), shown in ***Table B.3*** These reflect the current state of play around RE manufacturing in Australia. Manufacturing for wind and PV in WA may have lower values than the Australian average, since relatively small amounts of wind power have been deployed to date, and the utility PV market is in its infancy by global standards.

Nevertheless, there is an opportunity for local content and local manufacturing in WA, as foreshadowed by Beyond Zero Emissions (2019) in their Collie work. Should the government seek to promote the renewable energy industry through local content guidelines, there is considerable potential for greater manufacturing in Western Australia , particularly for wind generation.

Table 3.3 FTE employment numbers for an indicative 100 MW of new generation capacity.

Technology	Construction & Installation (FTE)	Operations & Maintenance (FTE)
Wind	280	22
Rooftop PV	580	16
Utility PV	230	11

The manufacturing of turbine nacelles is a highly advanced process, and the whole manufacturing process would be unlikely to come to WA. Wind turbine blades are very high-tech, designed to flex under load and have aerodynamic properties, much like aircraft wings, so any manufacturing would require licensing agreements in place. Nevertheless, some of this expertise already exists in the WA ship-building industry. Licensing transfer arrangements would be required, since a very small number of companies worldwide have the advanced capabilities required for manufacturing turbine blades.

However, some components could be manufactured in WA, with the appropriate policy environment. Wind turbine towers are currently being manufactured in Victoria by Keppel-Prince (Australian Manufacturing, 2017), as part of state-based local content rules. Similarly, leading global wind turbine design and manufacturing giant Vestas has set up a turbine assembly plant (final assembly of major manufactured components) and a maintenance training facility in an abandoned car making plant in Geelong (Vorrath, 2019).

Manufacturing such large and specialist componentry would require a secure pipeline of work to encourage investment in such production. However, with a Government plan for consistent deployment of wind energy, as recommended here, there would be a clear pipeline of work lasting for a decade and beyond.

For example, the Victorian Renewable Energy Target has delivered a steady pipeline of wind farm deployments in Victoria. Keppel-Prince, with some financial assistance from the Victorian Government, were able to add 50 workers to their existing 80 workers involved in tower Section manufacturing in 2017.

The Berrybank Wind Farm (300 MW) currently under construction in Victoria is illustrative of what can be achieved. Global Power Generation during the construction phase committed to achieve at least 64% local content and during operations phase have committed to at least 90% local content. Deakin University will also partner with the wind farm to undertake a research project into improving the efficiency of carbon-fibre production for wind turbine blades. Turbine blades now represent the largest single demand for carbon-fibre, using 40 per cent of global production.

Other potential manufacturing employment includes: High Voltage cable; control systems; specialised transport equipment; solar PV panel construction and framing; sun tracking technology manufacturing; footing reinforcements; ground mount fixings; and assembly of transmission towers.

Local content rules would oblige developers to consider more than lowest price available components from SE Asia. Furthermore, the WA government is very interested in more of the lithium battery supply chain occurring in WA.

Appendix B.4.1 describes a hypothetical local content analysis at various levels of local content for wind, PV and battery storage. ***Table B.5*** summarises the results of this sensitivity analysis. Starting with 782 manufacturing jobs in 2030 in the base scenario, a doubling of local content adds 229 highly-skilled jobs, and an overoptimistic quadrupling of local content almost doubles manufacturing jobs. Under this scenario, total manufacturing jobs increase from 782 to 1,413, and total employment in 2030 rises from 8,837 to 9,468.

A potential manufacturing hub could be established in the Collie/ Bunbury/ Kemerton region, as proposed by BZE (2019), to provide for new employment opportunities as the coal-based economy of Collie phases out.

On the other hand, it may be difficult to achieve a quadrupling of local content production in Western Australia. The relative isolation and small population of WA may make it difficult to justify capital intense start-up, depending on the sophistication of a given technology. The present lack of ambition from the state to embrace renewables impedes growth in the sector. However, recovery from the Coronavirus pandemic provides an opportunity to "build back better" with forward-looking industries, that require workers with high levels of requisite training and expertise. The rapid transition to a clean energy economy allows for new export opportunities stemming from a carbon-constrained global economy.

Once mandated by government, implementing a local content policy could be achieved by including clauses in power purchase agreements requiring a commitment from bidders to include local content provisions. Government will need to understand and stimulate the capabilities and capacities of local industry in order to achieve alignment with local content objective.

3.4 Regional Employment

A particularly positive attribute of clean energy infrastructure for the State is that employment will not be focused in just one area. Our projections illustrate that it will initially be spread across the South West of the state, and subsequently expand into existing mining areas. There is some flexibility in selection of sites (although they will mostly be positioned to take advantage of existing and newly-built transmission lines and renewable resources) so that, to some degree, socio-economic requirements can also be considered.

This has already been preempted in the Whole of System Plan being developed by Energy Policy WA. In this work, the SWIS has been divided into 10 'nodes', as shown in ***Figure 3.3***. Comprehensive modelling is underway, examining demand and supply in 30 min intervals over 20 years across each node, under various assumptions. One outcome of the modelling will be to show preferred locations for renewable generation in each node. Clearly, some of this generation will be in regional areas, with on-site construction and installation, and ongoing operations and maintenance jobs. A transition to renewables will strengthen regional economies.

Analysis of the SEN Jobs Model estimates the split between regional and metropolitan employment. This split was determined at the technology and job category level of our jobs numbers matrix for each year in the transition and then job-years were aggregated. Some technologies are more likely to be built in regional areas, e.g. wind farms. However, some of the employment associated with wind and solar farms are city-based, e.g. development, site selection, transport and some of construction management and engineering design. Some operations and maintenance also remains city based.

For the construction (C&I) and operations (O&M) work categories of wind and solar farms there is a

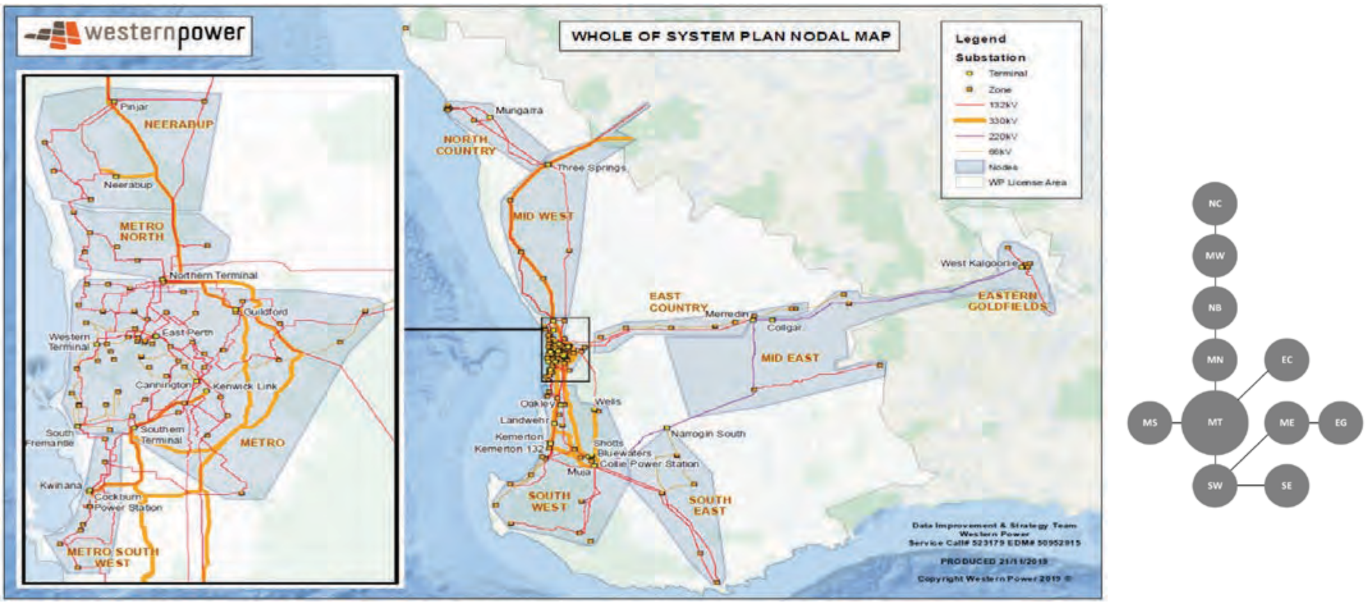


Figure 3.3 **Map & schematic diagram of nodes being modelled in the Whole of System Plan. Images courtesy of Energy Policy WA.** The maps on left indicate the HVACA lines divided into areas called nodes. On right is a schematic diagram of how these nodes are interconnected.

Table 3.4 **Regional composition of Jobs from (Rutovitz et al., 2020, Table 24)**

Regional composition of jobs		
Technologies	**C&I**	**O&M**
Wind	67.0%	73.3%
Utility PV	69.0%	54.6%

significant division between regionally–based and metropolitan–based work. The summary results in Table 24 from Rutovitz et al. (2020) are reproduced here in *Table 3.4* and have been adopted in our jobs model to add granularity to the metropolitan/regional job splits for some technologies. *Figure 3.4* shows the annual regional/metro split across all employment categories.

Other cells in our technology/job-role matrix were determined to be either predominantly regional or metropolitan. For example, we assumed that rooftop PV and prosumer batteries are predominantly metropolitan.

In the case of a technologies like OCGT we used the Wind C&I regional/metro split for their C&I and O&M jobs numbers, in the absence of superior data.

This analysis resulted in an estimated 6,000 regional jobs and 3,600 metropolitan jobs in 2030. Annual employment numbers by regional/metro split is illustrated in *Figure 3.4* for the period modelled in this report (2015-30). A renewable energy roll-out provides a majority of regional jobs, with a 58%/42% split in 2030. In terms of job-years over the 2020-30 period, 40,787 regional and 39,309 metropolitan job-years are projected, resulting in a 51%/49% average for the transition period.

With the largest transmission line infrastructure terminating at Collie, the Collie region is clearly well placed to secure substantial employment. Work by Beyond Zero Emissions (2019) in their "Collie at the Crossroads" report resulted in a prediction of over 1,800 jobs in the Collie region by 2030. Jobs are in RE manufacture, coal decommissioning and site remediation, and a range of other RE recycling and innovation activities.

The phased retirement of coal, and its replacement by clean generation by 2030, will impact on the Collie community, and state agencies are looking to facilitate the transition away from dependence on coal. In the context of this report, we find that significant employment opportunities exist in earth moving and coal decommissioning and demolition roles for a decade. This may be attractive to older workers not prepared to retrain into new roles in the clean state economy. An opportunity also exists for coal mine workers to redeploy into five years of Pumped Hydro projects, ideally in the Collie region. Collie is also well-placed as a hub for dispatching 'on-demand' power to provide grid reliability and energy security.

The Collie/ South West region has a continuing role in providing energy security. Emerging manufacturing hubs arising from local content requirements can provide further job opportunities.

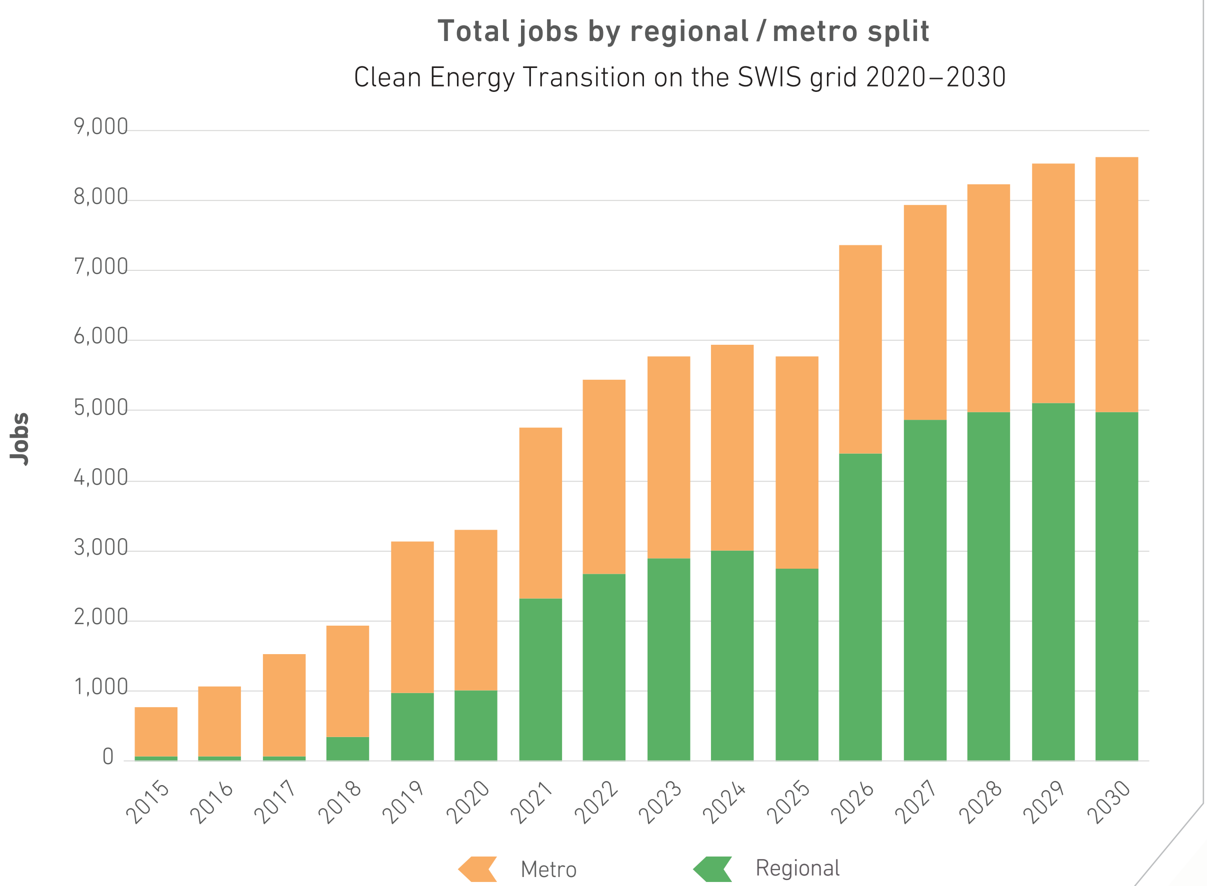


Figure 3.4 Total jobs split according to whether the employment is regionally or metropolitan based.

Photographer: Jason Thomas Image courtesy of Alinta and RATCH Australia.

Section 4

Discussion

Photographer: Jason Thomas Image courtesy of Alinta and RATCH Australia.

The scenario we have considered is one for 90% RE by 2030, assuming a steady pipeline of work to encourage and secure a smooth and rapid transition of the SWIS. This is technically achievable with current, commercially-proven technologies.

4.1 Energy Scenario

Based on the projected demand for energy in 2030, we modelled a scenario where 90% of grid demand energy is dispatched from clean energy sources, i.e. renewables firmed by batteries and PHES storage. 90% RE is simply a statistical average across the entire year. Grid managers are required to dispatch power at hourly and smaller intervals throughout the year. For the vast majority of hourly periods, 100% of energy demand would be supplied directly by RE and RE stored in batteries and PHES. At other times a mix of clean energy and fossil gas will be dispatched. For rare prolonged periods of low RE generation, only fossil gas will be dispatched. This is illustrated for indicative purposes showing typical summer and winter periods in ***Figure A.1***.

This was achieved with 11.7 GW of wind and solar generation complemented with 2GW of battery and PHES storage (11.24 GWh) plus 2.6 GW of gas-fired generation to provide balancing/reserve power. In general terms, the wind and solar generation complement each other well with solar generating during the day and wind generating during the night. The storage and gas fired generation cover the relatively short periods when neither is generating or not generating enough.

We expect a substantially increased load on the SWIS will occur by 2030, and continue, due to an uptake of Electric Vehicles (EVs), and extensive domestic, commercial and industrial fuel switching from gas. We expect that some of this demand will occur before 2030, but our modelling has not included this. If demand increases, and is met, then RE jobs will be expected to be even higher than presented here.

Technologies such as RE hydrogen generation and storage, and potentially Concentrating Solar Thermal generation may become available by 2030, and these may be able to contribute to meeting increased demand beyond 2030 and achieving the final 10% of RE. This may result in zero fossil generation on the SWIS, other than reserve OCGT and diesel generators for disaster preparedness.

We have not carried out detailed demand and supply energy modelling beyond 2030 to account for this level of potential change, because such projections involve so many variables, and predicting technology availability so far into the future is highly speculative. However, we explore some of the issues and opportunities briefly in ***Section 5***.

The prices of renewables continue to fall, to the extent that both wind and solar PV generally now match the marginal cost of generation of existing coal plants, which excludes capital costs (Lazard, 2019). Costs of Lithium battery storage also continue to fall (Lazard, 2019), contributing to cheaper energy reliability and security.

As RE is rolled out, there will be times when there is an overabundance of solar and wind energy. Some of this (Rooftop PV) already is used behind-the-meter, to heat water, run pool pumps, and charge batteries and electric vehicles. Smart devices like PV routers and smart appliances will increasingly be used to manage grid loads and take advantage of time-of-day (TOD) pricing structures. In addition, a market niche exists to use this excess energy for purposes not currently in use. One potential application of surplus energy is to electrolyse water to produce green hydrogen. This is a process which does not need to run continuously, but only when power is available. Utilisation levels currently need to be high for industrial scale electrolysis of RE hydrogen to be financially viable, but costs in electrolysers are falling in the same way PV cell costs have improved dramatically through R&D and economies of scale. When high volume production begins, learnings will also bring costs down.

A suitable location is near an OCGT plant. The hydrogen can be stored on site, and used when required to run the OCGT plant with potential elimination of fossil-fuel use. Another suitable location is near wind and solar farms that would otherwise be constrained behind the high voltage transmission lines connecting the farm to the grid (at time when there is not enough line capacity to dispatch the energy). RE hydrogen stored at low pressure and/or piped to local storage at low pressure could be used at a later time to meet the large seasonal scale storage needs of the SWIS grid during winter to get it to 100% RE. The economic and employment potential of excess renewable energy is explored further in ***Section 5***.

4.2 Clean Energy Jobs to 2030

Unlike the approach commonly taken by the resources industry, the jobs referred to in this report are direct jobs only. New jobs create indirect and induced jobs in multiplier effects, but these has not been taken into account in this report.

Or modelling shows that there will be 55,100 new RE job-years created with an average of 5,000 jobs per annum. This culminates in 2030 with 8,600 FTE jobs of which approximately 2,300 would be ongoing Operations and Maintenance (O&M) jobs.

The resources industry in WA has shown that construction work for new projects can be an industry in itself. Our work indicates that something as significant as the transition to high levels of RE will create a sustainable RE construction industry. A relatively high proportion of this new industry will be highly-skilled workers.

We estimate that two thirds of the new jobs will be in regional areas, thereby boosting the socioeconomic fabric of those areas. The bulk of construction will be serviced by a mobile workforce. However, Operations and Maintenance jobs are secure, permanent, well paid, skilled jobs, predominantly in the regions.

The majority of jobs considered in this report are related to new wind and solar energy developments. We found that, for each 100 MW of new generation, there are:

- 280 FTE C&I jobs and 22 FTE O&M jobs for wind
- 580 FTE C&I jobs and 16 FTE O&M jobs for rooftop PV
- 230 C&I jobs and 11 FTE O&M jobs for utility PV

These metrics can be applied to individual projects on different timelines. Project commencement in 2021 at the levels required may be difficult without immediate policy prescription and a pipeline of well advanced projects in development, but the figures can be translated across different time-horizons.

Short delays can be made up if the commercial fundamentals are attractive to project developers as seen in the over-delivery of new capacity from the VRET auctions for new wind and solar capacity. On the other hand, there may be projects in development which are simply waiting for the policy environment to be put in place to enable commercial returns that are bankable.

Some industry participants may consider our 10 year timeframe to 90% RE too aggressive. Others, mindful of an ever worsening climate prognosis, may consider that it is too slow. We also understand that achieving the modelled capacity by 2030 may be challenging. The scenario used specifies an ambitious build of Wind and Utility PV by 2030, in addition to continued growth in Rooftop PV. Achieving an additional 4 GW of Wind generation will require the equivalent of 20 Yandin or Collgar wind farms to be built in 10 years. However, attempting to achieve WA's share of the Paris target will require this level of investment, and the expected 2020 commissioning of the Yandin and Warradarge wind farms (214 MW and 180 MW) is at this order of required new capacity.

If the deployment schedule is extended, then the total number of manufacturing and construction and installation jobs will be similar (allowing for the impact of decline factors) but stretched over a longer timeframe. In other words, there will be fewer additional jobs created each year, but over a longer duration. The total O&M jobs in the final year will be identical, but with more O&M work created over the journey.

4.3 Policy Recommendations

Our view is that it will be difficult to reach 90% RE by 2030 without strong government reform and policy direction. Fortunately, there are multiple precedents that the State can follow to achieve this.

South Australia, Victoria and the ACT have their own state-based Renewable Energy Targets (RET). Victoria and the ACT also have their own renewable energy legislation, that could be adapted quickly for use in WA. The appointment of a Renewable Energy Advocate and strong leadership on renewables from the Victorian Government was decisive in their RE transition. The VRET was one piece in a suite of energy and emissions reforms made in concert in Victoria by the Andrews Government (echoing the first RET in Australia delivered by the Bracks Government in the 1990s).

A RET may be an appropriate mechanism in the Western Australian context but an alternative is **to simply set an implementation timeline for RE roll-out**, with an associate decommissioning timetable for fossil-fuelled generation, That timeline can become an overall market signal to industry and finance, and it can be done effectively in WA as the majority of fossil-fuelled generation is state owned.

This report shows that 90% RE by 2030 is technically feasible from an engineering perspective, but it may not be realistic from a business perspective, under business as usual approaches and a hands off Government approach. A hands off approach from Government invites a bumpy ride to 2030.

Obtaining and leasing land and securing finances can take years, even with state support, as has happened in South Australia. The government there has put several initiatives in place to support RE companies to invest in SA (Government of South Australia, 2020). These include an investment portal, investor guides and resources, case management support and assistance with development approvals. Such an approach can facilitate a rapid RE transition in WA. The revised Network Access Agreements proposed by Energy Policy WA may also streamline deployment of new generation capacity (Government of Western Australia, 2019b).

While South West WA has enviable wind and solar natural resources, the transition to 90% RE will require a commercial framework and clear conditions to facilitate renewable energy project developments. Existing commercial conditions are not conducive to RE projects, and there are a number of potential roadblocks which need to be addressed:

- Overcapacity of thermal (fossil fuel) generation on the SWIS grid (mostly owned by Synergy, a state owned monopoly gentailer)
- The possibility of both market and transmission line constraints being applied in a penalising way to developers of recent wind farms on the SWIS. This has the potential for the kinds of problems seen recently on the NEM, with international players retreating from the Australian RE market due to regulatory and infrastructure failures. The Network Access reforms being developed might mitigate this issue.
- Little legislative or policy vision in WA for rapid emissions reduction or a clean energy economy to inspire confidence in potential developers and financiers. Such investors tend to take a global outlook for investment opportunities.
- Synergy sells energy in the contested wholesale market below the cost of generation once maintenance and other costs are accounted for according to their most recent Annual Report headline numbers. This adds to the difficulties for new and existing entrants with RE proposals.

The DERR and WoSP have the potential to be extremely valuable reforms, and may yet provide the foundations for a comprehensive strategic roadmap for energy in WA. Tariff reform has been foreshadowed in the DERR, but details are not yet publicly available. The design of tariffs must promote opportunity benefits for energy users and decarbonisation. That is, in addition to protecting grid assets, these tariff structures must better reflect current conditions, support consumer behaviour, and encourage adoption of PV, PV-routers and smart appliances, battery storage and EV uptake in WA.

Similarly, reform of the Energy market framework and regulations (Government of Western Australia, 2019b), which is currently underway, needs to be completed, and in a way which supports RE. For storage, in particular, the current regulatory systems are inefficient and prolong the need for thermal generation. We note the recent moves by Western Power to install utility batteries for grid stability, but clearly much more needs to be done.

Once a timeline is set for serious adoption of clean energy, reverse auctions can be scheduled for new renewable capacity. They have been used in Victoria, South Australia, the ACT and Queensland and they can expedite the process of bringing new projects to market. They do this by offering both price certainty for the vendors and a demonstration of commitment from the state government to bring projects to reality in a timely way. The equity and finance sector is receptive to this kind of government support, as it flags that the supplier has a cooperative partner in government.

As the RE industry matures and grows in WA, the government will have the choice of directing growth through policy or a hands off 'industry will decide' approach. A hands-off approach is likely to create significant booms and busts in RE construction employment, such as those experienced in the National Electricity Market, where wind and solar development progressed erratically. The alternative choice is a managed approach with a clear timetable, where there is a steady flow of new jobs through an informed and well-directed government policy.

Other alternative macro level reforms would be for the Government simply to issue Synergy with emissions intensity targets or renewables targets and let Synergy work through the system reliability and security issues with Government support. On the other side of that policy debate is a deregulatory approach, that is, to privatise Synergy and allow it to be carved up in the market place and opened to more competition and greater "cost reflectivity" in energy pricing. Either way whole-of-system-planning will be required, since market participants are incapable of system change when operating simply as commercial entities in the generation and retail spaces. SEN makes no comment or advocacy for these policy options, but provides for discussion purposes only given their currency in the public debate.

In an isolated state like WA, a clear Government timeline for staged renewables rollout would enable commercial enterprises to invest in appropriate and sufficient manufacturing capacity. Without committed pipelines of work across a decade or more, it is difficult for local companies to justify investment in the plant equipment for manufacturing to compete with overseas operators.

As the world comes out of the Coronavirus pandemic, there are great opportunities for a government with vision to set a new course for future prosperity for WA. This is the perfect time for nation-building projects to be brought forward. For this transition, we need the State Government to lead by announcing a timetable for RE rollout, and then to coordinate the development of the required infrastructure and renewable energy and storage projects. This would create employment, decouple us from a reliance on fossil fuels, and support WA's progress towards the Paris climate goals.

Image courtesy of Goldwind Australia. (Stockyard Hill Wind Farm project).


C H I P O L

Section 5

Energy & Employment Growth to 2050

image courtesy of APA. Emu Downs Solar Farm

This report has primarily focused on clean-energy technology deployment and employment out to 2030. This is an achievable timeline for the SWIS to transition to 90% RE. Beyond 2030, RE employment is expected to continue at levels at least comparable to those in 2030, and possibly at much higher levels, dependent on the development opportunities the state embraces. As discussed in ***Section 5***.1, our expectation is that there will be substantial ongoing deployment of RE facilities beyond 2030, both on but mostly beyond the SWIS. This Section takes a cautiously hypothetical look at renewable energy and employment growth beyond 2030 to 2050.

5.1 RE Capacity to 2050

This work is not proposing a 'build it and they will come' approach – we are not proposing that the state builds excess generation capacity in preparation for new industry participants. Instead, we propose that given the, by 2030, very well demonstrated availability of cheap, secure and reliable renewable energy, opportunities open up for new industries needing cheap power and to improve their social licence. This in turn feeds into new possibilities for jobs in existing RE industries.

5.1.1 RE on the SWIS

We expect that several factors will substantially increase demand on the SWIS from 2030 (with some beginning to have an effect well before 2030). These include:

- Increased rollout of electric vehicles
- Fuel switching from gas to electricity in households and businesses (lower costs opportunities)
- Use of electricity for industrial process heat
- Production of Green Hydrogen
- New desalination plants to combat a drying climate (potentially as flexible demand)
- Use of electricity for green manufacturing within the SWIS – e.g. Aluminium that also has the potential to operate on the SWIS as flexible demand/load

Research by various bodies (Beyond Zero Emissions, 2010, page 4; 2018, page 42; Climate Works, 2016) indicates that these factors could potentially increase the energy needed on the SWIS by the order of 30-100% by 2050.

Large industrial users within the SWIS, who generate their own electricity, may choose to supply power to the SWIS grid, and benefit through time of use and other tariff schemes that provide value for dispatch in periods of greatest need on the SWIS when storage is low. In addition, renewed Demand-side Management (DSM) schemes that provide commercially attractive balancing services for the power system are very effective in high penetration renewable energy scenarios.

5.1.2 RE in the rest of the state

The deployment of RE will not be confined to the SWIS, and does not need to be restricted to a 2050 timeline. Cheap renewable electricity makes it possible to replace fossil fuel use in the industrial and mining sectors, through industrial heating, electrifying process components and powering ore moving machinery, especially underground where clean power technologies have OH&S pay-offs as well. Aspects of this are already under investigation as part of the Asian Renewable Energy Hub proposal (2017), and BP (Parkinson, 2020).

Green metals production is an area where Western Australia could be proactive in its industry policy. Professor Ross Garnaut and others (Lord, 2019b; Mazengarb, 2019, 2020; Wood & Dundas, 2020) advocate using renewable energy to stimulate a move down the pathway to minerals processing. Green steel processes, powered by RE, are currently being piloted around the world (Mazengarb, 2019), and present an attractive economic opportunity for the state. Large renewable generation facilities in the Pilbara can produce green hydrogen to make Green steel. Abundant RE electricity can be used to smelt Aluminium.

Lord (2019a) analysed green steel and aluminium potential in WA. He estimated that processing 20% of local iron resources would increase revenues by 90%, and create nearly 49,000 permanent jobs. An additional 16,000 on-going O&M jobs are created to supply new renewable energy for green steel. Similarly, 5,000 permanent jobs can be created by processing 75% of Australia's alumina output, with 2,200 O&M jobs in RE. The Asian Renewable Energy Hub (2017)is already developing plans for a 10-20 GW wind, solar and storage facility in the Pilbara.

Such industry innovation will require the government to act as a catalyst in some form or other, along the lines of the Renewable Hydrogen Strategy. A green metals strategy will be a major stimulus for wealth and jobs creation in Western Australia, and it requires massive amounts of RE to be realised.

In summary, there are many opportunities for RE to power innovative new industries, while also meeting state climate targets. The following Section conservatively estimates RE capacity growth out to 2050, and calculates the estimated employment resulting from this.

5.1.3 Capacity Growth

We did not specifically model for a scenario where demand and RE capacity increases to 2050. Instead, we extrapolated from the 2030 rate of deployment of renewables and battery storage seen on the SWIS. Growth was nominally adjusted by the inverse of the CAPEX (Graham et al., 2019) decline factor for each technology, thereby assuming that a similar amount of capital is expended each year on increasing RE capacity.

Under this assumption, approximately 28.5 GW of generation capacity could be available across the state by 2050. The vast majority of this is likely to be off the SWIS grid and used by large industrial consumers like mines and ore processing plants. Deploying battery storage at the 2030 rate would result in a total of 18 GWh of storage (including the 8 GW of PHES commissioned in 2030). This volume of cheap energy would enable industrial innovation such as more value adding in processing of raw materials, and products made with largely automated processes. If WA is to meet its Paris commitments and its Net Zero 'aspiration' by 2050, it will need large amounts of RE in numerous sectors, so what is projected here is reasonable. The following Section investigates the employment opportunities that could arise throughout the state.

5.2 Clean Energy Jobs to 2050

Given the projected energy capacity of 28 GW by 2050, following an ongoing trajectory of work, we applied our employment model to project RE jobs throughout the state. Because there is a relatively constant rate of capacity addition, project-based Manufacturing and C&I jobs vary from ~3,400 in 2031 to ~3,200 in 2050, with the decrease due to decline factors (technology improvements).

However, because O&M jobs are permanent, ongoing roles, they continue to increase, from ~3,100 in 2031, to ~5,500 in 2050.

A further source of employment after 2030 is the ongoing replacement and decommissioning of systems as they reach their end-of-life. The system lifetimes summarised in ***Table B.8*** indicate that significant amounts of PV and wind generation capacity will need to be replaced by around 2040.

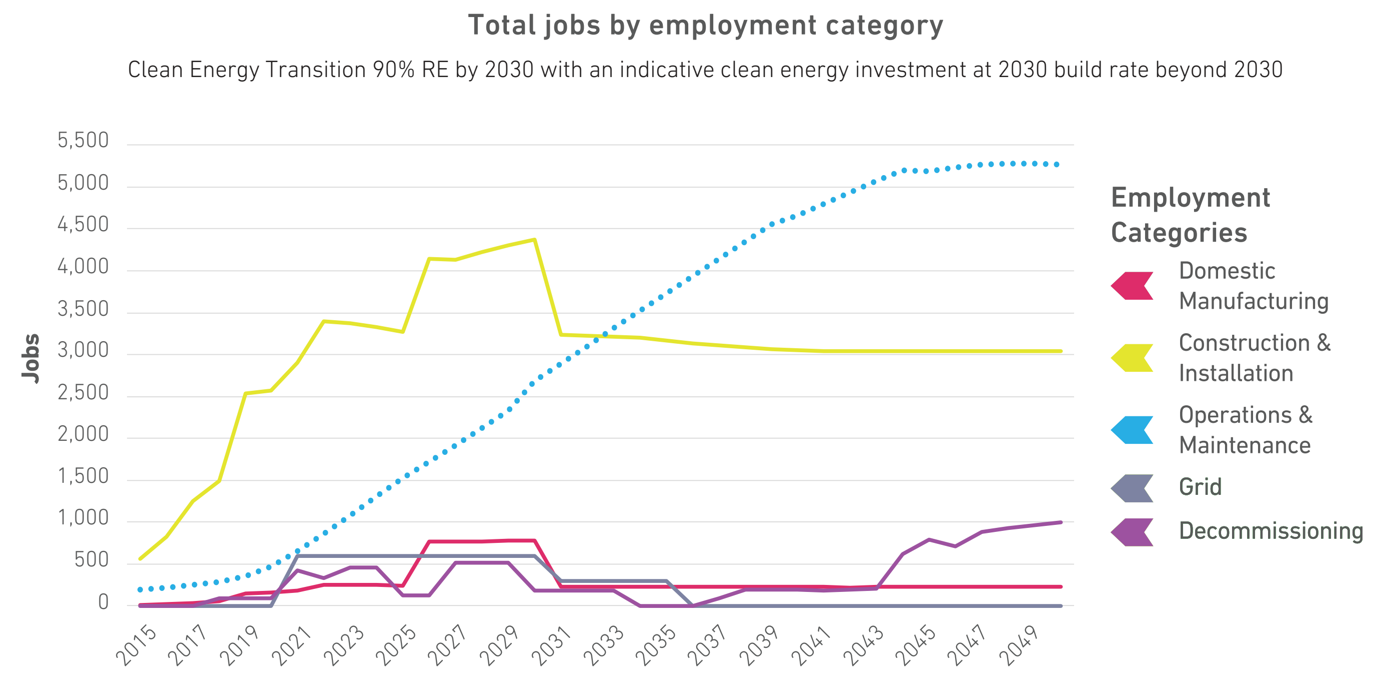


Figure 5.1 **Employment growth across the transition to clean-energy by job category, 2015 to 2050**

Rather than assuming obsolescent capacity will all be retired at the same time, we have spread the decommissioning over several years. This results in decommissioning jobs commencing in 2037. The resultant decommissioning jobs increase to 1,000 by 2050.

Under these assumptions, total FTE jobs increase from ~6,900 in 2031 to ~9,600 in 2050. This is equivalent to 132,801 job-years in direct employment.

Figure 5.1 illustrates these trends in employment across the different job categories. Of most interest is the comparison between the two major jobs categories: C&I (yellow) and O&M (blue dotted). C&I jobs increase rapidly in the 2020s as the RE roll-out commences, and then peak in the late 2020s, when the job-intensive PHES project commences. After that, C&I jobs remain steady until 2050, in line with the assumptions made in the scenario, that a relatively equal amount of capital will be spent each year.

However, the purpose of ***Figure 5.1*** is to compare the employment from C&I with that of O&M over the same time period and the same assumptions. The notable point is that O&M jobs continue to increase under currently published decline factors, and the blue dotted line intersects the yellow (C&I) line in approximately 2031. By 2050, permanent O&M jobs are clearly the largest contributor to RE employment. A high proportion of these are likely to be relatively highly skilled, and based in rural and regional areas.

Image courtesy of APA. Emu Downs Solar and Wind Farms

Section 6

Conclusions


Image courtesy of APA

This document presents a detailed analysis of the employment prospects for WA if the SWIS were to be transitioned to 90% Renewables by 2030.

We are confident that Western Australia can achieve 90% RE on the SWIS grid by 2030 if, and only if, there is determined period of Government reform over the decade to offer the kind of security that other states in Australia are presently offering developers and financiers of renewable energy projects.

We are setting the 90% RE level by 2030 to focus community and industry policy ambition around an aspirational but achievable goal for renewables. Moving in this direction will require the Government to commit to a world-leading transformation in WA's energy sector, and consider the associated reform challenges.

6.1 Clean Energy Outcomes

- Our target of 4,500 MW of rooftop solar PV for 2030 will be met by unimpeded growth of 'behind the meter' residential, commercial and industrial onsite rooftop PV, assuming a growth rate that is gentler than recent times, but still non-linear.
- Our energy model target of 5,000 MW of wind power will be met by an annual deployment at a level similar to the two wind farms currently being deployed on the SWIS (394 MW for Yandin Warradarge wind farms combined).
- There will be vastly reduced GHG emissions on the SWIS from a nearly clean (90% RE) grid energy by 2030.
- The use of RE will reduce emissions further, as a consequence of fuel switching in the built environment and transport sectors.
- The final step of moving from 90% RE to 100% RE may come about at very minimal additional cost through a variety of emerging technologies.
- This work envisages a future opportunity for new industries to exploit world class renewable energy prices in Western Australia, to process domestic mineral resources like bauxite, iron ore and lithium salts.
- The employment of C&I workers from the 2020-30 decade will continue in deploying wind and utility solar projects in the northern regions of WA.

6.2 Employment Outcomes

- Our employment model shows that 8,618 full time jobs would be delivered in 2030 under this scenario. This Jobs Report examines the technologies and their locations where jobs are likely to eventuate in our 90% RE scenario.
- Over the transition from 2020 to 2030, a total employment quantum of 55,000 job-years is projected on the SWIS grid (averaging to 5,000 jobs per year). Extending this to 2050, using a considerably more speculative projection results in 134,300 job-years in direct employment.
- The jobs model considers direct jobs only, and omits potential jobs in areas such as the maintenance of an expanded SWIS transmission grid and a revolutionised, DER-aware distribution grid.
- A local content policy would create many new skilled manufacturing jobs in WA. If a quadrupling of Australian averages could be achieved for component manufacturing and assembly it would add around 630 more skilled jobs, while a more realistic doubling would see 230 added manufacturing jobs by 2030.

Recovery from the Coronavirus pandemic provides an opportunity to build future-looking industries, with high levels of required training and expertise, and related export opportunities. This report outlines a positive vision for the state that shows what is possible with renewable energy. A planned but rapid clean energy transition beginning on the SWIS and continuing out to the North and East of WA can:

- Substantially assist the state to meet its 2050 net zero emissions aspiration,
- Decarbonise a large part of the economy
  - emissions reductions in the stationary energy sector
  - emissions reductions in transport, industry and the built environment via fuel switching to renewable generation and storage
  - reduce the use of fossil fuels
- Contribute to significantly to new employment across the state through the development of new industries
- Diversify and expand the WA economic base beyond extractive mineral and fossil gas industries that presently fail to value add prior to export.

Emu Downs Wind Farm. Image courtesy of APA

Appendix A

Energy Methodology

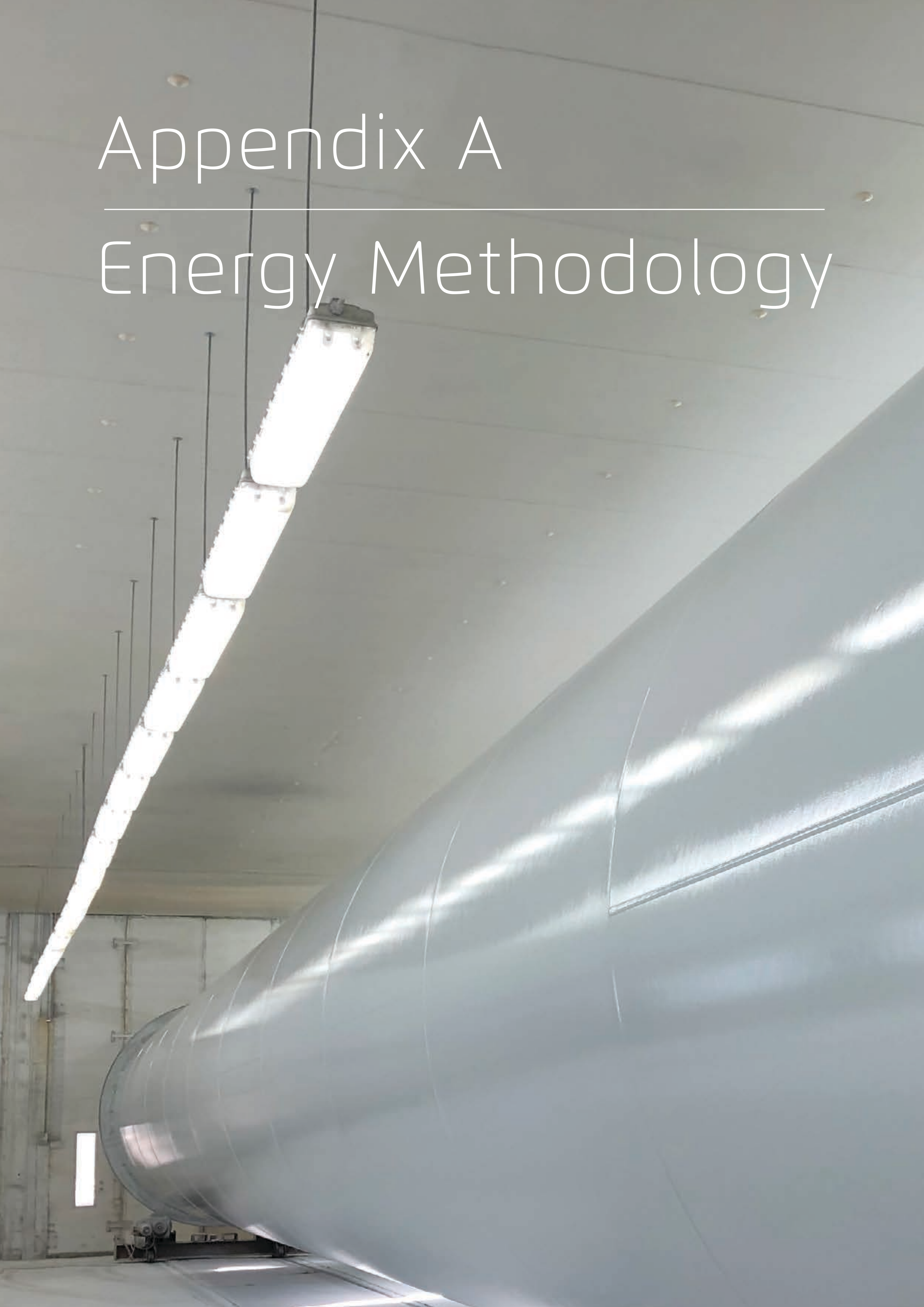


Image courtesy of Keppel Prince

A.1 Energy Modelling Software

Energy modelling was conducted using the open source SIREN – PowerBalance software developed by SEN (Sustainable Energy Now, 2016).

SIREN is the SEN Integrated Renewable Energy Network Toolkit simulation program, which draws upon Geographical Information System (GIS) data and NASA's MERRA-2 global hourly weather data. Energy modelling combines these data with the US Department of Energy National Renewable Energy Laboratory's "System Advisor Model" (SAM) for detailed models of various renewable technologies. It simulates an electricity network and enables users to create and evaluate scenarios for supplying electricity using a mixture of renewable and non-RE sources. SIREN calculates power output for each generator for every hour of the year and subtracts the actual load on the network for each hour. The results are hourly surplus and shortfall of generation for the scenario for a chosen year (8760 hours).

PowerBalance is then used to apply various storage and backup technologies to balance the power surplus/shortfalls with actual demand. SIREN and PowerBalance outputs result in a costed Renewable Electricity scenario, including additional transmission infrastructure needed. (The PowerBalance spreadsheet has recently been superseded by a coded version – PowerMatch, which was used to verify the PowerBalance results.)

The bulk of the PowerBalance modelling was done in 2016, using conservative cost projections sourced from the Australian Bureau of Resource and Energy Economics (2013), Bloomberg New Energy Finance (2015) and Lazard (2017). These cost assumptions are likely to be higher than current RE costs, but it was out of scope for this report to redo the entire modelling, as generation cost was not a formal consideration.

While our interest here was not in optimised system cost results, the relative technology costs played a role in arriving at the final generation mix, as merit-order dispatch means dispatching the lowest cost technologies that are available for each hourly period in the models. Dispatch is dependent on installed capacity at that time, plus on weather conditions for renewables (calculated in SIREN) and storage discharge capacity. By using relatively conservative costs, the modelling represents a realistic mix of technologies in capacities that would provide for reliable and cost-effective electricity provision, and is therefore a feasible option for the future.

A.2 Energy Scenario

Energy costs are defined in terms of the Levelised Cost of Electricity (LCOE) – which is an amortised cost of electricity production: a combination of costs of capital expenditure, operations and maintenance and fuel, over the lifetime of a generation source.

This scenario is just one example of how a 90% RE generation mix could look in 2030. There are many valid scenarios and associated pathways to achieve 90% RE, some of which may result in either higher or lower jobs numbers. For example, a higher PHES component and less battery storage creates more local jobs, because PHES is more construction-intensive. However, validation of the modelling gives us confidence that there will be this order of magnitude of jobs for a range of 90% RE scenarios.

The core scenario used in the jobs modelling is similar to that from SEN's 2016 modelling, but adjusted to reflect changes in the last 5 years. This includes:

- A higher component of rooftop PV, to reflect the substantially faster and ongoing uptake than was forecast in 2016
- A lower wind component as a result of increased rooftop PV.

The key criterion for selecting the core scenario was low cost (lowest LCOE) balance in the energy generation and storage mix, and suitability for local WA regional factors.

A.3 Generation Technologies used in our Modelling

In our modelling we have only included proven commercial RE technologies where substantiated cost and jobs factors are available.

A.3.1 Onshore wind

Wind turbines are a mature RE technology, with many thousands installed around the world. Wind farms typically occupy a land area of 26 sq. km per 100 MW, but turbine pads and access roads are a small portion of this and the rest is not cleared or disturbed. Wind turbine costs are still falling, but less so than in prior decades, as the technology continues to mature.

Wind generation is an important factor in high penetration of RE on the SWIS, because its geographic spread means that, if there are calm conditions in one region, wind can be blowing in another. As wind can generate around the clock, whenever the wind blows, it provides a complementary function to solar PV.

Existing and new (presently-under-construction) wind farms in WA are listed in ***Table A.1***

A.3.2 Solar PV

Utility-scale solar farms have been installed all over the world. They consist of arrays of solar PV modules pointed at the sun. The simplest technology has all panels fixed at the best average angle to the sun. More complex technologies enable the panels to rotate on a single axis to maximise insolation.

The efficiency of electricity generation and production of solar PV panels has been increasing rapidly over the last decade (with consequent price reductions), and this is likely to continue. The installed cost of PV is therefore still falling rapidly.

Rooftop solar PV uses the same technology as utility-scale solar, but it is installed in smaller quantities on residential and commercial premises.

Rooftop PV is a 'democratic' technology, in that individual consumers invest in their own system and have control of their own generation and consumption, as 'prosumers'.

A.3.3 Open Cycle Gas Turbines

OCGT units are suitable for fast start/ fast ramping and offer a suitable response to peak load demands in the power network. These turbines can be fuelled from liquid or gaseous fuels. Their lower efficiency means they are not suitable for primary generation. They require relatively low capital expenditure, but are expensive to run because of the relatively low efficiency and high cost of fuel.

A.3.4 Coal-fired generation and Combined Cycle Gas Turbines

Both Coal and CCGT generators are suited to 'always on' operation with nearly constant output. They take hours to start up and shut down, and cannot easily adjust to short duration swings of demand or intermittency associated with RE generation. In addition to the amount of GHG pollution they generate, they are poorly suited to the new generation paradigm of the 21st century.

Table A.1 FTE employment numbers for an indicative 100 MW of new generation capacity.

Existing Wind Farms	Capacity [MW]
Albany Wind Farm	21.6
Alinta Walkaway Wind Farm	89.1
Badgingarra Wind Farm	130.0
Blair Fox Beros Road Wind Farm	9.2
Blair Fox Karakin Wind Farm	5.0
Blair Fox West Hills Wind Farm	5.0
Bremer Bay Wind Turbine	0.6
Collgar Wind Farm	206.0
Denmark Community Wind Farm	1.4
Emu Downs Wind Farm	80.0
Grasmere Wind Farm	13.8
Kalbarri Wind Farm	1.6
Mt Barker Community Wind Farm	2.4
Mumbida Wind Farm	55.0
Total capacity	*620.8*
New Wind Farms to be commissioned in 2020	**Capacity** [MW]
Yandin Wind Farm	214
Warradarge Wind Farm	180
Total capacity	*394*

A.3.5 Batteries

Battery systems are essential components of all RE installations as they can respond extremely quickly to sudden changes in load and supply, such as those caused by generation trips, power line failure or sudden cloud shading. Battery storage sufficient to supply maximum single event lost generation for at least 15 minutes is needed, to allow fuelled backup generators to 'ramp up'. A well-known Australian example is the Hornsdale 'big battery' in South Australia (Parkinson, 2018).

A range of battery technologies have been developing and improving over the last decade with prices dropping substantially.

In this work, we distinguish between utility scale 'community', and 'prosumer' (behind-the-meter on individual premises) batteries. Both use the same technologies at different scales, although utility scale applications, especially in more remote locations, have also adopted non-lithium chemistries (e.g. flow batteries), while home batteries tend to favour variations on lithium ion chemistries. Lead acid batteries are no longer widely considered for home storage.

A.4 Renewables Transition Model

In order to meet the targets for the 90% RE scenario by 2030, a consistent and large amount of generation needs to be deployed. Our starting point was existing deployments of wind and rooftop PV with the current build rates. We gradually increase the deployment rate by a fixed amount each year to arrive at our modelled energy capacity targets for 2030. This provides for a consistent level of construction and manufacturing employment across the decade.

A government-mandated timeline for a sustained renewables rollout would enable commercial enterprises to invest in appropriate and sufficient construction and manufacturing capacity. Without this, it is difficult for local companies to justify investment in the plant and equipment to compete with overseas operators. The intention is to avoid the boom and bust cycles that wind and solar have seen on the National Electricity Market.

The following sub-sections explain details for the technologies deployed in this energy model.

A.4.1 Wind power in the energy model

Until 2018, no significant new wind farms have been deployed since the Collgar Wind Farm opened in 2011. In 2018 Badgingarra Wind Farm was commissioned for 130 MW of new capacity and this year it';s expected that construction will be completed on Yandin Wind farm (214 MW) and Warradarge Wind Farm (180 MW). These three wind farms with a combined potential of 524 MW.

The 90% scenario begins with 190 MW of new wind capacity commissioned in 2021, and double that, 380 MW in 2022 then growing annually at a stepped rate until 2030, where 456 MW is envisaged, to meet the modelled 2030 capacity of 5,000 MW. This steadily rising deployment rate is 20% over the decade.

From Rutovitz et al. (2020), we know it takes on average 1.8 years to deploy wind farms, with larger wind farms taking longer. Smaller wind farms, like the recently commissioned 130 MW Badgingarra plant, can be completed in just over one year.

Wind farms can begin exporting energy before all turbines have been erected provided regulatory approvals have been obtained, and network substation and grid connections have been completed

A.4.2 Photovoltaic power in the energy model

Rooftop PV and Utility scale PV are both modelled to have their deployment grow by 40% over the decade to meet the installed capacity targets in our 90% RE energy by 2030 scenario. That is, a total of 4,500 MW of Rooftop PV and 2,200 MW of utility scale, single axis mounted PV systems by 2030. Projecting a smooth increase in industry jobs is ideal for the industry, training and employment stability.

Projected new capacity for rooftop PV in 2021 is 260 MW (slightly less than the historical 2019 level of 269 MW), growing linearly by 12 MW per year to reach 364 MW deployed in 2030. Cumulatively, this equates to quadratic growth, at a significantly less steep growth curve than the last five years has seen.

Cumulatively, this equates to quadratic growth, at a significantly less steep growth curve than the last five years has seen. Over the last five years, rooftop PV growth has been approximately 25% per year (i.e. exponential) (Australian PV Institute, 2019). While PV systems continue to become cheaper to install for any given capacity, rooftop PV will continue to be a value driven proposition for residents and the owners and lease holders of commercial premises. Growth is likely, therefore, to remain significant in the medium term, and a quadratic growth rate in installed capacity is a conservative assumption, given historical growth for the last decade.

However, we expect that there will be natural limits to ongoing growth in PV behind the meter, with the ultimate limit being the amount of suitable roof space. Other underlying drivers will also be relevant, such as curtailment by grid operators and changes in price signals and subsidies.

The Distributed Energy Resources Roadmap (DERR) (Energy Transformation Taskforce, 2019) recognises how an excess of PV can be detrimental to grid security and reliability. While the DERR does not propose restricting PV growth, it does propose measures to curtail excess rooftop PV generation, and to consume it when needed. PV growth needs to be carefully managed with an emphasis on complementary wind power and storage, together with Demand Side Management technologies, to keep the system balanced.

A.4.3 Battery storage in the energy model

Modelled additional battery capacity starts with 10 MW of prosumer-, and 52 MW of utility-battery capacity in 2021, with annual additions growing to 110 MW and 68 MW respectively in 2030. This will provide a total installed base of 600 MW prosumer (1,620 MWh) and 600 MW utility (1,620 MWh) battery storage in 2030. Given the rapid cost decline due to economies of scale and learnings in Lithium Ion and other less common chemistries, and success stories of recent deployments of large capacity battery storage in other states of Australia, we see these numbers as reasonable. This view is underpinned by Vorrath (2020), who reported that 233 MWh of prosumer batteries were installed in 2019, Australia-wide. This equates to approximately 23 MWh in WA on population terms, more than twice the initial prosumer battery assumption modelled.

By comparison, South Australia has already installed or sanctioned 1,405 MW of utility storage (Maisch, 2019) for their smaller grid, that also has access to the greater NEM for load balancing.

Prosumer battery storage is expected to take the form of either dedicated home/ commercial storage systems or electric vehicles with grid connection capability (available commercially now). Total prosumer storage of 600 MW is equivalent to 120,000 5 kW home or commercial systems, currently at the lower end of capacity. This amounts to approximately 17% of houses in Perth installing a battery of this or greater specification by 2030.

A.4.4 Validation of the Energy Model

Ten variations of the energy model were investigated, with various combinations of technologies. Several of these models had a similar LCOE. One model (More Wind) had a slightly lower LCOE, a higher proportion of RE and less spilled energy. However, this model presumes a lower amount of Rooftop PV that is not consistent with current PV growth trends. Therefore, based on the popularity of rooftop PV, now increasingly in large commercial-scale installations, the chosen 90% scenario is more appropriate, even though it leads to a less optimal overall solution.

This validation that the model we have used for the basis of jobs modelling gives us confidence that the number of jobs is towards the lower (conservative) end of the available range, and there will be this order of magnitude of jobs for a range of 90% RE scenarios.

A.5 Need for Fuelled Backup Generation

RE technologies are inherently variable in their output. Wind speeds fluctuate by day and season, and solar PV output is greatest in the middle of the day, and these cause a mismatch between electrical power production and demand. The variable output from RE generation does not match the variable demand at any point in time, so energy shortfalls and surpluses need to be managed and balanced dynamically. Storage, curtailment and some fuelled generation can all be used to provide balance.

Figure A.1 shows modelled power generation every hour over two typical three-week periods, in summer and in winter, respectively. Output from wind and PV is shown in green and yellow, respectively. Fuelled backup is shown in orange. The contribution of batteries is shown in purple. Pumped Hydro is shown in blue. The hatched areas show the amount of surplus electricity that is generated at times.

In summer (top half of ***Figure A.1***), wind and PV meet and exceed demand on most days, supported by the small amount of storage. There are, however, several orange sections at the end of the three weeks, where OCGT peaking plant generation is required at night.

In winter (bottom half of ***Figure A.1***), there can be periods of almost two weeks where wind and solar only occasionally meet demand. Over that period, OCGT is needed almost continuously. These approximately two week-long periods only occur once or twice a year, but periods of a few days of prolonged OCGT use in the 85% model are not uncommon, other than in the summer months when heavy cloud cover is rare.

The modelling shown in ***Table 2.1*** shows that 2.6 GW of OCGT capacity is available on the SWIS. However, this is used rarely, so the combustion emissions (GHGs) are relatively low.

Peaking plants do not need to be fuelled by fossil gas. By 2030, it may be feasible to fuel them by Green Hydrogen (or derivatives), or sustainably farmed biofuels, achieving 100% RE on the SWIS. The solution that gets built for that last 10% will be influenced by technology costs, market trends and political leadership.

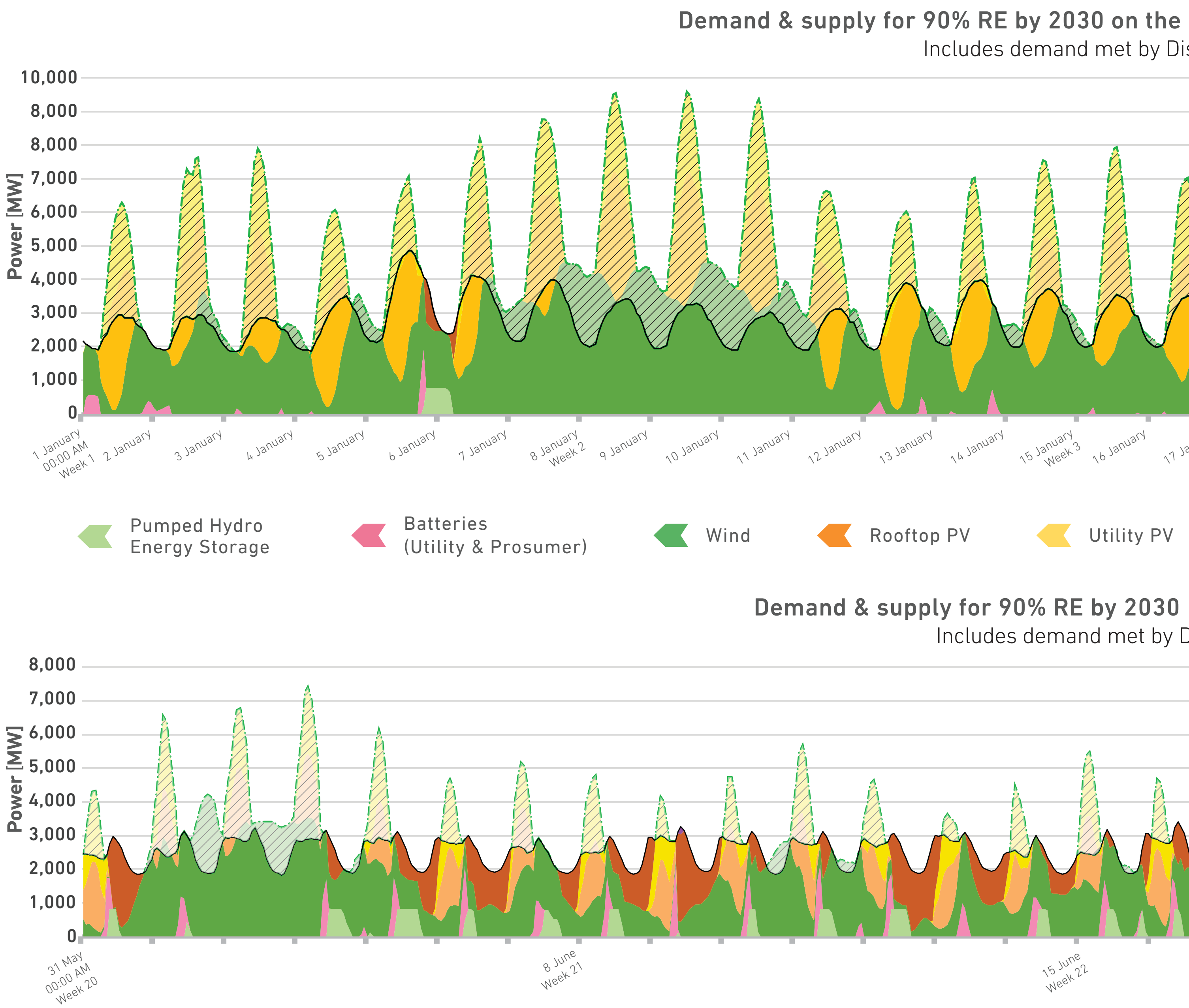
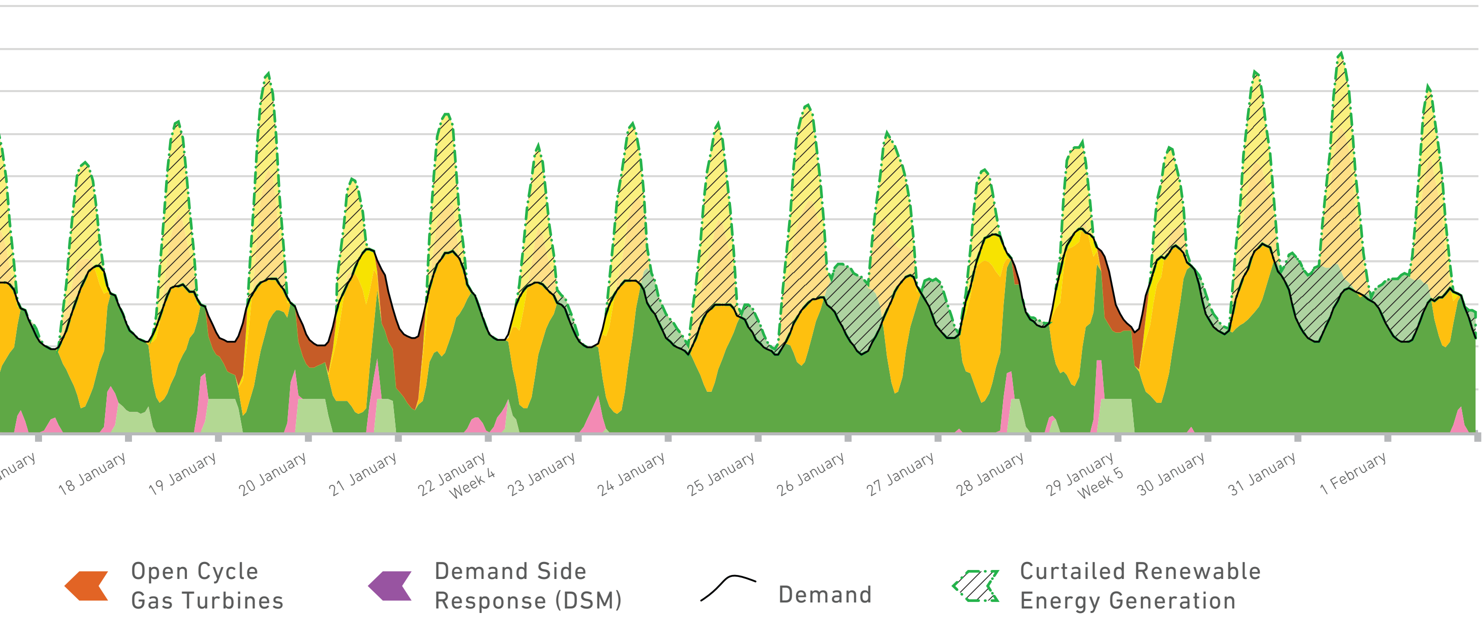


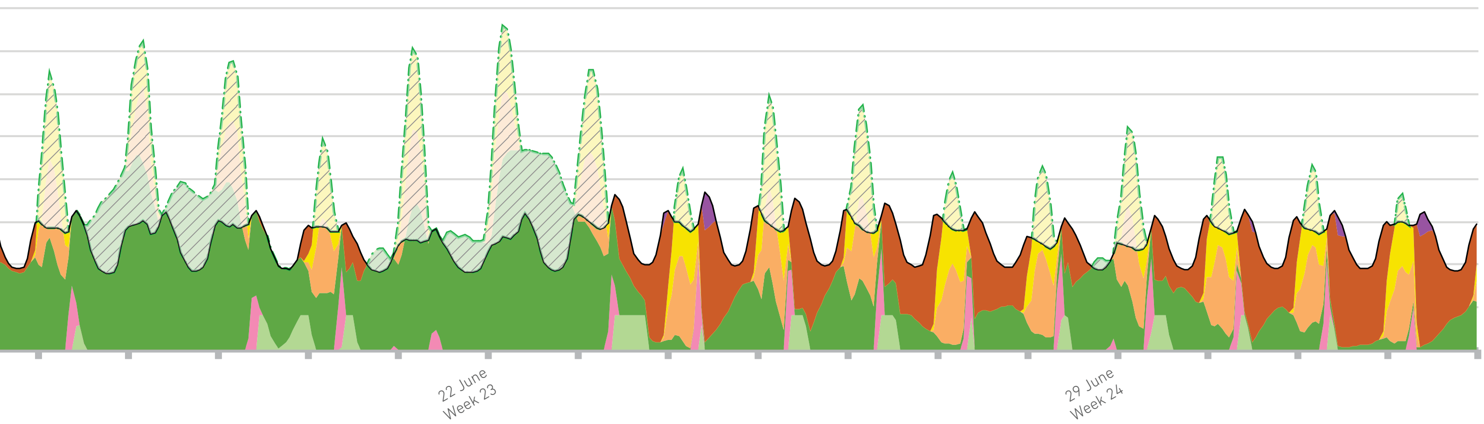
Figure A.1 Generation mix under a cost optomised 90% RE scenario with projected demand for 2030.
Four weeks in summer and four weeks in winter. Historical satellite derived weather data from 2014 used in SIREN modelling software. Supply and demand matching calculations performed using PowerBalance for 86% RE generation mix with some storage.

Image courtesy of Keppel Prince

SWIS — 1 January to 1 February (Summer)
stributed Energy Resources



on the SWIS — 31 May – 2 July (Winter)
Distributed Energy Resources



Appendix B

Jobs Model Methodology

Photo of Berrybank Wind Farm provided by Naturgy Group, Berrybank Wind Farm

B.1 Introduction

The Clean Energy Council (2018a, 2019) has published summary information about jobs in the renewable energy industry in its annual reports. Analysis of their data shows there is a strong a correlation between jobs and the power capacity of renewable energy projects deployed, and between jobs and investment levels (per state). A full description of the relationship is given in ***Appendix A.***

These relationships form the basis for our jobs modelling. Given a certain level of capital outlay on various technologies, we can predict the direct jobs associated with their deployment and operations. However care is needed when using aggregated data.

Previous CEC studies (2016a) have compared jobs against capacity for individual projects. Analysis of these findings show that there is a wide variation in jobs/ MW in projects of the same technology and similar capacity, due to:

- variations in the basis used for reporting of employment numbers for each project
- differences in the way projects are structured
- variations in site geology and other conditions

A limitation of such summary data is that the length of individual job components that are reported is unknown. Some jobs might be associated with tasks as short as two weeks, while other jobs may last for the lifetime of the project (25-40 years). In other words, a 'job' is an unspecified unit of measure that gets interpreted and reported in different ways by each project proponent. When averaged at the national and state levels, these different interpretations even themselves out so that states are somewhat in line with each other, showing a direct relationship, as seen in the 2018 and 2019 reports (Clean Energy Council, 2018a, 2019).

The outcome of this analysis is that more information is needed to form meaningful projections around real employment amounts. Academic analysis points to two concepts which enable this:

- The concept of job-years, described in Section B.1.1; and
- A breakdown of jobs into specific components.

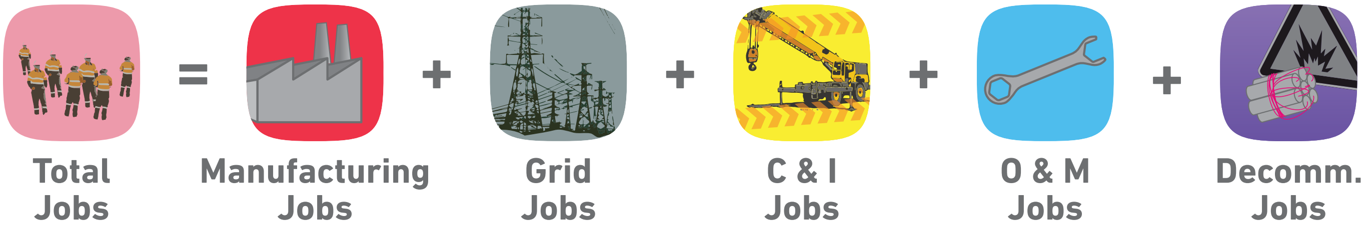


Figure B.1 Makeup of the total jobs associated with a renewable energy project.

The construction and ongoing operations of generation and storage technologies can be broken down into roles in the engineering design, planning, manufacturing, warehousing, transport, construction, installation, operations maintenance and decommissioning. These roles can be categorised as (Ram et al., 2020; Rutovitz et al., 2015):

- Manufacturing (Manuf.)
- Construction and Installation (C&I)
- Operations and Maintenance (O&M)
- Decommissioning and site remediation jobs (Decomm.)
- Transmission (Grid)

The employment associated with each of these categories is calculated to determine the total amount of jobs in an energy system, such as the South West Interconnected System (SWIS). This is illustrated in ***Figure B.1***.

The jobs model is based on work by Ram et al., (2019), derived from (Rutovitz et al., 2015). It has three major components, which are applied to each generation and storage technology to determine jobs on an annual basis.

For each employment category, the jobs are a function of the Installed Capacity (MW), multiplied by an Employment Factor and a Decline Factor, as shown in ***Figure B.2***. The Employment Factor (Section B.2) is the jobs per MW for each technology for each job category.

The Decline Factor (Section B.3) is a reduction in cost over time (and therefore jobs) due to the 'technology learning curve'. That is, over time, engineers have developed techniques to manufacture and install technologies for declining capital expense per unit of energy generation or storage. While there is no exact relationship, the jobs associated with deploying and maintaining energy technologies generally decline at a similar rate to declines in the Capital Expenditure (CAPEX) associated with a technology. For example, fossil fuel technology is relatively mature, and decline factors are low. Fuel costs are a major cost component of LCOE, and fuel efficiency gains for fossil fuel generation have plateaued in recent decades. On the other hand, battery storage technologies are still developing, and decline factors are relatively high.

Manufacturing jobs have a further component, which is the percentage of local manufacture (Section B.4). For example, wind turbines and solar panels are almost exclusively manufactured in other countries. In this context, Local Content refers to the proportion of manufacturing in WA, for example, solar panel frames.

In addition, ***Figure B.2*** shows how jobs are calculated for decommissioning old generating plants, and upgrading the transmission network (Grid) to enable appropriate power flows between new generation locations and the rest of the grid. Grid jobs are calculated by the number of kilometres of transmission infrastructure required, multiplied by a relevant employment factor. These are construction and electrical jobs – we have not calculated jobs for the operations or maintenance of these grid transmission assets, or the broader SWIS distribution network. With more generation comes more supply, so there would be induced jobs in distributing the additional power, but these are beyond the scope of this study.

Previous SEN jobs modelling used an energy model in combination with employment factors and local content factors. The addition of decline factors extends our model, derived from Ram et al., (2019), and Rutovitz et al. (2015).

B.1.1 Jobs vs Job-years

An important distinction is between the characteristics of jobs from each employment category.

Each generation plant being installed, using a particular technology, can be viewed as a project, with a fixed development and construction timeline, followed by an ongoing operational timeline. Section B.4 presents the time period required for a particular generation project.

Because of their 'project' nature, Manufacturing and Construction and Installation (C&I) jobs are measured in job-years. A job year is one full time equivalent (FTE)

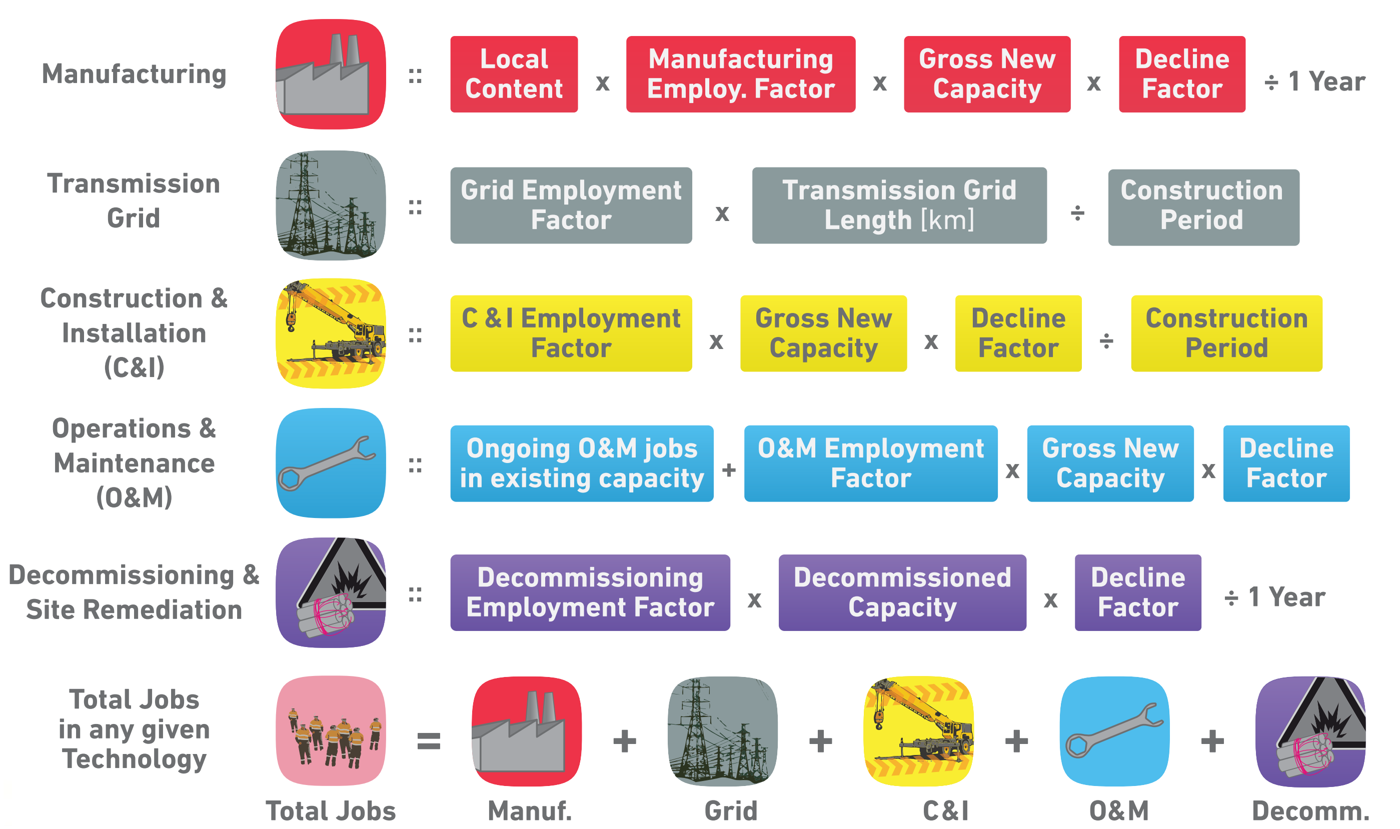


Figure B.2 Jobs equations for each job component (From Ram et al., 2019; Rutovitz et al., 2015).

employee working for one year. The relevant employment factor is job-years per MW of installed capacity.

Once a plant is commissioned, we calculate an ongoing, fixed number of Operations and Maintenance jobs, for the operational lifetime of the generation or storage asset. They are permanent jobs (FTEs). For wind, that means typically 25 years of work, and for solar farms using Single Axis Tracking (SAT) photovoltaic panels, 30-40 years.

Table B.1 summarises this discussion, showing the units appropriate to each job category. Because Manufacturing and construction and installation employment is project based, jobs could come and go as projects start and finish. That is why government policy guidance is important, to ensure an ongoing trajectory of work for renewable generation projects.

The illustration below provides an example of the equations shown in *Figure B.3* for C&I of a hypothetical 100 MW wind farm with an Employment Factor of 3.0 and a Decline Factor (see Section B.3) of 90%, and a nominal construction period of 2 years.

Additional capacity x Decline Proportion x Employment Factor
[MW] [%] [job.years.MW^{-1}]

100 MW (wind farm) x 90% (decline factor) x 3.0 job.years.MW^{-1} (C&I)
⇔ 300 job.years.~~MW~~.~~MW~~$^{-1}$ x 0.9
= 270 job.years
Given 2 year construction period for wind farms,
⇒ 270 job.years / 2 years
= 135 jobs (of two years duration each)

Table B.1 Units used for each job category

Category	Units
Manufacturing	job-years/MW
Construction and Installation (C&I)	job-years/MW
Operations and Maintenance (O&M)	job-years/MW (permanent FTE jobs)
Decommissioning & site remediation	job-years/MW
Grid jobs	job-years/MW

The result is 270 job-years of work created in construction. In order to determine annual jobs, we need to convert this volume of work in construction to annual jobs. That is, 270 job-years results in 135 jobs that last 2 years each. The construction of a wind farm will result in construction job durations from two weeks to two years, but the 270 job-years is the total amount of 'work' in job-years and the 135 jobs of two year duration is just the average outcome if all jobs were the same length as the construction project. It allows us to generate ( ) FTE (Full Time Equivalent) employment data for each year in the study period.

The equations proposed by Ram et al., (2019) include a further, Regional, factor. Because this work is restricted to the South West of Western Australia, regional factors are not relevant, and were not included in the model. Regional factors reflect that it can take longer to construct plant in locations without suitable infrastructure. This is a conservative assumption, and, if it had been included, it would have increased job numbers slightly. Our model also did not include fuel cost factors, because fossil-fuelled generation is being minimised.

Table B.2 Employment Factors used in this report. Mostly from Rutovitz et al. (2020).

Technologies	Manufacturing*	C&I	O&M
Wind Onshore	1.70	2.8	0.22
Rooftop PV	4.40	5.8	0.16
Utility PV	4.40	2.3	0.11
OCGT	0.93	1.3	0.14
Pumped Hydro Storage (PHES)	3.50	8.3	0.40
Prosumer Batteries	6.60	4.7	0.14
Utility Batteries	6.60	4.4	1.20

* This represents total manufacturing, without local content factors.

B.2 Employment Factors

Employment factors are the second set of inputs to our jobs model. As discussed in Section B.1, new build energy capacities are multiplied by Employment Factors which characterise the levels of employment in various roles associated with manufacturing, constructing and operating various energy generation and storage technologies.

Employment factors were researched for the seven different generation technologies used in the Energy Model. They are derived from data from completed projects reported in the literature, which vary markedly by date and source. The range of employment factor data is discussed in ***Appendix A***, validated by personal communication with representatives of various renewable energy projects. The outcomes of this review are summarised in ***Table B.2***.

The majority of these employment factors were taken from Rutovitz et al. (2020). This work arose from a six month survey and interview process conducted in 2019 with renewable energy developers and supply chains. Survey numbers were collated, screened for accuracy with the elimination of low quality data, and corrected for jobs not typically included in renewable energy developments, such as warehousing and transport. This was obtained from survey data and interviews with a major supply chain company that works with renewable power industries.

B.3 Decline Factors

As discussed in Section B.1, a learning curve is associated with generation technologies, generally accepted to decline at a similar rate to the CAPEX decline rate for that technology (Ram et al., 2020).

Wind farms have also seen a decline in CAPEX per MW of power capacity. In 2010, 1.9 MW capacity turbines were installed at Collgar, the largest existing wind farm in WA. In 2019, the Badgingarra Wind Farm installed turbines from same vendor, Vestas, of 4.2 MW capacity. While the 4.2 MW turbines might well be more expensive, and the labour and transport for installing them greater than the 1.9 MW turbines, the labour will be less than double than that for the smaller turbines installed nine years earlier. This means significantly less labour per MW of installed capacity. Even more aggressive CAPEX declines have been seen for solar PV systems and PV farms in Australia over the past 5 to 10 years.

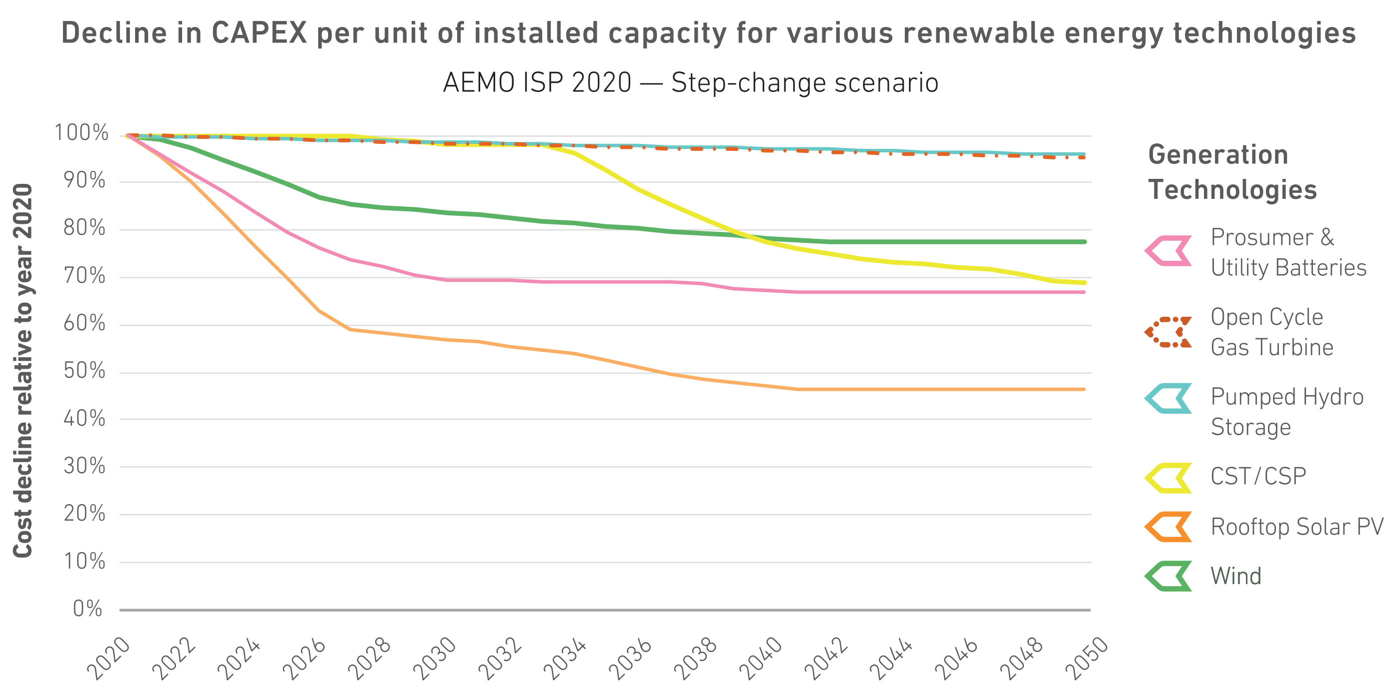


Figure B.3 Trends in Decline Factors for different technologies.

This growth in capacity for a given CAPEX, and labour associated with commissioning it, is characterised in the literature as a Decline Factor (DF). It can be expressed as a proportion of the labour (%) in a future year to that of a base year where the employment factor is known.

Similarly, due to improvements in PV panel and wind turbine reliability and life expectancy, the operations and maintenance (O&M) jobs associated with a MW of installed capacity is going to be lower for the life of that installed capacity than the same installed capacity ten years earlier.

Ram et al., (2019) used international Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) predictions to calculate Decline Factors in 5 year time segments out to 2050. In this work, we used contemporary Australian CAPEX and OPEX predictions from AEMO and CSIRO (Graham et al., 2019). Taking 2020 as the base year, the Decline Factor for year ***n*** is the ratio of the CAPEX or OPEX, respectively, of year ***n*** divided by the base year.

Some of the Decline Factors used in our modelling are shown in ***Figure B.3***. The decline factors for Coal, CCGT and Pumped Hydro are indistinguishable from OCGT, so are not displayed, for simplicity. The same argument applies to decline factors of both types of battery storage and both types of PV generation.

Figure B.3 shows that the technology learning curve for PV is strongest, with more than 50% efficiency gains to be expected by the 2040s. Battery technologies are expected by AEMO to become ~30% more efficient over this period, and wind technology ~20%. Our view is these are very conservative projections, in particular with regard to batteries storage.

It is important to note that Decline Factors will progressively reduce the employment per MW installed over time. It is not clear why CSIRO assumes costs will plateau for most of these technologies in the 2040s.

Table B.3 Local content factors for each technology. From (Rutovitz et al., 2020).

Technologies	**Construction Time** [years]	**Local Manufacturing Component** [%]
Wind Onshore	1.8	22.2%
Rooftop PV	1	3.5%
Utility PV	1	4.7%
OCGT	1	20.0%
Pumped Hydro	4	20.0%
Battery Utility	1	5.0%
Battery Prosumer	1	5.0%

B.4 Local Manufacturing Content

Employment from Manufacturing is multiplied in ***Figure B.2*** by a Local Content Factor.

Not all renewable electricity components can be manufactured in WA, e.g. wind turbines and solar panels. However, some components (e.g. wind turbine pylons and solar PV framing) could be manufactured in WA, as well as footing reinforcement, ground mount fixings, and assembly of transmission towers.

Table B.3 lists the estimated average Australian construction time for each technology, as well as the Local Content Factor for each of the technologies considered here. The local content factors are derived from a comprehensive review of RE construction projects in Australia in 2019 (Rutovitz et al., 2020).

Given Australia's relatively small market, and lack of manufacturing capacity, local content factors are relatively small. WA's local manufacturing base is relatively small, arguably smaller than in Eastern states. Local content factors may, therefore, be overestimated for the WA context.

Rutovitz et al. (2020) surveyed companies which supply local content to wind farm developers. ***Table B.4*** shows which componentry is manufactured in Australia, and which is manufactured elsewhere. The local content proportion is currently low, but need not stay like that, with a Government mandate.

Table B.4 Local content by percentage in surveyed wind farm developers From Rutovitz et al. (2020).

Component	% sourced onshore
Towers	14%
Blades	0%
Nacelles	0%
Inverters	0%
Grid connection/ cabling	71%
Control systems	12%
Concrete	100%
Transport Equipment	65%

Table B.5 Potential local content factors where the local manufacturing component has been doubled and quadrupled.

Local Manufacturing Factors			
Technologies	Multiplier		
	1x	2x	4x
Wind *	22.2%	44.4%	80.0%
Rooftop PV	3.5%	7.0%	13.9%
Utility PV	2.1%	4.2%	8.4%
Pumped Hydro Storage	20.0%	20.0%	20.0%
Prosumer Batteries	5.0%	10.0%	20.0%
Utility Batteries	5.0%	10.0%	20.0%

* Wind local content capped at 80% for 4x scenario

B.4.1 Modelling for Jobs Potential under Local Content Rules

A sensitivity model was created for local manufacturing, to investigate Western Australian manufacturing jobs under potential local content rules. The local content factors for Wind, Rooftop and Utility PV, and both Prosumer and Utility Batteries were doubled and then quadrupled to test the impact on manufacturing numbers, using the averages from Australia in ***Table B.3***, taken from Rutovitz et al. (2020).

The potential local content factors are shown in ***Table B.5*** for the RE technologies used in this report. Note that the quadrupled wind local content factor for Wind has been capped at 80%. Such a high figure is relatively unrealistic, but it underlines the scope and limitations of jobs potential for local content. No change has been made to Pumped Hydro local content across the three scenarios.

Table B.6 summarises the results of this sensitivity analysis. Starting with 782 manufacturing jobs in the base scenario, a doubling of local content adds 229 jobs, and a quadrupling of local content almost doubles manufacturing jobs. Under this scenario, total manufacturing jobs increase from 782 to 1,413, and total employment in 2030 rises from 8,837 to 9,468.

Table B.6 shows that local content factors have a relatively low influence on total RE employment. However, manufacturing employment is relatively highly skilled, and it provides for permanent jobs at higher pay rates. There is also a potential for manufacturing exports.

B.5 Decommissioning and Site Remediation.

The equations in *Figure B.2* include one for decommissioning obsolescent generating plants. This includes site remediation. Decommissioning factors for each technology are shown in *Table B.7*, drawn from Rutovitz et al. (2020) and Ram et al., (2019).

Decommissioning applies to fossil-fuel assets which are reaching their end of life. However, decommissioning also applies to RE assets will also reach their end of life. For instance, some wind and solar installations will reach end of life by 2036, and employment will accrue for decommissioning old RE assets, as well as constructing new ones.

Technology lifetimes are listed in *Table B.8*. Note that almost all the technologies shown in *Table B.8* have the same projected lifetime from 2015 to 2050. The only exceptions are Rooftop and Utility PV, where lifetimes are predicted to change in 2025 and 2040.

Table B.7 Decommissioning employment for each technology. From Ram et al., (2019) and Rutovitz et al. (2020).

Technologies	Decommissioning (Jobs/ MW)
Wind Onshore	0.72
Rooftop PV	1.21
Utility PV	0.80
Coal	1.65
OCGT	0.21
CCGT	0.21
Pumped Hydro	4.44
Battery Utility	0.80
Battery Prosumer	1.21

Table B.6 Changes in manufacturing and total employment to 2030 with a doubling and quadrupling of manufacturing jobs.

Scaling Factor	1x	2x	4x
Manufacturing Jobs	782	1,011	1,413
Total Jobs	8,837	9,066	9,468

Table B.8 Expected technology lifetime trends Taken from Ram et al., (2019)

Technologies	Lifetime		
	2015–24	2025–39	2040–49
Wind onshore	25	25	25
PV rooftop	30	35	40
PV Utility-scale	30	35	40
Coal	40	40	40
OCGT	35	35	35
CCGT	35	35	35
Pumped Hydro Storage (PHES)	50	50	50
Utility Battery Storage	20	20	20
Prosumer Battery Storage	20	20	20

Appendix C

Relationship Between Power Capacity and Employment

Image courtesy of Stockyard Hill Wind Farm, Goldwind Australia

The Clean Energy Council (2018a, 2019) publishes summary information about jobs in the renewable energy industry for each state. *Table C.1* lists state by state jobs data for 2018 and 2019, showing the number of jobs and investment. ***Figure C.1*** graphs jobs against MW capacity for 2018 and 2019 for each state. ***Figure C.2*** graphs jobs vs investment for the same set of projects.

Figure C.1 shows there is a strong a correlation between jobs and power capacity of renewable energy projects deployed, and between jobs and investment levels (per state). Jobs per MW appear to be lower in 2019 than 2018. The weighted averages are listed in ***Table C.1***, and reflect the slope of the trend lines.

Similarly, ***Figure C.2*** shows a linear relationship between total project investment in each state with total jobs in each state. In both figures, 2019 would appear to have less jobs than 2018 per investment and per capacity, in line with learnings and productivity gains.

This relationship, and the detailed industry studies that look more closely at these relationships are the basis for our jobs modelling. Given a certain level of capital outlay on various technologies we can confidently predict the direct jobs associated with their installation and construction, operations and maintenance and decommissioning at the end of their design lives.

Previous CEC studies (2016a) have compared jobs against capacity for individual projects. Analysis of these findings show that there is a wide variation in jobs/ MW in projects of the same technology and similar capacity, due to:

- variations in the basis used for reporting of employment numbers for each project
- differences in the way projects are structured
- variations in site geology and other conditions

A limitation of such summary data is that the length of individual job components that are reported is unknown. Some jobs might be associated with tasks as short as two weeks, while other jobs may last for the lifetime of the project (25-40 years). In other words, a 'job' is an unspecified unit of measure that gets interpreted and reported in different ways by each project proponent.

When averaged at the national and state levels, these different interpretations even themselves out so that states are somewhat in line with each other, showing a direct relationship, as seen in the 2018 and 2019 reports (Clean Energy Council, 2018a, 2019).

The outcome of this analysis is that more information is needed to form meaningful projections around real employment amounts. Academic analysis points to two concepts which enable this:

- The concept of job-years, described in Section B.1.1; and
- A breakdown of jobs into specific components, described in Section B.1.

Table C.1 Clean Energy Australia Reports of RE costs and deployment, 2018 & 2019 (Clean Energy Council, 2018a, 2019)

Clean Energy Council 2018 Report					
States	**Projects** [MW]	**Jobs**	**Investment** [$m]	**Jobs/MW**	**Jobs/$m**
Victoria	1,116	330	1,688	3.38	5.12
New South Wales	1,055	1,175	2,214	0.90	1.88
Queensland	2,121	3,196	4,091	0.66	1.28
Tasmania	116	200	280	0.58	1.40
South Australia	1,111	1,080	2,850	1.03	2.64
Western Australia	30	100	67	0.30	0.67
TOTAL	*5,549*	*6,081*	*11,190*	*0.91*	*1.84*
Unweighted Average				1.14	2.16
Range [min., max]				[0.3, 3.3]	[0.6, 5.1]

Clean Energy Council 2019 Report					
States	**Projects** [MW]	**Jobs**	**Investment** [$m]	**Jobs/MW**	**Jobs/$m**
VIC	3,140	2,894	5,034	1.09	1.74
NSW	3,800	2,320	4,714	1.64	2.03
QLD	4,941	4,681	10,003	1.06	2.14
TAS	262	358	580	0.73	1.62
SA	2,260	2,310	3,119	0.98	1.35
WA	395	500	945	0.79	1.89
TOTAL	*14,798*	*13,063*	*24,395*	*1.13*	*1.87*
Unweighted Average				1.05	1.79
Range [min., max]				[0.7, 1.6]	[1.3, 2.1]

Clean Energy Council Reports 2018 & 2019 jobs by capacity

Total project capacity by state

Figure C.1 Clean Energy Council Reports 2018 & 2019 job estimates, state total jobs by capacity for 2018 and 2019.

Clean Energy Council Reports 2018 & 2019 jobs by investment

Total project investment by state

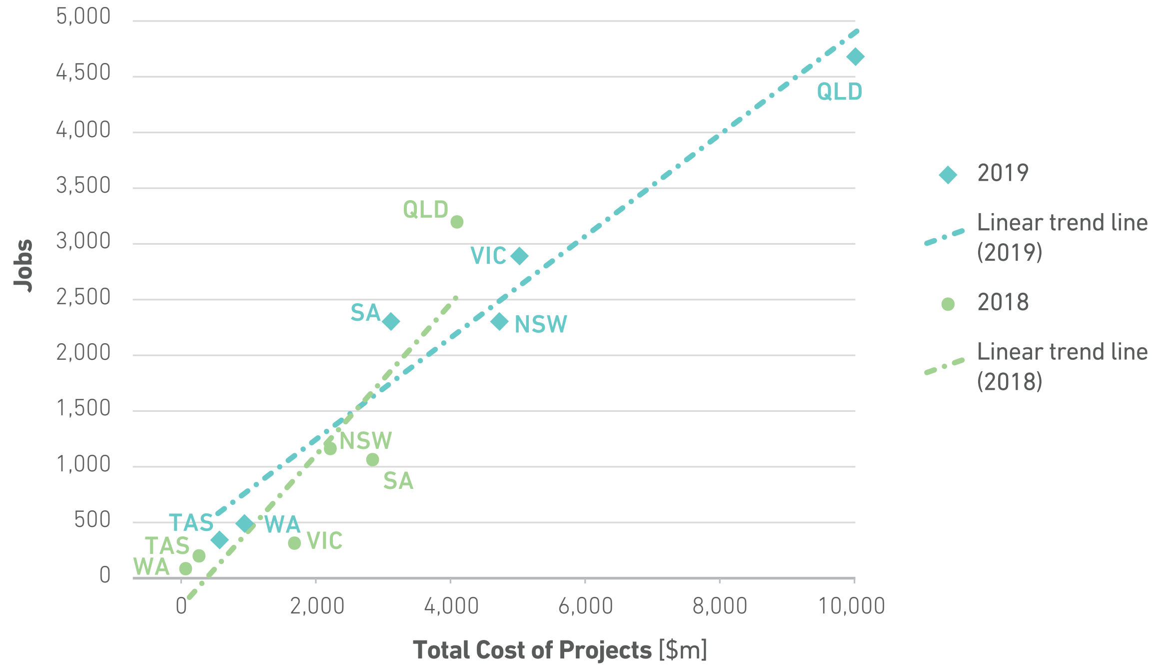


Figure C.2 Clean Energy Council Reports 2018 & 2019 job estimates, state total jobs by investment dollars for 2018 and 2019.

Appendix D

Review of Employment Factor Data

Image courtesy of General Electric

Employment factors were researched for the eight different generation technologies used in the Energy Model. Information was gained from published employment factors, published employment figures from completed renewable energy projects, with validation through speaking directly to stakeholders.

As discussed in Section B.2, employment factors have reduced over time, as part of the technology learning curve. For example, wind, solar and battery technologies all see significant learnings each year as engineers find smarter ways to get more efficiencies out of the technologies. Wind turbine rotors get larger, turbines are able to operate productively at bigger ranges of wind speeds and towers get higher, putting rotors into the path of more consistent wind. Any given size of wind farm can be developed with fewer turbines of a larger capacity. Consequently, labour costs are reduced, as the fewer, but larger, towers and turbines are constructed more quickly.

The technology learning curve has led to the employment factors selected in this work being at the lower end of the documented ranges.

D.1 Wind generation employment factors

Table D.1 summarises the most recent employment factor figures for wind generation. Some earlier figures were discarded because they were published 8-10 years ago, and the values were either outside the range of other values, or they had been updated by their original author. ***Table D.1***. contains employment factors for the three components of a generation facility: Manufacturing; Construction and Installation; and Operations and Maintenance, from various sources (Clean Energy Council, 2018b; Green Energy Markets, 2018; Ram et al., 2020; Rutovitz et al., 2020; Rutovitz et al., 2015; SKM, 2012).

The range of values is shown at the bottom of ***Table D.1***, and the variation is threefold for Manufacturing jobs, fourfold for C&I jobs, and 6-fold for O&M jobs. In Manufacturing jobs, there is a significant variation between pre-2016 data and more recent data. The most recent data from Rutovitz et al. (2020) was therefore used.

C&I jobs clustered around the range 2.8-3.2, with only the SKM (2012) data being greater. The lower end of this range was selected – an employment factor of 2.8. Some of the data indicates that C&I is decreasing for wind generation, e.g. Green Energy Markets (2018), and larger projects reported by the Clean Energy Council (Clean Energy Council, 2018b).

In terms of Wind Operations and Maintenance jobs, the dated SKM (2012) data is clearly an outlier. Of the other available values, a mid-range value of 0.22 jobs/ MW was chosen, from Rutovitz et al. (2020).

D.2 Photovoltaic generation employment factors

Employment factor information about Rooftop PV installations is sparse, as shown in ***Table D.2***. Ram et al., (2019) use data from Rutovitz et al. (2015), so the employment factors are based on 2015 data. Given the technology learning curve, the more recent Rutovitz et al. (2020) work appears to be more appropriate. An industry source (Edis, 2019) indicates that a C&I figure of 7.3 Job years/ MW may be too high, quoting a weighted average across four PV size ranges (to 100 kW) of 3.89 Job years/ MW.

Employment factor data for utility PV projects are shown in ***Table D.3***. Since the same solar panels are used for both rooftop and utility solar projects, Manufacturing employment factor information is the same as in ***Table D.2***, and the employment factor of 4.4 Job years/ MW was used.

Table D.1 Employment factor analysis for Wind generation

Source	Manufacturing [Job years / MW]	C&I [Job years / MW]	O&M [Permanent jobs / MW]
SKM (2012)	5.1	4.8	0.57
Rutovitz, Dominish, & Downes (2020)	4.7	3.2	0.30
Clean Energy Council Average Australian projects 90-270 MW (2018a)		1.8	
Clean Energy Council 2017 Average Australian projects <70 MW (2018a)		2.9	
Ram et al., (2019)†	4.7	3.2	0.30
Green Energy Markets (2018)	0.8*	1.2	0.10
Clean Energy Council (2020)	1.7	2.8	0.22
Range of values [min., max]	[1.7, 5.1]	[1.2, 4.8]	[0.10, 0.57]
Values selected in this study	*1.7*	*2.8*	*0.22*

* only including the Australian manufacturing component † Ram et al., (2019) use data from Rutovitz et al. (2015)

Table D.2 Employment factor analysis for Rooftop Solar PV

Rooftop Solar PV			
Source	Employment Category		
	Manufacturing [Job years / MW]	C & I [Job years / MW]	O & M [permanent jobs / MW]
Rutovitz et al. (2015)	6.7	13	0.7
Ram et al., (2019) *	6.7	26	1.4
Rutovitz et al. (2020)	4.4	5.8	0.16
Range of values [min., max]	[4.4, 6.7]	[5.8, 26]	[0.16, 1.4]
Values selected in this study	*4.4*	*7.3*	*0.22*

* Ram et al., (2019) use data from Rutovitz et al. (2015) and scale rooftop PV C&I jobs by 2.

More employment factor data is available for construction and installation for utility PV projects. The 2015 value of 13 Job years/ MW, used by (Ram et al., 2020; Rutovitz et al., 2015), is clearly a historical outlier. The remaining values range between 1.4 & 3.5, with employment factors decreasing inversely to the size of a project. Once again, we have chosen the most recent employment factor of 2.3 Job years/ MW from Rutovitz et al. (2020).

Once the historical outlier from Rutovitz et al. (2015) is discarded, the two other sources of O&M Jobs are only 10% apart, and the 0.11 Jobs/ MW of Rutovitz et al. (2020) was chosen for consistency.

D.3 Employment factors for other generation technologies

Employment factors for the other generation technologies used in this report are shown in ***Table D.4***. Only one or two sources are available for each technology. Where available, the Rutovitz et al. (2020) values, based on real data from Australia, are used. Where this is not available, the values from Ram et al., (2019) are used.

Table D.3 Employment factor analysis for Utility Solar PV

Utility Solar PV			
Source	**Employment Category**		
	Manufacturing [Job years / MW]	**C & I** [Job years / MW]	**O & M** [permanent jobs / MW]
Rutovitz et al. (2015)	6.7	13	0.70
Clean Energy Council, 2017 Average Australian projects 15 -20 MW (2018a)		3.5	
Clean Energy Council, 2017 Average Australian projects 50-150 MW (2018a)		1.9	
Clean Energy Council, 2017 Average Australian projects >300 MW, (2018a)		1.4	
Ram et al., (2019)*	6.7	13	0.70
Green Energy Markets (2018)		2.2	0.10
Rutovitz et al. (2020)	4.4	2.3	0.11
Range of values [min., max]	[4.4, 6.7]	[1.4, 13]	[0.10, 0.70]
Values selected in this study	*4.4*	*2.3*	*0.10*

*Ram et al., (2019) use data from Rutovitz et al. (2015)


Image courtesy of Keppel Prince

Table D.4 Employment factor analysis for Utility Solar PV

Utility Scale Batteries			
Source	Employment Category		
	Manufacturing [Job years / MW]	**C & I** [Job years / MW]	**O & M** [permanent jobs / MW]
Ram et al., (2019)	16.9	10.8	0.4
Rutovitz et al. (2020)	6.6	4.7	1.2
Values selected in this study	*6.6*	*4.7*	*1.2*

Prosumer Batteries			
Source	Employment Category		
	Manufacturing [Job years / MW]	**C & I** [Job years / MW]	**O & M** [permanent jobs / MW]
Ram et al., (2019)	16.9	21.6	0.8
Rutovitz et al. (2020)	6.6	4.4	0.21
Values selected in this study	*6.6*	*4.4*	*0.21*

Pumped Hydro Energy Storage (PHES)			
Source	Employment Category		
	Manufacturing [Job years / MW]	**C & I** [Job years / MW]	**O & M** [permanent jobs / MW]
Ram et al., (2019)	7	14.8	0.4
Rutovitz et al. (2020)	3.5	8.3	0.18
Values selected in this study	*3.5*	*8.3*	*0.18*

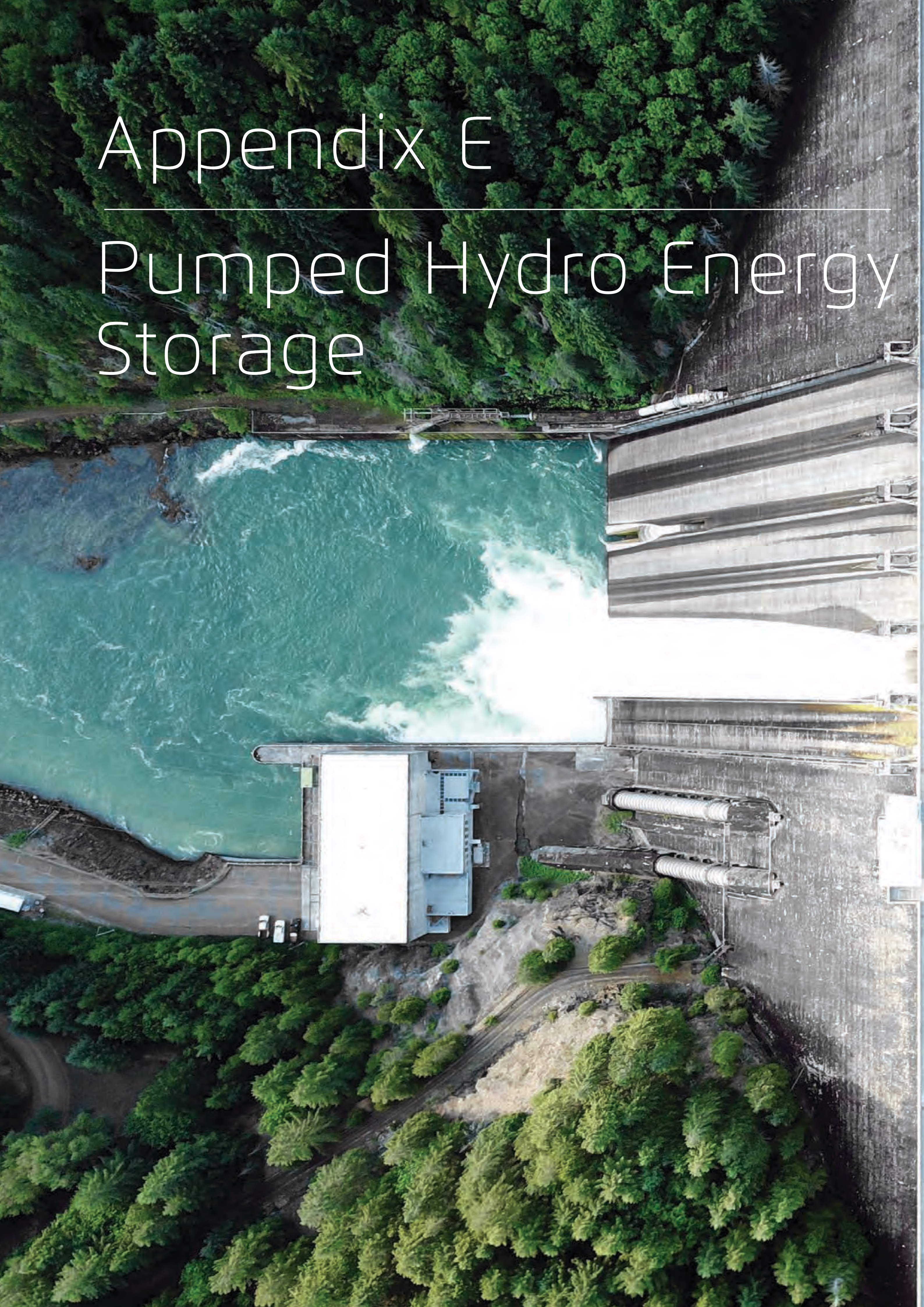
Concentrated Solar Thermal with Storage (CST+S)			
Source	Employment Category		
	Manufacturing [Job years / MW]	**C & I** [Job years / MW]	**O & M** [permanent jobs / MW]
Ram et al., (2019)	4	8	0.6
Values selected in this study	*4*	*8*	*0.6*

Open Cycle Gas Turbines (OCGT)			
Source	Employment Category		
	Manufacturing [Job years / MW]	**C & I** [Job years / MW]	**O & M** [permanent jobs / MW]
Ram et al., (2019)	0.93	1.3	0.14
Values selected in this study	*0.93*	*1.3*	*0.14*

Image courtesy of Keppel Prince

Appendix E

Pumped Hydro Energy Storage



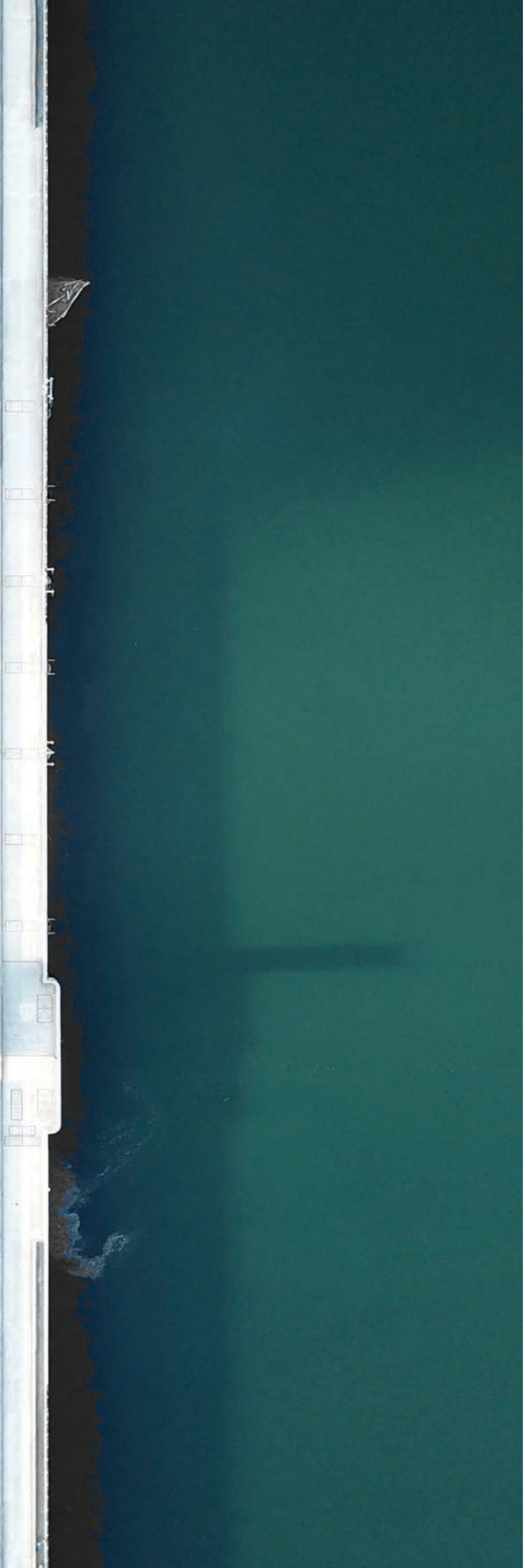


Image courtesy of unsplash.com, Dan Meyers

Pumped Hydroelectricity Energy Storage (PHES) uses surplus RE to pump water from a low reservoir to a high reservoir, for subsequent release when needed, through a hydroelectric generator. This storage technology enables a large amount of energy to be stored and to be converted into electricity relatively quickly. Our view is that although environmental aspects need careful consideration, PHES in certain locations can be an important storage component for the SWIS, with the added advantage that construction employment is relatively high.

An ANU report (A. Blakers et al., 2017; A. Blakers, Stocks, Lu, Anderson, & Nadolny, 2018) identified potential pumped-hydro sites in Australia, based on contour maps and satellite data. A. Blakers et al. (2018) used a head threshold of 200m in WA, in their algorithm for identifying suitable sites. This is lower than the 300 m used in other states, due to WA's flatter topography.

Where natural upper and lower reservoirs are not available, 'turkey-nest' construction methods can be used to build dam walls from land excavated in the middle of the storage pond. This method is what A. Blakers et al. (2018) proposed for Collie (***Figure E.1***) on the existing mine site.

Many other sites with significantly more total PHES capacity than we are projecting were identified by A. Blakers et al. (2018) in South-West WA. It is beyond the scope of this report to do detailed site pre-feasibility work, but the gross potential for PHES within the extent of the SWIS is for orders of magnitude more storage than required in Western Australia to go to 100% RE.

Figure E.2 shows a collection of potential upper reservoirs surrounding Collie which would result in energy storage of 5 GWh and a head of about 200m. The image shows three potential upper reservoir sites. Expansion beyond 5 GWh is not practical.

Harvey Reservoir, shown in ***Figure E.3***, has capacity of 56 GL. The upper reservoir is located about 3km to the NE. The head is 180m. This site could be expanded to 15 GWh but it would then require most of the volume of the Harvey reservoir. It is located close to an existing 330 kV transmission line.

Wellington reservoir, shown in ***Figure E.4***, has a capacity of 185 GL and is no longer used for water supply due to salinity levels. Good lower reservoirs with high water to rock ratio can be built to the west of the reservoir that enable a head of 150m. The reservoir volume required for 5 GWh of storage is then around 16 GL. The lower reservoir is approximately 10km from the nearest point of the upper reservoir.

Figure E.1 Conceptual Pumped Hydro installations in repurposed Collie coal mines. Image sourced from A. Blakers et al. (2018).

There is a range of class C, D and E greenfield sites south of Perth, much more than required to stabilise 100% renewable energy on the SWIS. Selection criteria and conservation issues are discussed below.

5 GWh/ 18h: https://nationalmap.gov.au/renewables/#share=s-8LWP8W9cxwyRKKEX

15 GWh/ 18h: https://nationalmap.gov.au/renewables/#share=s-8JROl6haRiOFYxvr

50 GWh/ 18h: https://nationalmap.gov.au/renewables/#share=s-8Sb6UyOYAFadqXz1

Further opportunities exist for 'cliff-ocean' storage north of Geraldton and east of Albany, which have height differentials in excess of 100m on degraded land. This could well complement the good wind resources in those areas and potentially improve the utilisation of transmission lines to/ from those areas to the main load centre of Perth.

Figure E.3 Harvey Reservoir incorporated in a PHES scheme with various potential storage capacities. Image is a screenshot from the ARENA Global Atlas (A. Blakers et al., 2018).

Figure E.2 Conceptual Pumped Hydro installations in repurposed Collie coal mine indicating three potential upper pond locations and a lower pond in the central of the image. Image provided by Professor Andrew Blakers for this report (A. Blakers, 2020).

Photographer: Jason Thomas Image courtesy of Alinta and RATCH Australia.

E.1 Environmental issues

For various reasons, the brownfield sites identified above may not proved to be suitable opportunities for PHES once detailed feasibility studies have been completed. However, the ARENA Global PHES Atlas built by Prof Blakers and his team (2018) has identified a large number of sites of varying scales (5 GWh to 150 GWh) on the Darling Scarp.

Most of the preferable sites for lower ponds are on previously cleared land, while most of the upper pond sites are existing water bodies or potential dams on partially cleared or forested land. Selection criteria would need to be established after consulting relevant local conservation experts since the impacts of climate change and clearing have so far been more pronounced in that part of the region when compared to the forest regions as a whole.

The combination of clearing and rainfall decline has also resulted in ongoing significantly reduced groundwater and stream flows in the region, and therefore this habitat is already under climate change pressure. However, this region is currently subject to extensive clear felling for bauxite, gold and to produce woodchips and GHG-intense fuels.

The environmental gains of moving to 100% renewables would have to be pragmatically weighed up against localised habitat destruction. This would need the involvement of local communities and conservation experts. Concerns such as local hydrology, forest health, habitat and connectivity, and any site specific values, and a preference for using heavily cleared and/ or degraded habitat would apply.

Potentially large areas of high conservation value Northern Jarrah forest might be put into secure conservation reserves such that the extensive mineral and wood pulp resource extraction currently occurring on the Darling Scarp are precluded. This would mitigate the environmental damage that PHES projects can bring.

The Snowy 2.0 project that is likely to proceed in Mt Kosciusko National Park in NSW has 44 times the storage capacity we are modelling in this project, for a sense of scale. We may achieve better conservation outcomes in WA with PHES than those that Snowy 2.0 is offering, albeit at a vastly reduced scale.

Figure E.4 Image is a screenshot of Wellington Reservoir from the ARENA Global Atlas (A. Blakers et al., 2018).

Bibliography

Photo of Berrybank Wind Farm provided by Naturgy Group, Berrybank Wind Farm

Asian Renewable Energy Hub. (2017). Renewable Energy at Oil & Gas Scale. Retrieved from https://asianrehub.com/

Australian Energy Market Operator. (2013). 100 per cent renewables study: Modelling outcomes. Retrieved from https://publications.industry.gov.au/publications/climate-change/system/files/resources/d67/100-percent-renewables-study-modelling-outcomes-report.pdf

Australian Energy Market Operator. (2019). 2019 forecasting and planning scenarios, inputs, and assumptions. Retrieved from https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/2019-20-Forecasting-and-Planning-Scenarios-Inputs-and-Assumptions-Report.pdf

Australian Manufacturing. (2017). Keppel Prince Engineering expands wind tower manufacturing capacity. Retrieved from https://www.australianmanufacturing.com.au/43954/keppel-prince-engineering-expands-wind-tower-manufacturing-capacity

Australian PV Institute. (2019). PV Postcode Data. Retrieved from https://pv-map.apvi.org.au/postcode

Beyond Zero Emissions. (2010). Stationary Energy Plan. Retrieved from http://bze.org.au/stationary-energy-plan/

Beyond Zero Emissions. (2018). Electrifying Industry. Retrieved from https://bze.org.au/research/manufacturing-industrial-processes/electrifying-industry/

Beyond Zero Emissions. (2019). Collie at the Crossroads: Planning a future beyond coal. Retrieved from https://bze.org.au/wp-content/uploads/Collie-at-the-Crossroads.pdf

Blakers, A. (2020). [(Pers. Comm.) Viable Pumped Hydro locations in SW WA].

Blakers, A., Lu, B., & Stocks, M. (2017). 100% renewable electricity in Australia. Energy Science and Engineering, 133(15 August), 471-482.

Blakers, A., Stocks, M., Lu, B., Anderson, K., & Nadolny, A. (2018). Sites for pumped hydro energy storage. Retrieved from http://re100.eng.anu.edu.au/research/phes/

Bloomberg New Energy Finance. (2015). Australian large-scale PV data. Retrieved from https://www.aemo.com.au/-/media/Files/XLS/2015_08_05-BNEF--Solar-PV-cost-data.xlsx

Bureau of Resource and Energy Economics. (2013). Australian Energy Technology Assessments. Retrieved from https://archive.industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/aeta/AETA-Update-Dec-13.pdf

Clean Energy Council. (2016a). Clean Energy Australia Report 2016. Retrieved from https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2016.pdf

Clean Energy Council. (2016b). Power Shift: A blueprint for a 21st century energy system. Retrieved from https://www.cleanenergycouncil.org.au/resources/resources-hub/power-shift-a-blueprint-for-a-21st-century-energy-system

Clean Energy Council. (2018a). Clean Energy Australia Report 2018. Retrieved from http://www.cleanenergycouncil.org.au/policy-advocacy/reports/clean-energy-australia-report.html.

Clean Energy Council. (2018b). Project Tracker. Retrieved from https://www.cleanenergycouncil.org.au/resources/project-tracker

Clean Energy Council. (2019). Clean Energy Australia Report 2019. Retrieved from https://assets.cleanenergycouncil.org.au/documents/resources/reports/clean-energy-australia/clean-energy-australia-report-2019.pdf

Clean Energy Council. (2020). Clean Energy at Work. Retrieved from Institute for Sustainable Futures, University of Technology Sydney: https://www.cleanenergycouncil.org.au/resources/resources-hub/clean-energy-at-work

Climate Works. (2016). Gas-electricity substitution projections to 2050. Retrieved from https://www.energynetworks.com.au/resources/reports/gas-electricity-substitution-projects-to-2050/

Department of Industry Science Energy and Resources. (2021). Technology Investment Roadmap Discussion Paper Retrieved from https://consult.industry.gov.au/climate-change/technology-investment-roadmap/supporting_documents/technologyinvestmentroadmapdiscussionpaper.pdf

Department of Primary Industries and Regional Development. (2019). Western Australian Renewable Hydrogen Strategy. Retrieved from http://www.drd.wa.gov.au/Publications/Documents/wa_renewable_hydrogen_strategy.pdf

Department of Water and Environmental Regulation. (2019). Issues Paper: Climate Change in Western Australia. Retrieved from https://consult.dwer.wa.gov.au/climatechange/issues-paper/user_uploads/climate-change-in-wa_2019.pdf

Edis, T. (2019). [(Pers. Comm.) Green Energy Markets' review of renewable construction costs].

Energy Transformation Taskforce. (2019). Distributed Energy Resources Roadmap. Retrieved from https://www.wa.gov.au/sites/default/files/2020-04/DER_Roadmap.pdf

Government of South Australia. (2020). Clean Energy Transition. Retrieved from http://www.energymining.sa.gov.au/clean_energy_transition

Government of Western Australia. (2019a). Distributed Energy Resources Roadmap. Retrieved from https://www.wa.gov.au/sites/default/files/2020-04/DER_Roadmap.pdf

Government of Western Australia. (2019b). Energy Transformation Strategy. Retrieved from https://www.wa.gov.au/organisation/energy-policy-wa/energy-transformation-strategy

Government of Western Australia. (2019c). Whole of System Plan Modelling Scenarios. Retrieved from https://www.wa.gov.au/sites/default/files/2019-08/Information-paper-Whole-of-System-Plan-Modelling-Scenarios.pdf

Graham, P., Hayward, J., Foster, J., & Havas, L. (2019). GenCost 2019-20: preliminary results for stakeholder review. Retrieved from ustralia: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/CSIRO-GenCost2019-20_DraftforReview.pdf

Green Energy Markets. (2018). Renewable Energy across Queensland's Regions. Retrieved from http://greenmarkets.com.au/images/uploads/GEM%20Reports/Industry%20Reports/Renewable_Energy_Across_Qld_Regions.pdf

Lazard. (2017). Levelized Cost of Energy 2017. Retrieved from https://www.lazard.com/perspective/levelized-cost-of-energy-2017/

Lazard. (2019, 7 Nov 2019). Levelized Cost of Energy and Levelized Cost of Storage 2019.

Lord, M. (2019a). Addendum to 'From Mining to Making': Western Australia's economic and employment opportunities from zero-carbon metals production.

Lord, M. (2019b). From mining to making: Australia's future in zeroemissions metal. Retrieved from *https://www.energy-transition-hub.org/files/resource/attachment/zero_emissions_metals.pdf*

Maisch, M. (2019). South Australia's third big battery energized. Retrieved from *https://www.pv-magazine-australia.com/2019/10/11/south-australias-third-big-battery-energized/*

Mazengarb, M. (2019). Another nail in coal's coffin? German steel furnace runs on renewable hydrogen in world first. Renew Economy. Retrieved from *https://reneweconomy.com.au/another-nail-in-coals-coffin-german-steel-furnace-runs-on-renewable-hydrogen-in-world-first-55906/*

Mazengarb, M. (2020, 6 May). Garnaut: Australia will lose competitive advantage if no clean energy transition. Renew Economy. Retrieved from *https://reneweconomy.com.au/garnaut-australia-will-lose-competitive-advantage-if-no-clean-energy-transition-83396/*

Mazengarb, M. (2019, 21 June). Berrybank wind farm begins construction with turbines made locally in old car factory. Retrieved from ***https://reneweconomy.com.au/berrybank-wind-farm-begins-construction-with-turbines-made-locally-in-old-car-factory-16297/***

Micallef, N. Naturgy Group (2020) [(Per. Comm.) Local content committements made by Global Power Generation for the construction and operations phase at BerryBank Wind Farm, Vicotria.]

Parkinson, G. (2018, 21 September 2018). True cost of Tesla big battery, and its government contract. Renew Economy. Retrieved from *https://reneweconomy.com.au/revealed-true-cost-of-tesla-big-battery-and-its-government-contract-66888*

Parkinson, G. (2019, 17 June 2019). South Australia's stunning aim to be "net" 100 per cent renewables by 2030. Renew Economy. Retrieved from *https://reneweconomy.com.au/south-australias-stunning-aim-to-be-net-100-per-cent-renewables-by-2030/*

Parkinson, G. (2020, 13 May 2020). BP looks to add 1.5 GW wind and solar for huge renewable hydrogen project in W.A. Renew Economy. Retrieved from *https://reneweconomy.com.au/bp-looks-to-add-1-5gw-wind-and-solar-for-huge-renewable-hydrogen-project-in-w-a-45931/*

Ram, M., Aghahosseini, A., & Breyer, C. (2020). Job creation during the global energy transition towards 100% renewable power system by 2050. Technological Forecasting & Social Change, 151(119682), 1-19.

Ram, Manish & Aghahosseini, Arman. (2019). Job creation during the global energy transition towards 100% renewable power system by 2050. Technological Forecasting and Social Change. Retrieved from *https://www.researchgate.net/publication/334359425_Job_creation_during_the_global_energy_transition_towards_100_renewable_power_system_by_2050*. See also Supplimentary Material link on bottom of page.

Rutovitz, J., Briggs, C., Dominish, E., & Nagrath, K. (2020). Renewable Energy Employment in Australia: Methodology. Prepared for the Clean Energy Council by the Institute for Sustainable Futures, University of Technology Sydney. Retrieved from *https://assets.cleanenergycouncil.org.au/documents/resources/reports/Clean-Energy-at-Work/Institute-for-Sustainable-Futures-renewable-energy-jobs-methods-report.pdf*

Rutovitz, J., Dominish, E., & Downes, J. (2015). Calculating Global Energy Sector Jobs: 2015 Methodology Update. Retrieved from *https://opus.lib.uts.edu.au/bitstream/10453/43718/1/Rutovitzetal2015Calculatingglobalenergysectorjobsmethodology.pdf*

SKM. (2012). Benefit of the Renewable Energy Target to Australia's Energy Markets and Economy, Report to the Clean Energy Council. Retrieved from *https://core.ac.uk/download/pdf/30678054.pdf*

Sustainable Energy Now. (2016). Clean Energy WA Study. Retrieved from *https://www.sen.asn.au/clean_energy_wa_study*

Sustainable Energy Now. (2017a). Renewable Electricity in WA: A Jobs Revolution. Retrieved from *https://bit.ly/2R0nRhS*

Sustainable Energy Now. (2017b). Renewable Electricity in WA: the Economic Argument. Retrieved from *https://bit.ly/2LgCw8I*

Teske, S., Dominish, E., Ison, N., & Maras, K. (2016). 100% Renewable Energy for Australia: Decarbonising Australia's energy sector within one generation. Retrieved from *https://www.uts.edu.au/sites/default/files/article/downloads/ISF_100%25_Australian_Renewable_Energy_Report.pdf*

Vorrath, S. (2019, 26 September 2019). Vestas wind turbine assembly plant opens at old Ford factory in Victoria. Renew Economy. Retrieved from *https://reneweconomy.com.au/vestas-wind-turbine-assembly-plant-opens-at-old-ford-factory-in-victoria-20839/*

Vorrath, S. (2020, 16 April 2020). Australians installed 22,661 home battery systems in 2019. Renew Economy. Retrieved from *https://reneweconomy.com.au/australians-installed-22661-home-battery-systems-in-2019/*

Wood, T., & Dundas, G. (2020). Start with steel: A practical plan to support carbon workers and cut emissions. Retrieved from *https://grattan.edu.au/wp-content/uploads/2020/05/2020-06-Start-with-steel.pdf*

SEN Jobs Report 2020

This analysis and report focusses on new jobs resulting from the transition to Renewable Energy (RE) within the South West Interconnected System (SWIS) system. The vision presented in this report is premised on reaching 90% of electricity provided by clean energy in the SWIS in 2030 (including rooftop energy behind the meter).

Our modelled transition to 90% RE by 2030 determined the following direct jobs:

- **55,100 job-years (2020-30) with an average of 5,000 jobs per annum.**
- **8,600 FTE jobs in 2030 of which approximately 2,700 would be ongoing operations and maintenance jobs.**
- **Approximately 50-60% of the jobs created can be in regional areas.**

Analysis of independent industry information on jobs created from the installation of new RE in Australia shows two major RE job categories will be created:

- **Repeat construction work for anything up 24 months per project, followed by**
- **Ongoing long-term operations and maintenance work.**

There will also be jobs created from the closure and rehabilitation of existing carbon-based energy systems such as the Muja power plants.

Resources developments in WA have shown that the construction work for new projects has become an industry in itself. This analysis indicates that something as significant as the transition to high levels of RE will create a sustainable RE construction industry.

Cover image courtersy of ACCIONA Australia

Sustainable Energy NOW