DEPARTMENT OF PLANNING, INDUSTRY AND ENVIRONMENT

JUNE 2021

TECHNICAL STUDY REPORT

ENGINEERING – RENEWABLE ENERGY

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GLOSSARY

Investigation Area	The investigation area for the Snowy Mountains SAP, encompassing an area of 72,211 ha including Jindabyne and the Alpine Resorts of Kosciuszko National Park.
Monero Ngarigo	Aboriginal linguistic group who traditionally occupied the eastern side of the Kosciuszko plateau and further north towards the Murrumbidgee River.
Snowy Mountain	The highest mountain range on the continent of mainland Australia, located in southern New South Wales and part of the larger Australian Alps and Great Dividing Range. The mountain range experiences large natural snowfalls every winter.
Special Activation Precinct	A Special Activation Precinct is a dedicated area in a regional location identified by the NSW Government to become a thriving business hub to create jobs, attract business and investors, support local industries and fuel economic development.

ABBREVIATIONS

ABS	Australian Bureau of Statistics
AC/ac	Alternating current
ACT	Australian Capital Territory
AD	Anaerobic Digestion
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AREMI	Australian Renewable Energy Mapping Infrastructure
ARENA	Australian Renewable Energy Agency
AS	Australian Standard
AUD	Australian Dollars
BECCS	Bioenergy with Carbon Capture and Storage
BESS	Battery Energy Storage System
BOM	Bureau of Meteorology
c	Cents (Australian dollar)
°C	Degrees Celsius
CBD	CBD
CHP	Combined Heat and Power
DAC	Direct Air Capture
DAPR	Distribution Annual Planning Report
DC	Direct Current
DER	Distributed Energy Resources
DEIP	Distributed Energy Integration Program
DNSP	Distribution Network Service Provider
DPIE	NSW Department of Planning, Industry and Environment
DRNSW	Department of Regional New South Wales
EbD	Enquiry by Design
EPA	Environment Protection Authority
EV	Electric Vehicle
FCAS	Frequency Control Ancillary Services

FY	Financial Year
GE	General Electric (company)
GIS	Geographic Information System
GJ	Giga Joules
GHI	Global Horizontal Irradiance
GL	Giga Litre
GSHP	Ground Source Heat Pump
GHG	Green House Gas
GST	Good and Services Tax
GWh	Giga Watt hours
H_2	Hydrogen
ha	Hectare
HNSW	Heritage New South Wales
HPV	Hydrogen Powered Vehicle
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IWCMP	Integrated Water Cycle Management Plan
kg	Kilogram
kL	Kilo Litre
km	Kilo metre
KNP	Kosciuszko National Park
KNP POM	Kosciuszko National Park Plan of Management
kV	Kilovolt
kVA	Kilovolt-ampere
kW	Kilowatt
kW_e	Kilowatt Electrical
KW_{TH}	Kilowatt Thermal
LCOE	Levelised Cost of Electricity
LGA	Local Government Area
LGC	Large-Scale Generation Certificates
LV	Low voltage

LVR	Low Voltage Regulator
m	Metre
mm	Milli Metre
MERRA	Modern-ERA Retrospective Analysis for Research and Applications
MJ	Mega Joule
MLF	Marginal Loss Factor
ML	Mega Litre
m/s	Metre per second
MV	Medium voltage
MW	Megawatt
MWp	Megawatt Peak
MVA	Mega Volt Ampere
MWh	Megawatt-hour
MWh_e	Megawatt-hour electric
MWp	Megawatt-Peak
NA	Not Available (Publicly)
NEM	National Electricity Market
Nm^3/h	Normal-Metre cube per hour
NPWS	National Parks and Wildlife Service
NRM	Natural Resource Management
NRMA	National Roads and Motorists' Association (Company)
NSP	Network Service Provider
NSW	New South Wales
OLTC	On-load tap changer
OpEN	Open Energy Networks
P50/P90/P99	50% (or 90% or 99% as applicable) probability of exceedance
PLC	Programmable Logic Controller
PPA	Power Purchase Agreement
PV	Photovoltaic
RAP	Registered Aboriginal Party
REC	Renewable Energy Certificate

RGDC	Regional Growth NSW Development Corporation
RET	Renewable Energy Target
SA	South Australia
SAP	Special Activation Precinct
SEPP	State Environment Planning Policy
SMRC	Snowy Monaro Regional Council
SRSC	Snowy River Shire Council
STCs	Small-scale Technology Certificates
STS	Sub transmission
STTM	Short Term Trading Market
SWOT	Strength, Weakness, Opportunities and Threat (analysis)
TfNSW	Transport for New South Wales
tpa	Tonne per annuum
UPS	Uninterruptible Power Supply
USD	United States Dollars
V	Volt
VIC	Victoria
VPP	Virtual Power Plant
W	Watt
Wp	Watt peak
WTG	Wind Turbine Generators
W_{TH}	Watt-Thermal
ZS	Zone Substation

EXECUTIVE SUMMARY

The NSW Government's Department of Planning, Industry and Environment (DPIE) has engaged WSP to conduct a technical study for the renewable energy opportunities in the Snowy Mountain region for the Snowy Mountains Special Activation Precinct (SAP) project. This report will inform the streamlined planning process for fast-tracking future development of the Snowy Mountains SAP by considering the renewable energy opportunities and constraints of the Snowy Mountains SAP.

WSP started the Project with the assessment of opportunities and constraints for the following renewable energy technologies to identify the suitable technologies for the development which will support the vision and aspirations of Snowy Mountains SAP. We have also undertaken the assessment of existing renewable energy infrastructure and electrical grid infrastructure in the region in the context of Snowy Mountains SAP.

- Biomass Energy
- Biogas (energy from waste)
- Solar Energy
- Wind Energy
- Hydro Energy
- Geothermal Energy
- Hydrogen.

Following the SWOT analysis based on the findings of the context analysis and input from stakeholders, WSP shortlisted and assessed the following opportunities:

TECHNOLOGY	DETAILS AND KEY CONSIDERATIONS
Large scale solar PV farms	— Three options of large-scale solar farms have been identified. — 2x10 MW solar farms identified in East Jindabyne. One of these options is more favourable because of its close proximity to a grid connected substation (66/11 kV Jindabyne East S/S). — 1x27 MW solar farm identified towards the south-east boundary of the Snowy Mountains SAP. The distance (aerial route) of Option 3 from the Jindabyne 66/33/11 kV Substation is 8.4 km. Typically solar farm developers would prefer to develop a solar farm in close proximity to the grid connection point, as a long transmission line requirement may add a number of technical, financial, legislative and project execution constraints or complexities. — An upgrade of substation infrastructure is not expected to be required from the thermal limitation perspective. — Establishing support mechanisms in the Snowy Mountains SAP to aggregate investors and to facilitate power purchase agreements between consumers and solar developers will significantly expedite the deployment of larger scale systems in the region.
Distributed Generation – Rooftop/Car park Solar PV	Rooftops and large open car park areas within the Snowy Mountains SAP alpine resorts and Jindabyne town could be used for the installation of solar PV systems with no additional land requirement. The potential PV capacity is expected to increase as the Snowy Mountains SAP area continues to develop. We have assessed the indicative capacity estimation throughout the Snowy Mountains SAP upon completion of the development of the Snowy Mountains SAP. Indicative

TECHNOLOGY	DETAILS AND KEY CONSIDERATIONS
	estimates of the distributed rooftop solar PV in the Jindabyne town area upon completion of the Snowy Mountains SAP development will be ~59.16 MWp. A pre-approval process is recommended to streamline the grid connection process by engaging with local utilities and local retailers to discuss any grid/economic constraints for connection. A feed-in-tariff structure is recommended to simplify the investment option for small end users. It is also recommended that high level engagement with energy retailers located near the Snowy Mountains SAP be undertaken to provide assistance to negotiate favourable feed-in tariffs.
Renewable Energy Power Purchase Agreement (PPA)	There is a huge opportunity to combine all the energy consumers within the Snowy Mountains SAP in to one consortium and enter into a SAP level PPA with Snowy Hydro. Accredited renewable energy purchase will support Snowy Mountains SAP's sustainability aspirations and supply green and cheaper electricity to the consumers. There are some challenges which make management of the Snowy Mountains SAP level consortium complex and difficult due to the large number of members being small consumers. However, the precedents of similar contracts demonstrate the strong potential for an SAP level PPA.
Geothermal Energy	Numerous buildings in the area may be suitable for geothermal retrofitting. Once installed, these systems can be installed either to provide heating and cooling, or to augment the existing air conditioning system while consuming reduced energy. Little information, however, has been found on the geothermal resource as deep underground exploration can be costly.
Hydrogen	There is potential for hydrogen to be produced using excess power available from the Jindabyne town's distributed Solar PV generation. Hydrogen technology is highly scalable and could initially be implemented as a small-scale trial, and, increase eventually as the excess power through renewable energy sources can be available in the future. The economic viability of large-scale green hydrogen production is likely to be contingent upon the supply of sufficient and cheaper renewable energy. Locally produced hydrogen could enable the transition to a clean vehicle fleet within the Snowy Mountains SAP serving the transport logistics network. Access to technical and financial support from state and federal government is likely to be necessary to progress the prospects for hydrogen in the Snowy Mountains SAP. With further improvements, this technology provides significant environmental advantages over other forms of long-term energy storage such as batteries which use precious resources in limited supply.
BESS	Battery energy storage solutions (BESS) can be integrated with any PV option chosen, due to the high scalability of the technology. Currently, large scale BESS profit from storing energy generated by renewable energy generation systems to provide frequency control ancillary services (FCAS) in the grid. Furthermore, BESS can be integrated with solar car parks to directly charge electric vehicles, or with rooftop PV to be used by individual households.

TECHNOLOGY	DETAILS AND KEY CONSIDERATIONS
	Implementation of BESS can turn non or semi dispatchable generation (solar) into dispatchable generation and thus supply energy during peak demand periods. Indicative capacity for the BESS system for the integration with identified solar PV opportunities can be up to four times (MWh) of the solar PV system size in MW, e.g. for the integration with a 1 MW solar PV system, indicative size of the BESS would be 1 MW with 1–4 MWh of energy storage capacity.
Emerging Industries	Ongoing evaluation of the up-take of electric vehicles in the region is necessary to adequately respond and develop the required changes to the Snowy Mountains SAP renewable energy strategy. As the electric vehicle market grows, there are greater opportunities to develop charging stations to support tourism in the area. Currently there are few charging stations within the region, highlighting the potential for growth. Although geothermal pools can help increase tourist attractions in the area, none have been identified in the Snowy Mountains SAP region based on the information currently available to WSP. As stated in the Geothermal section of this table above, the Snowy Mountains SAP region's geothermal resources is limited and because the resource is found deep underground, exploration can be expensive and the process difficult to carry out. For effective integration of all the energy and storage sources of the Snowy Mountains SAP, there will be an opportunity to implement a hybrid virtual power plant or community virtual power plant in the Snowy Mountains SAP. The virtual power plant will manage the demand and generation period gap while optimising financial outcome for the generation and storage system owners.

The renewable energy technology opportunities outlined and shortlisted in this report clearly support the renewable aspirations of the Snowy Mountains SAP. Development of these opportunities will reduce the reliance on fossil fuels, thereby reducing carbon emissions and toxic pollution into the environment. Encouraging development related to these opportunities will bring the investment in to Snowy Mountains SAP and can help create local jobs, while creating market signals for further research into these technologies.

1 INTRODUCTION

Special Activation Precincts (SAPs) are dedicated areas in regional NSW identified by the NSW Government to become thriving hubs. The SAP program facilitates job creation and economic development in these areas through infrastructure investment, streamlining planning approvals and investor attraction.

The SAP program adopts a collaborative and integrated whole-of-government approach, bringing together the local Council and a range of other relevant State and local agencies.

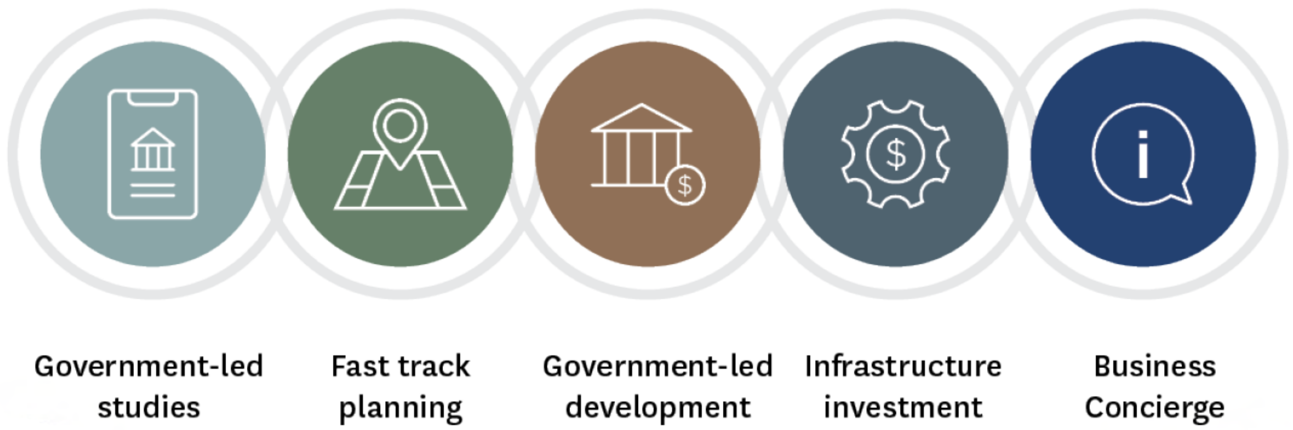
SAPs are unique to regional NSW. By focusing on planning and investment, their goal is to stimulate economic development and create jobs in line with the competitive advantages and economic strengths of a region.

On 15 November 2019, the NSW Government announced its commitment to investigating the Snowy Mountains SAP, to revitalise the Snowy Mountains into a year-round destination and Australia's Alpine Capital, with Jindabyne at its heart. The Snowy Mountains SAP is being delivered through the $4.2-billion Snowy Hydro Legacy Fund.

Different components of each SAP are led by different teams within the NSW Government:

- The **Department of Regional NSW** assesses potential locations for inclusion in the program and considers government investment for essential infrastructure to service the SAPs.
- The **NSW Department of Planning, Industry and Environment** (the Department) is responsible for the planning of SAPs. The Department leads the master planning process, including community and stakeholder engagement, the technical studies required to inform the preparation of a master plan and development of the simplified planning framework for each Precinct.
- The **Regional Growth NSW Development Corporation** (Regional Growth NSW) is responsible for delivering and implementing Special Activation Precincts. This includes attracting investment, providing support to businesses, developing enabling infrastructure, and creating strategic partnerships to foster education, training and collaboration opportunities.

The five core pillars of the Special Activation Precincts are:



The planning framework for each Special Activation Precinct includes three key parts:

STATE ENVIRONMENTAL PLANNING POLICY (ACTIVATION PRECINCTS) 2020	SPECIAL ACTIVATION PRECINCT MASTER PLANS	SPECIAL ACTIVATION PRECINCT DELIVERY PLANS

— Identifies each Special Activation Precinct.
— Requires that an Activation Precinct Certificate be sought prior to a development application or complying development certificate being issued, to ensure the development is consistent with the Master Plan and Delivery Plan.
— Provides zoning and land use controls for each Precinct.
— Identifies Exempt and Complying Development pathways for certain development.
	— Made by the NSW Department of Planning, Industry and Environment and approved by the Minister.
	— Identifies the Vision, Aspirations and Principles for the Precinct.
	— Provides more detailed land use controls where required.
	— Identifies Performance Criteria at a Precinct-scale for amenity, environmental performance and infrastructure provision.
	— Identifies the matters to be addressed as part of the Delivery Plan.
		— Prepared by Regional Growth NSW and approved by the Planning Secretary.
		— Identifies site-level development controls.
		— Provides detailed strategies and plans for:
		  — Aboriginal cultural heritage
		  — Environmental protection and management
		  — Protection of amenity
		  — Infrastructure and services
		  — Staging.
		— Provides procedures for ongoing monitoring and reporting.

1.1 MASTER PLANNING

The master planning process for the SAPs adopts an evidenced based approach to determining the best outcome for the precincts. It is designed to ultimately provide a clear pathway for the right types of future development, in the right locations.

The process involves the engagement of a range of technical experts to investigate the study area and prepare technical studies (such as this report) to demonstrate their findings. Each of the technical studies are specifically designed and scoped for each SAP and tailored to the needs of the study area.

Importantly, the master planning process for the Snowy Mountains SAP will build on work already undertaken for portions of the study area as part of the Go Jindabyne master plan.

To achieve integrated and balanced planning outcomes, technical experts and other stakeholders work together at a series of enquiry by design workshops throughout the master planning process. At these workshops, opportunities and constraints are discussed and assessed to inform how the precinct should be shaped. This includes the evaluation of matters such as environmental impacts and benefits, transport opportunities, infrastructure capabilities, stormwater, economic viability and many others. These workshops are designed to give technical experts and decision makers a chance to ensure the identified vision, aspirations and principals for the precinct are guiding the outcomes.

The technical reports will ultimately inform the development of planning controls for the Snowy Mountains SAP to guide the precincts development. These controls will be contained in the master plan, Special Activation Precincts SEPP and delivery plan and will relate to important matters such as amenity, environmental performance and infrastructure provision.

Throughout the planning process, community, stakeholder and industry consultation takes place. Ongoing consultation provides an opportunity for community members and landowners to contribute and help shape the vision for the project.

1.2 SNOWY MOUNTAINS SAP

The Snowy Mountains region is one of Australia's most iconic natural environments. In addition to hosting some of Australia's premier alpine destinations, the Snowy Mountains is home to over 35,000 people and Australia's highest peak, Mount Kosciuszko. The traditional custodians of the Snowy Mountains are the Monero Ngarigo people, in connection with the Walgalu, Ngunnawal and Bidhawal people.

The Snowy Mountains are located in the south east of NSW. This region forms the northern part of the Australian Alps which extends south into Victoria. Predominantly the region is accessed from Canberra which is located approximately 150 kilometres to the north. To the south and west of this region is the sparsely populated high country. The township of Jindabyne situated on Lake Jindabyne provides a hub for the region, with opportunities for tourism and facilities supporting the regional catchment.

Jindabyne is located 175 km south of Canberra and 60 km south-west of Cooma. Jindabyne has evolved into the gateway to the Snowy Mountains and currently services 1.4 million visitors each year who travel to the region to enjoy its unique tourism and recreational offerings (Destination NSW, June 2020 report). There are approximately 35,500 residents of the Snowy Mountains, of which 3,500 residents live in Jindabyne (including Kalkite, East Jindabyne and Tyrolean Village).

Portions of the Snowy Mountains are within Kosciuszko National Park. Kosciuszko National Park is the central segment of the Australian Alps Bioregion containing the highest mountains in Australia and is the largest national park in NSW (NSW National Parks and Wildlife Service, 2006). The park possesses exceptional diversity of alpine plant communities, containing threatened ecological communities (TECs) and providing habitat for a number of rare and threatened species (National Parks and Wildlife Service, 2006). The park contains most of the alpine endemic species found on the Australian mainland (National Parks and Wildlife Service, 2006).

The Snowy Mountains region is home to the Monero Ngarigo people, the tribal homeland stretches from the western slopes of the coastal ranges to the eastern side of the Kosciuszko plateau and further north. Included in the Ngarigo land is the peak of Mount Kosciuszko and the Snowy Ranges. European settlers accessed the region in 1823, and between the late 1830s to 1957 the Monaro highland region was grazing by cattle and sheep. The original town of Jindabyne was settled in the 1840s on the banks of the Snowy River where the main river crossing took place. A bridge was constructed over the river in 1893, contributing to the success of the town. In 1949 the Snowy Mountains Scheme was introduced which consisted of plans to dam and divert water from the Snowy River. By 1964 the dam had created Lake Jindabyne and the township relocated to where it is today. The old town disappeared under Lake Jindabyne in 1967. Although losing much of its built heritage, Jindabyne, as we know it today, was rebuilt and has continued to steadily grow leveraging its tourist and agricultural offerings (Ozark Environment and Heritage, 2020).

Today, the Snowy Mountains region plays a crucial role within the regional and state economy, with its local population swelling with an additional 1.4 million international and domestic visitors each year (Destination NSW, June 2020 report). The region's unique natural environment allows locals and visitors to participate in a diverse array of recreational activities year-round, with many visitors still experiencing the region through the peak winter season.

Priorities for the Snowy Mountains SAP are to capitalise on the unique cultural and environmental attributes which attract 1.4 million visitors annually to the region, revitalise the Snowy Mountains into a year-round destination, and reaffirm Australia's Alpine Capital (Destination NSW, June 2020 report). The revitalisation is to focus on year-round adventure and eco-tourism, improving regional transport connectivity, shifting towards a carbon neutral region, increasing the lifestyle and wellbeing activities on offer, and supporting Jindabyne's growth as Australia's national winter sports training base.

1.3 STUDY AREA

The Snowy Mountains SAP Investigation Area encompasses 72,211 hectare (ha) of land and within this study area are several key areas called 'development opportunity areas':

- Jindabyne growth opportunity areas: parcels of land located primarily to the south and west of the existing Jindabyne township, but also at East Jindabyne
- Jindabyne centre opportunity areas: areas within the existing town of Jindabyne
- Tourism opportunity areas: areas both near the town of Jindabyne and in the Kosciuszko National Park.

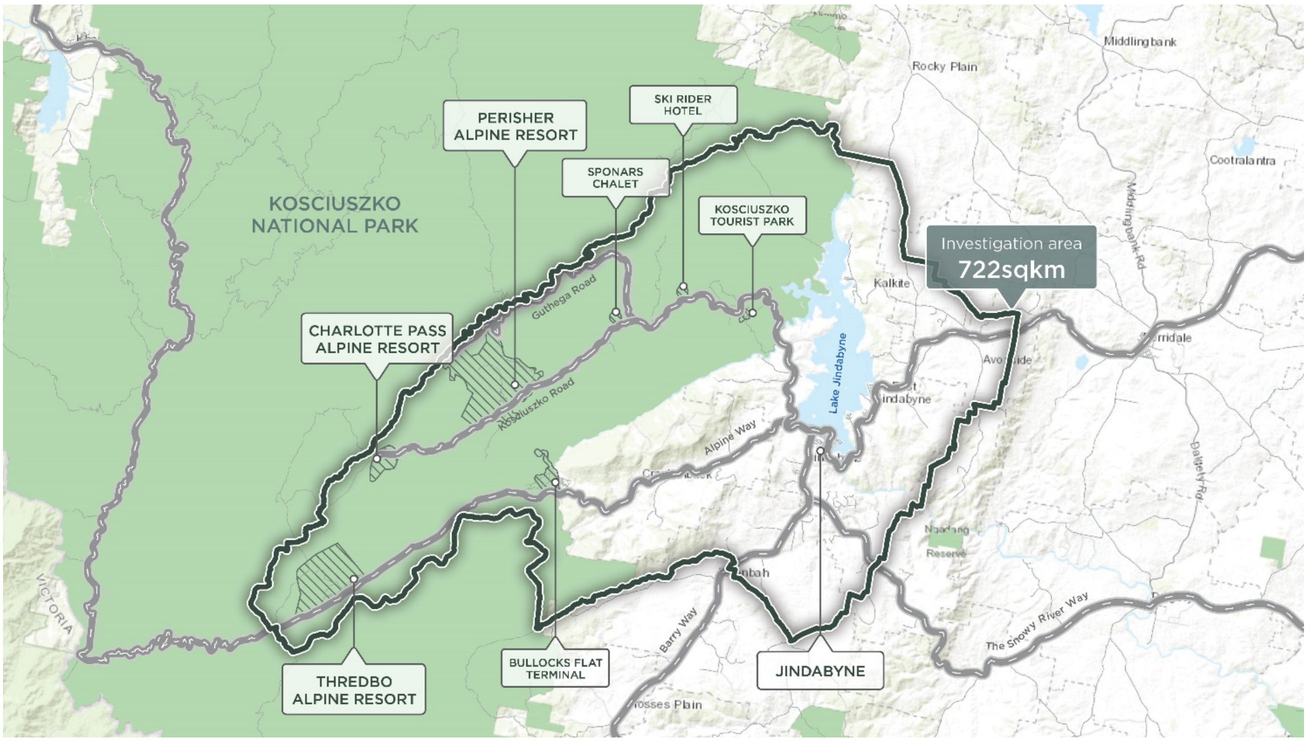


Figure 1.1 Study area

1.4 PURPOSE OF THIS REPORT

This Technical Study forms part of the Engineering Package for the Snowy Mountains Special Activation Precinct (SAP). This report builds on the context analysis reporting and input from the Strategic Framework Workshop to provide a holistic view of the issues, opportunities and constraints within the Snowy Mountains SAP study area. It explores stakeholder issues and current and future constraints to investigate strategic projects for the Snowy Mountains area. This Technical Study has been prepared through collaboration with the NSW Government, Snowy Monaro Regional Council and other stakeholders including representatives from the Alpine Resorts.

The recommendations from this report will combine with other technical studies in the disciplines of engineering, planning, environment, economics and legislation to inform the Master Planning for the Snowy Mountains SAP.

1.5 BACKGROUND INFORMATION

WSP has used publicly available data and data provided by the various stakeholders of the Project to prepare this report. Apart from the references provided in the report, the details of the information used to prepare this report are summarised in Section 11 of this report.

2 CONTEXT ANALYSIS

Section 2 and Section 3 provide a comprehensive overview of existing studies and data, and relevant policies, standards and guidelines which are crucial to preparing the Renewable Energy Technical Study for the Snowy Mountains Special Activation Precinct (SAP). The Context Analysis will review all available data sources, including but not limited to documents contained within the Snowy Mountains SAP Library. This context analysis has been done on technical and local area knowledge to provide a snapshot of the existing context, opportunities and constraints of the Snowy Mountains study area.

Section 2 and Section 3 of provide a summary of various renewable energy technology areas that have been assessed for the project including:

- Biomass Energy
- Biogas (Energy from Waste)
- Solar Energy
- Wind Energy
- Hydro Energy
- Geothermal Energy
- Hydrogen
- Regional plans and strategies for carbon negativity
- Existing renewable energy infrastructure
- Transmission infrastructure.

2.1 INFORMATION AND DATA USED

WSP has undertaken the detailed review of the following documents:

Table 2.1 Information and data used

ITEM	TYPE	DESCRIPTION	DATE
1	Report	Snowy Mountains SAP Regional Context Analysis (Hill Thalis)	2019
2	Report	Snowy Mountains SAP Strategic Technical & Regulatory Issues Report (Aurecon)	2020
3	Report	Snowy Mountains SAP Strategic Design Report and P50 Estimate (Aurecon)	2020
6	Plan	Go Jindabyne Draft Master Plan (Hill Thalis)	2019
7	Plan	Southeast and Tablelands Regional Plan 2036	2017
8	Plan	Snowy Monaro Local Strategic Planning Statement (LSPS)	2020
9	Paper	SMRC Planning and Land Use Discussion Paper	2019
10	Paper	Fact Sheet – Achieving Net-Zero Emissions by 2050	2016
11	Plan	Net Zero Plan Stage 1:2020–2030	2020

2.2 AREA'S ALIGNMENT WITH STRATEGIC PLANS AND POLICIES

The Fact Sheet: *Achieving Net-Zero Emissions by 2050* by the NSW Government states that the Government has committed to an aspirational objective of achieving net-zero emissions by 2050. To achieve this long-term objective, *Net-Zero Plan Stage 1:2020–2030* aims to deliver a 35% cut in emissions by 2030 (compared to 2005 levels).

Table 2.2 below summarises the alignment statements for the Snowy Mountains SAP area with the key strategic plans and policies of the Government from a renewable energy perspective.

Table 2.2 Summary of alignment statement for the Snowy Mountains SAP area – renewable energy

REPORT/PLAN/POLICY TITLE	STATEMENT OF ALIGNMENT
Snowy Mountains SAP Regional Context Analysis (Hill Thalis) report	The Jindabyne area will have a contribution to achieve a carbon neutral region that sets the national benchmark for the integration of tourism and development in natural settings.
Snowy Mountains SAP Strategic Design Report and P50 Estimate report	*"The electrical concept design for the Jindabyne SAP should accommodate existing and planned infrastructure, as well as be flexible enough to establish and not preclude the SAP from achieving long term energy objectives"*
Jindy Draft Master Plan (Hill Thalis)	— *"Jindabyne's unique alpine environment continues to support year-round tourism and sustainable activities, particularly by protecting natural areas, enhancing access to Lake Jindabyne, activating its waterfront and adopting renewable energy."* — *"The tranquil water of Lake Jindabyne are also an active energy source and integral part of the Snowy Hydro Electric Scheme."* and Hinterland housing types must demonstrate carbon neutrality including being energy self-sufficient.
Southeast and Tablelands Regional Plan	One of the priority growth sectors in the regional growth plan is identified as renewable energy to diversify the economy of the Southeast and Tablelands region. Direction 6 of the regional plan was identified to position the region as a hub of renewable energy excellence and relevant identified actions were to: — *Identify opportunities for renewable energy industries.* — *Encourage co-location of renewable energy projects to maximise infrastructure, including corridors with access to the electricity network.* — *Promote best practice community engagement and maximise community benefits from renewable energy projects.* — *Promote appropriate smaller-scale renewable energy projects using bioenergy, solar, wind, small-scale hydro, geothermal or other innovative storage technologies.* Direction 17 directs building community capacity to deliver and own renewable energy and, promote the use of advance technology vehicles.

REPORT/PLAN/POLICY TITLE	STATEMENT OF ALIGNMENT
Snowy Monaro Local Strategic Planning Statement (LSPS)	Planning Priority #12 from this Plan states that *"While the Snowy Monaro is already a renewable powerhouse in terms of Snowy Hydro and Boco Rock Wind Farm, there is no major solar power generation occurring within the region. In line with Council's vision to become a centre for renewable energy, opportunities for solar power generation and other renewable energy can be investigated and supported in suitable locations"*. According to this plan, Snowy Monaro Council will support the implementation of large-scale renewable energy projects outside of scenic protection areas and will work towards net zero emissions target.

2.3 EXISTING RENEWABLE ENERGY INFRASTRUCTURE

WSP has identified that two hydro-electric power projects are already operational within the Snowy Mountains SAP investigation area:

- Jindabyne Dam Mini Hydro Power Station – 1.1 MW (Nameplate capacity)
- Guthega Power Station – 60 MW (Nameplate capacity).

Table 2.3 below summarises the operational renewable energy projects located in the Snowy Mountains SAP investigation area and in the regional (Southeast and Tableland) area and its potential contribution to energy usage of the Snowy Mountains SAP area.

Table 2.3 Renewable energy infrastructure and its contribution

INFRASTRUCTURE TYPE	DESCRIPTION[1]	NAMEPLATE CAPACITY	CONTRIBUTION
Solar Energy Projects	Capital East Solar Farm	0.7 MW	This small solar farm is located at Bungendore, NSW which is a substantial distance from the Snowy Mountains SAP's investigation area. There would be minimal contribution of energy from this solar farm to the investigation area. The investigation area and the regional area do not have any operational solar farms larger than the Capital East Solar Farm.
Wind Energy Projects	Boco Rock Wind Farm	113 MW	These wind energy projects are located outside the direct boundary of the Snowy Mountains SAP area, hence, contribution of these wind energy projects to the Snowy Mountains SAP energy usage cannot be quantified. However, if any Snowy Mountains SAP energy consumer buys electricity from the electricity retailer company which source their electricity from any of these wind farms than we can consider virtual contribution to Snowy Mountains SAP's energy usage by these wind farms.
	Capital Wind Farm	140.7 MW	
	Woodlawn Wind Farm	48.3 MW	
	Cullerin Range Wind Farm	30 MW	
	Gullen Range Wind Farm	165.5 W	
	Gunning Wind Farm	46.5 MW	
	Taralga Wind Farm	106.8 MW	

[1] Projects registered with AEMO/NEM as a Generator in Southeast and Tableland region

INFRASTRUCTURE TYPE	DESCRIPTION[1]	NAMEPLATE CAPACITY	CONTRIBUTION
Hydro Energy Projects (Located within Snowy Mountains SAP	Jindabyne Dam Mini Hydro Power Station	1.1 MW	Guthega Power Station has generated 125–160 GWh of energy every year (2011–2016) and it is forecasted to be operational with its full capacity (forecast available until 2026) [1]. Guthega Power Station is connected within the network infrastructure of the investigation area, so it can be assumed that Guthega Power Station provides baseload power support to the investigation area. Additionally, the total energy generated by Guthega Power Station every year is higher than the annual energy usage of the investigation area (estimated at ~79 GWh[2]). Jindabyne Dam Mini Hydro Power Station is registered as a Non-scheduled generator in the NEM. Jindabyne Dam Mini Hydro Power Station historical generation data is not available publicly.
	Guthega Power Station	60 MW	
Hydro Energy Projects (Southeast and Tableland region)	Brown Mountain Power Station	5 MW	Due to the distance between the Snowy Mountains SAP and these hydro energy projects, the contribution of these hydro energy projects to the Snowy Mountains SAP energy usage cannot be quantified. However, if any Snowy Mountains SAP energy consumer buys electricity from the electricity retailer company which source their electricity from any of these hydro power stations than we can consider virtual contribution to Snowy Mountains SAP's energy usage by these hydro power stations.
	Burrinjuck Power Station	27.2 MW	
Bio Energy Project	Woodlawn Bioreactor Energy Generation Station (Land fill gas)	7.5 MW	This land fill gas-based project would generate adequate energy to supply 30,000 houses [2], however, due to the distance between the Snowy Mountains SAP and this project, contribution of this Bio Energy project to the Snowy Mountains SAP energy usage cannot be quantified.

WSP notes that there are two additional large renewable generators in close proximity to the Snowy Mountains SAP area, namely Murray 1 and Murray 2 Power Stations. Any potential renewable energy contribution from these two generators to the Snowy Mountains SAP will be considered in the next phase.

[2] Calculated based on forecasted Average Load Demand for 2021 in Section 2.3 as 10.02 MVA
10.02 x 0.9(Power factor) x 24(hours) x 365(days) = 78.9 GWh (Estimated annual energy consumption)

3 RESOURCE DATA ASSESSMENT AND CONSTRAINTS

3.1 BIOMASS AND BIOFUEL

3.1.1 INFORMATION AND DATA USED

The analysis for renewable energy opportunities for Biomass and Biofuel has been based on the following information sources:

Table 3.1 Information and data used

ITEM	TYPE	DESCRIPTION	DATE
1	Website Database	Australian Bureau of Statistics – Agricultural census data	April 2019
2	Website Database	AREMI – Bioenergy databases (2015–2020)	NA
3	Report	Oakley Greenwood – Gas Price Trends Review 2017	March 2018
4	Report	Riverina Murray Region Agricultural Profile	November 2018
5	Website Database	NRM Regional organisation map	NA
6	Website Database	Main statistical Area Map	July 2019
7	Website Base	Land use map	November 2018
8	Website Database	STTM – Quarterly Prices	March 2020
9	Website	Alternative Fuels Data Centre	NA
10	Report	Biodiesel Blends in Space heating equipment	2001
11	Report	Techno-Economic Evaluation of Biodiesel production from Waste Cooking Oil – A Case Study of Hong Kong	2015
12	Website	Capital Region of New South Wales	June 2020
13	Article	NSW stockfeed source preserved for use by drought-impacted producers	June 2018
14	Website	Renewable Space Heating	December 2016
15	Website Database	Biodiesel Production and Distribution	NA
16	Report	Biodiesel Blends in Space Heating Equipment	May 2004
17	Report	Techno-Economic Evaluation of Biodiesel Production from Waste Cooking Oil – A Case Study of Hong Kong	February 2015
18	Website	Environment & Sustainability	N/A
19	Website	Green Resorts	N/A

3.1.2 RESOURCE AND FEASIBILITY ASSESSMENT

Biomass can produce energy for productive purposes in various forms and via different pathways such as:

- heat via combustion
- electricity via combustion and Rankine cycle power generation (or steam engines for small scale applications)
- electricity via pyrolysis or gasification and gas engine generation
- electricity via anaerobic digestion and gas engine generation
- gas via anaerobic digestion
- liquid fuel via fermentation processes.

The biomass resources that are available within the region includes:

- residue from cereal crops such as: wheat, oats, barley, maize, triticale
- residue from fruit farms such as grapes and various citrus fruits
- residue from crops grown for hay
- forestry residue.

WSP has previously been involved in detailed feasibility studies for biomass electricity generation and from these studies, it has been observed that the cost of collecting distributed bioenergy resources can be a key impediment to the viability of their utilisation. Where these resources are already aggregated at a central point as a result of agricultural processing operations (e.g. sugar cane bagasse, almond shell and hull, grape marc), cost effective utilisation becomes possible. Typically, the business case is most sound where this residual biomass can be used on-site to reduce disposal challenges, or in a cogeneration application to maximise the utilisation of the biomass energy produced.

3.1.2.1 AGRICULTURAL RESIDUES

The Snowy Mountains SAP region is located in the South East NSW Natural Resource Management (NRM) region of New South Wales. The area falls under the Snowy Monaro Local Government Area (LGA) within the Capital Region Statistical Area Level 4 region.

Within the immediate area of the Snowy Mountains SAP, land use is predominantly nature conservation as a result of bordering the Kosciuszko National Park and for grazing purposes (within the south-east region of the Snowy Mountains SAP) [3].

Land use for grazing within the Capital Region is primarily used for the following purposes:

- Intensive uses – typically land that has high levels of interference with natural processes. This may be intensive horticulture (e.g. shadehouses or glasshouses) or intensive animal husbandry (e.g. feedlots, piggeries or stockyards and saleyards).
- Grazing native vegetation – land use that involves domestic stock grazing on native vegetation that has either limited or no deliberate attempt at pasture modification.
- Modified pasture – has been significantly modified or where the initial vegetation has since been replaced.

Most of the cropping activities are concentrated in the northern part of the Capital Region outside of the Snowy Monaro region, however the Snowy Monaro region does produce some quantities of cereal crops and vegetables (Figure 3.1).

The Snowy Monaro region is a large producer of livestock which is further discussed in section 3.2.

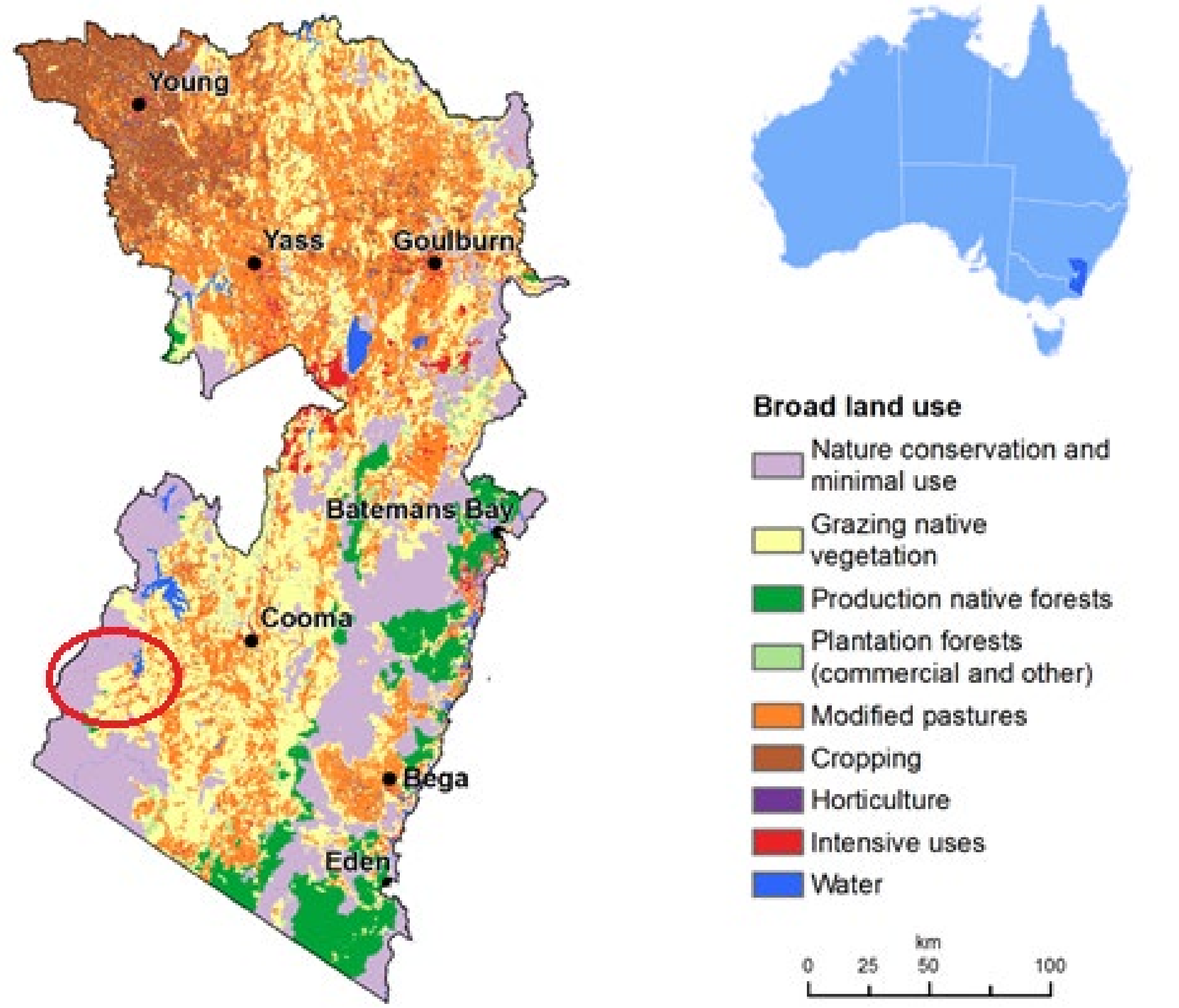


Figure 3.1 Broad land use in the Capital Region with Snowy Mountains SAP study area indicated by the red circle [3]

The Agricultural census data published by the Australian Bureau of Statistics (ABS) provides a reliable resource for agricultural derived biomass. Table 3.2 below highlights the key agricultural biomass sources in the Capital Region and Snowy Monaro LGA and provides commentary on their limitations.

Table 3.2 Key agricultural biomass resources in the Capital Region and Snowy Monaro LGA

METRIC	CAPITAL REGION (1)	SNOWY MONARO LGA(1)	COMMENTS
Combined wheat, barley and triticale area (ha)	73,964	4,044	It is reasonable to assume that cereal straw may be available at approximately 1:1 ratio with grain yield. For reference, 200,000 tonnes per annum of cereal straw would power a 30 MW baseload power plant. However, the cost of straw is relatively high (indicatively $8/GJ) and there is a general trend towards low tillage farming, which retains the straw in-field.
Combined wheat, barley and triticale produced (tpa)	227,777	9,813	
Average wheat, barley and triticale yield (t/ha)	2.77	2.43	
Oats area (ha)	10,410	453	
Oats production (tpa)	16,492	503	

METRIC	CAPITAL REGION (1)	SNOWY MONARO LGA(1)	COMMENTS
Oats yield (t/ha)	1.58	1.11	
Non-cereal crops (Canola oil seed) area (ha)	46,905	1,142	–
Non-cereal crops (canola oil seed) production (tpa)	85,187	2,751	–
Non-cereal crops (canola seed) yield (t/ha)	1.82	2.41	–
Grapes – Area (ha)	755	2	Grape marc is utilised as a fuel for existing industrial processes such as distilleries and as drought feed for cattle [4].
Grapes – production (tpa)	5,170	6	
Grapes – yield (t/ha)	7.15	3.05	

Notes:

Data is from the 2015–16 Agricultural Commodities issue from the ABS for the Capital Region. WSP is aware that there is a more recent issue of Agricultural Commodities data, however it is not refined into LGA regions and therefore provides limited information for the Snowy Mountains SAP area. Compared to the 2017-18 publication for the Capital Region, the size of some farming areas and the number of livestock head have changed but the proportions of land use is similar.

Data is from the 2015–16 Agricultural Commodities issue from the ABS as this is the most recent issue in which the data has been refined into the LGA regions.

Table 3.2 above shows that cereal crops are one of the most widely grown crops within the Snowy Monaro region, however, quantities within a reasonable radius of the Snowy Mountains SAP region is unlikely to be sufficient for large scale power generation.

Biomass has been used in space heating applications whereby the biomass is burned in small boilers to heat buildings. However, these systems have typically been fuelled with woody biomass as opposed to straw. Furthermore, security of supply can be a challenge for biomass systems [5].

Agricultural residue can also be used in regenerative agriculture processes which aim to maintain and improve soil quality and avoid degrading soil biodiversity. These techniques have shown potential for carbon sequestration; however, the scope of this report is limited to the investigation of energy resources for producing electricity and heat.

3.1.2.2 FORESTRY

The Kosciuszko National Park lies to the west of Lake Jindabyne. The Snowy Mountains SAP region includes a portion of the national park around the Charlotte Pass Alpine Resort and the Ski Rider Alpine Resort amongst others. Figure 3.2 below shows the nearby production forests that may provide residues.

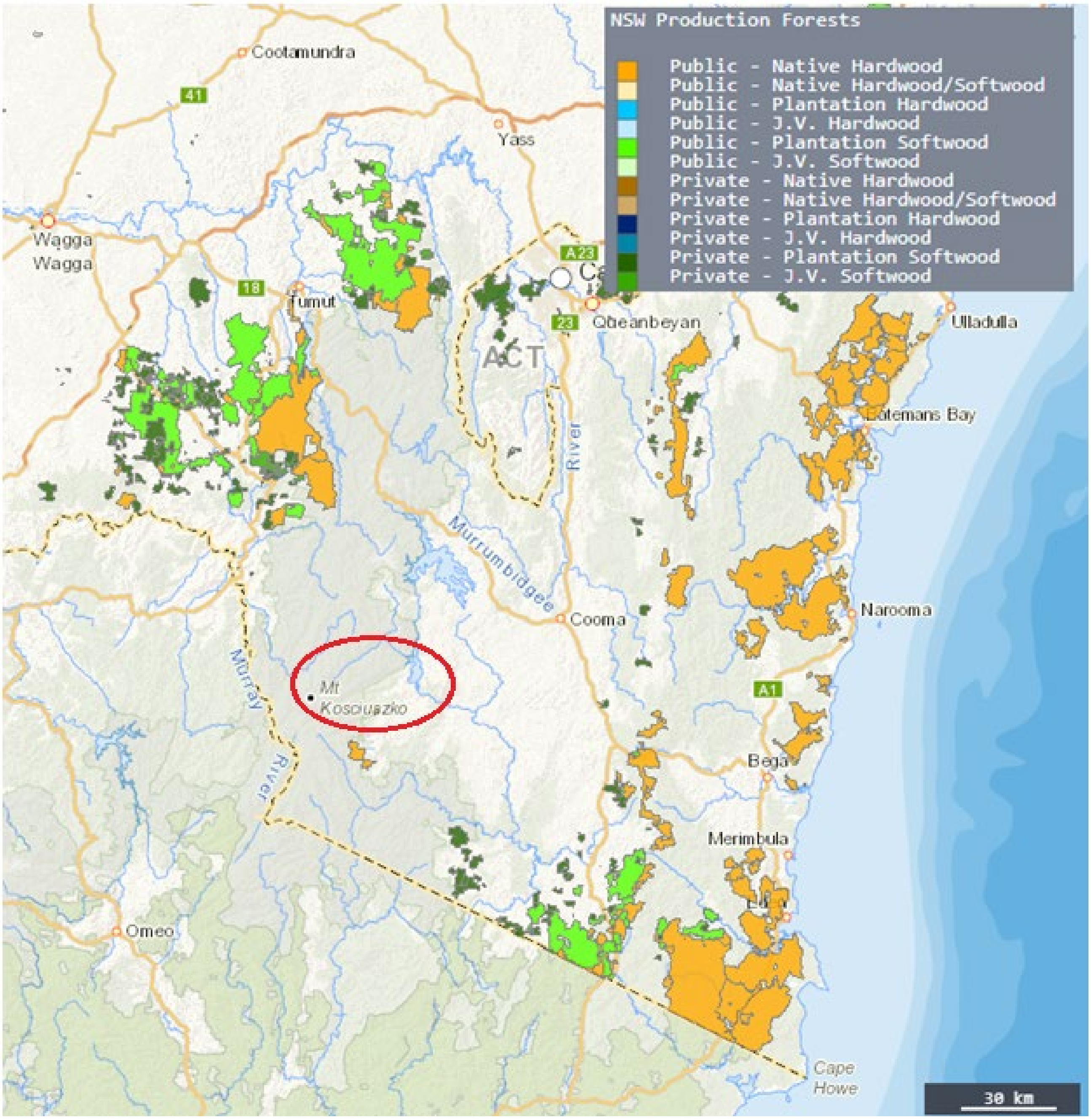


Figure 3.2 AREMI – NSW production forests with Snowy Mountains SAP study area indicated by the red circle

Table 3.3 shows the estimated forestry residue according to AREMI's bioenergy database.

Table 3.3 AREMI forestry residue data

FORESTRY RESIDUE QUANTITIES (TONNES/ANNUM)	TUMUT REGION	EDEN REGION	BADJA + MONARO SOUTH REGIONS COMBINED
Harvest Residue	214,000	360,000	7,900
Sawmill Residue	250,000	41,000	Negligible
Softwood Harvest Residue	213,000	99,000	Negligible

The Eden region is approximately 90 km from the Snowy Mountains SAP. The Tumut area borders the Snowy Mountains SAP area however, it should be noted that the Tumut region extends to the north to approximately 200 km away from the Snowy Mountains SAP. The following figures provide snapshots from the AREMI database to illustrate the forestry resources available in and within the surrounding areas of the Snowy Mountains SAP.

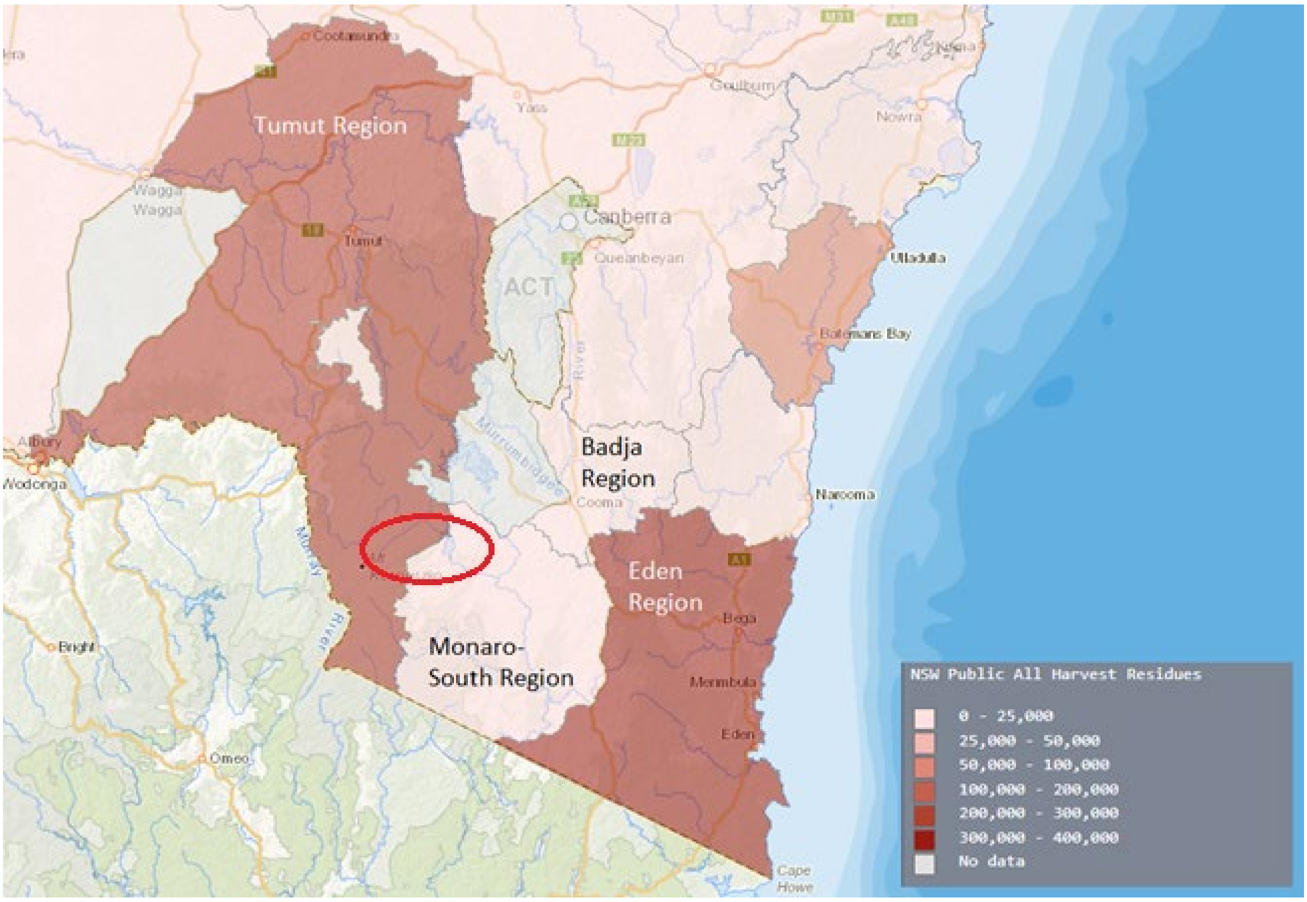


Figure 3.3 AREMI – NSW public all harvest residues with Snowy Mountains SAP study area indicated by the red circle

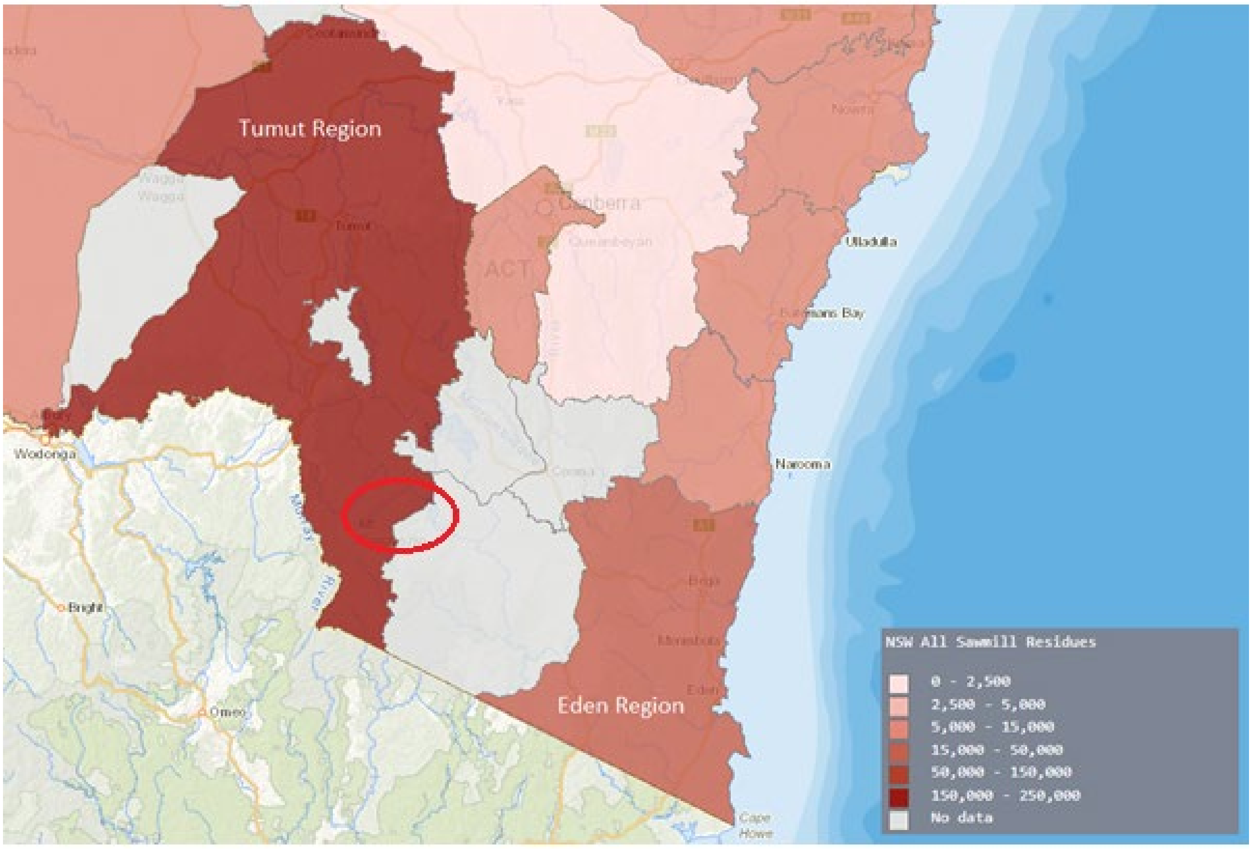


Figure 3.4 AREMI – NSW all sawmill residues with Snowy Mountains SAP study area indicated by the red circle

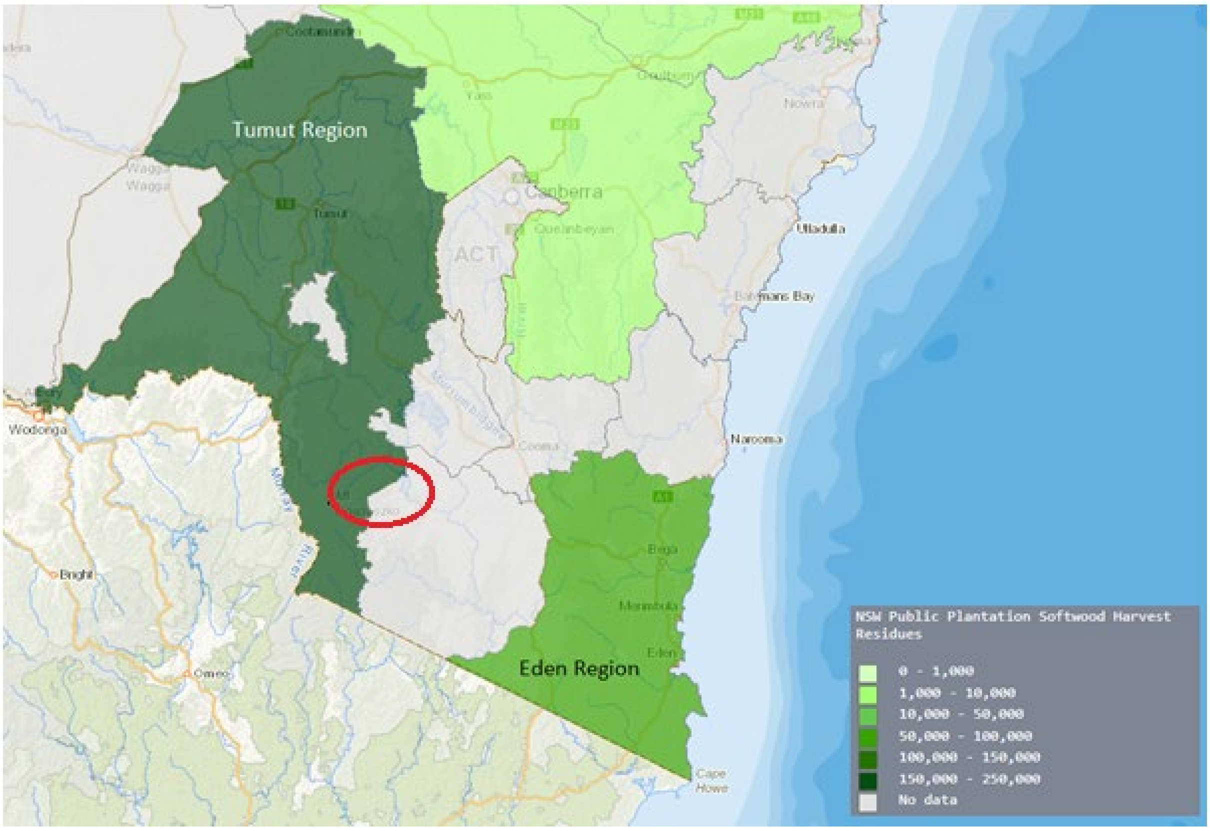


Figure 3.5 AREMI – NSW public plantation softwood harvest residues with Snowy Mountains SAP study area indicated by the red circle

3.1.2.3 OTHER RESIDUES

Biodiesel represents an alternative fuel source and is produced from vegetable oil, yellow grease, used cooking oils or animal fats. The oil or fat is mixed with a small short-chain alcohol such as methanol in the presence of a catalyst (e.g. sodium hydroxide or potassium hydroxide) in a ratio of approximately 10:1 [6]. This would form 10 parts of biodiesel, and 1 part of glycerin. The biodiesel could then be used to fuel vehicles such as trucks or buses. It may also be mixed with oil for heating purposes [7]. Glycerin may be used to manufacture pharmaceuticals and cosmetics.

The major cost in producing biodiesel arises from the cost of the feedstock [8]. Equipment for a biodiesel plant could include storage tanks, mixers, reactor, separator and extraction column in addition to the raw material inputs being the oil or fat, alcohol and catalyst. The catalyst may be basic, acidic or an enzyme. Depending on which type of catalyst is selected, the total cost of equipment may vary from around USD 820,000 to USD 2.1 mil for a system that is capable of producing 8 kilotons per year [8].

Noting the features of the Snowy Mountains SAP area, there are several resorts that provide accommodation, meals and other facilities to their guests. These resorts may therefore provide a source of used cooking oil or other similar waste, however it should be noted that these resorts are already undertaking recycling programs. For example, Thredbo already recycles used cooking oil into biodiesel [9].

Alternatively, information on waste composition from the Bombala Waste depot, the Jindabyne Landfill and Cooma Landfill indicates that there may be some oil that is typically disposed of into landfill which may be suitable for use as a biodiesel feedstock. The amount of oil received by these landfills in 2019 was stated to be approximately 33 tonnes, which could potentially be used to produce approximately 33 tonnes of biodiesel, assuming that all of the oil received could be collected and is suitable for processing into biodiesel. Details on the type or composition of the oil were not provided.

3.1.3 ASSESSMENT

In 2017, the average natural gas price delivered to a large industrial customer in NSW was $10.46/GJ and $19.83/GJ for small industrial customers [10]. These prices were the results of the trend of continuously increasing prices for natural gas. The data presented in Table 3.4 is an approximate indication of the relative cost of the most relevant biomass streams as discussed above. The resulting delivered cost should be taken as an indication only, but still illustrates that potentially cost-effective alternative fuels to natural gas are available for combined heat and power systems if considerable volumes can be drawn upon from facilities that are close to the Snowy Mountains SAP.

Comparing the gas prices to the prices for the quantity and delivery of biomass in Table 3.4 shows that the adoption of biomass may be a more economical option compared to natural gas for heat or power and would be aligned with the aim for a carbon negative region.

Table 3.4 Indicative biomass economics for the Snowy Mountains SAP area

BIOMASS SOURCE	TYPICAL MOISTURE CONTENT (%)	LOWER HEATING VALUE (GJ/TONNE)	APPROX. DELIVERED COST ($/TONNE)	APPROX. DELIVERED COST ($/GJ)
Cereal straw	8–12	14	80–100	6–8
Grape Marc	50–55	8	25	3
Wood chip	40–50	8–12	50	4–6
Forestry Residue				
Sawmill Residue (dry)/ shavings	<15	20	150	7.5

Note: Biomass energy content and cost data is derived from WSP real project experience, including:

- laboratory testing of biomass samples
- indicative quotes through to firm quotations/agreements from biomass suppliers

Pricing for forestry residue is highly uncertain due to lack of current actual production volume, though WSP is aware that trials have been conducted by NSW Forestry.

Due to the higher cost of biomass combustion equipment, a price differential in the fuel is needed to justify the additional capital expenditure, so only the most cost-effective options from those presented above are likely to be able to sustain a business case. Biomass also tends to have relatively low bulk density, therefore road transport of the biomass can sometimes be volume limited and become costly.

The delivered biomass costs in Table 3.4 are applicable for delivery from a distance of approximately 100 km. As such, higher costs may be applicable if the biomass is sourced from the northern-most parts of the Tumut region or from coastal regions in Eden.

Overall, based on the above analysis of resources and potential constraints for bioenergy, the Snowy Mountains SAP has a low scope for biomass energy projects due to the relatively low quantities of biomass available within the Snowy Mountains SAP area. Transportation of biomass from the wider Snowy Monaro region to the Snowy Mountains SAP presents additional environmental considerations (emissions from transport haulage) and greater transportation costs.

3.2 BIOGAS (ENERGY FROM WASTE)

3.2.1 INFORMATION AND DATA USED

The analysis for renewable energy opportunities for Biogas has been based on the following information sources:

Table 3.5 Information and data used

ITEM	TYPE	DESCRIPTION	DATE
1	Website Database	ARENA	NA
2	Website Database	2016 Census QuickStats	2016
3	Publication	The World Bank – What a Waste: A Global Review of Solid Waste Management	March 2012
4	Website Database	Fact sheet – Biogas: Converting Waste to Electricity	October 2017
5	Report	Saleyard Survey 2018–19	2019
6	Report	NSW State of the Environment	N/A
7	Report	NSW Alpine Resorts Environmental Performance Report	2017
8	Report	Food and Garden Organics Best Practice Collection Manual	2012
9	Report	Small Scale Biogas production from organic waste and application in mid-income countries – a case study of a Lebanese community	2019
10	Report	Annual Waste Report: Bombala Waste Depot – 227	2019
11	Report	Annual Waste Report: Jindabyne Landfill 20060	2019
12	Report	Annual Waste Report: Cooma Landfill – 6194	2019
13	Report	Capacity and Robustness Review for Perisher Valley Sewage Treatment Plant	2019
14	Report	Go Jindabyne Utilities and Servicing Strategy	2019
15	Report	Treated effluent in the aquatic environment: impact assessment of endocrine disrupting chemicals	2012
16	Publication	Sustainable biogas production in municipal wastewater treatment plants	2015
17	Publication	Green Gas – Facilitating a future green gas grid through the production of renewable gas	2018
18	Report	Biosolids Snapshot	2012

3.2.2 RESOURCE AND FEASIBILITY ASSESSMENT

Biogas is produced by digesting organic materials in an oxygen-free environment by using an anaerobic digester. The digester breaks down the organic material, producing biogas and digestate. Anaerobic digesters can take the following organic streams and produce biogas:

- livestock waste
- crops and crop waste
- wastewater
- food waste.

Waste streams that may be suitable for biogas that may be available in the region include:

- waste from livestock (cattle, sheep, goats, pigs and poultry)
- food waste (from resorts and urban areas included in the Snowy Mountains SAP).

Biogas can be used to generate electricity (via engine or turbine) or heat (via boiler or heater). Alternatively, the biogas may be further processed into biomethane, which could potentially be injected into the natural gas network. The digestate produced through the digestion process is a nutrient-rich liquid or solid product. Liquid digestate can be used as a fertiliser spray on farms, which can reduce the use of synthetic fertilisers in the area. Solid digestate may be suitable for livestock bedding, or compost. The composition of the digestate depends on the feedstock used in the digester [11].

3.2.2.1 LIVESTOCK RESIDUE

The Snowy Monaro region's largest commodities produced are livestock products and wool. In the 2015/16 Agriculture survey, the Snowy Monaro LGA reported the livestock figures in Table 3.6.

Table 3.6 Key livestock resources in the capital region

METRIC (1)	CAPITAL REGION	SNOWY MONARO
Sheep and Lambs	4,722,761	925,370
Cattle	436,667	91,647
Pigs	82,058	106
Poultry	324,011	4,552
Goats	3,789	1,268

(1) Data is from the 2015/16 Agriculture census. WSP notes that more recent data is available however, this data is not refined down to the LGA regions.

The figures in Table 3.6 suggest that most of the livestock waste that can potentially be collected will arise from cattle and sheep and lambs. The most efficient and cost-effective approach to collecting the livestock waste would be from a facility where the livestock are concentrated such as saleyard, as opposed to from grazing pastures.

The Cooma Livestock selling Centre is owned by the Snowy Monaro regional council and is located approximately 52 km from the Snowy Mountains SAP area. In 2018/19 the Cooma livestock Selling centre handled 17,623 cattle and 11,087 sheep [12]. Using these figures and the assumptions in Table 3.6, it is estimated that approximately 117,600–863,800 m^3 of biogas per year can be produced, which can then be converted to heat or electricity. Transportation of livestock waste from Cooma to Jindabyne is likely to be prohibitive due to environmental and health implications.

3.2.2.2 DOMESTIC WASTE

In addition to livestock waste, other organic waste such as food waste can also be digested and used to produce biogas. The NSW local government collects data from all landfill operators in NSW through mandatory monthly and annual reports, which have been used in this analysis [13]. It is estimated that the average household (with an average of 2.6 people per household) creates 24.2 kg of total waste per week, or equivalently, each person creates 9.4 kg of waste per week. The average weekly household waste is comprised of:

- 4.9 kg in dry recyclables
- 5.6 kg in organic waste
- 11.7 kg residual waste.

These amounts total 22.2 kg, with the remaining 2 kg of waste being collected by drop-off and cleaning services. The 2016 census showed there were approximately 11,600 private dwellings with an average of 2.3 people per household in the Snowy Monaro LGA with approximately 2,000 dwellings with an average of 2.4 people per dwelling in Jindabyne. It is therefore estimated that there may be approximately 3,400 tonnes of organic waste disposed of by households per year in the Snowy Monaro LGA, or 580 tonnes of organic waste per year from just the Jindabyne area. WSP notes that the average household in Snowy Monaro and Jindabyne has fewer people on average compared to the average NSW household, therefore the tonnage of organic waste that is available may be less than this figure.

The NSW EPA also produces reports periodically that summarises the outcomes of monitoring and reporting against environmental values for the resorts in the Kosciuszko National Park including Charlotte Pass, Perisher, Thredbo and Selwyn Snowfields. These resorts also have the objective of reducing the amount of waste sent to landfill in favour of increasing recycling and energy recovery [14]. The most recent data reported was from the 2015–16 period in which 1,143 tonnes of waste in total was sent to landfill by these resorts during the study period.

The total organic waste that could be collected for energy or heat production from the Snowy Mountains SAP and local area is shown in Table 3.7. A collection rate of 66% was used as this is the NSW target recovery rate to be achieved by 2014, thus it was assumed that the target rate was achieved.

Table 3.7 Energy or heat generated from organic domestic waste

ESTIMATE	JINDABYNE RESIDENTS	SNOWY MONARO RESIDENTS	RESORTS	COMMENT
Total organic waste available (t)	580	3,400	370	Potential organic waste that may be collected from resorts from the NSW EPA [14]. Potential waste from residents of the local area based on 2016 census data [13].
Organic waste collected (t)	380	2,200	240	Organic waste collected assuming a 66% collection rate [15].
Potential biogas produced (m^3/yr)	44,000	255,600	27,700	Potential biogas that may be produced from the organic waste from collected organic waste [16].
Energy content of biogas produced (MWh_{th}/yr)	260	1500	170	Assuming calorific value of biogas of 21.6 MJ/m^3 [16].
Potential electricity generated (MWh_e/yr)	93	540	58	Assuming 35% efficiency of conversion to electricity.

Further, NSW authorities have funded two waste initiatives – the *Waste Less, Recycle More* initiative, which encourages businesses to recycle more and better manage their wastes, and the *Don't be a Tosser!* anti-littering campaign, which attempts to divert waste from the open environment into landfill.

It must also be noted that some of the resorts from which the waste data was collected are already operating recycling and recovery plans. Perisher has previously participated in a compost trial with the National Parks and Wildlife service, whilst Thredbo has invested in a closed-loop raid composter, which consumes some of their organic waste. Therefore, adding a competing use for organic waste may not be viable.

Per the landfill data for 2018–2019, the organic wastes received at Jindabyne Landfill is approximately 230 tonnes per data shown in Table 3.8. This is slightly less than the estimate based on population.

Table 3.8 Jindabyne Municipal landfill data

WASTE TYPE	QUANTITY (TONNES)
Batteries	6.27
Co-mingled Recyclables	720.21
Composts or mulches	19.56
E-waste	2.41
Ferrous (iron or steel)	633.62
Mattresses	36.99
Mixed waste	2,067.11
Oil	18.11
Tyres	1.75
Vegetation or garden	211.11
Total	**3,717.14**

Note:

WSP assumes the waste category Mixed Waste is not organic waste.

3.2.2.3 WASTEWATER

Wastewater collected from the sewage system will typically contain solids which can be collected at the treatment facilities and digested to produce biogas in an anaerobic digester (AD). The wastewater treatment plants receive sewage sludge from the wastewater network, which contains mixed sludge. The sludge is collected from the treatment stages in the wastewater treatment plant and may be sieved to increase the dry solid content, thereby thickening the sludge. The sludge is then pumped into the AD and mixed continuously until the microorganisms have broken down the organic matter in the sludge, producing raw biogas. The resulting raw biogas is further treated through drying to remove any hydrogen sulphide and other trace elements in order to produce a highly combustible gas which, when fired, avoids excessive corrosion or deposition in the combustion equipment [17]. The processed biogas is then piped out from the AD into storage vessels for later use.

Biogas can be used directly in CHP plants to produce electricity and heat [18]. Alternatively, the biogas can be further processed into biomethane, which can potentially be added to the natural gas grid, or similarly combusted directly for power and heat [18].

Biosolids collected from wastewater treatment plants could also be used in alternate energy generation processes such as direct combustion via a boiler in an Energy from Waste plant, or gasification whereby the biosolids are converted into synthesis gas under high temperature and pressure conditions [19]. In Australia however, most of the biosolids produced have typically been used for agricultural applications including as a soil conditioner, soil replacement product and as fertiliser [19].

Within the Snowy Mountains SAP there are several wastewater treatment facilities including:

- Thredbo Sewage Treatment Works
- Perisher Range Sewage System
- Charlotte Pass Sewage Infrastructure
- Jindabyne Sewage Treatment Plant.

Table 3.9 below summarises the available data on these facilities.

Table 3.9 Sewage treatment facilities

SEWAGE TREATMENT FACILITY	CAPACITY	AVERAGE DRY WEATHER FLOW
Perisher Range Sewage System	2000 kL/day	1,400 kL/day (1)
Jindabyne Sewage Treatment Plant	2,400 kL/day after augmentation works	1,770 kL/day
Thredbo Wastewater Treatment Plant	N/A	150 kL/day off peak, >1 ML/day during peak

(1) This is the reported daily dry weather flow as opposed to the average dry weather flow

Existing wastewater treatment facilities that have digesters onsite to process the solids contained in the wastewater have average dry weather flows in the range of 18 ML/day to over 300 ML/day. The indicative size of the plants for the Snowy Mountains SAP treatment facilities given the facility flow rates would be in the order of 100 kWe.

3.2.2.4 ASSESSMENT

The biogas that may be generated from domestic waste and wastewater is insufficient for even medium scale application. Utilisation of these resources for small scale application is unlikely to be cost effective.

Utilisation of livestock waste is problematic due to difficulties in collecting the waste if not already amalgamated at a central location and transporting the waste to the Snowy Mountains SAP area.

3.3 SOLAR ENERGY

3.3.1 INFORMATION AND DATA USED

The analysis of the renewable energy opportunity for solar energy is based on the following sources:

Table 3.10 Information and data used

ITEM	TYPE	DESCRIPTION	DATE
1	Technical Data	Vaisala dataset	June 2020
2	Technical Data	Google Earth elevation profiles	NA
3	Report	Regions and Marginal Loss Factors: FY 2020–21	April 2020

3.3.2 TECHNOLOGY

Energy received from the sun in the form of heat and light is called solar energy. Utilising solar energy to create electricity is called solar power. There are currently two established solar power technologies; solar photovoltaics (PV) and solar thermal. Solar photovoltaics use semi-conductor technology which converts solar energy directly into electricity. Solar thermal uses mirrors to concentrate solar energy onto a receiver to be used as heat in a conventional Rankine cycle to produce electricity. To date there has been limited use of solar thermal technology in the Australian electricity network. Recently, SolarReserve failed to achieve financial close for a 150 MW solar thermal plant, despite receiving a time extension of approximately one year and a $110 million loan from the Commonwealth. With the SolarReserve case in mind, the higher cost compared to solar photovoltaics and the significant uptake of solar photovoltaics in Australia, solar thermal technology is not financially viable at present. This report will deal with the feasibility of solar photovoltaic technology in the Snowy Mountains SAP.

3.3.3 RESOURCE AND FEASIBILITY ASSESSMENT

Solar photovoltaic technology is typically ground mounted or rooftop mounted. Ground mounted operations generally are utility scale solar farms and require large surface area whereas rooftop applications are generally industrial or residential scale and are limited by the space available on the roof.

The Snowy Mountains area and greater South East and Tablelands region does not commonly create favourable conditions for utility scale solar. There are several factors in determining optimum locations for utility scale solar projects:

- Solar Resource (The effective solar energy resource and the PV module productivity impacts of ambient temperatures)
- Grid Capacity
- Land Suitability (constructability and shading)
- Marginal Loss Factors (Current “marginal loss factors” and risk of further decline in marginal loss factors).

An assessment of these parameters for the Snowy Mountains SAP area is provided below.

3.3.3.1 SOLAR RESOURCE

With respect to the effective solar energy resource (being expected PV module production due to the combination of solar irradiance and ambient temperatures [higher ambient temperatures leading to lower production]), Table 3.11 below provides a comparison of the Snowy Mountains SAP and various NSW locations that have been considered or currently have utility scale solar farms.

Table 3.11 Solar resource comparison of various potential NSW locations

CONNECTION POINT	GLOBAL HORIZONTAL IRRADIANCE (GHI) ($KWH/M^2/ANNUM$)	AVERAGE DAYTIME AMBIENT TEMPERATURE (°C)	TEMPERATURE-ADJUSTED IRRADIANCE ($KWH/M^2/ANNUM$)*	NORMALISED SOLAR PRODUCTION
Coleambally	1881.5	21.0	1911.6	94%
Culcairn	1818.3	19.4	1858.9	92%
Darlington Point	1884.7	20.9	1916.0	95%
Dubbo	1938.8	21.0	1969.8	97%
Hunter Valley	1784.5	19.9	1820.6	90%
Moree	2010.1	23.0	2026.1	100%
Nevertire	1970.1	21.9	1994.3	98%

CONNECTION POINT	GLOBAL HORIZONTAL IRRADIANCE (GHI) (KWH/M^2/ANNUM)	AVERAGE DAYTIME AMBIENT TEMPERATURE (°C)	TEMPERATURE-ADJUSTED IRRADIANCE (KWH/M^2/ANNUM)*	NORMALISED SOLAR PRODUCTION
New England	1882.2	17.4	1939.1	96%
Polo Flat	1700.6	15.0	1768.8	87%
Snowy Mountains SAP	1754.5	13.1	1838.0	91%
Wagga Wagga	1843.9	19.2	1886.6	93%

*Note: the temperature adjusted irradiance normalizes production given different module efficiencies at different ambient temperatures during production hours. The solar production in above Table 3.11 is normalised with respect to the solar production at Moree-NSW.

Variation across NSW is limited, however the Snowy Mountains SAP is 9% lower than the highest effective solar resource location in NSW (being Moree, which was the location chosen for one of the earliest large scale solar projects in NSW). Although some locations in NSW have better irradiance, Snowy Mountains SAP's irradiance level can still make a viable business case to host utility and small-scale solar farms.

As Snowy Mountains SAP has comparatively lower GHI than other locations in NSW, use of Bi-facial solar panels may optimise energy to ground coverage ratio by producing more electricity from the same ground coverage of mono-facial solar panels. Additionally, the Albedo value in the Snowy Mountains SAP area would be better due to glare from the snow-covered land in the region which will provide further gains compared to generation from Bi-facial modules from other areas without snow-covered land in NSW. WSP will consider Bi-facial solar panels in the next stage of evaluation and modelling.

3.3.3.2 LAND SUITABILITY

Modern utility scale solar projects require indicatively 2–3 hectares per MWac of capacity i.e. they require a large land area. Ideally, suitable land for large scale solar farms would have following qualities:

- large areas of flat land
- minimal constraints (e.g. biodiversity, waterways)
- close proximity to grid infrastructure.

For Snowy Mountains SAP, there are multiple factors which would make a large-scale solar project less viable from a land perspective. These key factors are:

- limited availability of land within the Snowy Mountains SAP area as a majority of the land within the Snowy Mountains SAP is Scenic Protection Area
- limited suitability of the topography of the available land outside of Scenic Protection Areas
- there are other preferred land uses which may have minimum to no impact compared to a large-scale solar power project
- Snowy Mountains SAP is focused on year around tourism, and as such it is necessary to protect scenic views, the environment and biodiversity of the Snowy Mountains SAP area.

The western and south-west area of the Snowy Mountains SAP is part of the Kosciuszko National Park and is not usable for large scale solar as large areas of natural vegetation would have to be cleared and some of this area is within the Scenic Protection Area land use.

The southern area of the Snowy Mountains SAP consists of the "Go Jindabyne Master Plan Study Area" and the Mowamba River (with north-facing slopes) and may be suitable for small to medium size solar PV systems with fixed tilt mounting structures. Large-scale solar projects may have an impact on the scenic view of the Snowy Mountains SAP area as discussed above.

The Eastern side of the Snowy Mountains SAP area is divided into two portions for the assessment: i) south of Kosciuszko Road and ii) north of Kosciuszko Road. North of Kosciuszko Road shows relatively undulating terrain, but this is the most favourable area within the Snowy Mountains SAP area for large scale solar, however, as discussed above a large-scale solar PV projects may have an impact on the scenic view of the Snowy Mountains SAP area. Figure 3.6 below shows designated Scenic Protection Areas and the Go Jindabyne MasterPlan Study Area within the Snowy Mountains SAP boundary.

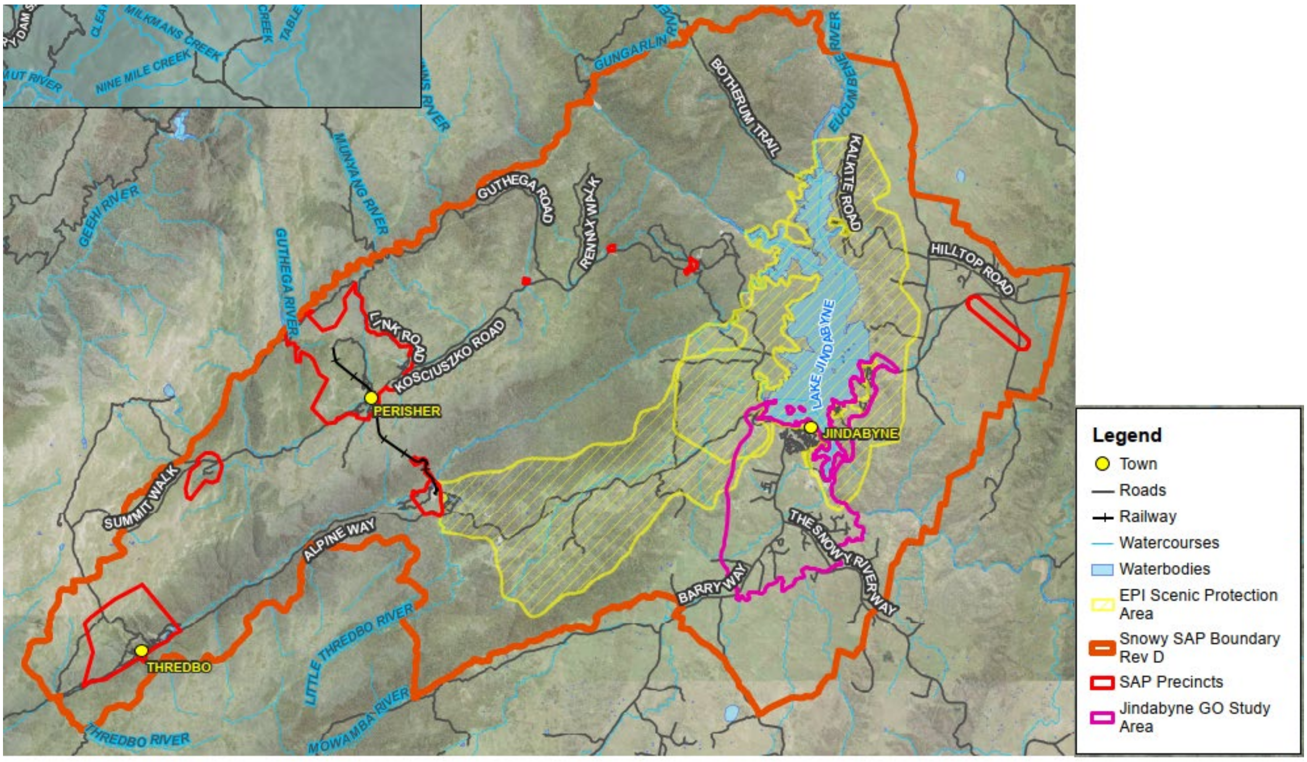


Figure 3.6 Scenic Protection Area and Go Jindabyne Master Pplan Study Area

A possible opportunity to overcome the limited usable land within the Snowy Mountains SAP could be to implement floating solar on Lake Jindabyne. However, Lake Jindabyne is a Scenic Protection Area under the Snowy River Local Environment Plan that aims to protect visual quality, sense of isolation and functions of the lake relating to recreation and water storage, hence it is unlikely that a large scale floating solar farm on Lake Jindabyne is permissible. Alternatively, a medium to small scale floating solar PV plant could be a potential opportunity for the Snowy Mountains SAP. Additional potential benefits from a small to medium floating solar system could be: i) reduction in evaporation of lake water and ii) reduction in algae growth which would help the Precinct towards its carbon negative aspiration.

Grid infrastructure capacity is separately reported on by WSP in Section 3.8.

3.3.3.3 MARGINAL LOSS FACTORS

Marginal loss factors are an economic instrument used to drive locational investment decisions by the Australian Energy Market Operator. They proportionately impact on revenue, with low MLFs penalising revenue and high MLFs providing "bonus" revenue. Marginal loss factors are estimated by WSP based on AEMO's 2020–21 Marginal Loss Factor allocations to NSW load and renewable energy generators. Table 3.12 represents the estimated MLF for some of the operational renewable energy projects in the region [20].

Table 3.12 Estimated MLF of operational renewable energy projects in the region

PROJECT	GENERATOR ESTIMATED MLF (2020/21)
Brown Mountain Hydro	98.0%
Boco Rock Wind Farm	95.3%
Guthega Hydro	91.0%
Jindabyne Hydro	**98.0%**
Capital Wind Farm	96.7%
Woodlawn Wind Farm	96.7%
Woodlawn Bioreactor	101.0%

The estimated MLF for the renewable energy projects in Southeast and Tablelands region seems to be better than some of the other regions of NSW. This supports the development case for utility scale renewable energy projects including solar PV in the Snowy Mountains SAP.

3.3.4 ASSESSMENT

Overall, based on the above high-level analysis of resources and potential constraints for solar energy in the Snowy Mountains SAP, WSP assesses that there is a moderate scope for solar energy projects subject to availability and preferences for land use. The likely most suitable area would be the north eastern area of the Snowy Mountains SAP, however from the preliminary assessment, the terrain appears to be undulating and surrounded by mountains making the design and construction of any potential solar farm more complex than current industry projects. Potential lower yield from shading due to the terrain would also need to be considered. The findings in this section are indicative at this point. Further site studies should be considered prior to commercial decisions being made on the development of large-scale solar energy projects in the Snowy Mountains SAP.

Distributed generation through rooftop solar PV and small-scale solar PV generation could be considered as an opportunity for the Snowy Mountains SAP area. Rooftop solar does not need any additional land and can be installed on the roofs of existing buildings. Small scale solar can be installed on a community owned property or small area of land. Both these opportunities do not require substantial investment and there are multiple investment models currently being obtained in the small-scale market, e.g. community owned small scale solar, and potential subsidies to rooftop solar etc.

3.3.5 METHODOLOGY FOR GROUND TRUTHING OF SATELLITE/DESKTOP DATA

Table 3.11 is based on the satellite solar resource dataset provided by Vaisala. Due to the high accuracy of satellite datasets, most solar projects in Australia have been developed without taking any ground measurements of solar irradiance, and relying entirely on these long-term satellite datasets.

For example, Vaisala can provide 30-minute resolution data for global horizontal irradiance, direct normal irradiance, diffuse horizontal irradiance, wind speed and direction and ambient temperature spanning from 1998 to present. Vaisala has validated the accuracy of their dataset by comparison with several hundred high-accuracy ground measurement stations globally, including 11 Bureau of Meteorology (BOM) ground measurement stations in Australia.

The uncertainty of Vaisala data is in the range of +/-3 to 4% and is considered a “bankable” satellite dataset.

3.4 WIND ENERGY

3.4.1 INFORMATION AND DATA USED

The key database used for the analysis of the potential wind regime in the Project area is the Australian Renewable Energy Mapping Infrastructure (AREMI), from the Australian Renewable Energy Agency (ARENA) [21]. The wind speed predictions are based on a 10 year dataset from the Modern-ERA Retrospective Analysis for Research and Applications (MERRA) database [22]. A view on the current and future aspect of wind energy in the state of New South Wales has been inferred from the Energy Hub of the NSW Government [23].

3.4.2 RESOURCE ASSESSMENT AND METHODOLOGY FOR GROUND TRUTHING OF SATELLITE/DESKTOP DATA

WSP has undertaken a preliminary review of the wind resource potential within and surrounding the Snowy Mountains SAP area. Due to the high-level nature of this study and lack of wind measurements on site, WSP has relied upon publicly available wind speed data [21]. Wind speed estimates from the AREMI map are derived from the MERRA Reanalysis database and are not validated against ground-based measurements. WSP has previously assessed the wind speeds from the MERRA database against ground-based measurements and has noted biases up to 30% in some cases.

As such, the wind speed estimates are only considered here on a relative basis, using a comparison study against operational and approved wind farms within 200 km of the Snowy Mountains SAP area. The closest operational site is Boco Rock Wind Farm, located approximately 45 km east of the Snowy Mountains SAP area. Other operational wind farms in the region include Capital Wind Farm and Woodlawn Wind Farm located near Lake George, 155 km north-east of the Snowy Mountains SAP area. The closest prospective wind farm is Granite Hills Wind Farm, located near Nimmitabel. Other prospective sites include Rye Park Wind Farm and Coppabella Wind Farm. Both are considered as bankable projects.

Figure 3.7 shows all operational and prospective wind farms in the vicinity of the Snowy Mountains SAP area.

Boco Rock Wind Farm is located approximately 10 km southwest of Nimmitabel and consists of 67 GE 1.7 MW Wind Turbine Generators (WTGs). The 113 MW project was built in 2013 and commissioned in 2015. Capital Wind Farm was built in 2008 and consists of 67 Suzlon S88 2.1 MW WTGs while Woodlawn Wind Farm was built in late 2011.

The Yass Valley region is also a region of high wind farm activity, with a number of large-scale commercial wind projects approved and under construction. For example, the 244 MW Bango Wind Farm is proposed to consist of 46 GE Cypress 5.3 MW WTGs and is currently under construction.

As mentioned previously, the wind speeds from the AREMI map are modelled from the MERRA Reanalysis database and has not been validated against ground-based measurements. The map is based solely on outputs from a weather model. A comparison study should be undertaken by any perspective developer to compare the reported wind speeds at the study area against the operational and other prospective sites in New South Wales. This would allow for a proper comparison between sites and helps mitigate the uncertainty associated with the absolute values.

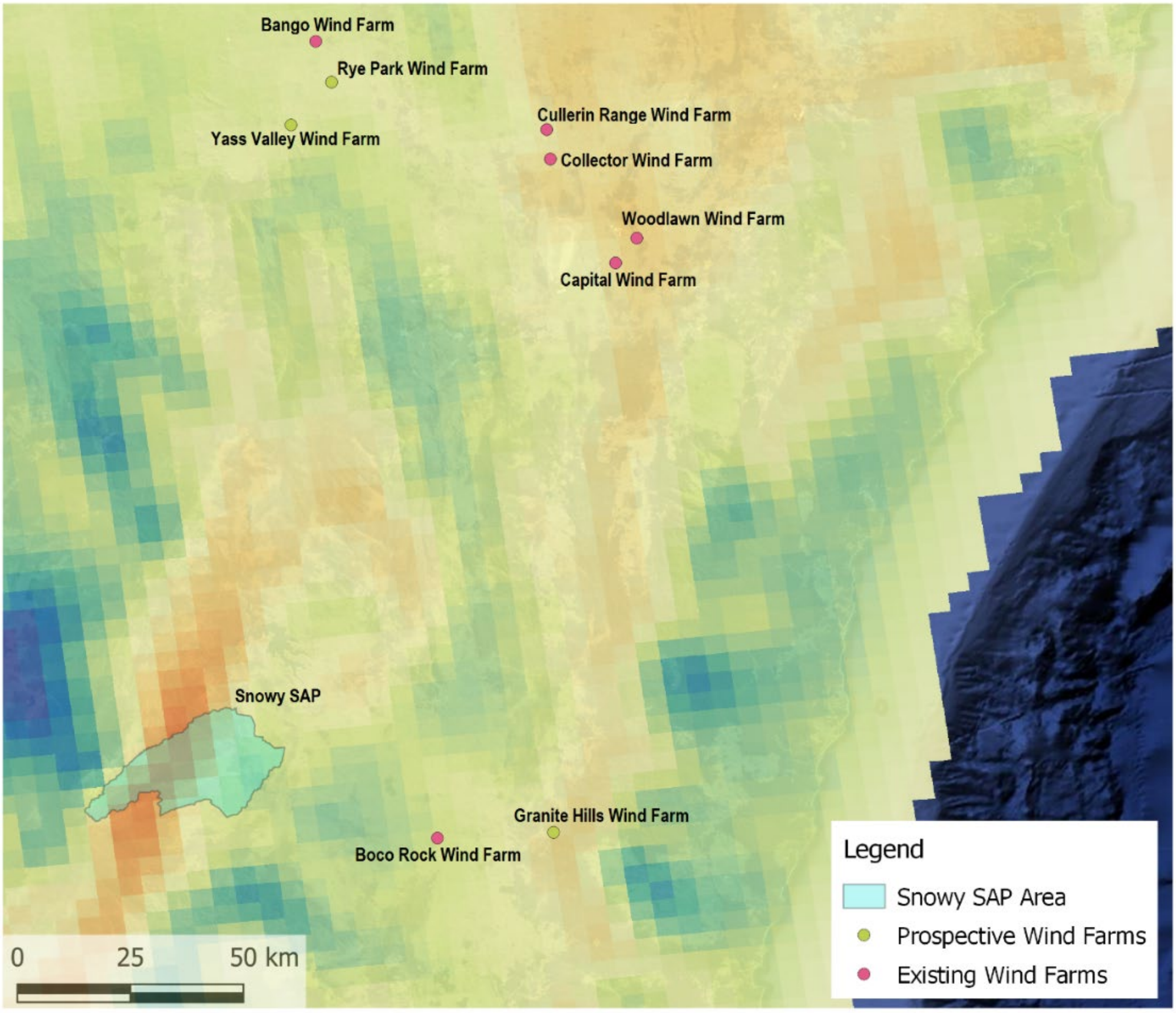


Figure 3.7 Operational and prospective wind farms within 200 km of the study area

Table 3.13 shows the wind speed estimates for each wind farm region, as reported by the AREMI map.

Table 3.13 Wind speed comparison

	DISTANCE FROM			WIND SPEED AT 150 m	WIND SPEED DIFFERENCE		
	Nimmitabel	Bungendore	Yass		Nimmitabel	Bungendore	Yass
	[km]			[m/s]	[%]		
SAP area	50	170	180	6.5–10.4 (8.5 on average)	+14.9	0.0	-2.3
Nimmitabel Region	–	–	–	7.4	–	–	–
Bungendore Region	–	–	–	8.5	–	–	–
Yass Region	–	–	–	8.7	–	–	–

3.4.3 ASSESSMENT

WSP notes that the wind speeds reported at 150 m over the Snowy Mountains SAP area ranges between 6.6 m/s and 10.4 m/s. The reported wind speeds are on par with the reported wind speeds at the operational and prospective sites in the Bungendore and Yass areas and higher than the wind speeds reported near Nimmitabel. This indicates that the Snowy Mountains SAP area may benefit from similar wind regimes as the other wind farm regions within New South Wales.

The area south and east of Lake Jindabyne are observed to experience lower winds (approx. 6.4 m/s) while the area to the north and west of the lake are reported to experience more favourable wind resources. Mount Kosciuszko National Park has the highest estimated wind speed (10.4 m/s at 150 m) while the northern section of the Snowy Mountains SAP area is subject to wind speeds in the order of 7.9 m/s. As these areas are national parks, constructability needs to be assessed for this opportunity after guidance from other stakeholders at the Preliminary Enquiry by Design workshop.

While the western portion of the Snowy Mountains SAP area is reported to have a more favourable wind resource, the terrain appears to be also more complex and as such, may be subject to some constructability constraints. WSP notes that WTG suppliers should be consulted at an early stage to discuss the suitability of WTGs for this region.

Due to the high-level nature of this study, WSP recommends that the advice presented here be used as indicative only and that detailed studies, including onsite wind monitoring, be conducted before any commercial decision regarding the development of a wind asset, are made.

3.5 HYDRO ENERGY

3.5.1 INFORMATION AND DATA USED

The analysis for renewable energy opportunities for Hydro power have been based on the following information sources:

Table 3.14 Information and data used

ITEM	TYPE	DESCRIPTION	DATE
1	Website Database	AEMO Data Archive	NA
2	Plan	Essential Energy Asset Management Distribution Annual Planning Report	December 2019
3	Paper	Discussion paper on the assessment and adoption of environmental flows for small run-of-river hydropower schemes	2011

3.5.2 RESOURCE AND FEASIBILITY ASSESSMENT

WSP has undertaken resource and feasibility assessment for potential cases of hydro power industries in which the Snowy Mountains SAP could have opportunities and constraints. The hydro solutions assessed included:

- Conventional Hydropower and Pumped Hydro
- Run-of-River
- Snowy Hydro PPA.

3.5.2.1 CONVENTIONAL HYDROPOWER AND PUMPED HYDRO

The Snowy Mountains SAP area makes up a relatively major part of the Snowy Scheme catchment. Within the Snowy Mountains SAP, the 60 MW Guthega power station is located on the border a few kilometres north of the Perisher Range Alpine Resort. Guthega is the smallest of the original seven hydroelectric stations and has contributed approximately 3.6% of the Snowy Scheme's total generation of 2,950 GWh between 2011 and 2019. In the previous three years, Guthega has generated on average approximately 125 GWh per annum. The Jindabyne Mini Hydro station is also located within the Snowy Mountains SAP boundary. Finished in 2009, it is only 1 MW and is used to capitalise on the previously wasted energy of water releases at Lake Jindabyne. WSP was unable to find generation data for Jindabyne Mini Hydro from public sources although it is expected to be insignificant with respect to Snowy Scheme's total generation.

Water in Lake Jindabyne is also used at the Murray 1 and Murray 2 power stations. The Jindabyne pumping station transports the water through two tunnels from Lake Jindabyne to the Geehi reservoir, where it is used for generation at the Murray power stations. The specific volume of water pumped from Lake Jindabyne was unobtainable in the public domain therefore WSP is unable to quantify the generation contributions of the lake. Snowy 2.0 is a pumped hydro project which links the Tantangara and Talbingo dams using approximately 27 km of tunnels. The project is forecast to provide 2,000 MW of capacity and a total storage of 350,000 MWh although first generation is not expected until early 2025.

The above is intended to highlight that the region is already largely exploited for conventional large-scale hydropower and pumped hydro. With respect to small-scale pumped hydro we note it is typically not economically viable for energy storage in comparison to Lithium-ion or Sodium-sulphur battery technology.

Figure 3.8 Map of Snowy Scheme

3.5.2.2 RUN-OF-RIVER

Run-of-river hydropower typically makes use of a small section of a river with notable change in elevation. A weir or similar intake structure is installed at the top of the scheme, and a portion of the river's natural stream flow is diverted through a low friction waterway to a powerhouse located adjacent to the lower reach of the river. For modern run-of-river schemes the portion of water diverted is typically subject to environmental assessment to determine an acceptable volume. An example of a local Australian run-of-river scheme is the Rubicon scheme. First constructed in 1922 on the Rubicon and Royston Rivers, the scheme now consists of five units which provide 13.5 MW of hydroelectric power. A small run-of-river scheme could be beneficial to the alpine resorts in the area if it could power a portion of their load.

The Snowy Mountains SAP area is home to several creeks and three main rivers, the Thredbo River, Snowy River, and the Eucumbene River all flow into Lake Jindabyne. Both the Snowy River and Eucumbene River have already been dammed at points upstream of Lake Jindabyne for the Snowy Hydro Scheme and are considered unsuitable for new development. The Thredbo river is un-dammed prior to Lake Jindabyne and runs next to the 33 kV line between the Bullocks Flat and Thredbo zone substations. WSP has previously completed a study to identify all possible run-of-river hydro sites on the eastern seaboard. Thredbo River was recognized as a potential location for a small run-of-river scheme.

The Thredbo River starts at Mount Leo and passes through the Thredbo Alpine Resort before terminating in Lake Jindabyne. The river is currently used for tourism activities such as white-water rafting and fishing in the Spring when water flow is at its peak due to the melting snow.

As noted above, run-of-river schemes reduce the flow of the river between the weir and the powerhouse. This change in flow can impact the ecology of the river and reduce the habitat availability, decrease species diversity, and restrict the movement of fish. It is also largely incompatible with the current tourism uses of the waterway.

Another downside is that the period of peak demand for electricity and the lowest hydro generation align in winter. The ski season is energy intensive compared to the rest of the year due to the high number of tourists and increased loads required for snow guns and chairlifts. During this time, ice can form on Thredbo river and inflows are low leading to constraints in the operation of the scheme and lower generation.

Overall, a small run-of-river scheme on Thredbo River would provide benefits although it would come with a number of environmental and stakeholder risks. Spring tourism in the area relies on the river for multiple activities which could be negatively affected. Any feasibility assessment of such a concept would need to carefully consider these impacts.

3.5.2.3 SNOWY HYDRO POWER PURCHASE AGREEMENT

Late last year, a partnership between Lion Breweries, the Australian Hotels Association, and Tourism Accommodation Australia was signed for a Power Purchase Agreement (PPA) with Engie's Silverleaf Solar Farm. For the next 10 years, the group of companies will purchase the energy generated by the solar farm at a lower price than from energy retailers. The media has reported that they will see energy cost savings of up to 40%.

There is potential for a consortium of Thredbo Alpine Village, Perisher Ski Resort and Charlotte Pass Snow Resort to organise a PPA with Snowy Hydro. Energy costs at the three resorts most likely make up a significant portion of their total expenses therefore savings in the area could go a long way to freeing up capital for further development. The PPA would also boost the group's "green image" and potentially gain the attention of the media. Red Energy, one of Snowy Hydro's retailers, state on their website that they have partnerships with Perisher, Thredbo and Charlotte Pass. WSP is not privy to the details of these partnerships with respect to pricing and energy supply type. If the PPA option or 100% green power has not already been explored then it would be a great opportunity for the three resorts to join forces and negotiate a deal.

3.5.3 ASSESSMENT

A small-scale run-of-river scheme on the Thredbo River could be explored, although its potential negative effects (e.g. on tourism) would require careful consideration. The most feasible outcome would be to encourage Snowy Hydro to sign a PPA with a consortium of the alpine resorts in the region. The resort's energy savings could be carried on to tourists or used to develop the area.

3.6 GEOTHERMAL ENERGY

3.6.1 INFORMATION AND DATA USED

This analysis for renewable energy opportunities for geothermal has been based on the following information sources:

Table 3.15 Information and data used

ITEM	TYPE	DESCRIPTION	DATE
1	Technical Whitepaper	Status of the Geothermal Industry in Australia, 2000–2005, Chopra, Proceedings World Geothermal Congress	April 2005
2	Technical Whitepaper	Country Update – Australia, Beardsmore, Proceedings World Geothermal Congress	April 2015
3	Technical Report	Australian Renewable Energy Agency – Report to the board – Looking Forward: Barriers, Risks and Rewards of the Australian Geothermal Sector to 2020 and 2030 10 June 2014.	June 2014
4	Website Database	Geoscience Australia Website OZTemp Interactive GIS Data	July 2019
5	Technical Resource	Geoscience Australia Onshore Energy and Minerals Division – Granite Heat Production Map	July 2007
6	Technical Resource	NSW Renewable Energy Resources Map – Geothermal, NSW Department of Planning and Environment	January 2019
7	Website Database	AREMI – Geothermal Databases (2016)	N/A
8	Website	GTD Projects	2017
9	Brochure	Slashing power in the Snowy Mountains	2012
10	Report	Geothermal Space Heating	N/A

The key data set used for this high-level feasibility assessment was Geoscience Australia's OZTemp Well Temperature Data online database. This resource is an updated and improved version of the AUSTHERM05 borehole temperature database created by Chopra and Holgate in 2005 and previously managed by the Bureau of Minerals Resources (now Geoscience Australia). This has been generated using temperatures recorded at the bottom of more than 5,700 deep drill holes, most of which were drilled for petroleum exploration supported by more detailed local investigations by companies. The data from these sources has then been extrapolated to give predicted temperature figures for up to five km depth. The extrapolated temperature can be horizontally interpolated between drill holes, and contoured to produce a continuous map of temperature at five km depth across the entire continent (the technique pioneered by Somerville et al. 1994 in creating the Geotherm94 database).

Other key inputs were the Renewable Energy Resources Map – Geothermal produced by the NSW Department of Planning and Environment (item 6 above), and the National-scale maps published by Geoscience Australia showing the distribution of high heat producing granites and sedimentary basins. Together with other information such as basin depth, these provide a national framework and basis for identifying areas likely to have the greatest heat potential.

3.6.2 RESOURCE AND FEASIBILITY ASSESSMENT

3.6.2.1 BACKGROUND

High temperature geothermal systems with circulating fluids above 150°C can be utilised for electricity generation, but are restricted to locations near active or recent volcanism. Heat sources for lower-temperature systems (<150°C) in Australia include high-heat-producing basement rocks, or geologically recent volcanic systems [24].

The main barrier to the implementation of these systems is locating zones with heat, fluid and sufficient permeability to provide viable flow rates of warm fluid. Permeability associated with natural fracture systems is considered to have the best chance of providing a viable geothermal reservoir and therefore, efforts are typically focused on identifying natural fracture systems.

Extrapolation of available data indicates that the geothermal resource in the Snowy Mountains SAP will not have sufficient heat for electricity generation, or combined heat and power systems, as these would require fluid with a temperature over 150°C to be available. In the Snowy Mountains SAP area, at a depth of 5 km, a temperature around 120°C may be achieved. This implies that the most likely potential options for using a geothermal resource would be low heat direct use options such as fish farming (30°C), swimming pools (40°C), or direct space heating applications (50°C+) [25].

Direct space heating is one of the earliest uses of geothermal heat and makes use of pumped wells or downhole heat exchangers. If the temperature is not sufficient for heating requirements, a heat pump can be installed to increase the temperature [26].

In NSW there are a number of geothermally heated artesian baths such as the Pilliga Hot Artesian Bore, which was drilled 564 m deep and supplies water at 37°C and the Moree Artesian baths which supply water at 41°C [27]. There is also a geothermal pool in the Yarrongobilly area in the Kosciuszko National Park, which is permanently heated to 27°C by a natural spring [28].

The possibility of supplementing the geothermal heat with waste heat to reach sufficient temperatures to allow electricity generation exists but is likely to be costly.

3.6.2.2 RESOURCE ASSESSMENT

The principal requirements for a viable geothermal system typically includes the geothermal resource's heat, fluid and permeability. The characteristics of the fluid can be broken down into its year-round availability and flowrate potential. Favourable permeability is required to reheat the fluid. The heat element of the geothermal system is the temperature of the fluid.

If sufficient heat is available, but the fluid or permeability is unfavourable, then as a secondary option, the permeability and fluid can be introduced in the form of an Enhanced Geothermal System. However, this option attracts an additional cost as it involves additional work such as underground rock fracturing and bringing in sufficient fluid.

HEAT

Around the area where the Snowy Mountains SAP is located, there are relatively large areas of outcropping granites and some under cover granites. Outcropping granites have a higher likelihood of containing very low levels of uranium, thorium and potassium. The decaying of these elements with time produces heat with no health or environmental risks. The heat from these formations can become trapped under overlying rocks, which creates a higher likelihood for finding potential geothermal resources. However, in the region where the Snowy Mountains SAP is located, the actual temperature and heat data points have a generally low capacity for geothermal development.

The nearest borehole to the Snowy Mountains SAP is borehole ID NSW213 CUL034 Snowy Mountains 5146, which recorded a temperature of 14.43°C at a depth of approximately 245 m. The next closest boreholes are listed in Table 3.16.

Table 3.16 Data from boreholes near the Snowy Mountains SAP area [21]

BOREHOLE	DEPTH (m)	TEMPERATURE (^{0}C)	DISTANCE FROM SAP (km)
NSW213 CUL034 Snowy Mountains 5146	245	14.43	–
NSW231 CUL112 Bombala	200	–	91
NSW218 CUL043 Captains Flat EZ7	263	19.29	135
NSW216 CUL037 Dromedary 2	220	–	160
NSW214 CUL035 Narooma	300	–	160

Temperature data was not recorded for the Bombala, Dromedary and Narooma boreholes. The Captains Flat borehole, being some 135 km from the site is sufficiently far that the temperature at this borehole may not be an accurate representation of the geothermal resource at the Snowy Mountains SAP area.

FLUID

The ground water supply in the Snowy River shire which encompasses the Snowy Mountains SAP stems from a low yield system that typically meets drinking water standards. The groundwater level in this area can be difficult to accurately determine because private bores can be operated under a NSW Department of Infrastructure Planning and Natural resources license. Thus, the data available would be collected only from those boreholes used for the council's extraction [29].

In the immediate areas surrounding the Snowy Mountains SAP, groundwater level trends for upper aquifers had been stable, although in 2017–18, the nearest groundwater levels (measured around the Burrowa Pine Mountain National park, 90–100 km from the Snowy Mountains SAP) were reportedly below average [30].

PERMEABILITY

Between Jindabyne and the Murrumbidgee river, the main geological features primarily include large masses of granite [31]. These formations generally have low permeability when they are found without fractures, or may lack a natural groundwater flow. To enhance the efficiency for a system using these formations, artificial fractures may need to be created in the rock to allow fluid circulation [32].

3.6.2.3 FEASIBILITY ASSESSMENT

ELECTRICITY AND DIRECT HEAT USE

A high level feasibility assessment based on the data reviewed and on the basis of the key factors being heat, fluid and permeability as above, indicates that the geothermal resource available in the Snowy Mountains SAP area is unlikely to be able to sustain electricity generation or direct heat use.

Although only one borehole has been drilled in the immediate area, based on the OzTemp mapping and NSW Renewable Energy Resources map, the data indicates that further exploration is unlikely to find sufficiently high temperatures for power generation. Furthermore, sufficient temperatures for other recreational uses such as fish farming, pool heating and space heating will require a suitable resource, which the current available information does not show to be present in the Snowy Mountains SAP area.

GROUND SOURCE GEOTHERMAL HEAT PUMPS

An alternative use for geothermal resources is through installing heat pumps. These devices use the earth as a heat exchanging medium instead of the outside air temperature. In this way, they are able to effectively heat or cool a space by taking advantage of the relatively constant temperature of the earth several metres below the surface and can be used to heat medium to large scale buildings. This is achieved by transferring heat from the ground for space heating applications, or taking heat from a space within a building and pumping it underground to cool the space. The design of geothermal heat pumps will typically use two water circuits with heat exchangers to transfer the heat from the underground circuit to the heating/cooling circuit. The underground circuit is typically installed around 3 m below the surface where the temperature is around 12–13°C regardless of the air temperature at the surface. This is much lower than the temperature required for direct space heating.

Similar systems that use the same basic heat exchanging concept are already in use in buildings in the Snowy Mountains SAP. Thredbo Leisure Centre for example uses electric heat pumps to recover heat from snowmaking ponds (see Table 3.17). In addition to commercial buildings, this technology can be used for domestic residences [33].

Table 3.17 Facilities with heat pump technology installed

FACILITY	LOCATION	PURPOSE
Thredbo Leisure Centre	Thredbo	Uses electric heat pumps to recover heat from snowmaking ponds to provide heat for swimming pools [34].
Contemporary Alpine Getaway	Jindabyne	Uses a water to water heat pump system for floor heating [33].
Snowy Region Visitor Centre	Jindabyne	Uses geothermal heating, ventilation and cooling [35].
Residence	Berridale	Uses heat pumps to heat the house [33].
Homestead	Berridale	Heat pumps installed with ducted heating and cooling for the house [33].
Residence	Cooma	Ground sourced heat pump supplies hot water to the house. Later upgraded with a heat pump for pool heating [33].
Residence	Cooma	Ground sourced heat pump supplies heat to radiators fitted for heating and fan convectors for heating and cooling of the house [33].

3.6.3 *METHODOLOGY FOR GROUND TRUTHING OF DESKTOP DATA*

The current resources data indicates that ground temperatures within and around the Snowy Mountains SAP area is expected to be sufficiently low. It is noted that this data uses extrapolation of nearby borehole data and as such, there may be natural formations within the area which have geothermal potential. The cost of undertaking these ground truthing exercises may not warrant the potential benefits due to the likely low probability of finding a suitable resource.

However, **if** further investigation were to be done, then the methodology suggested would be:

- Investigate the geothermal resource using drill holes directly in the Snowy Mountains SAP region to obtain more accurate and relevant data. These drill holes would only need to be drilled to a shallow or modest depth to determine the thermal regime in the sub-surface. This heat flow potential need only be large enough to lower a temperature gauge and not necessarily support fluid flow. These would be able to provide more direct estimates for potential temperatures at the depth of interest. The next level of cost would involve deeper drill holes with connecting instrumentation to ascertain likely pressures and sustainable mass flow rates.
- Carry out geochemical sampling of any surface springs, mineral deposits or gas discharges within or close to the Snowy Mountains SAP. This method has the advantage of relative ease of access as the samples are taken from features at the surface, and through analysis of the chemical composition, can accurately determine the ground temperatures hundreds of metres below.
- Further investigation and assessment of detailed log data from petroleum exploration efforts. Analysis and interpretation of petroleum exploration wellbores would provide an understanding of the sub-surface structure and rock stresses and would help inform a more accurate prediction of the likely heat, fluid and permeability properties.
- Further investigation can be performed by the assessment of 3D seismic, Automated Fracture Extraction (AFE) data in conjunction with regional geomechanically models.

3.7 HYDROGEN

While not directly a form of renewable energy, and not envisaged as a part of the scope of this study at this stage, in the context of this study, hydrogen as storage of electrical energy and heat source is of primary importance. This section discusses hydrogen as a form of electrical energy storage (noting that biomass inherently provides chemical energy storage, as does liquid fuels etc.) and a high level opportunity commentary as a heat source.

The Australian government is currently encouraging the innovation, production and utilisation of hydrogen as a source of energy and for energy storage. Recent funding allocations to hydrogen pilot projects by ARENA include:

- $7.5 million to build a demonstration scale 500 kW electrolyser at its facility in western Sydney (NSW) [36]
- $22 million in R&D funding into exporting hydrogen, supporting 16 research projects across nine Australian universities and research organisations [36]
- $1.28 million for the Australian Hydrogen Centre which will assess the feasibility of blending renewable hydrogen into gas distribution networks in Victoria and South Australia [37]
- ~$1 million for the Feasibility of Renewable Green Hydrogen project in Queensland [38].

There could be a couple of opportunities for hydrogen gas to play a role to achieve Snowy Mountains SAP's carbon negative aspiration by implementing pilot projects or by using proven methods. There is a potential to consider hydrogen as a form of energy storage in the Snowy Mountains SAP's energy strategy if there is an excess of renewable energy and recycled wastewater in the Snowy Mountains SAP. It is expected that the hydrogen generation and energy storage system would be collocated with these resources.

3.7.1 ELECTRICAL ENERGY STORAGE

Hydrogen is a colourless, non-toxic, highly combustible gas which consists of one proton and one electron. It is the most abundant element in the universe, however, hydrogen does not occur naturally on earth as a gas (H_2). It is generally found bonded to other elements, the most common examples being water (H_2O) and methane (CH_4).

Electricity can be generated from hydrogen through a fuel cell. A fuel cell is a device that converts chemical potential energy into electrical energy. Fuel cells share a similarity to batteries as they both convert the energy produced by a chemical reaction into usable electric power, however, the fuel cell will produce electricity as long as fuel (hydrogen and oxygen) is supplied, without losing charge and only produces water, heat and electricity. Since oxygen is readily available in the atmosphere, the other major requirement is a supply of hydrogen.

There are two common methods to produce hydrogen from its bonded forms; electrolysis and steam-methane reforming. Steam-methane reforming is a method that results in large amounts of hydrogen being produced, however, this method is harmful to the environment as it requires methane and produces carbon dioxide and carbon monoxide which are greenhouse gasses. In the electrolysis process, electricity is run through water to separate the hydrogen and oxygen atoms. For this process to be made green, the electricity used must be produced using a renewable resource.

The global market for hydrogen is in its infancy, however, economies in Japan, Canada and China have already indicated strong targets for hydrogen powered vehicles (HPVs) for 2030 and out to 2050, for the purposes of reducing emissions associated with transport. HPVs offer some key advantages over electric vehicles for larger trucks and buses, the travel range is longer for smaller vehicles and the net environmental impact is much lower than batteries which often require mining of scarce resources such as lithium.

Hydrogen fuel cell technology is in its early stage of commercialisation and thus current opportunities appear limited.

3.7.2 HEAT SOURCE

Hydrogen can be blended with the natural gas which can be delivered to the consumers of the Snowy Mountains SAP. A study undertaken by the government of South Australia found that the addition of 10% hydrogen (by volume) to a typical natural gas blend has no significant impacts or implications on gas quality, safety and risk aspects, materials, network capacity and blending [39].

Hydrogen sourced through renewable energy sources will play a significant role in achieving net zero carbon emissions by replacing natural gas in industrial and domestic heating.

3.8 ELECTRICAL NETWORK INFRASTRUCTURE ASSESSMENT

3.8.1 *INFORMATION AND DATA USED*

The analysis for electrical network infrastructure has been done based on the following information sources:

Table 3.18 Information and data used

ITEM	TYPE	DESCRIPTION	DATE
1	Report	Essential Energy – Asset Management Distribution Annual Planning Report	December 2019
2	Report	TransGrid – NSW Transmission Annual Planning Report 2019	June 2019
3	Report	Go Jindabyne Utilities and Servicing Strategy	July 2019
4	Website Data	AEMO-Interactive Map	-NA-
5	Diagram	AEMO-High Voltage Network System Diagram	April 2019

3.8.2 *INTRODUCTION*

This section considers the assessment of the existing transmission infrastructure and available capacity around the Snowy Mountains SAP region based on a desktop assessment of publicly available information.

The report addresses the following:

— review of documents from Australian Energy Market Operator (AEMO), TransGrid and Essential Energy to identify the system loading and constraints in the electrical network in the Snowy Mountains SAP area
— review of key transmission system equipment ratings.

3.8.3 *EXISTING DISTRIBUTION INFRASTRUCTURE*

WSP has identified the existing distribution substations which are in the proposed Snowy Mountains SAP area. The majority of these distributions belong to Essential Energy and Jindabyne pumping station which is a private asset. These substations along with the capacity are given in Table 3.19 below.

These existing infrastructures on the site have been identified based on the information available from the Asset Management Distribution Annual Planning Report (DAPR) – 2019 and the interactive map available from the Australian Energy Market Operator (AEMO).

Table 3.19 Distribution substation in the Snowy Mountains SAP Region

SUBSTATION STATION NAME	SUBSTATION VOLTAGE LEVEL (kV)	TRANSFORMER MVA CAPACITY (MVA)
Snowy Adit Substation (supplied by Munyang Substation)	132/66/11 kV	1 x 10 MVA 1 x 30 MVA
Jindabyne Substation (supplied by Cooma Substation)	66/33/11 kV	2 x 30 MVA (66/11 kV) 1 x 15 MVA (66/33 kV)
Jindabyne East Substation (supplied by Cooma Substation)	66/11 kV	2 x 10 MVA
Blue Cow Substation (supplied by Munyang Substation)	33/11 kV	1 x 8 MVA
Smiggin Switching Station	33 kV	-NA-

SUBSTATION STATION NAME	SUBSTATION VOLTAGE LEVEL (kV)	TRANSFORMER MVA CAPACITY (MVA)
Perisher (supplied by Munyang Substation)	33/11 kV	2 x 10 MVA
Bullocks Portal (supplied by Munyang Substation)	33/11 kV	1 x 6.25 MVA
Bullocks Flat (supplied by Munyang Substation)	33/11 kV	1 x 6.25 MVA
Thredbo (supplied by Munyang Substation)	33/11 kV	2 x 16 MVA
Jindabyne Pump Station	132 kV	-NA-

The forecast loads for the sub-transmission feeder and STS and ZS servicing the Snowy Mountains SAP area have been provided by Essential Energy in the DAPR-2019 report. Based on this, WSP has estimated available capacity for each substation which are in the Snowy Mountains SAP. These are summarised in Table 3.20 below.

Table 3.20 Distribution substation loading in the Snowy Mountains SAP Region

SUBSTATION SWITCHING STATION NAME	INSTALLED CAPACITY (MVA)	AVAILABLE CAPACITY FOR THE YEAR 2021 (MVA)
Snowy Adit Substation (supplied by Munyang Substation)	1 x 10 MVA 1 x 30 MVA	9.9 MVA 17.7 MVA
Jindabyne Substation (supplied by Cooma Substation)	2 x 30 MVA (66/11 kV) 1 x 15 MVA (66/33 kV)	46.6 MVA 13.3 MVA
Jindabyne East Substation (supplied by Cooma Substation)	2 x 10 MVA	15.4 MVA
Blue Cow Substation (supplied by Munyang Substation)	1 x 8 MVA	1.9 MVA
Smiggin Switching Station	-NA-	-NA-
Perisher (supplied by Munyang Substation)	2 x 10 MVA	8.7 MVA
Bullocks Portal (supplied by Munyang Substation)	1 x 6.25 MVA	5.15 MVA
Bullocks Flat (supplied by Munyang Substation)	1 x 6.25 MVA	5.25 MVA
Thredbo (supplied by Munyang Substation)	2 x 16 MVA	17.7 MVA
Jindabyne Pump Station	-NA-	-NA-

From the above Table 3.20, it is observed that these substations are catered by either Munyang or the Cooma substation. The forecast loading for the sub-transmission feeders and the zonal substations supplied by these substations are provided by Essential Energy in the DAPR-2019 report and are presented in Figure 3.9 and Figure 3.10 below. The report identifies no system limitations for the Cooma and the Munyang sub-transmission system for the year 2020/2021.

COOMA – Identified System Limitations	
SYSTEM LIMITATION	Refer to DAPR Section
Nil	

Sub-transmission feeder load forecast

Feeder #	Feeder Voltage kV	Feeder Origin	Feeder Destination	Summer						Winter					
				Line Rating MVA	Line Forecast MVA					Line Rating MVA	Line Forecast MVA				
					19/20	20/21	21/22	22/23	23/24		2020	2021	2022	2023	2024
974	132	TransGrid Cooma 132/66kV STS	Bega 132/66kV STS	128	16.8	16.8	16.8	16.8	16.8	143	22.1	22.1	22.1	22.1	22.1
97R	132	TransGrid Cooma 132/66kV STS	Steeple Flat 132/66kV STS	140	81.0	81.0	81.0	81.0	81.0	157	74.6	74.6	74.6	74.6	74.6
82D	66	TransGrid Cooma 132/66kV STS	Jindabyne East ZS	20	9.7	9.7	9.7	9.7	9.7	39	20.6	20.6	20.6	20.6	20.6
84J	66	TransGrid Cooma 132/66kV STS	Cooma 66/11kV ZS	70	5.3	5.3	5.4	5.4	5.5	78	6.4	6.4	6.4	6.4	6.4
84L	66	TransGrid Cooma 132/66kV STS	Cooma 66/11kV ZS	64	5.3	5.3	5.4	5.4	5.5	71	6.4	6.4	6.4	6.4	6.4
82J/1	66	Snowy Adit 132/66/11kV ZS	Snowy Lookout Sw Stn	12	0.0	0.0	0.0	0.0	0.0	20	0.0	0.0	0.0	0.0	0.0
82J/2	66	Jindabyne ZS	Snowy Lookout Sw Stn	12	0.0	0.0	0.0	0.0	0.0	19	0.0	0.0	0.0	0.0	0.0
82R	66	Jindabyne East ZS	Jindabyne ZS	20	4.4	4.4	4.4	4.4	4.4	39	15.0	15.0	15.0	15.0	15.0
888/1	66	TransGrid Cooma 132/66kV STS	Rhine Falls Sw Stn	16	3.9	3.9	3.9	3.9	3.9	25	4.6	4.6	4.6	4.6	4.6
888/3	66	Rhine Falls Sw Stn	Adaminaby ZS	16	3.6	3.6	3.6	3.6	3.6	25	4.4	4.4	4.4	4.4	4.4
888/4	66	Rhine Falls Sw Stn	Eucumbene Tee	15	0.5	0.5	0.5	0.5	0.5	25	0.4	0.4	0.4	0.4	0.4
888/6	66	Eucumbene Tee	Eucumbene ZS	15	0.3	0.3	0.3	0.3	0.3	25	0.3	0.3	0.3	0.3	0.3
888/7	66	Eucumbene Tee	Snowy Adit 132/66/11kV ZS	20	0.0	0.0	0.0	0.0	0.0	39	0.0	0.0	0.0	0.0	0.0
849/1	33	Adaminaby ZS	Providence Portal ZS	7	1.8	1.8	1.8	1.8	1.8	12	2.7	2.7	2.7	2.7	2.7
849/2	33	Providence Portal ZS	Mt Selwyn Tee	7	1.1	1.1	1.1	1.1	1.1	12	1.9	1.9	1.9	1.9	1.9
849/3	33	Mt Selwyn Tee	Cabramurra ZS	8	1.1	1.1	1.1	1.1	1.1	12	1.7	1.7	1.7	1.7	1.7

Figure 3.9 Essential Energy Cooma supply area forecast loads (DAPR-2019)

MUNYANG – Identified System Limitations	
SYSTEM LIMITATION	Refer to DAPR Section
Nil	

Sub-transmission feeder load forecast

Feeder #	Feeder Voltage kV	Feeder Origin	Feeder Destination	Summer						Winter					
				Line Rating MVA	Line Forecast MVA					Line Rating MVA	Line Forecast MVA				
					19/20	20/21	21/22	22/23	23/24		2020	2021	2022	2023	2024
56	33	Smiggin Sw Stn	Perisher ZS	20	1.3	1.4	1.4	1.4	1.4	23	16.0	18.4	18.2	17.9	17.8
57A	33	Smiggin Sw Stn	Perisher ZS	20	0.7	0.7	0.7	0.7	0.7	23	6.8	6.8	6.8	6.8	7.0
57B	33	Smiggin Sw Stn	Perisher ZS	20	0.5	0.5	0.5	0.5	0.5	23	4.5	4.5	4.5	4.5	4.7
No.1 Perisher	33	TransGrid Munyang 132/33kV STS	Smiggin Sw Stn	38	2.0	2.0	2.0	2.0	2.0	41	16.0	18.4	18.2	17.9	17.8
No.2 Perisher	33	TransGrid Munyang 132/33kV STS	Blue Cow Tee	38	1.7	1.8	1.8	1.8	1.8	49	13.9	16.0	15.7	15.5	15.4
No.2 Perisher	33	Blue Cow Tee	Smiggin Sw Stn	38	1.6	1.7	1.7	1.7	1.7	49	14.3	16.5	16.3	16.1	16.0
60/2	33	Bullocks Portal ZS	Bullocks Flat ZS	19	2.1	2.1	2.1	2.1	2.1	23	15.5	16.4	16.1	15.8	15.5
58	33	Bullocks Flat ZS	Thredbo ZS	6	0.5	0.5	0.5	0.5	0.5	14	10.0	10.0	10.0	10.0	10.0
59	33	Bullocks Flat ZS	Thredbo ZS	6	1.4	1.4	1.4	1.4	1.4	14	6.7	7.2	7.0	6.8	6.7
Bullocks Portal Line	33	Perisher ZS	Bullocks Portal ZS	20	2.4	2.4	2.4	2.4	2.4	23	15.5	16.4	16.1	15.8	15.5

Figure 3.10 Essential Energy Munyang supply area forecast loads (DAPR-2019)

3.8.4 *EXISTING TRANSMISSION INFRASTRUCTURE*

WSP has identified the following existing transmission substations which are in the proposed Snowy Mountains SAP area which belong to TransGrid. These substations along with the installed capacity are given in Table 3.21 below.

Table 3.21 Transmission substation in the Snowy Mountains SAP Region

SUBSTATION STATION NAME	SUBSTATION VOLTAGE LEVEL (kV)	TRANSFORMER MVA CAPACITY (MVA)
Guthega 132 kV switching station	132 kV	-NA-
Munyang Substation	132/33/11 kV	2 x 60 MVA
Cooma Substation	132/66 kV	2 x 60 MVA

As per TransGrid – NSW Transmission Annual Planning Report 2019, the maximum demand at Munyang 33 kV substation is forecasted as 33 MVA in the year 2021 and for the Cooma, 132 kV substation is forecasted as 57 MVA. Based on these, WSP has estimated the available capacity for these substations as provided in Table 3.22 below.

Table 3.22 Transmission substation loading in the Snowy Mountains SAP Region

SUBSTATION SWITCHING STATION NAME	INSTALLED CAPACITY (MVA)	AVAILABLE CAPACITY IN THE YEAR 2021 (MVA)
Guthega 132 kV switching station	-NA-	-NA-
Munyang Substation	120 MVA	87 MVA
Cooma Substation	120 MVA	63 MVA

The report also provides the line/feeder utilization which indicates that the transmission lines in the Snowy Mountains SAP region are not loaded to the full extent. The expected line utilisation or the line loadings are shown in Figure 3.11 and are tabulated in Table 3.23 below.

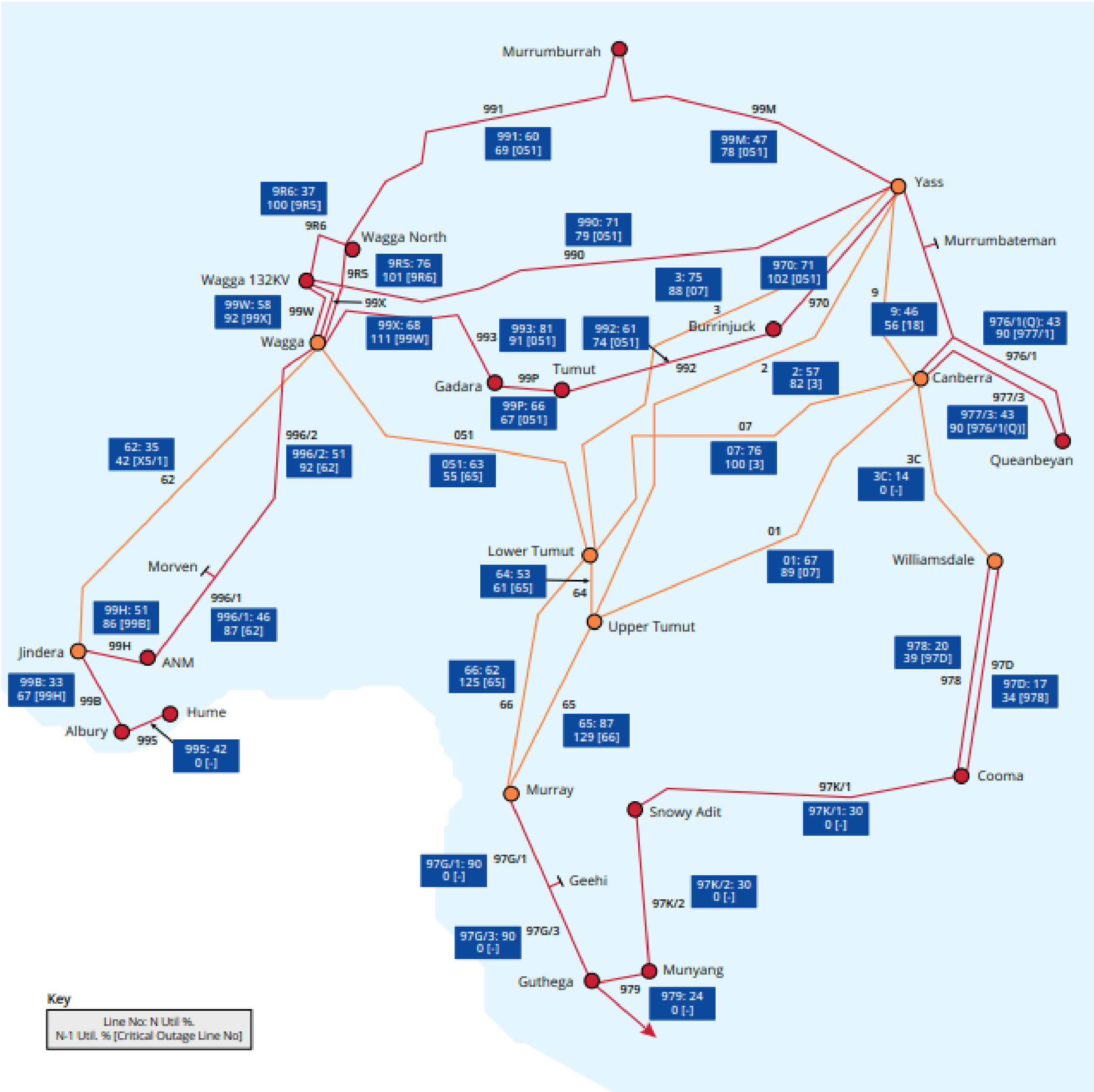


Figure 3.11 Line utilisation near Snowy Mountains SAP region

Table 3.23 Transmission line loading in Snowy Mountains SAP area

LINE NAME	% LINE LOADING
Cooma to Snowy Adit	30%
Snowy Adit to Munyang	30%
Munyang to Guthega	24%

3.8.5 ASSESSMENT

The feeder rating (MVA) and the feeder loading (MVA) as per the forecast is represented in Figure 3.12 below.

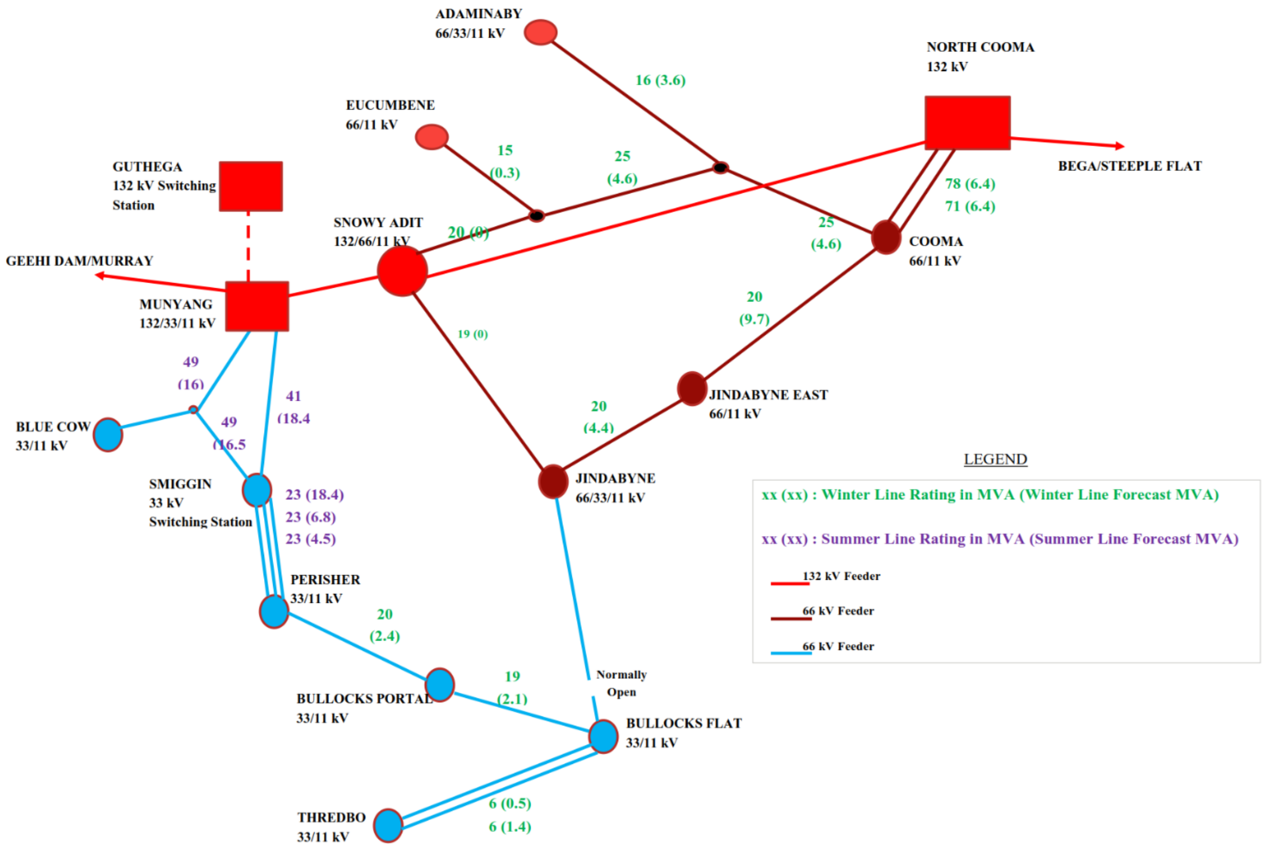


Figure 3.12 Feeder rating and forecasted line loading in MVA

Based on the desktop assessment carried out for the Transmission and Distribution network within the Snowy Mountains SAP area, the transmission and distribution infrastructure is not thermally constrained.

3.9 CARBON NEGATIVE PRECINCT

3.9.1 ALIGNMENT WITH SCIENCE-BASED TARGETS

It is proposed that the strategy for establishing the Snowy Mountains SAP as a carbon negative precinct is best formed through close alignment with established climate science trajectories including the Paris Climate agreement. These science-based targets are intended to ensure global climate temperature growth is limited to no more than 2°C by 2050. The carbon goals discussed below are intended to reach alignment with these global commitments.

Within the science based targets approach is necessary to adopt a hierarchy of offsets including avoidance of emissions through enhanced design, inclusion of renewable energy as a first preference supply and finally offsetting of remaining un-avoided emissions.

3.9.2 STANDARDS AND SCOPE

A carbon negative precinct is a precinct that offsets or sequesters a larger carbon equivalent impact than it produces. The first step in establishing a carbon negative precinct is to define the standards and scope of emissions by which a carbon negative outcome will be measured. The scope should be independently verifiable, subject to third party review and capable of being monitored and managed through operation.

It is understood that the scope of the carbon outcome is to include all scope 1, 2 and 3 emissions associated with the precinct inclusive of energy generation, agriculture, transport, public and private building energy consumption. In establishing the specific scope boundary of the emissions, it is necessary to apply the relevancy test to determine which emissions may be directly influenced and controlled under the development of the Snowy Mountains SAP.

The following standard is nominated for application to the Snowy Special Activation Precinct:

- **Climate Active Carbon Neutral Standard for Precincts:** This is the Commonwealth Government's recognised standard for Carbon neutrality for buildings and precincts, it includes all operational emissions associated with the precinct as well as upstream and downstream dependent emissions associated with resource consumption and waste generation associated with the precinct. The Climate Active standard has been rebranded from its former name as the National Carbon offset standard.

In order for the Snowy Mountains SAP to become a certified carbon negative precinct, the below steps will need to be followed:

- **Emission Boundary:** Defining the emission boundary is the first step towards carbon negative precinct aspiration. The emission boundary to be established is to identify the source of emissions and determine whether to include the source in the emission calculation or not based on its geographical location, stage of establishment/operation and relevance. The emission boundary can be set to exclude the existing emissions of the Snowy Mountains SAP area and include the new developments over which the Snowy Mountains SAP can have control through policies.
- **Calculation of the emissions:** The second step in going carbon negative is to quantify the greenhouse gases emitted within the Precinct boundary. All activities or sources of the Precinct that lead to greenhouse gas emissions need to be identified including transportation, electricity consumption and generation, and associated upstream and downstream emissions such as waste generation etc. The quantified consumption data from the emission sources are to be converted into carbon dioxide equivalent (CO2e) or greenhouse gas emissions.
- **Emission reduction:** A precinct specific emission reduction strategy is to be developed and maintained. The measures need to be undertaken to reduce precinct carbon emissions by following the emission reduction strategy. Reduction achieved in carbon emission by updating existing infrastructure or operations (which were excluded from the Emission Boundary) can be credited to offset the overall emission if there is a direct link between the Snowy Mountains SAP and this infrastructure/operation.
- **Emissions offset:** Additional measures need to be taken for the Precinct to ensure that it create the practices and systems which remove more carbon from the atmosphere then it emits.

Below are the measures and interventions identified for the primary emission sources. These are challenging to quantify at this stage but could support the carbon negative aspiration of the Snowy Mountains SAP:

3.9.3 ELECTRICITY AND HEAT, SCOPE 1 AND 2 EMISSIONS

The precinct consumption of primary energy including electricity and heat are likely among the major sources of carbon emissions associated with its operation and hence to achieve a carbon negative certification precinct, the priority focus should be to minimise and offset the carbon emissions associated with these uses through electricity and heat consumption in the Snowy Mountains SAP.

The Snowy Mountains SAP should target to reduce carbon emissions associated with energy consumption by applying practices (Standards) including:

- reduction in precinct energy demand through energy efficiency measures
- improved energy efficiency by utilising efficient equipment and control strategies in all establishments (domestic, commercial and industrial). Government can provide some support (e.g. tax rebate) for the upgradation of the energy efficient equipment
- develop requirements to utilise carbon neutral equipment and services
- minimise the direct use of fossil fuels within the precinct such as natural gas and diesel
- develop and encourage requirements for onsite renewable energy supply to localised uses
- develop requirements and opportunities for broad take-up of offsite renewable energy power purchase agreements.

3.9.4 TRANSPORTATION

Reduction in carbon emission in the transportation sector of the Precinct can be achieved by:

- maximise opportunities for zero carbon transport options for short trips such as bicycles and walking. This would also include the creation of associated infrastructure to maximise their usage such as bike paths, bike parking facilities, end of trip facilities and pedestrian friendly walking paths and infrastructure
- discourage the use of single occupant personal vehicle use within the precinct. This can involve restrictions of cars in some areas
- promote and enforce vehicle emission standards for vehicles used within the precinct. These may include electric vehicles and hydrogen vehicles combined with well-considered incentive schemes for their uptake
- establish efficient and well-utilised mass transit solutions such as fuel-efficient public transport infrastructure development to support electric vehicles (e.g. charging stations) (and hydrogen stations in the future).

3.9.5 AGRICULTURE AND FORESTRY

To remove more carbon from the atmosphere than the overall emission from the Precinct, agriculture and forestry can play a pivotal role. Agriculture activity can contribute a measurable portion of the carbon footprint of the precinct. Forestry captures carbon from the atmosphere and stores carbon for long periods of time as part of the natural carbon cycle. Forestry can also be used as a means of offsetting carbon emissions within the precinct by directly removing carbon from the atmosphere. The following measures could be taken in the agriculture and forestry sectors as part of the Snowy Mountains SAP’s carbon negative aspiration:

- incentivise the practice of carbon farming initiatives (e.g. pasture cropping, natural fertilisers, compost, cover cropping etc.)
- seek opportunities for complementary carbon abatement measures such as the processing of woody biomass into biochar and promote associated land management practices. Promote carbon (soil) sequestration to prevent carbon from being released into the air
- promote the use of fuel-efficient machinery and vehicles for farming
- promote afforestation and reforestation activities within the Precinct
- seek opportunities for best practice low-carbon livestock management such as carbon friendly feedstocks.

3.9.6 TECHNOLOGY

The Precinct should encourage and allow innovative technologies and practices to remove as much carbon as possible from the atmosphere. Currently, there are several technological solutions available to support the path to achieve the carbon negative aspiration.

Technological solutions like Bioenergy with Carbon Capture and Storage (BECCS) which involves the capture and permanent storage of carbon dioxide from processes where biomass is burned to generate energy. BECCS can include power plants using biomass and refineries producing biofuels through fermentation (ethanol) or gasification (biogas) of biomass. We are currently investigating the opportunities around generating energy from Bio energy as discussed in Section 3.1 and Section 3.2 of this report, implementation of technologies like BECCS could be more relevant in the Precinct.

Another relevant technological solution for the Precinct could be Direct Air Capture (DAC) which is the process of mechanically removing carbon dioxide directly from the air. DAC technology is currently in the early stages of development with substantial need for cost optimisation. However, DAC technology implementation should be considered in the future for the Precinct due to its benefit of being a modular design and requires less infrastructure installation.

3.9.7 EMBODIED CARBON IN CONSTRUCTION

When considering the overall carbon neutrality of the entire precinct it is recommended to utilise a recognised standard such as the Climate Active Carbon Neutral Standard for Precincts. Notably embodied carbon is currently not formerly considered within that standard however embodied carbon is a developing issue that will likely be incorporated into future versions of that standard and it is noted that embodied carbon should be considered where relevant.

Within the Climate Active standard, it is important to account for scope 3 downstream carbon emissions based on the test of relevancy. In the instance of a Special Activation Precinct where planning, governance and construction activities are highly influenced by a designated authority, it is highly likely that embodied carbon in construction should be considered as part of the carbon emissions boundary. Embodied carbon in construction can include all scope 3 emissions associated with the production, procurement and installation of materials necessary for the construction of building and infrastructure projects. This would also include transport of materials and transport associated with construction practices including labour for construction. It is recommended that the embodied emissions of construction are measured, recorded and monitored for all projects within the Snowy Mountains SAP so that appropriate offsetting and reduction activities can be undertaken. This would constitute a more future ready approach.

4 TECHNICAL STUDY

The remainder of this report is structured as follows:

- Section 5 compares various renewable energy resources and identifies deliverable renewable energy opportunities including its potential capacity, current infrastructure availability and additional infrastructure requirements.
- Section 6 gives an overview of the alignment of identified opportunities with broader sustainability and circular economy aspirations for the Snowy Mountains SAP.
- Section 7 gives an overview of the energy supply demand of the Snowy Mountains SAP and provides an overview of the energy landscape in Australia.
- Section 8 analyses the new and emerging industries and investment opportunities in the renewable energy industry.
- Section 9 discusses the delivery considerations to attract renewable energy businesses.

5 IDENTIFYING DELIVERABLE OPPORTUNITIES

5.1 SWOT ANALYSIS

Based on WSP's analysis of renewable energy opportunities and constraints in the Context Analysis Report, WSP has carried out a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of all renewable energy opportunities that could be developed in the Precinct.

Table 5.1 below shows the SWOT analysis for the following renewable energy sources:

- Biomass and Biofuel
- Biogas
- Solar energy
- Wind power
- Hydropower
- Geothermal energy, and
- Hydrogen.

Table 5.1 SWOT analysis

RENEWABLE ENERGY SOURCES	STRENGTH	WEAKNESS	OPPORTUNITIES	THREATS
Biomass and Biofuel	— Sources of biomass exist within the Snowy Monaro region e.g. wheat and forestry residue.	— Low volume of agriculture residue within a viable radius of the Snowy Mountains SAP. — Low volume of forestry residue production within a viable radius of the Snowy Mountains SAP. — Low bulk density of biomass means transport may be volume limited and thus have higher cost. — Small sized biodiesel production facilities (as restricted by resource availability in the Snowy Mountains SAP) may not be commercially viable. — Higher cost of biomass combustion infrastructure means project(s) may not be commercially viable.	— Space heating through combustion of woody biomass. — Combined heat and power systems as an alternative to natural gas. — Biodiesel production from oil generated from resorts.	— Security of supply of resources is a major challenge for any biomass system. — General trend towards low tillage farming which retains the residue in-field is likely to reduce quantities of resources available. — Climate change impacts may reduce quantity of resources available. — Uptake of electric vehicles and/or hydrogen may reduce demand for biofuels.

RENEWABLE ENERGY SOURCES	STRENGTH	WEAKNESS	OPPORTUNITIES	THREATS
Biogas	— Largest commodities produced in the Snowy Monaro region are from livestock products. — Several wastewater treatment facilities in the Snowy Mountains SAP.	— Distance from the Snowy Mountains SAP and livestock selling centre (Cooma). — Domestic, commercial and municipal waste quantities likely insufficient for reliable supply. — Utilisation of domestic waste and wastewater for small scale application is unlikely to be cost effective. — Current practice is to leave livestock waste on field.	— Approximately 117,600–863,800 m^3 of biogas per year could potentially be produced from livestock residue within the region. — Potential electricity generation ~151 MWh_e/Year from organic domestic waste. — Indicative size of energy generation plants for Snowy Mountains SAP wastewater treatment facilities in the order of 100 kW_e.	— Transportation of livestock waste from Comma to Snowy Mountains SAP is likely to be prohibitive. — Recycling practices already in place by the resorts, compete for use of organic waste. — Future recycling and waste management practices further limiting resource availability. — Development of hydrogen production may reduce demand for biogas.
Solar Energy	— Range of suitable locations (e.g. land, water, rooftop). — Snowy Mountains SAP's irradiance level can make a viable business case to host utility and small-scale solar farms. — MLF for the region better than other NSW regions for renewable energy projects.	— Ground mounted solar projects require a large land area (2–3 hectares per MWac). — Limited availability of land within the Snowy Mountains SAP area. — Limited suitability of topography in the available land areas. — Intermittent generation. May require storage to be viable.	— Large scale solar farm (>10 MWac). Ground mounted. — Medium scale Solar Farm (5 MWac-10 MWac). Ground mounted. — Small scale solar farm (100 kWac–5 MWac). Ground mounted. — Distributed solar PV (in the range of kW). Rooftop mounted. — Floating Solar PV system.	— Other preferred uses of the available land over solar farms. — Potential Environmental constraints of a solar farm. — Visual impact of solar farm on scenic view of the Snowy Mountains SAP. — Other preferred uses of lake over floating solar PV system.

RENEWABLE ENERGY SOURCES	STRENGTH	WEAKNESS	OPPORTUNITIES	THREATS
Wind Energy	— Reported wind speed at 150 m height in the Snowy Mountains SAP area is higher than reported wind speeds near Nimmitabel (location of Boco Rock Wind Farm) and other areas with wind farms.	— Limited availability of land within the Snowy Mountains SAP area. — Limited suitability of the topography in available land areas.	— The Snowy Mountains SAP area likely has similar wind regimes as other wind farm regions within New South Wales. — Wind energy, in particular small-scale wind turbines.	— Constructability due to complex terrain and national park areas where reported wind speed is higher than other areas of the Snowy Mountains SAP. — Other preferred uses of the Snowy Mountains SAP land over a wind farm. — Potential Environmental constraints. — Visual impact of wind farm on scenic view of the Snowy Mountains SAP.
Hydro Power	— The Snowy Mountains SAP area makes up a relatively major part of the Snowy Scheme catchment.	— The region is already largely exploited for conventional large-scale hydropower and pumped hydro with additional generation going in e.g. Snowy 2.0. — Potential lower generation from new hydro scheme during the peak energy demand season of the Snowy Mountains SAP (Winter).	— A small-scale run-of-river scheme on the Thredbo river could be explored. — Potential for a consortium of alpine resorts of the Snowy Mountains SAP to organise a PPA with Snowy Hydro.	— Small-scale pumped hydro is typically not economically viable for energy storage compared to battery storage technologies. — Potential environmental impact of a run-of-river hydro project. — Potential incompatibility with current tourism uses of the Thredbo waterway. — Spring tourism in the area relies on the river for multiple activities which could be negatively affected.

RENEWABLE ENERGY SOURCES	STRENGTH	WEAKNESS	OPPORTUNITIES	THREATS
Geothermal Energy	— At a depth of 5 km, a temperature around 120°C may be achieved. — Many references of utilisation of geothermal heat pump in the Snowy Mountains SAP area and surrounding.	— The geothermal resource in the Snowy Mountains SAP is unlikely to have sufficient heat for electricity generation or direct heat use. — Low temperature direct use options such as fish farming, pool heating, and space heating will require a suitable resource, which the current available information does not show to be present in the Snowy Mountains SAP area.	— Use of geothermal heat pumps for space heating/cooling systems.	— Cost of technology for large scale application. — Competing uses of land/land not viable for construction/drilling. — Draw down of the geothermal resource may reduce its viability over time.
Hydrogen	— Water and Grid infrastructure availability in the Snowy Mountains SAP.	— No large-scale renewable energy projects currently within the Snowy Mountains SAP to produce SAP region green hydrogen. — Early stages of technology commercialisation. — Cost of technology may not be viable for small scale generation and storage applications.	— Hydrogen as a storage mechanism for electrical energy. — Hydrogen as a heat source (blended within natural gas network). — Hydrogen as a fuel source for hydrogen fuel cell vehicles.	— Significant development in hydrogen fuel cell technology and progress in the industry is required before full scale commercialisation. — Growth of biofuels, biogas and/or electric vehicles reduces demand for hydrogen.

5.2 IDENTIFICATION OF DELIVERABLE OPPORTUNITIES

Based on the above SWOT analysis and input from the project stakeholders, WSP has assumed the following key factors to shortlisting the opportunities:

Table 5.2 Renewable energy opportunities' short listing

#	OPPORTUNITY	FACTORS	SHORTLISTED?
1	Biomass and Biofuel	— Likely low resource availability within viable proximity to the Snowy Mountains SAP. — Likely limited viability for a business case.	No
2	Biogas	— Waste transportation constraints. — Low quantities of resource available locally. — Likely limited viability for a business case.	No
3	Large scale solar PV farms ($\geq$10 MWac)	— Limited availability & suitability of land within the Snowy Mountains SAP area. — Potential environmental constraints. — Visual impact on scenic views and tourism.	Yes
4	Large scale solar PV farms ($\leq$10 MWac)	— Requires smaller land parcel. — Limited visual impact if located strategically.	Yes
5	Floating solar	— Requires no land. — Potential visual impact on scenic view and tourism. — There are likely other more preferred uses of the lake. — Likely to receive strong community resistance.	No
6	Distributed Generation – Rooftop/Car park Solar PV	— No land requirement. — Limited visual impact. — No requirement of additional network infrastructure (in addition to the PV module and corresponding systems). — Minimal direct negative impact on environment. — Distributed capital expenditure.	Yes
7	Wind Energy	— Limited availability & suitability of land within the Snowy Mountains SAP area. — Potential environmental constraints. — Visual impact on scenic views and tourism. — More complex constructability due to complex terrain and national park areas.	No

#	OPPORTUNITY	FACTORS	SHORTLISTED?
8	Hydro power	— Existing conventional hydropower and pumped hydro in the region. — Environmental impact of a run-of-river hydro project. — Incompatibility with current tourism uses of the Thredbo waterway.	No
9	Geothermal Energy	— Likely inadequate resource for electricity generation or direct heating use. — Cost of technology for large scale application likely prohibitive. — Geothermal heat pumps for space heating/ cooling systems is likely a viable option.	Yes
10	Hydrogen	— No large-scale renewable energy projects currently directly within the Snowy Mountains SAP. — Potential viability constraints of technology for small scale generation and storage applications however this will need to be tested in the future. — Significant development in hydrogen fuel cell technology and progress in the industry is required before full scale commercialisation. — Potential use of Hydrogen as a supplement to natural gas. — Potential use of Hydrogen as a fuel for hydrogen fuel cell vehicles.	Yes
11	Renewable energy PPAs	— No requirement for on-site renewable energy generation facility. — Many available energy providers in the market. — Challenges can be turned into an opportunity for the Snowy Mountains SAP to be Australia's first SAP level PPA. — Easy carbon offset for energy consumption.	Yes

From Table 5.2 above, WSP has shortlisted the opportunities in Table 5.32 below for further development consideration in the Snowy Mountains SAP area. Furthermore, in addition to the opportunities shortlisted above, WSP has also included opportunities for Battery Energy Storage Systems (BESS) integrated with identified solar PV opportunities.

5.2.1 RENEWABLE ENERGY GENERATION – LARGE SCALE SOLAR PV

WSP has undertaken an analysis of potential suitable locations for large scale solar PV farms based on the parameters specified in Section 3.3.3.2 for the Context Analysis of this report, and identified indicative locations and indicative capacity of large scale solar PV farm development opportunities as illustrated in Figure 5.1 below:

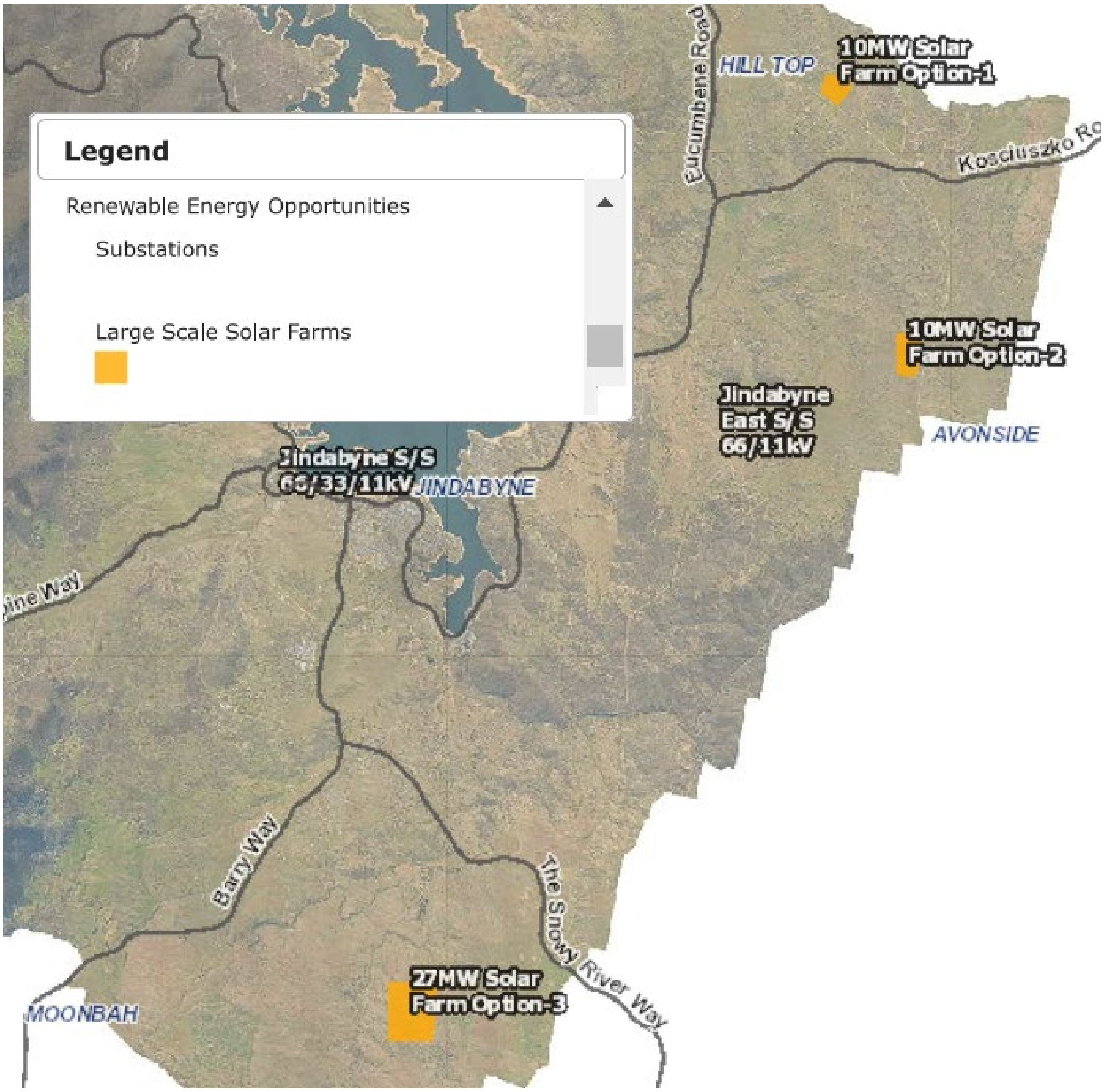


Figure 5.1 Potential opportunities for large scale solar farms in the Snowy Mountains SAP

WSP considers that either of the two 10 MW solar farms presented above in Figure 5.1 (Option 1 or 2) may be suitable for development. The location of Option 2 is considered to be more favourable, compared to Option 1, because of its close proximity to a grid connected substation (66/11 kV Jindabyne East S/S).

WSP also undertook further assessment of the available land outside of various constraint areas (scenic protection and national park, and zones defined in the Snowy Structure Plans dated 17 December 2020 [40]) and identified one land parcel with potential suitability for the development of large scale solar PV.

Option 3, shown above in Figure 5.1, was identified, and is located towards the south-east boundary of the Snowy Mountains SAP. Option 3 comprises of ~78 hectares of land and can accommodate ~27 MW capacity of solar PV. The distance (aerial route) of Option 3 from the Jindabyne 66/33/11 kV Substation is 8.4 km. WSP notes that the actual length of the transmission line needed to connect to this location (Option 3) is expected to be substantially longer than the measured aerial route distance due to various on-ground factors such as geographic suitability for the transmission line route and right of way (easement) issues. WSP has typically observed that solar farm developers would prefer to develop a solar farm in close proximity to the grid connection point, as a long transmission line requirement may add a number of technical, financial, legislative and project execution constraints or complexities.

5.2.1.1 INDICATIVE LAND REQUIREMENT

As indicated in Section 3.3.3.2 of the Context Analysis Report [41], ground mounted solar farms require indicatively 2–3 hectares per MWac of capacity.

5.2.1.2 INFRASTRUCTURE REQUIREMENTS

WSP assumes that only one of the two 10 MW large-scale solar farm opportunities would be considered in the master plan (either Option 1 or 2 as discussed in Section 5.2.1), and which would be connected to the Jindabyne East 66/11 kV substation. Currently, Jindabyne East 66/11 kV substation has capacity to accommodate a grid connection for a 10 MW generation facility [42], so an upgrade of substation infrastructure is not expected to be required to accommodate this opportunity, based on the thermal capacity of the substation equipment. However, it is recommended that any potential developer carries out a detailed technical assessment of the grid connection capacity and regulatory requirements, to ensure that such a development is able to meet the NSPs and AEMO's compliance requirements before making any commercial decisions.

Option 3 is expected to be able to connect to the Jindabyne 66/33/11 kV substation. Currently, this Jindabyne 66/33/11 kV substation has capacity to accommodate grid connection of a 30 MW generation facility [42] so an upgrade of substation infrastructure is not expected to be required to accommodate this opportunity, however only thermal capacity of the equipment has been considered in this assessment. Any prospective developer would be required to undertake detailed grid studies by considering wider distribution and transmission network models before any commercial decision should be made.

5.2.2 SOLAR CAR PARKS AND DISTRIBUTED ENERGY GENERATION

WSP has divided the potential of energy generation from alpine resorts and Jindabyne town areas into two distinct opportunities: 1) Solar car parks; and 2) Distributed energy generation via rooftop mounted solar PV systems.

5.2.2.1 SOLAR CAR PARKS

WSP has identified an opportunity whereby the large open car park areas within the Snowy Mountains SAP alpine resorts and Jindabyne town could be used for the installation of solar PV systems. This would also provide the following key benefits:

- better safety for the vehicles
- collocation opportunity of the car park with energy generation and hence no additional land requirement for the energy generation infrastructure
- in future, energy generated via the car park solar PV systems could be used to charge electric vehicles generating a circular economy and supporting the Snowy Mountains SAP's carbon negative aspirations.

WSP has made the following assumptions in regard to the estimated indicative capacity of potential solar car park PV systems:

- Open car park areas at Smiggin Holes, Perisher Valley, Thredbo Village, Bullocks Flat and Jindabyne town have been considered in the calculation.
- Fixed tilt single slope mounting structures with 560 Wp [43] PV modules considered. Based on WSP's experience conducting energy yield assessments of solar PV farms using bi-facial modules, typical bi-facial energy gain is in the range of 3–5%. A detailed study should be undertaken by any prospective developer to the use of bi-facial PV modules over mono-facial modules and its cost to benefit analysis for the individual location.
- An approximate area of 4,980 m^2 would be required for a 1 MWp solar PV system installation.
- As per the Snowy Structure Plans dated 17 December 2020 [40], some of the existing car park areas of Thredbo Village and Bullocks Flat have been considered for redevelopment in the future. These areas have been excluded from the capacity estimation.

Figure 5.2 below shows the area considered for the Perisher Valley open car park area for the indicative capacity estimate. The figure also represents the granularity of the area considered for all four open car park locations.

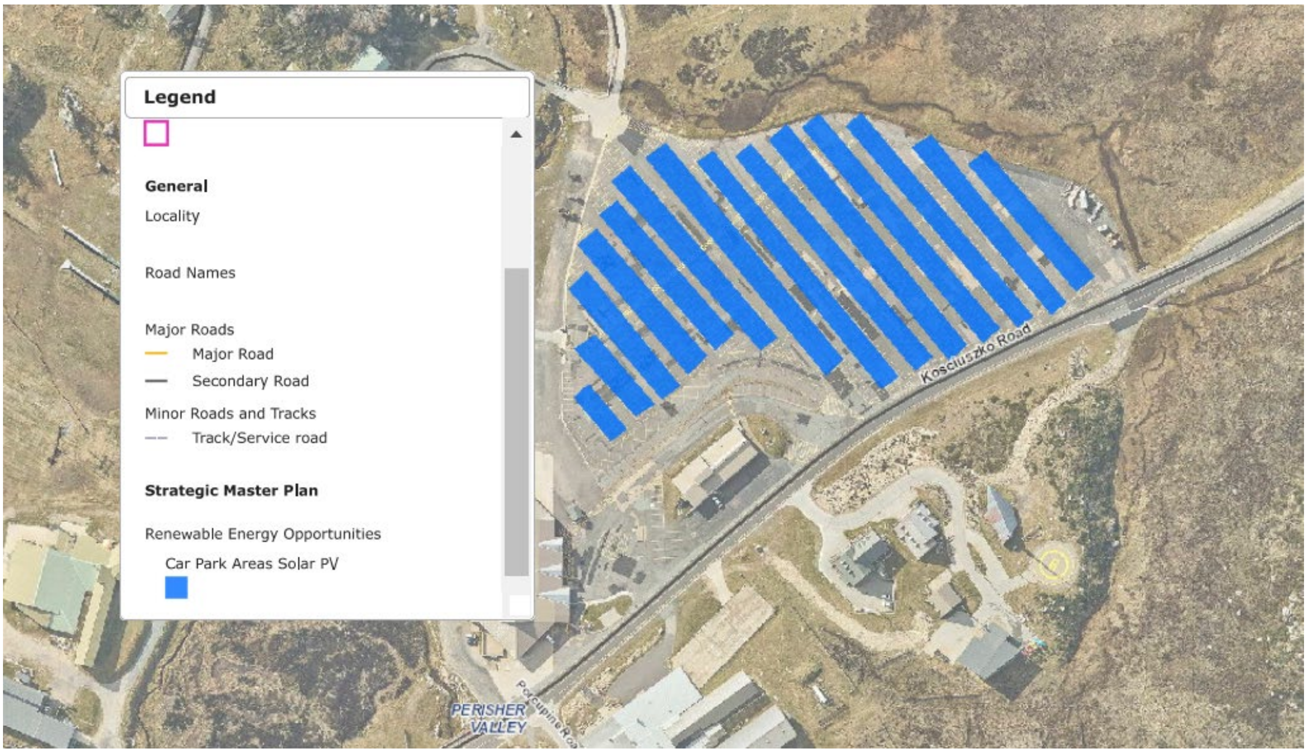


Figure 5.2 Car park area considered in capacity assessment – Perisher Valley

Based on the above assumptions, WSP has estimated the indicative total capacity of solar car park PV systems in the Snowy Mountains SAP, as per Table 5.3 below.

Table 5.3 Estimated indicative capacity – solar car park in the Alpine resort area

#	NAME OF THE OPEN CAR PARK AREA	TOTAL MEASURED AREA FOR THE INSTALLATION (m^2)	ESTIMATED CUMULATIVE SOLAR PV CAPACITY (MWP)
1	Smiggin Holes	7,913	1.59
2	Perisher Valley	16,108	3.23
3	Thredbo Village	5,596	1.12
4	Bullocks Flat	18,526	3.72
5	Jindabyne town[3]	8,115	1.63

If all the identified opportunities in Table 5.3 are realised, a total estimated capacity of 11.3 MWp of solar PV will be added from solar cark parks.

5.2.2.2 DISTRIBUTED ENERGY GENERATION

To simplify the identification of these opportunities, WSP has divided the distributed energy generation opportunities into two parts: i) key resorts, hotels and accommodation located outside of Jindabyne town and Thredbo village, utilising the building roofs to install rooftop solar PV systems at their premises and ii) opportunities within the area of Jindabyne town and Thredbo village.

ALPINE RESORTS, HOTELS AND ACCOMMODATION

WSP has divided the distributed energy generation opportunities of alpine resorts, hotels and accommodation areas in to two stages: a) Existing Development b) Future Development (Snowy Structure Plans).

A) EXISTING DEVELOPMENT

WSP has undertaken a desktop analysis of the existing space available for rooftop installation at the resorts, hotels, fire station and accommodations and identified that a cumulative generation capacity potential of 1.62 MWp[4] exists at these premises combined. Detailed information of the premises considered for the calculation of the indicative generation capacity is provided in Appendix A of this report. Figure 5.3 and Figure 5.4 below show premises considered for rooftop installations in Perisher Valley and Charlotte Pass areas respectively.

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[3] Only large open car park areas of the buildings have been considered in the estimation. The car park areas where surroundings may result in shading have been excluded from consideration.

[4] Assumption for the calculation of the capacity:

i) 25% of the roof area will be available and considered usable for the installation, and

ii) 6000 m^2/MWp area of the available roof area will be required considering that all solar PV panels of 560 Wp capacity shall be installed in a single north facing orientation.

Figure 5.3 Existing area considered in capacity assessment – Perisher Valley

Figure 5.4 Existing area considered in capacity assessment – Charlotte Pass

B) FUTURE DEVELOPMENT (AS PER SNOWY STRUCTURE PLANS)

WSP has undertaken a desktop analysis of the availability of space for rooftop solar PV installations within the future development of the Snowy Mountains SAP resorts areas according to the Snowy Structure Plans [40]. WSP has identified that a cumulative generation capacity potential of 1.76 MWp[5] will exist at these premises upon the completion of the development according to the Snowy Structure Plans. Figure 5.5 and Figure 5.6 below show future development areas considered for rooftop installations in Perisher Valley and Charlotte Pass areas respectively.

Figure 5.5 Future development area considered in capacity assessment – Perisher Valley

[5] Assumption for the calculation of the capacity:

iii) 50% of the new development areas will have buildings (ground coverage)

iv) 25% of the roof area will be available and considered usable for the installation, and

v) 6000 m^2/MWp area of the available roof area will be required considering that all solar PV panels of 560 Wp capacity shall be installed in a single north facing orientation.

vi) All the overlapping future development areas with the existing development areas have been excluded from the capacity estimation

Figure 5.6 Future development area considered in capacity assessment – Charlotte Pass

OPPORTUNITIES WITHIN THE AREA OF JINDABYNE TOWN AND THREDBO VILLAGE

WSP has undertaken a high-level analysis of the roof area available for solar PV system installations in the existing Jindabyne town, the East Jindabyne area and suitable areas from the projected growth areas in the Snowy Structure Plans [40]. WSP has also considered the general industrial area located south of Jindabyne town within the indicative capacity calculation.

For the calculation of available roof area in existing development, WSP has made the following assumptions:

- 80% of the measured land area is assumed to be rooftop space of the houses/buildings, out of which 25% is considered to be available and usable for the installation. This is based on assumptions on the buildings' orientation, load bearing capability of the structure and other factors. Note, this report does not provide an assessment of the structural suitability of the roofs. This assessment will need to be done prior to confirmation of the suitability of any rooftop space for solar PV installations.
- 25% of the measured land area of the general industrial area has buildings with roofs suitable for PV installations.
- 6,000 m^2/MWp area of the available roof area will be required considering that all solar PV panels of 560 Wp capacity shall be installed in a single north facing orientation.

Figure 5.7 below shows existing areas of the Jindabyne town and East Jindabyne, considered in the calculation for the indicative capacity of rooftop solar PV systems for distributed generation.

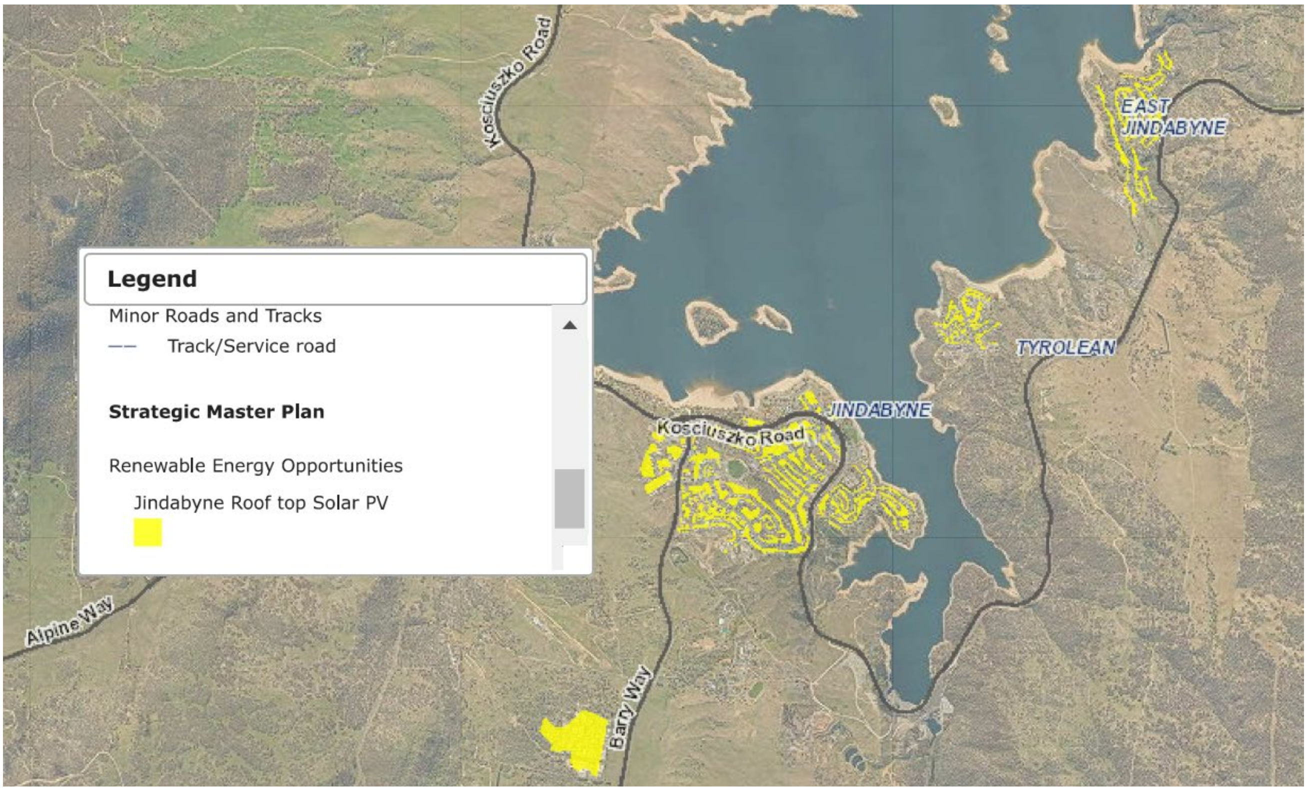

Figure 5.7 Areas considered in capacity assessment – Jindabyne town and East Jindabyne

WSP has identified that the indicative total capacity of rooftop solar PV systems in the existing Jindabyne town area is 26.9 MWp (22.99[6] MVA). Based on the same assumptions used for the estimation of indicative capacity for existing Jindabyne town area[7], the suitable projected growth areas (Figure 5.8 below) of Jindabyne town will have potential to add a further 32.26 MWp[8] (27.56[9] MVA) of distributed generation (including additional areas of solar car parks, if any) at the completion of Snowy Mountains SAP's full development (by 2061). Hence the total indicative rooftop solar PV capacity in Jindabyne town area at the completion of the Snowy Mountains SAP development is ~59.16 MWp (50.55 MVA). Appendix B of this report represents the detailed information for the calculation of projected growth areas and the resulting potential capacity of rooftop solar PV.

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6 Assumption: MVA= (MWp/1.3)/0.9, where 1.3 is the typical DC/AC ratio for solar PV system and 0.9 is the Power Factor. Jindabyne town solar PV system peak total AC capacity = (26.9/ 1.3)/0.9 = 22.99 MVA.

7 50% of the measured land area is assumed to be rooftop space of the houses/ buildings (instead of assumed 80% for existing development)

8 This estimation excludes the areas projected as Town Centre redevelopment area in the Snowy Structure Plans. These excluded areas have been considered in the indicative capacity estimation of existing Jindabyne Town.

9 Assumption: MVA= (MWp/1.3)/0.9, where 1.3 is the typical DC/AC ratio for solar PV system and 0.9 is the Power Factor. Jindabyne town projected growth development solar PV system peak total AC capacity = (32.25/ 1.3)/0.9 = 27.56 MVA.

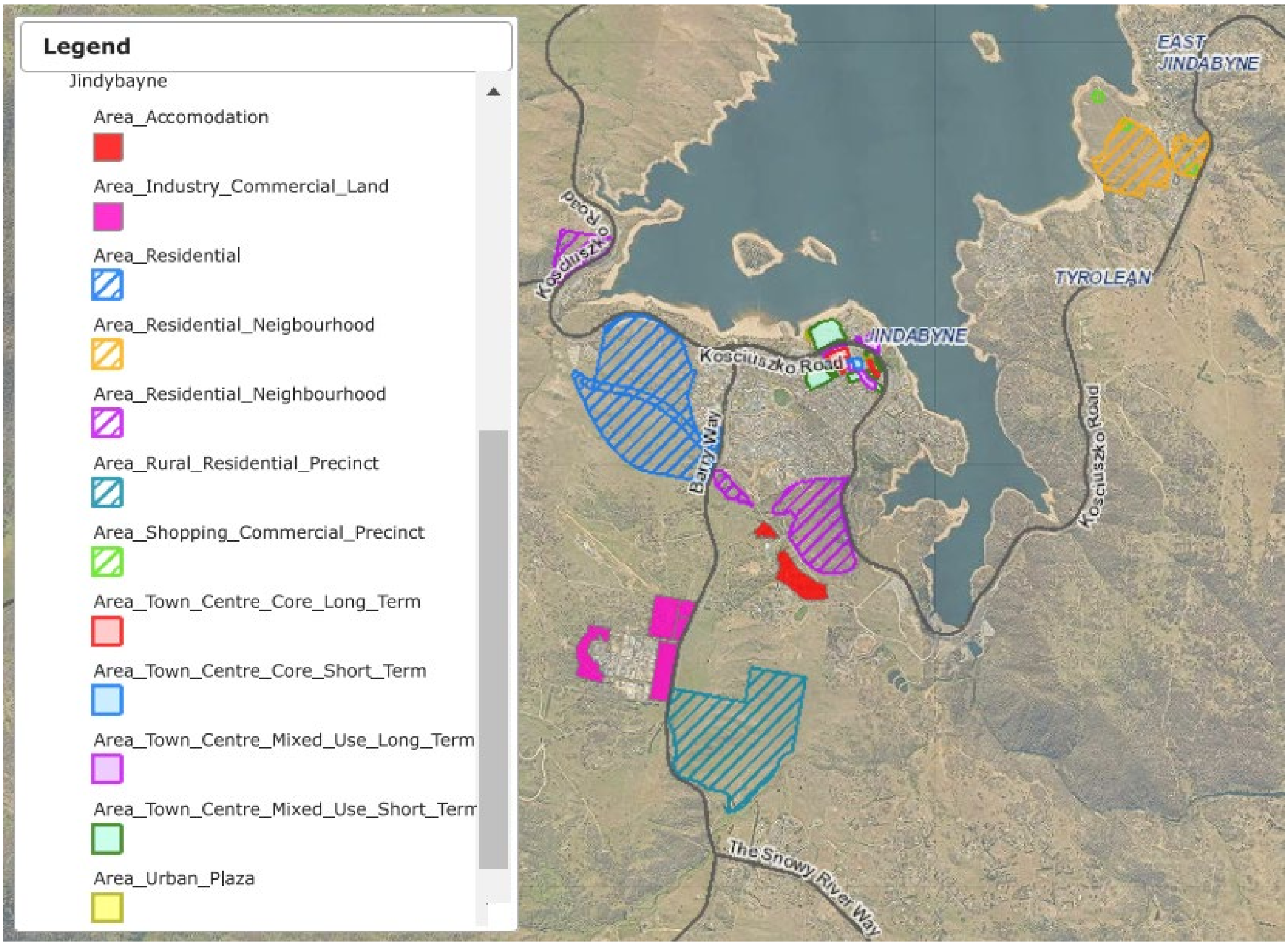

Figure 5.8 Areas considered in capacity assessment from projected growth areas – Snowy Structure Plans

Figure 5.9 below shows areas of the existing Thredbo village, considered in the calculation for the indicative capacity of rooftop solar PV systems for distributed generation.

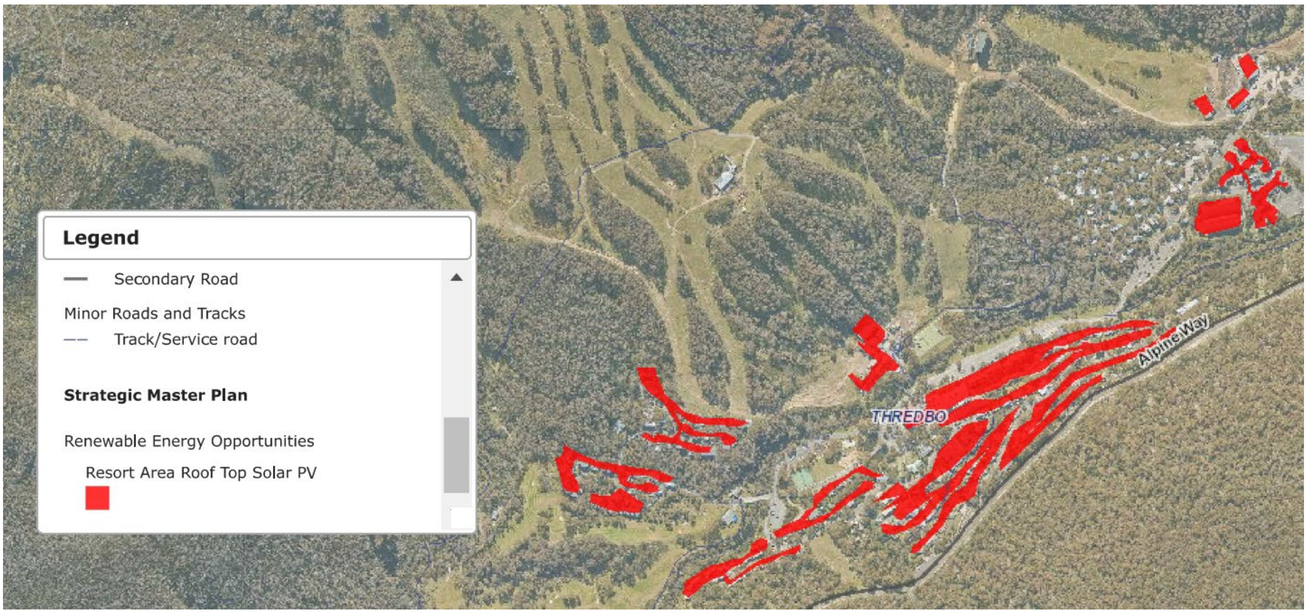

Figure 5.9 Areas considered in capacity assessment – Existing Thredbo Village

WSP has identified that the indicative total capacity of rooftop solar PV systems in the existing Thredbo village area is 3.1 MWp, based on the same assumptions used in the Jindabyne analysis above.

Figure 5.9 below shows project growth areas of the Thredbo village per the Snowy Structure Plans, considered in the calculation for the indicative capacity of rooftop solar PV systems for distributed generation.

Figure 5.10 Areas considered in capacity assessment – projected growth – Thredbo Village

WSP has identified that the indicative total capacity of rooftop solar PV systems in the Thredbo village's project growth area is 0.78 MWp, based on the same assumptions used in the Jindabyne analysis above.

Table 5.4 below summarises the distributed solar PV opportunities for Alpine Resorts, Jindabyne town and the Thredbo village area.

Table 5.4 Summary of indicative capacity estimation with existing and future developments

AREA	CAPACITY OPPORTUNITY WITH EXISTING DEVELOPMENT (MWP)	CAPACITY OPPORTUNITY WITH FUTURE DEVELOPMENT (MWP)	TOTAL CAPACITY AT THE COMPLETION OF SAP DEVELOPMENT (MWP)
Alpine resorts	1.64	1.76	3.40
Jindabyne Town	26.90	32.26	59.16
Thredbo village	3.10	0.78	3.88

5.2.2.3 EFFECTS OF SNOW ON SOLAR PV SYSTEMS

As the opportunities identified are within alpine resort areas experiencing seasonal snowfall, WSP has found a number of studies undertaken investigating effects of snow on the energy generation from a solar PV system in similar environments to Snowy Mountains SAP.

The following are the key findings of the studies:

1) Study undertaken at South-Eastern Ontario – Canada found that the losses due to snowfall are dependent on the angle and technology being considered. The effects of increased albedo[10] in the surroundings of a PV system can increase expected energy yields, particularly in the case of high tilt angle systems [44]. Findings of this study also state that "*Over the two years studied, which had low levels of snowfall when compared to historic data, the losses ranged from 3.5%–1% of expected yearly yield for sites in south-eastern Ontario" (Canada).*
2) Study undertaken at Northern Alberta – Canada showed that solar panels which has the snow removed only experienced 1% to 5% more production than the panels which were left un-maintained over a 3-year time span. It is also to be noted that the solar panels will melt snow off a greater pace than surrounding shingles as they operate at temperature above the ambient temperature and have a much smoother surface. [45]

Findings from the studies above suggest that the impact of snow on energy generation from solar PV system in Snowy Mountains SAP area is not expected to be significant.

5.2.2.4 INDICATIVE LAND REQUIREMENT

Solar car park systems do not require any additional land area as it will be collocated within the vehicle parking area.

Rooftop solar systems do not require land as it is typically mounted on the roof space available on residential, industrial or commercial buildings.

5.2.2.5 INFRASTRUCTURE REQUIREMENTS

SOLAR CAR PARKS IN THE ALPINE RESORT AREAS

Comparing the capacity of the respective distribution substations of the identified solar car park areas and the estimated solar car park capacity, Table 5.5 below provides an overview of the indicative substation infrastructure requirements to accommodate the solar car park opportunities.

Table 5.5 Substation infrastructure requirement – solar car park opportunities

#	NAME OF THE OPEN CAR PARK AREA	ESTIMATED CUMULATIVE SOLAR PV CAPACITY (MW_P)	NAME OF THE CONNECTED DISTRIBUTION SUBSTATION	SUBSTATION CAPACITY AT RESPECTIVE SUBSTATION	UPGRADE REQUIREMENT AT SUBSTATION
1	Smiggin Holes	1.59	Smiggin Switching	N/A[11]	None
2	Perisher Valley	3.23	Perisher	2 X 10 MVA	None
3	Thredbo Village	1.12	Thredbo	2 X 16 MVA	None
4	Bullocks Flat	3.72	Bullocks Flat	1 X 6.25 MVA	None

[10] Albedo is a measure of the reflectivity of a surface. The albedo is typically expressed as a percentage of the total solar radiation incident on a surface that is reflected as diffuse light.

[11] Smiggin has a 33 kV switching station without transformer

WSP assumes that identified car park solar PV installations of Jindabyne town will be connected to the Jindabyne 66/33/11 kV Substation via the distribution network of the Jindabyne town, hence its estimated indicative capacity (1.63 MW) has been considered in the infrastructure requirement assessment for distributed generation of Jindabyne town.

DISTRIBUTED GENERATION

Rooftop solar PV systems will be installed on the premises behind the meter. The premises are assumed to already be connected to the grid and that all excess energy from the distributed energy systems shall either: i) be stored in an energy storage system located within the same premises (behind the meter BESS) or ii) shall be transmitted to a community scale energy storage system (BESS or Hydrogen) or iii) a combination of (i) and (ii).

In the case of option (i), the upgrade of the 11 kV reticulation network of Jindabyne town or Thredbo village may not be required, and the Jindabyne substation is likely to be able to accommodate this scenario without further requirement for upgrade.

In the case of options ii) and iii), the excess energy shall be transmitted via the 66/33/11 kV Jindabyne substation through the distribution network system. Jindabyne 66/33/11 kV substation has a capacity to accommodate 60 MVA of power transfer at 66/11 kV (and 15 MVA at 66/33 kV). Table 5.6 below summarises the 66/33/11 kV Jindabyne substation upgrades required under different scenarios.

Table 5.6 Jindabyne Substation upgrade requirement

SCENARIOS	PEAK DISTRIBUTED PV CAPACITY (MVA)	AVERAGE ELECTRICAL LOAD DEMAND (MVA)	EXCESS POWER IN PEAK HOURS(MVA)	UPGRADE REQUIREMENT[12] AT SUBSTATION
Existing Development	24.38[13]	9.20 [46]	15.18	None
Projected Growth	27.56	113.6[14]	None	None
Fully Developed SAP	51.94	122.8	None	None

The above Table 5.6 shows that the existing 66/33/11 kV Jindabyne substation can transfer the excess power without the need of any capacity upgrade for the three scenarios presented.

The indicative average electrical load demand of Thredbo village by the year 2061 is estimated to be 19.9 MVA[15] and the peak indicative generation by distributed generation from Thredbo village is 3.31 MVA[16]. The existing thermal capacity of the transformer(s) at Thredbo substation is 2x16 MVA hence there are not expected to be any upgrades required to accommodate distributed solar PV system generation in Thredbo Village.

A detailed grid study including voltage stability study will be require before the implementation of option ii) and iii).

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[12] This is based on the thermal capacity of the equipment. It is recommended that a detailed analysis for the voltage drop, line loadings, power loss, system security, voltage stability, etc., should be undertaken before making any commercial decision.

[13] Assumption: MVA= (MWp/1.3)/0.9, where 1.3 is the typical DC/AC ratio for solar PV system and 0.9 is the Power Factor.
Jindabyne town solar PV system peak total AC capacity = (26.9/1.3)/0.9 = 22.99 MVA.
Jindabyne town car park peak total AC capacity = (1.63/1.3)/0.9 = 1.39 MVA.

[14] Considered from WSP's Infrastructure and Service Technical Study Report (Rev C).

[15] Considered from WSP's Infrastructure and Service Technical Study Report (Rev C).

[16] Assumption: MVA= (MWp/1.3)/0.9, where 1.3 is the typical DC/AC ratio for solar PV system and 0.9 is the Power Factor.
Thredbo village solar PV system peak total AC capacity = (3.88/1.3)/0.9 = 3.31 MVA.

5.2.3 GEOTHERMAL HEAT PUMP

Geothermal heat pump systems – also known as Ground Source Heat Pumps (GSHPs) – typically consume little energy and are installed with long design lives [47]. These systems can be installed either to provide heating and cooling, or to augment the existing air conditioning system. They also require little maintenance, with typical activities including only checking of the water quality and treatment if needed, inspecting filters and cleaning as necessary, and checking the control system to ensure it is operating as intended [48]. Their application in Australia has historically been limited to commercial buildings, but some residential dwellings have also had GSHP systems installed. [47]

5.2.3.1 LOCATION AND EXPECTED CAPACITY

For new buildings where the GSHP system is included in the design, the piping can be laid out under the building itself to minimise space depending on the configuration of the piping loops. Alternatively, the piping can be extended underground outside of the building's footprint. The heating or cooling load of a building depends on a number of factors including:

- the orientation of the building – the heating or cooling requirement can be impacted by sun, wind and shading effects
- space usage – whether the building space is used as an office, computer room, factory or other
- physical dimensions, construction materials and features such as windows, doors, stairways or others
- occupancy characteristics including the number of people and the duration of occupancy
- equipment such as lighting, motors, appliances and where they are located within the building
- ventilation and insulation. [49]

A previous study for a town in Italy where ski resorts are located found the following heating and cooling loads in Table 5.7.

Table 5.7 Heating and cooling loads for buildings [50]

BUILDING TYPE	HEATING LOAD (W_{TH}/M^2)		COOLING LOAD (W_{TH}/M^2)	
	Good Insulation	Poor Insulation	Good Insulation	Poor Insulation
House (1)	25	100	30	38
Office (2)	63	145	75	85
Hotel (3)	45	98	20	38

(1) A house in this study was defined as a single-family detached house
(2) An office in this study was defined as a small two storey office building
(3) A hotel in this study was defined as a multi storey hotel.

WSP has divided the geothermal opportunities into two stages: a) Existing Development b) Future Development (Snowy Structure Plans). The existing development areas are the currently existing significant residential and commercial buildings. The future development areas considered include only those areas that will be newly developed into commercial or residential areas. Redevelopments have not been revised as they are considered under the existing development areas.

EXISTING DEVELOPMENT

Potential buildings that may be suitable for a GSHP system retrofit that are currently existing are identified in the following sections of this report. These buildings were selected based on the general assumption that:

- basic thermal efficiency works have already been undertaken including building sealing and insulation
- they are situated in an area where there is land available to lay the underground piping and access for the digging or trenching equipment to the site
- a GSHP system could be retrofitted and the building is suitable for the work and has good insulation
- the GSHP systems could be either horizontal or vertical closed loop systems

— small buildings (footprints of less than 250 m^2) would be one storey and larger buildings are two storeys
— for the purposes of determining the required heating/cooling loads in W/m^2, the building type was assumed based on the size of the footprint – for example, if the measured footprint of the building was less than 400 m^2 it was assumed to be a "house" with the required heating/cooling loads shown in Table 5.7.

Retrofitting a GSHP system can be difficult due to the groundwork required including drilling boreholes for vertical systems, or laying pipes in a large area for horizontal systems [51]. However, some retrofit projects have been carried out within the approximate area of the Snowy Mountains SAP as indicated in Section 3.6 of the Context Analysis Report, indicating there is potential for the installation of these systems into the existing buildings in the Snowy Mountains SAP. The heating and cooling loads for the existing development areas have been estimated for good and poor insulation to show the heating and cooling loads that may be required. WSP recommends that GSHP systems are only fitted to buildings with good insulation.

PERISHER VALLEY

The buildings within the Perisher valley area that were considered as potentially suitable for a GSHP system are shown in Figure 5.11.

Figure 5.11 Area considered for geothermal capacity – Perisher Valley

In this area there are a number of small buildings that were not considered as they appear to be close to neighbouring buildings, limiting the area available for laying the necessary piping. Where multiple buildings border an open area, only one was considered to avoid competing uses for the area.

Table 5.8 below shows the footprint of the buildings highlighted in Figure 5.11 and a high-level indication of heating / cooling load required by the buildings indicated. These estimates were made assuming that the area measured based on the roofing is a reasonable representation of the internal area that can be heated or cooled.

Table 5.8 Estimated heating and cooling loads for buildings considered – Perisher Valley

BUILDING	FOOTPRINT (M^2)	SYSTEM	BUILDING TYPE	STOREYS	HEATING - GOOD INSULATION (KW)	HEATING - POOR INSULATION (KW)	COOLING - GOOD INSULATION (KW)	COOLING - POOR INSULATION (KW)
Perisher Valley 1	4333	Horizontal	Hotel	2	390	849	173	329
Perisher Valley 2	706	Horizontal	Office	2	89	205	106	120
Perisher Valley 3	582	Horizontal	Office	2	73	169	87	99
Perisher Valley 4	1207	Horizontal	Hotel	2	109	237	48	92
Perisher Valley 5	2149	Horizontal	Hotel	2	193	421	86	163
Perisher Valley 6	1770	Horizontal	Hotel	2	159	347	71	135
TOTAL					**1014**	**2227**	**572**	**938**

Note:

Commercial or residential type is based on the size of the building footprint

Most of the buildings were assumed to be commercial in nature, owing to their relatively large footprints such as resorts and small hotels and other facilities.

CHARLOTTE PASS

The buildings in Charlotte Pass that were considered as potentially suitable for a GSHP system retrofit are indicated in Figure 5.12. These buildings were assumed to be the resort and other small hotels or hostels and residential buildings.

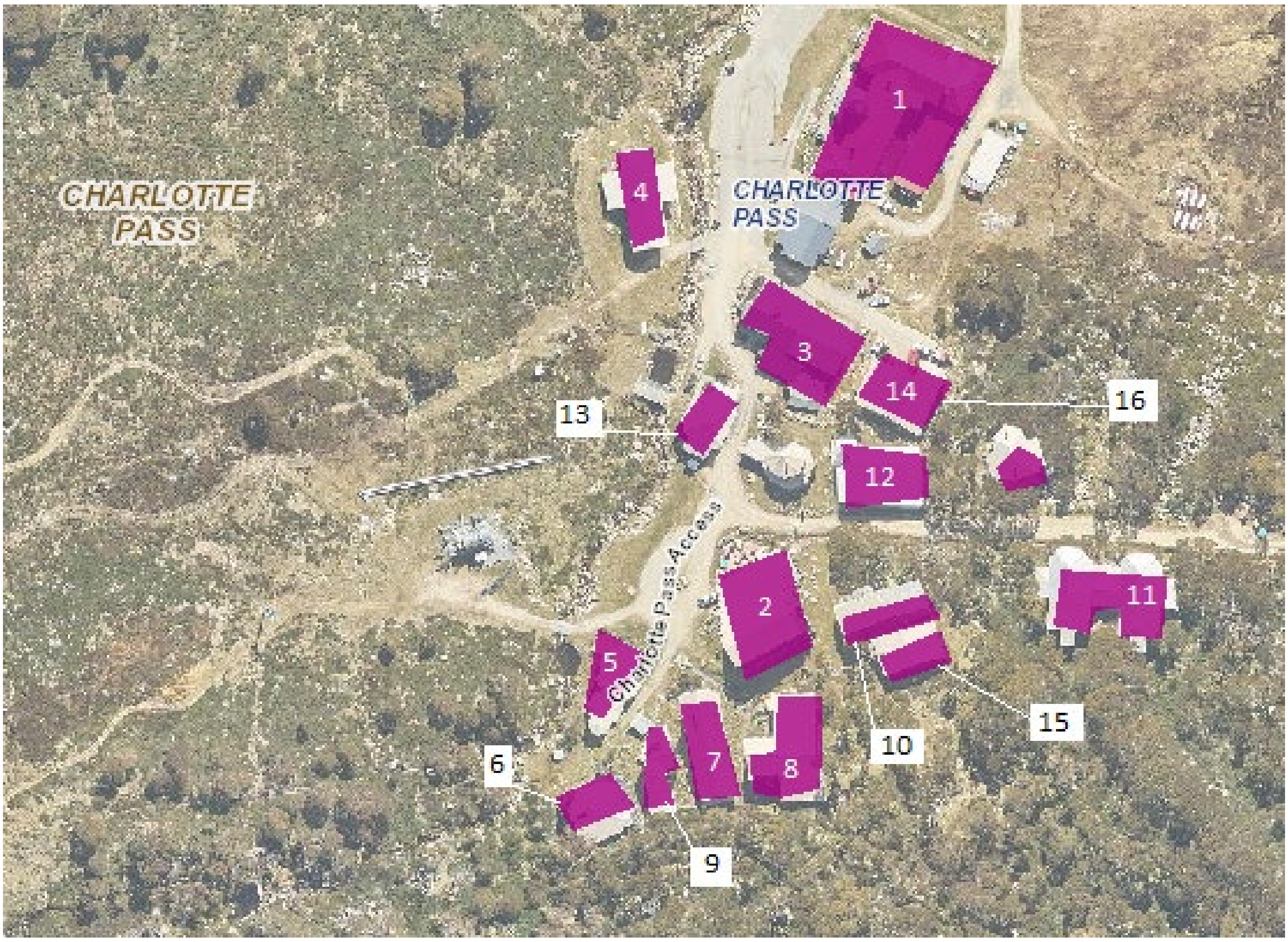

Figure 5.12 Area considered for geothermal capacity – Charlotte Pass

Table 5.9 below shows the estimated heating and cooling loads for the buildings considered in the Charlotte Pass area.

Table 5.9 Estimated heating and cooling loads for buildings considered – Charlotte Pass

BUILDING	FOOTPRINT (M^2)	SYSTEM	BUILDING TYPE	STOREYS	HEATING - GOOD INSULATION (KW)	HEATING - POOR INSULATION (KW)	COOLING - GOOD INSULATION (KW)	COOLING - POOR INSULATION (KW)
Charlotte Pass 1	1542	Horizontal	Hotel	2	139	302	62	117
Charlotte Pass 2	626	Horizontal	Office	2	79	182	94	106
Charlotte Pass 3	668	Horizontal	Office	2	84	194	100	114
Charlotte Pass 4	271	Horizontal	House	2	14	54	16	21
Charlotte Pass 5	243	Horizontal	House	1	6	24	7	9
Charlotte Pass 6	208	Horizontal	House	1	5	21	6	8
Charlotte Pass 7	321	Horizontal	House	2	16	64	19	24
Charlotte Pass 8	440	Horizontal	Office	2	55	128	66	75

BUILDING	FOOTPRINT (M^2)	SYSTEM	BUILDING TYPE	STOREYS	HEATING - GOOD INSULATION (KW)	HEATING - POOR INSULATION (KW)	COOLING - GOOD INSULATION (KW)	COOLING - POOR INSULATION (KW)
Charlotte Pass 9	167	Horizontal	House	1	4	17	5	6
Charlotte Pass 10	215	Horizontal	House	1	5	22	6	8
Charlotte Pass 11	481	Horizontal	Office	2	61	139	72	82
Charlotte Pass 12	361	Horizontal	House	2	18	72	22	27
Charlotte Pass 13	181	Horizontal	House	1	5	18	5	7
Charlotte Pass 14	313	Horizontal	House	2	16	63	19	24
Charlotte Pass 15	167	Horizontal	House	1	4	17	5	6
Charlotte Pass 16	123	Vertical	House	1	3	12	4	5
Total	**6327**				**513.77**	**1328.182**	**509.01**	**639.51**

THREDBO VILLAGE

The area within Thredbo Village that was included in the geothermal capacity estimate was similar to that used for the solar estimate. Most of the buildings in the area appeared to be residential in nature, with some small accommodation buildings (see Figure 5.13). The residential properties appeared to be tightly packed, suggesting that they may be suitable for vertical systems only but access for the digging equipment may be difficult.

Figure 5.13 Area considered for geothermal capacity – Thredbo Village

The larger buildings highlighted in Figure 5.13 represent larger ski accommodation buildings and hotels. Their footprints are listed in Table 5.10.

Table 5.10 Estimated heating and cooling loads for buildings considered – Thredbo Village

BUILDING	FOOTPRINT (M^2)	SYSTEM	BUILDING TYPE	STOREYS	HEATING - GOOD INSULATION (KW)	HEATING - POOR INSULATION (KW)	COOLING - GOOD INSULATION (KW)	COOLING - POOR INSULATION (KW)
Thredbo 1	4401	Horizontal	Hotel	2	396	863	176	334
Thredbo 2	1658	Horizontal	Hotel	2	149	325	66	126
Thredbo 3	3671	Horizontal	Hotel	2	330	720	147	279
Thredbo 4	1645	Horizontal	Hotel	2	148	322	66	125
TOTAL	**11375**				**1024**	**2230**	**455**	**865**

JINDABYNE

The buildings in Jindabyne that were included in the geothermal capacity estimate was similar to that for the small and medium scale solar as shown in Figure 5.7. These areas are more tightly packed than Perisher Valley or Charlotte Pass and would contain mostly residential buildings with some larger buildings for commerical purposes and playing fields. Within this area, the approximate footprint of a sample of 46 buildings was measured and found to have an average footprint of approximately 237 m^2. For the purpose of this high level estimate, it was assumed that this represented the average footprint for the suitable portion of properties in Jindabyne.

Figure 5.14 Area considered for geothermal capacity – Jindabyne areas

Further assumptions were made for the high-level estimate of the heating/cooling load of the area, being:

- Of the land measured, 70% was covered by potentially suitable buildings, noting that this is less than the 80% used in Section 5.2.2.2 for the rooftop solar PV capacity estimation because it is assumed that the roof area is typically larger than the enclosed footprint of the building itself due to patios and other covered outdoor areas that are typically included in residential properties.
- The majority of buildings appeared to be residential in nature, therefore it was assumed that using the heating and cooling loads of a house in W/m^2 as per Table 5.7 is adequate.
- Of the suitable buildings, there would be a 50% uptake in GSHP systems.
- The average house footprint of 237 m^2 is approximately representative of the average house in Jindabyne township.
- 50% of suitable houses that install a GSHP system are 2 storeys and both storeys have the same footprint.

Table 5.11 below shows the estimated heating/cooling load that may be met by installation of a GSHP system in the Jindabyne area based on the assumptions above and those stated in Section 5.2.3.1.

Table 5.11 Estimated heating/cooling load met by GSHP in Jindabyne

LOADING TYPE	LOADING (W_{TH}/m^2)	TOTAL HEATING/ COOLING AREA CONSIDERED (m^2)	TOTAL LOAD IN JINDABYNE (kW_{TH}) MET BY GSHP
Heating – Good Insulation	25	405,830	10,146
Cooling – Good Insulation	30		12,175

Notes:

Total heating/cooling area = Total building footprint x portion of land covered by suitable houses x Portion of suitable houses that would install GSHP x number of houses with two storeys

Total building footprint estimated as 773,009 m^2 per Figure 5.14.

FUTURE DEVELOPMENT

WSP has undertaken a desktop analysis for the potential geothermal opportunity for new development areas based on data for the Snowy Structure Plans. For project growth areas, the following assumptions were made to estimate the geothermal opportunity:

- For Perisher Valley, Charlotte Pass and Thredbo Village, 50% of the net site area would be indoor areas that are suitable for GSHP heating and cooling. For Jindabyne, it was assumed that 60% of the lot size was suitable indoor area.
- The buildings may have multiple storeys as indicated by the Snowy Structure Plans. Where the buildings are expected to be within a height range, the average of the minimum and maximum height was taken. For example, for buildings that were specified as being either one or two storeys, the average of 1.5 storeys was used. When buildings were specified as being either two or three storeys, the average of 2.5 storeys was used.
- The buildings will have good quality insulation as this will improve energy efficiency for heating and cooling and minimise the size of the GSHP system.
- Buildings that are planned to be apartments will be similar in layout to a hotel and therefore have loads of 45 W/m^2 heating and 20 W/m^2 cooling.
- Residential buildings and townhouses are assumed to be similar in layout to a house and therefore have loads of 25 W/m^2 heating and 30 W/m^2 cooling.

Table 5.12 summarises the heating and cooling capacity for GSHP systems to be provided in the new development areas considered in the geothermal opportunity. The areas considered were new development areas only. Areas that were identified in the Snowy Structure Plan as a redevelopment were not considered as they were accounted for in the existing developments. WSP has identified that a total capacity of 44.8 MW heating and 49.4 MW cooling will exist at these premises upon the completion of the development according to the Snowy Structure Plans.

Table 5.12 Geothermal opportunity in project growth areas

LOCATION	DEVELOPMENT AREA DESCRIPTION	ESTIMATED INDOOR AREA (m^2)	GOOD INSULATION – HEATING LOAD (kW)	GOOD INSULATION – COOLING LOAD (kW)
Perisher Valley	Multistorey apartment buildings and townhouses.	118,500	4,493	2,790
Charlotte Pass	Multi-storey apartment buildings.	8,000	360	160
Thredbo Village	Multistorey apartment buildings and townhouses.	79,750	2,899	1,940
Jindabyne	Single and double storey houses.	1,229,985	37,054	44,465
Total	Total geothermal loading in the selected growth areas.	1,436,235	44,805	49,355

The geothermal loads in Table 5.12 are the capacities of GSHP systems that could be installed based on the underlying assumptions discussed above. WSP has not made an assessment on whether the technical aspects required to support the operation of the GSHPs have been met.

Figure 5.15 shows the areas identified for growth in Perisher Valley in purple that will be new developments and were considered in the geothermal opportunity within Perisher Valley.

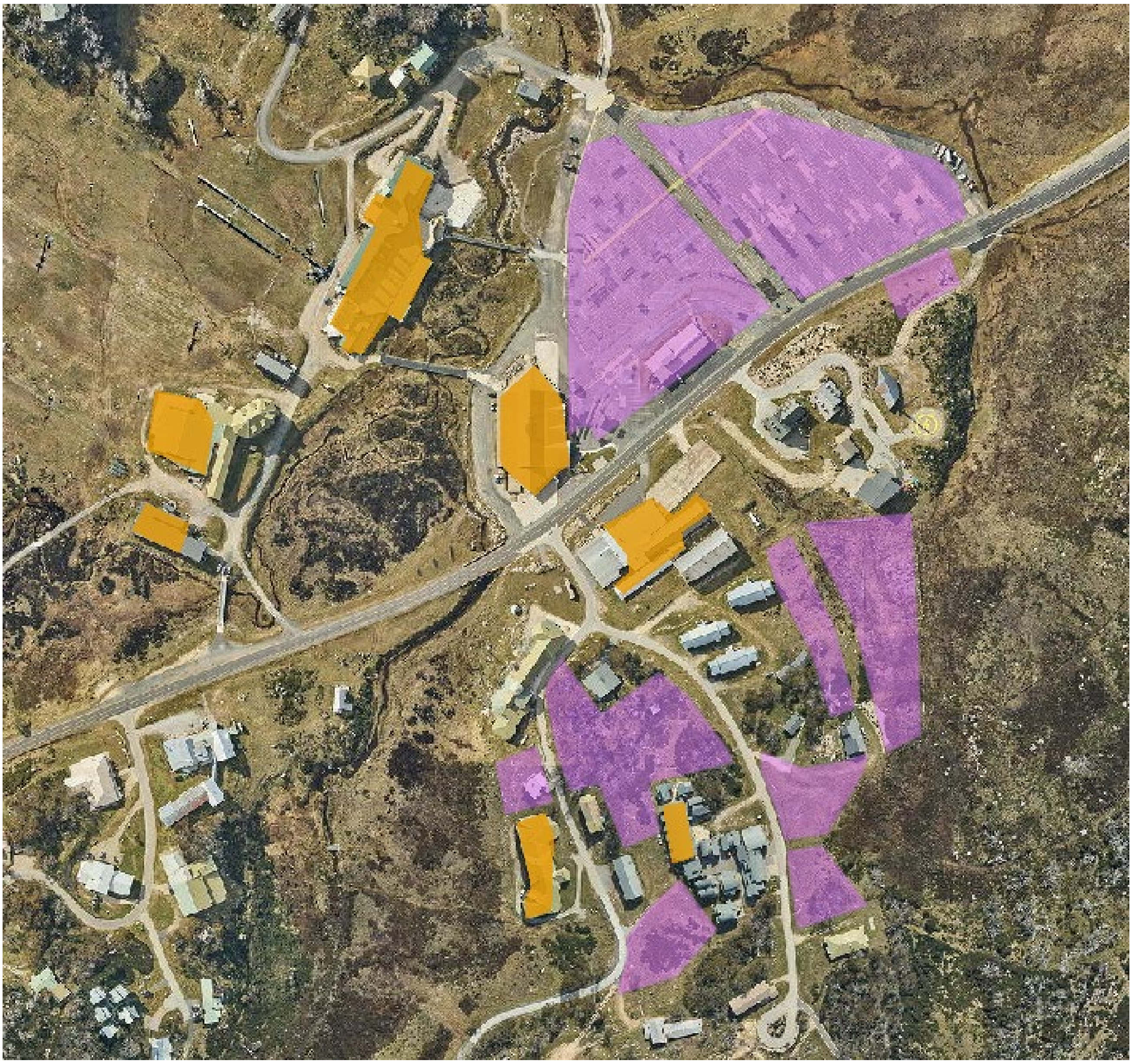

Figure 5.15 New Development areas (purple) and existing development areas (orange) considered in the geothermal opportunity for Perisher Valley

Figure 5.16 shows the new development areas considered for geothermal opportunity for Charlotte Pass in yellow and the buildings considered which are Existing Development in purple.

Figure 5.16 New development areas (yellow) and existing development areas (purple) considered in the geothermal opportunity for Charlotte Pass

Figure 5.17 shows the new developments in Thredbo Village that were considered in the geothermal opportunity for Thredbo Village in purple and the buildings considered under the existing development in blue.

Figure 5.17 New development areas (purple) and existing development areas (blue) considered in the geothermal opportunity for Thredbo Village

Figure 5.18 shows the new development areas considered in the geothermal opportunity for Jindabyne in relation to the estimated existing development.

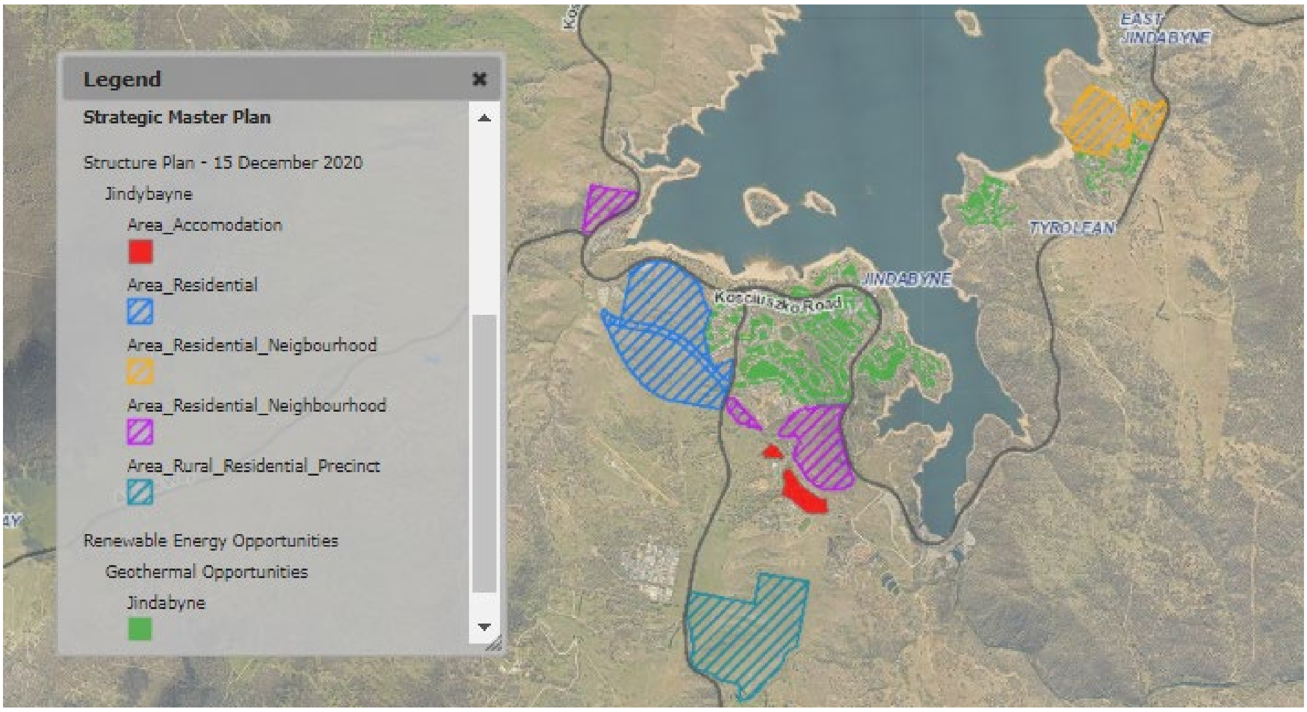

Figure 5.18 New development areas (Structure plan areas) and existing development areas (green shaded areas) considered in the geothermal opportunity for Jindabyne

5.2.3.2 INDICATIVE LAND REQUIREMENT

GSHP systems consist of underground piping arranged horizontally or vertically as shown in Figure 5.19 [52]. New properties that are below 160 m^2 are generally better suited to vertical looping systems [53]. The vertical configuration is better suited to applications where space is limited but tends to be the more costly orientation as a result of needing to drill deeper holes. By comparison, the horizontal configuration requires more space but does not require the pipes to be buried as deeply.

Figure 5.19 GSHP piping configurations; (left) horizontal and (right) vertical

Space for the pumping and heat exchanging equipment on the property is also required to operate and control the GSHP system. The equipment footprint can vary depending on the system, but a space of 1 x 2.5 m is typically sufficient [54].

VERTICAL LOOP SYSTEMS

For vertical loop systems, a general rule of thumb for the capacity of a loop is 5–6 kW per 100 m of depth [55]. These systems can be installed either underneath, or adjacent to the building it will be supplying and can generally be installed in most soil types [55]. Typical boreholes for the pipes will be approximately 250 mm in diameter. If multiple boreholes are needed, they may be drilled five to six metres apart. When installing vertical loop systems, the main limitation is whether there is space for the drilling rig to access the site [54].

For the single storey residential properties under consideration that would require a vertical loop such as the properties in Jindabyne, one loop reaching a depth of 100 m or equivalently, multiple loops to a shallower depth is likely to be sufficient to meet the heating and cooling needs depending on the level of insulation in the building (see Table 5.13). Similarly, for two storey residencies, two loops reaching 100 m in depth or similarly, four loops reaching approximately 50 m would likely suffice if the building had relatively good insulation. It is noted that drilling to a depth of 100 m is impractical and as such, if a vertical system is required, multiple bores would likely be required. Where sufficient land is not available to install a GSHP system to cater to the full heating and cooling requirements of the building, a lower capacity system may be installed to augment the existing air conditioning system.

Table 5.13 Indicative GSHP system capacity

BUILDING	SINGLE STOREY		DOUBLE STOREY		COMMERCIAL (3)	
Building quality	Good insulation	Poor insulation	Good insulation	Poor insulation	Good insulation	Poor insulation
Required GSHP System Capacity (kWth)	5.9	23.7	11.8	47.3	159.3	346.9
Boreholes (1)	2 x 55	7 x 65	4 x 55	14 x 65	45 x 65	98 x 65

Notes:

(1) Number of boreholes and borehole depth is indicative and based on literature values. Heat transfer capacity is based on an average 5.5 kW per 100 m of borehole depth [55] [56].

(2) The cost of installing the boreholes is assumed to be AUD80/m in 2018 dollars. The cost of the GSHP is based on a cost of AUD2,000/kW in 2018 dollars. Costs include the equipment and installation of the system [56]

Note the size used is per Perisher 6 as shown in Table 5.8. This is included as an example of a GSHP system for a commercial building. Other commercial buildings of different sizes will require different sized GSHP systems.

It was assumed that vertical systems would be able to be installed under the surface of the yards of respective properties and then returfed, hence no additional land is required.

HORIZONTAL LOOP SYSTEMS

Due to their configuration, horizontal ground loops require more land to be available for installation and once installed, this land should not be used for future plantations or construction because of the risk of roots damaging the pipes or altering the heat transfer characteristics of the soil. Horizontal loops can be laid out in a straight rectangular formation, or in a slinky formation as shown in Figure 5.20. The slinky loops require less land, but need more piping and thus, attract additional costs [57].

Figure 5.20 Part of the "slinky" system at Main Ridge [58]

The amount of land required for the horizontal loops depends on the type and characteristics of the soil at the site as shown in Table 5.14. The soil in the Australian alps tends to be low in clay content and is typically well drained [59]. For the purposes of this high-level estimate, it was assumed that the extraction/absorption capacity of the soil in the areas under consideration is approximately 20 W/m^2.

Table 5.14 Extraction/absorption per square metre for horizontal loop systems [60]

GROUND TYPE	EXTRACTION/ABSORPTION POWER (W/M^2)
Dry, sandy ground	10–15
Moist, sandy ground	15–20
Dry, clay ground	20–25
Moist, clay ground	25–30
Ground with ground water	30–35

The buildings that are suspected to be residential in nature tended to be relatively close to the neighbouring buildings which limits the potential for installing a horizontal loop system. Therefore, this configuration was only considered for those buildings which appeared to be near a plot of clear, open land. These were typically the larger, commercial buildings such as the Perisher Ski Resort. However, due to their size, these buildings would require a larger GSHP system capacity and hence a larger loop field. For example, the land required for the loops to supply some of the larger commercial buildings is shown in Table 5.15 for reference.

Table 5.15 Land required for horizontal loops for select buildings

BUILDING (1)	HEATING LOAD(2) (KW_{TH})	LAND REQUIREMENT FOR HORIZONTAL LOOPS	
		Conventional horizontal (m^2)	Slinky (m^2)
Perisher Ski Resort	159	7,965	3,540
Perisher Snow Sports School	390	19,499	8,666
Kosciuszko Chalet (Charlotte Pass)	139	6,939	3,084

(1) Table does not include all commercial buildings in the areas considered

(2) Land requirement estimate assumes that the buildings have good insulation

Using the estimates in Table 5.15 as an approximate guide to the land required for larger commercial buildings, it may be more practical to install multiple pipes in the same trench, with the trade-off being that the trench would need to be deeper in order to accommodate the additional pipes [61]. Alternatively, vertical systems for these buildings may also be installed. This has been done for other buildings such as the Geoscience Australia building in Canberra [48]. The Geoscience Australia building has a floor area of 30,700 m^2 and has a GSHP system with an installed capacity of 2.5 MW_{th} [48]. This system included 350 boreholes in a closed vertical loop configuration with approximately 200 GSHPs [55].

5.2.3.3 INFRASTRUCTURE REQUIREMENTS

To operate GSHP systems, electricity is required in addition to a circulating fluid such as water or refrigerant [58]. Additional equipment such as the pipes and piping accessories and circulating pumps are also required.

ELECTRICITY

Due to the nature of these systems, they consume electricity for the purpose of circulating heat around the system as opposed to generating heat or cooling [62]. In general, the pumps required to circulate the heat transfer fluid have a low electrical load and would typically not exceed 50 W_e of electrical energy requirement per kW_{th} of load [63]. Using this general rule, the indicative electricity consumption for a GSHP installed in selected buildings is shown in Table 5.16 as an example of the electricity consumed by a particular building. A high-level estimate for the total power consumption for the pumps in the GSHP systems is provided in Table 5.17.

Table 5.16 Estimated electricity consumption of GSHP system in residential properties and commercial buildings

ENERGY USE	SINGLE STOREY HOUSE (1)	DOUBLE STOREY HOUSE (2)	PERISHER SKI RESORT (3)
GSHP System Capacity (kWth)	5.9 – 23.7	11.8 – 47.3	159.3 – 346.9
GSHP Electricity Consumption (kWe)	0.3 – 1.2	0.6 – 2.4	8.0 – 17.3

(1) Assumes a footprint of 237 m^2 based on the sample of houses measured in Jindabyne

(2) Assumes a footprint of 237 m^2 for both levels based on the sample of houses measured in Jindabyne

(3) Electricity consumption for Perisher Ski Resort is provided as a guide for the electricity consumption for a commercial building

These loads are unlikely to require the premises to do any upgrades to support the additional load. For example, modern split system air conditioning units can be rated at 2.5–5 kW_e and typically do not require upgrades to be powered.

Table 5.17 Aggregated electricity consumption by GSHP systems for existing developments

AREA	HEATING		COOLING	
	Load (kW_{th})	GSHP power consumption (kW_e)	Load (kW_{th})	GSHP power consumption (kW_e)
Perisher	1014–2227	51–111	572–938	29–47
Charlotte Pass	514–1328	26–66	509–640	25–32
Thredbo Village	1024–2230	51–111	455–865	23–43
Jindabyne	10,146–40,583	507–2,029	12,175–15,422	609–771

The electricity consumption of the systems depends on the level and quality of insulation of the buildings. For example, if all of the buildings under consideration in Jindabyne had relatively good insulation, a GSHP system with a smaller capacity would suffice and the collective electricity consumption of the GSHP systems would be approximately 0.5 MW during winter. However, if all of the buildings had relatively poor insulation, then the electricity consumption could be approximately 2.0 MW. Therefore, the properties looking to install a GSHP system should only do so if the building is well insulated and if not, the insulation should be upgraded prior to installing the GSHP system.

Table 5.18 provides a high-level indication of the additional electricity consumed by the GSHP systems that could be installed in the new development areas in the project growth areas. This assumes the buildings are designed and constructed with good quality insulation.

Table 5.18 Aggregated electricity consumption by GSHP systems for new developments in the project growth areas

LOCATION	HEATING		COOLING	
	Load (KW_{TH})	GSHP power consumption (KW_E)	Load (KW_{TH})	GSHP power consumption (KW_E)
Perisher Valley	4,493	225	2,790	140
Charlotte Pass	360	18	160	8
Thredbo Village	2,899	145	1,940	97
Jindabyne	37,054	1,853	44,465	2,223
Total	**44,805**	**2,240**	**49,355**	**2,468**

HEAT TRANSFER FLUIDS

Open loop GSHP systems take advantage of ground water reservoirs under the surface. These systems are able to circulate larger quantities of water and can therefore achieve higher efficiencies [64]. However, they require favourable hydrogeological conditions to be present at the site to be feasible. Generally, the average system will use 4.2 L/min of groundwater per kW of capacity while operating [52]. Furthermore, because these systems circulate ground water – taking it from the reservoir to extract heat before returning it to the ground – the discharge water must be carefully handled [64].

Closed loop systems are not restricted to locations where the hydrogeological requirements are met and hence can be installed in a wider range of locations. The circulating fluid may be water or refrigerant and is enclosed within the system and hence, does not come into contact with the ground when operating correctly. The rate at which the fluid circulates depends on the capacity of the pumps and sizes of pipes and fittings.

5.2.4 HYDROGEN

There are three main uses for hydrogen in the energy sector as highlighted in Section 3.7 of the Context Analysis Report, being:

- as an energy storage medium for power generation
- blending with natural gas for use in direct heating
- use as a fuel source for hydrogen fuel-cell vehicles.

Using hydrogen to store electricity primarily involves using a large scale hydrogen fuel cell to convert hydrogen into electricity in times of high demand or low renewable output. This method of usage is not considered in this report due to the low round trip efficiency of the process.

Hydrogen can also be blended with natural gas and be used for heating, cooking, or for powering backup generators. Within the Snowy Mountains SAP, distributing the blended gas would likely be via canisters delivered by trucks as there is no large gas distribution network within the Snowy Mountains SAP.

Alternatively, hydrogen can be used in hydrogen fuel cell vehicles. These vehicles feed pressurised hydrogen gas into a fuel cell to convert the chemical energy into electrical energy, which then powers the drive train of the vehicle.

There are two main pathways to generating hydrogen for energy storage as outlined in Section 3.7.1 of the Context Analysis Report –through steam-methane reforming, or water electrolysis. Water electrolysis using renewable energy such as excess power from a solar farm or power generated by distributed solar PV generation identified in Section 5.2.1 of this report would align this technology option with the carbon negative aspirations of the Snowy Mountains SAP and is the pathway that is further considered in this report.

Outside of its use in the energy sector, Hydrogen can also be used as a feedstock in both agricultural and industrial applications. Hydrogen can be converted into Ammonia (NH_3) for use as a key chemical agent in fertilisers. Further ammonia can be used as an environmentally friendly refrigerant due to its low GHG emission factor. Currently the biggest use of hydrogen globally is as an industrial chemical agent. This type of use is likely to form part of the transition strategy in establishing a hydrogen market in Australia and regionally.

5.2.4.1 LOCATION AND EXPECTED CAPACITY

In section 5.2.1 of this report it is estimated that there may be approximately 15.18 MVA of excess power available from the existing Jindabyne town's distributed Solar PV generation (assuming all identified distributed solar PV opportunities are installed).

Three hydrogen plant sizes were considered in this report; small, medium and large. The largest individual size considered was 10 MW because this technology is highly modular and therefore it is recommended that the capacity of the plant be increased in stages as the Snowy Mountains SAP is developed (see Table 5.19). Therefore, the capacity of a potential hydrogen plant can be expanded as either the demand for hydrogen increases, or excess available power becomes available.

The base case option for a hydrogen plant was taken to be a centralised plant located near Jindabyne substation. As one of the larger residential areas within the Snowy Mountains SAP, Jindabyne will have the largest concentration of vehicles – either passenger vehicles, buses or trucks – which could be replaced by hydrogen fuel cell vehicles as the Snowy Mountains SAP develops, and thus would benefit from the hydrogen plant within the local area.

Table 5.19 Electrolyser characteristics

SCALE	SMALL [65]	MEDIUM [65]	LARGE [66]
Input Power (MW)	1.5	5.0	10
AC Power consumption (kWh/Nm^3 H_2)	5.0–5.4	5.0–5.4	4.3
Hydrogen Production rate (Nm^3/h)	300	1,000	2,000
Output pressure (bar)	31 (1)	31 (1)	0.3
Tap water consumption (l/Nm^3 H_2)	< 1.4	< 1.4	< 1

(1) Originally specified as barg, standard atmospheric pressure was taken as the reference

Table 5.20 shows the potential uses of the hydrogen produced. This assumes:

- the plant will operate at its rated capacity continuously for six hours per day
- the plant operates when there is excess solar generated. However, market data would suggest that it is likely that hydrogen facilities are more economically feasible if operated continuously
- at maximum capacity, electrolysers tend to have a lower conversion efficiency therefore for the small and medium scale electrolysers, a value of 5.4 kWh_e was assumed. For the large scale electrolyser, the nominal value of 4.3 kWh_e was assumed [67].

Table 5.20 Hydrogen output and uses

SCALE	SMALL	MEDIUM	LARGE
Input Power (MW)	1.5	5	10
Operating hours	6		
Hydrogen production (kg/day)	162	539	1079
Equivalent Passenger Vehicles per day (1) [68]	27–54	90–180	180–360
Equivalent Buses per day (2) [68]	4–5	13–18	27–36
Equivalent Trucks per day (3) [69]	5	17	34

(1) Assumes all of the hydrogen produced will be consumed by passenger vehicles with a 3–6 kg on-board hydrogen fuel tank. CSIRO Hydrogen road map indicates that a 6 kg tank would allow for a range of 500–800 km.

(2) Assumes all of the hydrogen produced will be consumed by buses with a 30–40 kg on-board hydrogen fuel tank

(3) Assumes all of the hydrogen produced will be consumed by trucks with a 32 kg on-board fuel tank. Based on the Hyundai XCIENT fuel cell truck with 36 t pull-cargo [69] Approximate range of 400 km.

5.2.4.2 INDICATIVE LAND REQUIREMENT

Hydrogen plants can be relatively small installations depending on their rated output as shown in Table 5.21.

Table 5.21 Indicative hydrogen plant footprint

SCALE	SMALL [65]	MEDIUM [65]	LARGE [66]
Plant footprint (m^2)	83 (1)	113 (2)	480 (3)

(1) Based on a 20 ft standard shipping container parallel to a 40 ft shipping container
(2) Based on two parallel 40 ft shipping containers adjacent to a 20 ft shipping container
(3) Estimated footprint is based on a footprint per kW_e of 0.048 m^2/kW_e [70]

STORAGE

In addition to the plant itself, the storage vessels and ancillary equipment will also require space. Hydrogen can be stored above ground in pressure vessels, or below ground in salt caverns if feasible [71]. The below ground option for storing hydrogen is better suited to larger scale applications (i.e. 210,000 kg/30 days) and regardless, there are no known natural salt caverns within the Snowy Mountains SAP and hence, above ground tanks would be a more suitable option for the Snowy Mountains SAP [68].

Storage of bulk quantities of hydrogen introduces the inherent risk of fires when leaks are present. As such, additional safety measures for the storage tanks may need to be taken, such as positioning away from ignition sources, areas where the tanks may be impacted and potential chemical leaks that may compromise the tank. The NSW Hazardous Planning Advisory Paper No. 4 advises that heat radiation of 4.7 kW/m^2 or more is sufficient to cause injuries such as second degree burns after 30 seconds of exposure [72]. This mechanism is used as a risk quantifying mechanism for determining the risk of fatality in the event of a catastrophic failure. For the large-scale electrolyser plant (10 MW) that operates at 6 hr/day, 1,079 kg of hydrogen gas would be produced. If this amount of gas was stored under pressure but not liquified, a buffer zone of more than 100 m is recommended [73].

Noting that chemical batteries are currently the leading energy storage technology as they provide a proven, low risk technology solution for energy storage across different scales, hydrogen based energy storage has some advantages over many existing chemical battery storage technologies such as the following:

- Chemical batteries require the use of increasingly rare and mining-intensive minerals such as lithium.
- The energy storage density of hydrogen is significantly greater than chemical storage such as lithium.
- Chemical battery systems are difficult to safely dispose of at the end of life.
- Hydrogen storage is much more capable of providing seasonal energy storage and transportable energy storage.

The expected storage requirements for the various hydrogen options are presented below in Table 5.22.

Table 5.22 Hydrogen storage requirements

SCALE	SMALL		MEDIUM		LARGE	
Plant Operating Hours (h)	6		6		6	
Days of Storage	14		14		14	
Hydrogen Production (kg/day)	162		539		1,079	
Hydrogen production (Nm^3/day)	1,800		6,000		12,000	
Storage Pressure (bar)	30 (1)	150	30 (1)	150	30	150
Hydrogen Density at storage pressure (kg/m^3 at 25°C)	2.8	10.9	2.8	10.9	2.8	10.9
Storage Vessel Volume (m^3)(2)	825	225	2,750	700	5,475	1,400
Storage Vessel Footprint (m)	14 x 14 m	9 x 9 m	20 x 20 m	12 x 12 m	24 x 24	14 x 14 m

(1) The small and medium electrolysers produce hydrogen at approximately 30 bar. Thus, the plants at these scales do not require additional compression prior to storage

(2) Assumes a spherical storage vessel [74]

5.2.4.3 INFRASTRUCTURE REQUIREMENTS

Water electrolysis requires electricity and water as an input and will produce hydrogen and oxygen as products. These plants therefore require a connection to an electricity source and a source of water, as well as storage vessels for the gases produced.

ELECTRICITY

Hydrogen has poor energy density on a volumetric basis and hence there is a balance between the number and size of tanks required (i.e. needing more tanks for a lower storage pressure) and the cost of obtaining and operating compression equipment. For example, the power required to compress the hydrogen for storage can range from negligible amounts to 4.4 kWh/kg of hydrogen gas as shown in Table 5.23. A general rule of thumb for estimating the amount of compression energy required is in the order of 10% of the electrolyser power requirement. For example, the total power demand for the small scale plant would be 1.5 MW + 10% (1.65 MWe).

Table 5.23 Compression work for hydrogen storage

STORAGE PRESSURE (BAR) (1)	HYDROGEN DENSITY (kg/m^3)	ENERGY FOR COMPRESSION [68]
30–35	2.77	Negligible for the large scale electrolyser plant. The small and medium scale electrolysers considered in this report produce hydrogen at 31 bar, therefore the hydrogen may not need further compression [65].
50–150 bar (1)	3.95–10.9	0.2–0.8 kWh/kg H_2
350 (1)	23	4.4 kWh/kg H_2

(1) Assumes compression from 30 bar

Considering the hydrogen production amounts for the small, medium and large scale electrolysers for the Snowy Mountains SAP, this power consumption could be significant if storing large amounts of hydrogen at relatively high pressure (see Table 5.24).

Table 5.24 Estimated power consumption for hydrogen compression

SCALE	SMALL	MEDIUM	LARGE
Hydrogen production (Nm^3/day)	1,800	6,000	12,000
Hydrogen production (kg/day)	162	539	1,079
Compression power, 50 bar (kWh/day)	32	108	216
Compression power, 150 bar (kWh/day)	129	431	863
Compression power, 350 bar (kWh/day)	712	2,373	4,746

For on-board storage in vehicles such as passenger cars and trucks, hydrogen is carried at a relatively high pressure to achieve a reasonable volumetric energy density. The hydrogen storage tank for a passenger vehicle will typically be pressurised to 700 bar [68]. Trucks may also carry hydrogen at 700 bar, but will typically carry it at 350 bar because they have more on-board storage space [68]. Therefore, it is likely that if hydrogen is used for fuel cell vehicles, the refuelling stations will need compressors capable of compressing the hydrogen to 350 bar or 700 bar if it is stored at a lower pressure. Alternatively, the hydrogen may be compressed prior to storage [68].

WATER

Electrolysers use an electric current to split water molecules, forming hydrogen and oxygen gases. They therefore rely on a supply of water. Table 5.25 shows the water consumption for the small, medium and large scale electrolysers under consideration in this report.

Table 5.25 Electrolyser water consumption

ELECTROLYSER	SMALL	MEDIUM	LARGE
Tap water consumption (l/Nm^3 H_2)	1.4	1.4	1
Operating hours	6		
Hydrogen production (Nm^3/day)	1,800	6,000	12,000
Water consumption (l/day)	2,520	8,400	12,000
Water consumption (kL/year)(1)	920	3,066	4,380

(1) Assumes the electrolyser operates continuously for 6 hr/day for 365 days per year

The Snowy River Shire Council's (SRSC) licenses are governed by the Water Act 1912, permitting it to withdraw water from Lake Jindabyne, Lake Eucumbene and the Snowy River. In this analysis it was assumed that the electrolyser would be located on the outskirts of Jindabyne near the Jindabyne Substation, and therefore the closest water supply is Lake Jindabyne.

The water may potentially be sourced directly from Lake Jindabyne, or from the water mains. Sourcing water directly from Lake Jindabyne would likely require further infrastructure and environmental planning considerations and licensing applications if permitted. Withdrawing the water from the mains may be feasible considering the relatively low quantities of water required per Table 5.25.

The SRSC holds licenses to withdraw water from Lake Jindabyne in the volumes shown in Table 5.26. The combined withdrawal allowed under the SRSC's license is 1,122 ML/year. The water demand from Jindabyne is forecast to increase as shown in Table 5.26, and only exceeding the total amount the SRSC is allowed to withdraw as per the 2012 IWCMP in the year 2040. Lake Jindabyne has a capacity of 668 GL which can potentially support this increase in demand, pending license approvals.

Table 5.26 Water supply license volumes in 2012 IWCMP [75]

WATER SUPPLY SCHEME	WATER SOURCE	VOLUME (ML/YEAR)
Berridale and East Jindabyne	Lake Jindabyne (Intake at East Jindabyne)	467
Jindabyne	Lake Jindabyne	577
Kalkite	Lake Jindabyne	78
TOTAL		**1,122**

Table 5.27 Jindabyne annual demand forecasts

YEAR	ANNUAL DEMAND FORECAST (ML/YR)
2030	975–1,050
2040	1,350–1,450

Compared to the demand forecasts in Table 5.27 for Jindabyne, the water consumption of the largest electrolyser is less than 1% of the forecast demand of Jindabyne and is therefore a relatively small component of the overall water consumption of the town. However, it should be accounted for during the license renewal process to ensure the withdrawal limits are adequate.

HYDROGEN GAS BLENDING

An alternative use for hydrogen is to blend it with natural gas for heating, cooking or for powering generators. Adding hydrogen to natural gas displaces part of the fossil fuel consumed and hence, aids in decarbonising the natural gas sector. Relatively small amounts of hydrogen (10–15% by volume) can be added to natural gas and be used with conventional household appliances without needing alterations or upgrades of the devices [68]. A complete displacement of natural gas with hydrogen would require an upgrade of the existing appliances because of the different energy content and other characteristics [68].

There is no large gas distribution network within or near the Snowy Mountains SAP though, the closest being the Eastern Gas pipeline which is approximately 65 km from Jindabyne [76]. Therefore, the blending of hydrogen with natural gas can be an idea for the future if and when the natural gas network is established in or near to Snowy Mountains SAP area.

5.2.5 BATTERY ENERGY STORAGE SYSTEMS (BESS)

WSP has identified the following opportunities for the implementation of Battery Energy Storage Systems (BESS) in the Snowy Mountains SAP:

- BESS integrated with Solar PV Farm(s)
- BESS integrated with Solar Car Park(s)
- BESS integrated with roof-top solar PV system(s).

5.2.5.1 BESS INTEGRATED WITH SOLAR PV FARMS

BESS integrated with large scale solar PV farms usually store the energy generated by the solar PV plant to dispatch it when the National Electricity Market (NEM) prices are more favourable. There are business cases available in Australia for the development of independent grid connected large scale BESS. Such systems can earn revenue through storing energy from the grid when the NEM prices are low and dispatching energy when the NEM prices are higher, and through the provision of frequency control ancillary services (FCAS) to the grid.

BESS integrated with large scale solar PV farms can have a number of potential advantages including:

- revenue addition to the Project based on the energy dispatch strategy
- support to the grid network and system strength.

A BESS system is sized according to its installed capacity (MW) and its storage capacity (MWh). The required installed capacity is a function of how quickly energy is to be stored and/or exported. The sizing of a BESS storage capacity for any project is related to the intended services to be provided by such a system. BESS systems intended to provide short-term storage solutions or primarily FCAS services would likely have a lower storage capacity than one intended to store an entire day’s generation. It is anticipated that a BESS installed in parallel to a solar farm would be required to store energy during peak solar production times. This is anticipated to overlap with lower energy prices, particularly as solar penetration continues to increase across the NEM. Storage during these periods would help to shift exported generation to peak demand periods (for example during the evening peak when the solar farm is no longer generating). This can help the facility to maximise revenue through storing energy during periods of low energy prices, and benefitting from peak demand pricing at other times.

WSP understands, from engagements with BESS equipment providers, that the current market trend is for batteries to be sized with at least one hour storage (e.g. a 1 MW battery would have a minimum storage capacity of 1 MWh).

Table 5.28 below shows an indicative capacity range of a BESS associated with each of the ground mount solar PV options identified in Section 2.2.1.1. WSP highlights that the ranges of the BESS sizes provided below are indicative only, the selection of exact size of BESS system for the respective solar PV opportunity will be dependent upon the business and financial strategies of individual developer.

Table 5.28 Indicative BESS size range for solar PV farms

OPTION #	DESCRIPTION	INDICATIVE BESS INSTALLED CAPACITY (MW)	INDICATIVE RANGE OF BESS STORAGE SIZE (MWH)
1	10 MW solar PV farm + BESS	10	10–40
2	10 MW solar PV farm + BESS	10	10–40
3	27 MW solar PV farm + BESS	27	27–108

5.2.5.2 BESS INTEGRATED WITH SOLAR CAR PARK(S)

WSP highlighted in Section 5.2.2.1 that, in future, energy generated via the car park solar PV systems could be used to charge electric vehicles by storing energy generated from car park solar PV systems into the BESS. Table 5.29 below shows the indicative range of size of the BESS for the identified solar car park opportunities.

Table 5.29 Indicative BESS size range for solar car parks

#	NAME OF THE OPEN CAR PARK AREA	ESTIMATED CUMULATIVE SOLAR PV CAPACITY (MWP)	INDICATIVE RANGE OF BESS SIZE (MW/MWH)
1	Smiggin Holes	1.59	1.59/1.59-6.36
2	Perisher Valley	3.23	3.23/3.23-12.92
3	Thredbo Village	1.12	1.12/1.12-4.48
4	Bullocks Flat	3.72	3.72/3.72-14.88
5	Jindabyne town	1.63	1.63/1.63-6.52

WSP highlights that the ranges of the BESS size provided in Table 5.29 are indicative only, the selection of exact size of BESS system for the respective solar PV opportunity will be dependent upon the business and financial strategies of the individual developer.

5.2.5.3 BESS INTEGRATED WITH ROOF-TOP SOLAR PV SYSTEM(S)

WSP assumes that the point of connection for the BESS integrated with individual roof-top solar PV system will be behind the meter. The size of the BESS integrated with roof-top solar will be dependent upon the size of individual roof-top solar PV system and the system owner's discretion as to how much of the excess energy the system owner wants to feed into the network.

WSP also highlights an opportunity for the community BESS system which may store excess energy from the distributed roof-top solar PV system and dispatch it back to the grid based on developer/operator's business model. However, a detailed business case and public interfaces need to be assessed by the prospective developer and DPIE.

5.2.6 RENEWABLE ENERGY POWER PURCHASE AGREEMENTS

WSP has identified in Section 3.5.2.3 of this report, the opportunity for the electricity consumers of Snowy Mountains SAP to purchase accredited renewable electricity from Snowy Hydro (or any other renewable energy generator) to support the Snowy Mountains SAP's development and carbon negative aspiration.

In all power purchase agreement scenarios it is important to ensure renewable energy supplies to the region consist of accredited renewable energy, this means the supplies must be derived from eligible renewable energy sources eligible to participate in the National Renewable Energy target and that energy generators are registered with the clean energy regulator and capable of creating Large Scale Renewable Energy Certificates.

There are increasingly more diverse and flexible methods of procuring renewable energy from accredited suppliers, two of the main mechanisms to purchase renewable or carbon neutral electricity by any consumer(s) within the Snowy Mountains SAP would include:

i) **Purchase of energy from Snowy Hydro through a Power Purchase Agreement (PPA)** – This mechanism is suitable for an individual consumer with substantial energy demand or a consortium of customers whose energy demand comprises a substantial value when aggregated. There is a huge opportunity to combine all the energy consumers of the SAP in to one consortium and enter into a SAP level PPA with Snowy Hydro (or any other renewable energy generator or supplier), however there are some challenges which make management of the SAP the Snowy Mountains SAP level consortium complex and difficult, typically, where the large number of members are small consumers. If the Snowy Mountains SAP level consortium will take place than it would be the first of its kind in Australia by the date of this report. Some similar precedent exists for similar arrangements are discussed below.

ii) **Individual green-power retail contracts** – This mechanism would be suitable for individual residential or commercial consumers or consumers which do not want to (or cannot) be a member of a larger consortium for a PPA. In this mechanism, individual consumers can purchase accredited green power from their retailers to offset their carbon emissions.

5.2.6.1 POWER PURCHASE AGREEMENT WITH SNOWY HYDRO

There are multiple successful precedents available in Australia where different businesses formed a consortium and signed a renewable energy PPA. Some of the key examples are:

- the consortium of Telstra, Coca-Cola Amatil, Melbourne University and Monash University entered into a PPA with Murra Warra I Wind Farm, Victoria securing a record low energy price [77]
- the consortium led by the City of Melbourne on behalf of 14 organisations secured a PPA with Pacific Hydro to get the energy from their 80 MW Crowlands Wind Farm, Victoria [77]
- a consortium of Victorian Water Authorities collaborated to purchase renewable energy supplies from the Kiamal Solar Farm for the Victorian water infrastructure plants. [78]

As WSP has stated in Section 3.5.2.3 of this report, there is potential for a consortium of Thredbo Alpine Village, Perisher Ski Resort and Charlotte Pass Snowy Resort to organise a PPA with Snowy Hydro (or any other renewable energy generator). Perisher Ski Resort is already committed to purchasing 100% renewable energy to achieve zero net emissions by 2030 [79].

Table 5.30 below shows indicative estimation of the annual electrical energy consumption for the key areas of Snowy Mountains SAP.

Table 5.30 Indicative estimation of annual electrical energy consumption of Snowy Mountains SAP

AREA	EXISTING/HISTORICAL (GWH)	ADDITION WITH PROJECT GROWTH (GWH) [17]	TOTAL AT FULLY DEVELOPED SAP – YEAR 2061 (GWH)
Jindabyne Area	~79 [41]	~377.84	~456.84
Thredbo Alpine Village	~9.7[18] [80]	~65.69	~75.39
Perisher	No data available	~42.31	~42.31
Charlotte Pass Alpine Resort	No data available	~6.27	~6.27
Smiggin Holes Resort, Kosi Tourist Park, Sponars Chalet and Bullocks Flat	No data available	~17.07	~17.07

Based on the indicative estimation of annual energy consumption shown in Table 5.30 above, WSP is of the opinion that the annual energy usage by the entire Snowy Mountains SAP could build a considerable business case for Snowy Hydro (or any other renewable generator) to enter into a PPA.

Snowy Hydro operates nine hydro power stations (including Tumut 3 pumped storage power station and Jindabyne pumping station) and six gas and diesel power station in NSW, Victoria and South Australia with a total generation capacity of 5,500 MW. Snowy Hydro's current business model involves procurement of cheap solar and wind energy, combined with Snowy Hydro's own hydro-electricity, and sell it to customers through long-term energy supply contracts. Snowy Hydro usually enters into energy supply contracts through its subsidiary energy retailer company "Red Energy", for example:

- Macquarie University of Sydney, NSW has recently entered into a seven year energy supply contract with Red Energy to supply ~54 GWh of renewable energy per year for its North Ryde campus in Sydney [81].
- Dexus, a real estate investment trust company has entered into a seven year energy supply contract with Red Energy to supply renewable energy for their 40 buildings in NSW [82].
- Royal Automobile Club of Victoria (RACV) has entered into a five year energy supply contract with Red Energy to supply 21 GWh of renewable energy per year for all its Victorian clubs, resorts and office buildings [83].

Similarly, Snowy Hydro (and its subsidiary Red Energy) has entered into many long-term renewable energy PPAs to commercial and industrial customers. A discussion to explore this opportunity for Snowy Mountains SAP was undertaken between Snowy Hydro representative, DPIE, RGDC and WSP on 16 December 2020. Key points of discussion were as below:

- Snowy Hydro would be interested in such a precinct level PPA and is able to cater the energy demand of the Snowy Mountains SAP with renewable energy.
- Snowy Hydro personnel indicated that a "*load following PPA*[19]" would be more suitable and are willing to take the discussion forward.

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17 Calculated based on estimated built area (m^2) at fully grown SAP and energy intensity ($kWh/m^2/year$)

18 Data provided by DPIE

19 A hedging product that follows the usage of the electricity consumer [124]

— There are some inherent risks and challenges in the precinct level PPA, such as:

  a uncertainty regarding the uptake of the PPA subscription by the customers of the precinct, which presents a risk to the retailer

  b the businesses of the precinct may not be willing to commit to the typical term of a PPA, hence, a flexible mechanism for the contract term may be required. However, Snowy Hydro have indicated that they are open to consider the PPA arrangement from a holistic perspective, with some flexibility around the contract terms (e.g. a contract term of 5 years).

— Red Energy would be responsible for negotiating the agreements with the customers or consortium.

WSP understands that this will be an on-going discussion between DPIE, RGDC and Snowy Hydro in the next phase of the Project.

5.2.6.2 RETAIL ELECTRICITY CONTRACT

There are many energy retailer companies in Australia which provide the options to their customers to choose the source of their electricity from renewable energy generators or carbon neutral electricity. Table 5.31 shows some of the energy retailer companies of New South Wales which provide the options to source a fixed portion of their electricity usage from renewable sources or be carbon neutral electricity to their customers [84].

Table 5.31 Renewable energy retailer companies – New South Wales

#	ENERGY RETAILER COMPANY	OPTIONS IN % OF ELECTRICITY USAGE TO CHOOSE TO SOURCE FROM RENEWABLE ENERGY GENERATORS OR CARBON NEUTRAL	ADDITIONAL COST FOR THE RENEWABLE ELECTRICITY/CARBON NEUTRALITY	REFERENCE
1	ActewAGL	10, 25,50,100 and 200	5.5 c/kWh	[85]
2	AGL	10, 20, 100	$1/Week for residential customers $4/Week for business customers	[86] [87]
3	CovaU Energy	25, 100	1.5 c/kWh for 25% 5.0 c/kWh for 100%	[88]
4	Diamond Energy	20, 50, 100	Information not available	–
5	Discover Energy	10, 20, 100	4.95 c/kWh	[89]
6	Energy Locals	10, 20, 50, 100	None	[90]
7	Energy Australia	10, 25, 100	None	[91]
8	Enova Energy	50, 100	3.9 c/kWh	[92]
9	Origin	25, 50, 100	65c/Week for 25% 1.40 c/kWh for 50% 2.80c/kWh for 100%	[93]
10	Powershop Australia	100	None	[94]
11	Red Energy	100	5.83 c/kWh	[95]

Table 5.31 above shows that, there are a few energy retailer companies which provide carbon neutral electricity to their customers at no extra cost whereas some of the energy retailer companies charge additional cost for the carbon neutral electricity to their customers, hence, some form of financial support would be desirable to encourage the adoption of renewable or carbon neutral electricity due to the additional cost.

5.2.7 INDICATIVE COST OF SHORT-LISTED OPPORTUNITIES

Table 5.32 below represents a high-level indicative cost for the shortlisted opportunities.

Table 5.32 Indicative cost for the shortlisted opportunities

TECHNOLOGY	SCALE		
Solar			
	Large-scale Solar PV Farms	Car Parks	Roof-top
Indicative Capex ($/Wp)	1.25–1.55	1.20–1.60	0.88–1.40[1]
BESS			
	Per MW of AC capacity	Per MWh of battery	–
Indicative Capex (million $)	0.35–0.40	0.35–0.40	–
Geothermal			
Building Type	Single Storey Residential	Double Storey Residential	Commercial
Indicative Capital Cost	21,640–87,810	43,280–179,780	576,382–1,258,470
Hydrogen			
Plant Size	Small (Input-1.5MW)	Medium (Input-5 MW)	Large (Input-10 MW)
Indicative Capital Cost (million $)	5.5–6.0	18.2–18.5	36.6–37.0

Notes:

(1) Price range includes both the up-front incentive available for small-scale systems through the Renewable Energy Target (STCs) and GST – they represent the total out-of-pocket cost of the system to the customer.

The price ranges indicated in this table are based on the current market price ranges available publicly and from WSP's in-house data. Emerging technologies, such as BESS and Hydrogen, are expected to have a trend of declining price ranges along with their technological advancements.

5.2.8 INDICATIVE ELECTRICAL ENERGY OFF-SET WITH SOLAR PV

WSP has modelled simulations using the industry standard modelling software (PVsyst 7.0) to calculate indicative energy generation from each of the three types of solar PV opportunities identified in Section 5.2.1 and Section 5.2.2. Total indicative energy yield by each of the three types of solar PV opportunities in the Snowy Mountains SAP is presented in Table 5.33 below (refer Appendix C for the modelling assumptions).

Table 5.33 Indicative energy generation from identified solar PV opportunities

OPPORTUNITY	CAPACITY OPPORTUNITY WITH EXISTING DEVELOPMENT (MWP)	INDICATIVE ENERGY GENERATION (GWH/YEAR)	TOTAL CAPACITY AT THE COMPLETION OF SAP DEVELOPMENT (MWP)	INDICATIVE ENERGY GENERATION (GWH/YEAR)
Large Scale Solar	--	--	43.29[20]	79.22[21]
Car Park-Solar PV	11.30	18.08[22]	11.30	18.08
Distributed Generation – Solar PV	31.64	45.15[23]	66.44	94.80
Total	42.94	63.23	121.03	192.10

WSP highlights that the indicative generation shown in Table 5.33 above is based on Year 1 energy yield estimation only. Currently, solar PV modules have typical degradation rate of ~2% after Year 1 and ~0.45% from Year 2 onwards until the end of the product design life. Table 5.34 below shows the percentage of the electrical energy consumption of the Snowy Mountains SAP that can be offset by solar PV generated electrical energy:

Table 5.34 Electrical energy off-set by solar PV generation

	ESTIMATED INDICATIVE ELECTRICAL ENERGY CONSUMPTION (GWH/YEAR)	INDICATIVE ENERGY GENERATION (GWH/YEAR)	% OFFSET BY SOLAR PV GENERATED ELECTRICAL ENERGY
Snowy Mountains SAP (Total with existing development)[24]	88.70	63.23	71.28%
Snowy Mountains SAP (Total at fully developed SAP-Year 2061)	597.88	192.10	32.13%

[20] (10 MWac+27 MWac) 37 MWac*1.17=43.29 MWp, where 1.17 is the DC loading assumed for the modelling.
[21] Energy yield of 1830 kWh/kWp
[22] Energy yield of 1600 kWh/kWp
[23] Energy yield of 1427 kWh/kWp
[24] Only considered Jindabyne area and Thredbo Alpine village area (due to unavailability of the data)

5.3 RENEWABLE ENERGY DEVELOPMENT AND GRID

Based on the desktop assessment carried out by WSP, there is no overloading of the existing transmission infrastructure within the Snowy Mountains SAP region. The majority of the existing substations operate as load centres supplying electricity to customers such as aged care homes, schools, residential and commercial customers, including tourists. The renewable generation discussed in Section 5.2.1 will help the network to supply these loads locally and hence reduces the stress on the existing transmission infrastructure. Hence, it appears that no further capacity addition at the transmission system infrastructure is needed for the integration of renewable energy within the Snowy Mountains SAP area or to meet additional generation.

The ability of the power system to temporarily provide large amount of energy to manage disturbances while maintaining voltage control is called System Strength. TransGrid's 2019 Transmission Annual Planning Report [96] and system strength report by AEMO [97] do not mention any system strength requirement in the substations near the Snowy Mountains SAP area. The data regarding the system strength is available up to 2038–2039 in AEMO's map [98] and no short fall in the system strength or a short fall in fault levels are identified. Based on these reports, the system is inferred to be strong for connection of renewables in this area. Also, the Guthega Power Station and Jindabyne Pumping Station which are synchronous generation in nature, will contribute to the fault current and boost the system strength.

As per the Transmission Annual Planning Report by TransGrid [96] the Murray-Guthega Tee (connection line) Geehi 132 kV line traverses Schlink Pass in Kosciuszko National Park at an altitude of 1800 m. The line is subjected to many transient faults in winter due to ice loading and in summer due to lightning strikes. Auto-reclose was commissioned in April 2019 to improve reliability. In addition to this, there are various refurbishment programs planned in the coming years such as refurbishment of rusted steel towers and replacement of conductor fittings, earth wires and insulators at risk of failure, replacement of wood pole structures etc. These will increase the reliability and system security of the transmission system in the Snowy Mountains SAP area.

Based on the desktop assessment, WSP does not see any requirement for additional substation or line upgrades at the transmission system level to incorporate the identified renewable energy options.

One of the issues with the increased PV penetration at the customer level is that it can cause a range of issues on existing distribution networks. In particular, the very end of the distribution network where most residential, aged care homes and small commercial customers are connected, the LV network, is where most problems are expected to occur. The most immediate issue is voltage rise. High PV injection behind the meter to LV networks during low customer demand (middle of the day) can increase voltage on the LV networks above the stipulated +10% as required by most of the distribution codes. This sometimes results in reduced power quality. In order to mitigate this, a detailed assessment is required before connecting the solar PV to the distribution network. Some of the below mentioned network augmentation or a combination of these may be required to mitigate these problems:

- **Transformer upgrade/reconductoring**: This includes replacing a distribution transformer to include an off-load tap changer with additional manual buck taps, increasing the distribution transformer rating and/or increasing the quality of the LV conductor. An off-load tap changer adjusts the voltage ratio between the HV network and the LV network.
- **On-load tap changer (OLTC):** An OLTC automatically adjusts the output voltage at the distribution substation (DSS) in real-time, based on load characteristics on the LV network. In this study, the distribution transformer was replaced with a transformer fitted with an OLTC.
- **Low voltage regulator (LVR):** LVR(s) use a controllable transformer to increase or decrease the voltage on LV networks.

Implementing EV charging by solar PV as discussed in Section 5.2.2.1 above will help to mitigate the voltage rise to a certain level but it is recommended to carry out a detailed assessment before doing any of the above network augmentations.

6 SUSTAINABILITY

The Snowy Mountains SAP's aspiration for Sustainability and Wellness is explained as follows: "*As a region, the Snowy Mountains will be a national leader in environmental resilience and sustainability, with investment in renewable energies, green infrastructure and carbon sequestration, aspiration for a carbon-negative future, opportunities to connect with nature, and continued protection of the vulnerable alpine environment of Kosciuszko National Park*".

The identified renewable energy opportunities in Section 2.2 of this report will strongly support the sustainability aspiration of the Snowy Mountains SAP. Considering the constraints identified in the Context Analysis Report, WSP has shortlisted the most feasible opportunities which can provide renewable energy to the Snowy Mountains SAP to not only offset its carbon emissions from energy consumption within the precinct but generate a net positive climate outcome. The identified renewable energy opportunities would substantially address the requirements of a sustainably developed precinct. In parallel with these renewable energy initiatives we would seek to ensure these initiatives achieve a triple bottom line outcome for not only renewable energy but for best practice environmental impact assessment and economic objectives including local jobs creation.

WSP has already mentioned in the Context Analysis Report and Section 2.2 of this report the impacts of the identified renewable energy opportunities on various aspects of sustainable development. However, Table 6.1 represents a high-level summary of the impacts of each identified renewable opportunity in regard to the three basic pillars of sustainability; namely economic, environmental and social sustainability.

Table 6.1 Identified renewable energy opportunities and sustainability

IDENTIFIED OPPORTUNITY	ECONOMIC	ENVIRONMENTAL	SOCIAL
Ground Mounted Solar PV	**Positive:** — Low Levelised Cost of Electricity (LCOE) — Supports circular economy — Investment attraction opportunities. **Issue/Constraints:** — Medium capital cost if battery storage is incorporated — Low direct job creation during operations.	**Positive:** — Climate Positive/Carbon offset — No air pollution — No water pollution — No greenhouse gas emissions. **Issues/Constraints:** — Land requirement — Potential impact on flora and fauna of the Snowy Mountains SAP — Consider whole of life cycle of PV modules specifically during the manufacture and at the end of design life, and embodied energy — Land management below the array — Issues of environmental impact of materials used in manufacture.	**Positive:** — Jobs creation during construction — Improves affordability of electricity — Up-skilling/training. **Issue/Constraints:** — Visual impact — Potential occupancy of public spaces or greenfield spaces.

IDENTIFIED OPPORTUNITY	ECONOMIC	ENVIRONMENTAL	SOCIAL
Solar Car Park	**Positive:** — Low/moderate Levelised Cost of Electricity (LCOE) — Supports circular economy including electric vehicles — Investment attraction opportunities. **Issue/Constraints:** — Medium capital cost if battery storage is incorporated — Low direct job creation during operation.	**Positive:** — Climate Positive/Carbon offset — No new greenfield land requirement — No impact on flora and fauna of the Snowy Mountains SAP — No air pollution — No water pollution — No greenhouse gas emissions — Reduced heat island effect. **Issues/Constraints:** — Whole of life considerations of PV modules specifically during manufacturing and at the end of design life.	**Positive:** — Jobs creation during construction — Improves affordability of electricity — Up-skilling/training — Improves resort/car park functionality, improving weather protection. **Issue/Constraints:** — Potential visual impact.
Rooftop Solar PV	**Positive:** — Low Levelised Cost of Electricity (LCOE) — Lower capital cost — Supports circular economy if linked via virtual power plant system. **Issue/Constraints:** — Medium capital cost if battery storage is incorporated.	**Positive:** — Climate Positive/Carbon offset — No land requirement — No air pollution — No water pollution — No greenhouse gas emissions. **Issues/Constraints:** — Whole of life considerations of PV modules specifically during manufacturing and at the end of design life.	**Positive:** — Indirect jobs creation — Improves affordability of electricity — Potential for revenue generation for locals. **Issue/Constraints:** — Potential visual impact.

IDENTIFIED OPPORTUNITY	ECONOMIC	ENVIRONMENTAL	SOCIAL
Geothermal Heat Pump	**Positive:** — Potential to reduce overall electricity requirement for premises or precinct — Minimal maintenance costs. **Issue/Constraints:** — Medium capital cost depending on system utilised e.g. higher cost for vertical loop system.	**Positive:** — Potential climate positive outcome — Low relative land requirement — No direct air pollution — No direct water pollution — No direct greenhouse gas emissions. **Issues/Constraints:** — Potential environmental impacts from refrigerant system leakage — Requirement for drilling in a potentially high strength rock and some land disturbance.	**Positive:** — Potential for better living conditions i.e. warming/ cooling — Indirect jobs creation — Minimal visual impact. **Issue/Constraints:** — Potential noise during operation — Some infrastructure/space required within premises building.
Hydrogen	**Positive:** — Supports circular economy including fuel cell vehicles — Supports energy storage — Funding available through ARENA to develop this technology. **Issues/Constraints:** — No commercialised industry developed in Australia yet — Requires input of water and electricity, i.e. operational costs — Currently high capital costs — Uses for hydrogen currently unproven/ undeveloped.	**Positive:** — Replacement for petrol/ diesel for vehicles — Replacement for heating and gas consumption — Use in agriculture (for fertiliser production) — "Green" energy storage system — No direct air pollution — No direct water pollution — No direct greenhouse gas emissions — Small physical footprint. **Issues/Constraints:** — Requires supply of potable water (seawater under development) — Adds a competing use for water.	**Positive:** — Job creation — Develops Australia's hydrogen industry. **Issues/Constraints:** — Hazardous storage risk — Potential for community opposition — Potentially opens competition from "clean coal" technology or natural gas reformation.

IDENTIFIED OPPORTUNITY	ECONOMIC	ENVIRONMENTAL	SOCIAL
Renewable Energy PPA	**Positive:** — No capital cost — No additional infrastructure required — Supports circular economy. **Issue/Constraints:** — Electricity providers typically charge a premium for “green” energy.	**Positive:** — Climate Positive/Carbon offset — No land requirement — No air pollution — No water pollution — No greenhouse gas emissions. **Issue/Constraints:** — More beneficial if the supply is from new renewable energy projects above the RET.	**Positive:** — Indirect jobs creation.

Overall, it can be assessed from Table 6.1 above that the impacts of all identified renewable energy opportunities for the Snowy Mountains SAP will mainly have positive impacts on the economic, environmental and social pillars of sustainable development.

6.1 POTENTIAL OFFSITE IMPACTS

WSP has identified key offsite impacts from the delivery of the identified renewable energy opportunities. Table 6.2 below represents the offsite impacts from the identified renewable energy opportunities.

Table 6.2 Offsite impacts of the identified renewable energy opportunities

IDENTIFIED OPPORTUNITY	POSITIVE	NEGATIVE	TO BE ASSESSED
Solar PV	— Greenhouse gas emission reduction	— Potential visual impact (due to glare)	— PV module recycling at end of design life
Geothermal Heat Pump	— Greenhouse gas emission reduction	— Land disturbance from drilling — Noise management	— Potential groundwater disturbance depending on borehole depth
Hydrogen	— Greenhouse gas emission reduction	— Consumption of water — Cost of production	— Visual impact (aesthetic)
Renewable Energy PPA	— Greenhouse gas emission reduction	— Potential negative ecological footprint (location specific to where the energy is being generated)	— Carbon footprint analysis for the selected renewable energy generator

7 CHANGING ATTITUDES AND THE ENERGY LANDSCAPE

7.1 CHANGING ATTITUDES

Energy markets are becoming increasingly complex, with competing and interdependent factors driving strategic planning and investment decisions. At a macro level, the National Electricity Market, which services the eastern and southern states and ACT, has traditionally been heavily dominated by coal-fired electricity generation. Coal has, historically, been a cheap and reliable energy source available to Australia. There is increasing scrutiny, however, on the energy (and in particular the electricity) sector's contribution to climate change. Being heavily dependent on coal as a primary energy source has resulted in Australia's energy sector being carbon intensive, and policy makers are under increasing pressure to mitigate the impacts of climate change by diversifying the energy mix.

In NSW, in 2018/19, approximately 81% of electricity generated was from burning coal. This is set to change dramatically in the medium term as ageing coal-fired plants are susceptible to outages and reliability concerns, and they can be increasingly expensive to operate. Four of the state's five remaining coal-fired power stations are expected to reach the end of their operational lives by 2035, by which time only around 25% of the current coal-based electricity generation will remain [99].

Conversely, the proportion of electricity derived from renewable energy sources has been increasing year on year. In 2019, renewable energy generation accounted for 24% of Australia's total electricity generation (compared to 21.3% in 2018.) In NSW 17.1% of electricity was generated from renewable energy sources (compared to 15% in 2018.) [100] The increased uptake of renewable energy generation (as shown below in Figure 7.1) has been supported by various policies and strategies as discussed in section 7.2. There is also increased civil pressure on state and federal governmental agencies to be significantly more ambitious in its renewable energy targets, in order to meet and exceed climate mitigation commitments.

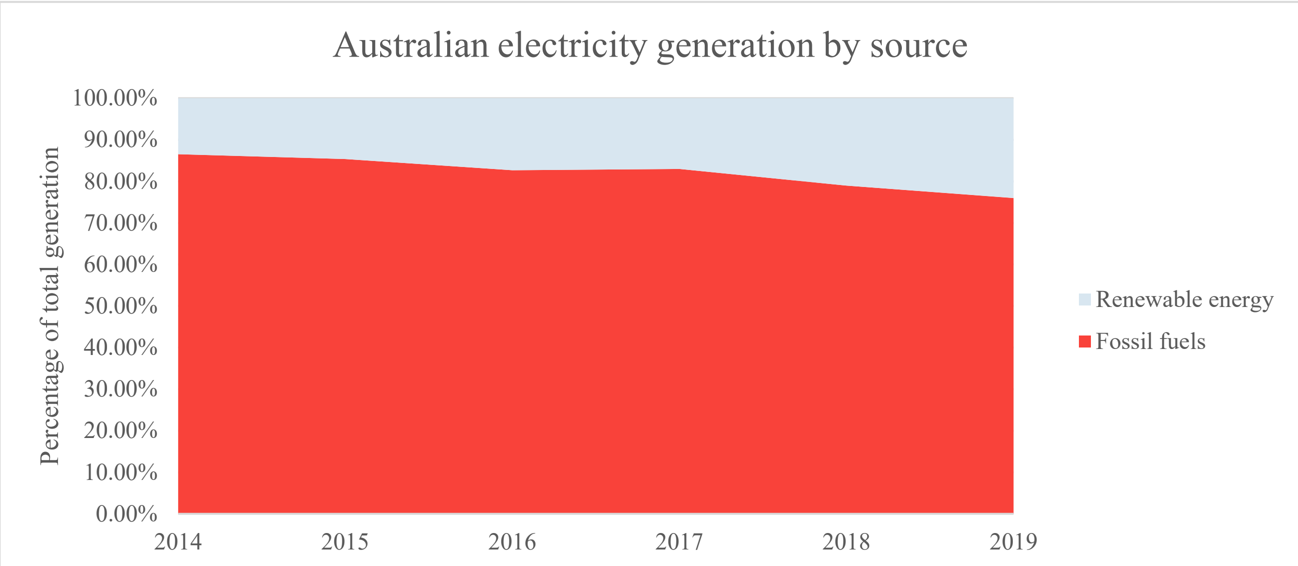

Figure 7.1 Recent shift in national electricity generation from fossil fuels to renewable energy sources

Utility scale solar and wind farms are getting bigger, with some individual projects of over 1 GW under development and renewable energy construction costs have been dropping year-on-year. This is related to increased competitiveness in the production of equipment and improvements in equipment performance, but also to the sheer economies of scale seen on these large projects. Renewable energy facilities are becoming increasingly competitive with traditional thermal electricity generation options, as shown below in Figure 7.2 This does not include potential costs associated with transmission infrastructure upgrades that may be required, which can be prohibitive, depending on the strength of the local grid into which the project is connecting.

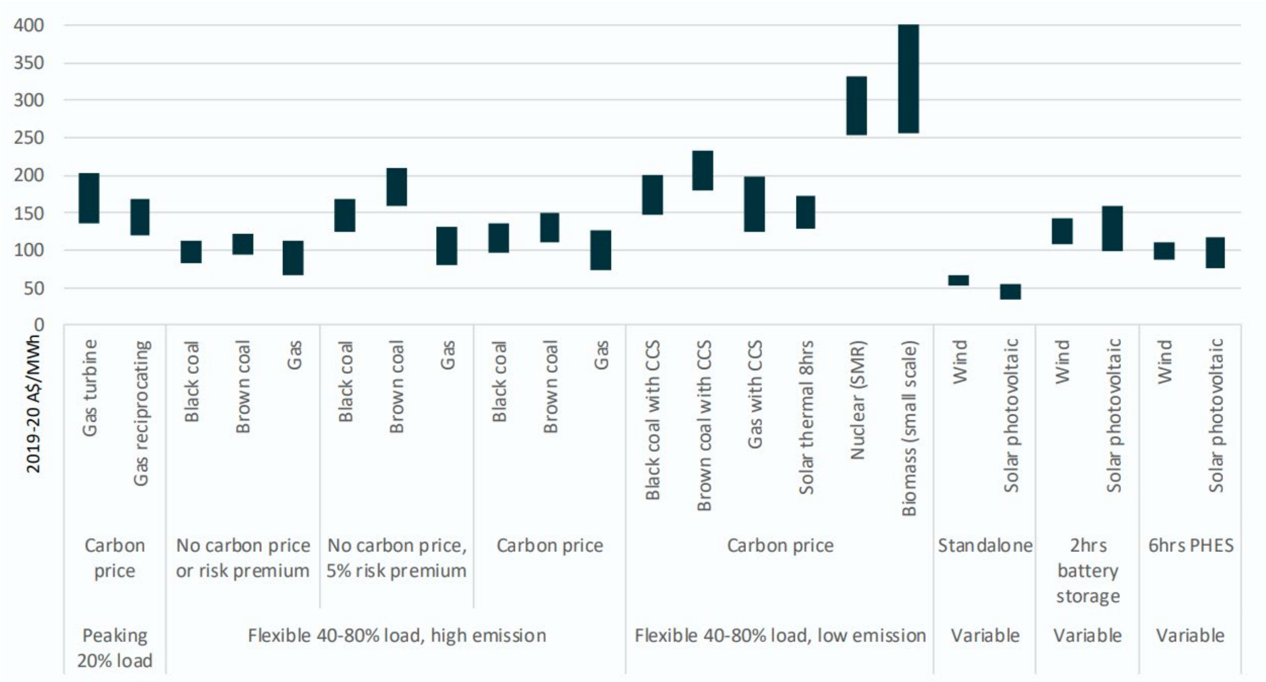

Figure 7.2 Levelised cost of electricity by technology and category for 2019/20 (AUD/MWh) [101]

However, there has been a general trend of increasing wholesale electricity prices in Australia, and households and businesses have been facing increasing pressure from rising tariffs. The average spot price of wholesale electricity has increased from an average of \$36/MWh in 2014/15 to \$92/MWh in 2018/19 [99].

Many businesses and households have been responding to these increasing tariffs by opting to install small-scale embedded generation systems on their buildings or homes. There was an estimated 2.2 GW of rooftop solar installed across Australia in 2019 and small-scale solar contributed 5.3% of the total electricity generated for the year. NSW had the highest number of installations (nearly 80,000) and nearly 2½ million solar PV systems have been installed across Australia since 2010. Small-scale battery system installations are also increasing, with 22,000 systems installed in 2019, resulting in a total storage capacity of over 1 GWh. [100]

The electricity market is therefore undergoing an enormous transformation. What was once a fairly straightforward centralised system, based on traditional fossil fuel thermal generation is shifting to a decentralised, distributed system with multiple project and system owners. Consumers are increasingly focused on the reliability of their electricity supply and the associated environmental impact, while remaining sensitive to the overall price. More end users are now also looking for increased autonomy and agency, and are interested in investing directly in small-scale solar and battery storage systems.

7.2 ENERGY LANDSCAPE

A successful energy market addresses three main considerations: security of supply, sustainability and affordability. This has framed much of the discussion and debate on energy policy in Australia and considerable work is being done in providing direction and clarity in the energy sector. As a relatively new entrant to the energy market, Distributed Energy Resources (DER) are playing an increasingly important role.

The various regulatory and industry agencies tasked with energy planning and strategy are in the process of developing and refining their approach to facilitating the uptake of DERs without compromising the security of the electricity network. As such, the plans, frameworks and programmes presented below are largely in their infancy. It is, however, recommended that these plans and programmes are monitored, to identify any potential impacts and apply any industry recommended learnings to this Project.

It is envisaged that the model to be adopted for this Project is that Snowy Mountains SAP will provide support for infrastructure planning to attract private investment in distributed energy systems. Such planning and support will need to be underpinned by a solid understanding of the regulatory and technical requirements being developed by the respective agencies, and how best to align with their current and forecasted priorities.

7.2.1 DISTRIBUTED ENERGY RESOURCES – REGULATORY ENVIRONMENT

INTEGRATED SYSTEM PLAN AND RENEWABLE INTEGRATION STUDY

The Australian Energy Market Operator (AEMO) issued their Draft Integrated System Plan (ISP) in December 2019. In this, they outline what they refer to as the least-regret energy system where "*the least-cost and-regret transition of* the NEM *is from a centralised coal-fired generation system to a highly diverse portfolio dominated by DER (Distributed Energy Resource) and VRE (utility-scale Variable Renewable Energy), supported by dispatchable resources and enhanced grid and service capabilities to ensure the power system can reliably meet demand at all times*." Under the ISP modelling work, AEMO is projecting that Distributed Energy Resources could provide 13%–22% of the total underlying energy consumption by 2040. [102]

As the NEM generation mix becomes increasingly decentralised, AEMO is focusing more on the regulatory framework surrounding distributed energy systems. DERs may not currently be subject to the same performance requirements as their utility-scale counterparts, where the limitation of the network to handle intermittent generation has resulted in difficulties and delays in projects receiving approval to connect to the grid. Security of supply may also require more firm generation or synchronous condensers, which have been mandated for some recent large-scale renewable projects.

In their Renewable Integration Study published in April 2020, AEMO proposes to submit a rule change to establish the minimum technical standards for DERs in the NEM, together with the Energy Security Board, the Australian Energy Regulator and the Australian Energy Market Commission, focusing on "*power system security, communication, interoperability and cyber security requirements*." [103]

The outcomes of such regulatory changes may impact the technical requirements to be met by the distributed energy opportunities pursued under this Project.

OPEN NETWORKS – HYBRID FRAMEWORK FOR DER MARKET ACCESS

Energy Networks Australia and AEMO have initiated a joint project called Open Energy Networks (OpEN) to address challenges and benefit from opportunities associated with Distributed Energy Resources in Australia. OpEN has focused on investigating potential frameworks that "*facilitate market access for all stakeholders, including DER owners, aggregators, third parties, network operators and retailers, while ensuring uncompromised system integrity and security*." [104]

Under the Hybrid Framework developed by OpEN, DERs would be able to access and bid on AEMO's distribution services market platform (comprising wholesale and ancillary services markets), via an aggregator and/or energy retailer, while operating within the technical requirements of the Distribution System Operator.

DERs set up as part of this Project, seeking to benefit from access to AEMO's market platform would be expected to comply with any framework developed as part of this work.

DISTRIBUTED ENERGY INTEGRATION PROGRAMME FRAMEWORK

The Australian Renewable Energy Agency (ARENA) has established a Distributed Energy Integration Program (DEIP), which is a collaboration of government agencies, market authorities and industry and consumer associations, with a focus on DERs. One of the work packages of a consumer representative working group is the development of the New Energy Compact. This Compact, which is expected to be further refined by the DEIP, seeks to guide energy reform, regulation, policies and measures. The draft guiding principles developed by the DEIP in November 2019, and set out in the New Energy Compact are shown below in Table 7.1 [105]. This provides a useful framework against which the objectives of the Project can be assessed, to ensure that the Project aligns with overarching DER planning currently under development in Australia.

In addition to the Principles presented below, it is also important that DERs take into consideration the local environment and community. Appropriate planning will help to minimise any negative impact on the local ecology, waterways, forests etc. DER plans should also align with community expectations and requirements, with due consideration given to potential visual, noise and heritage impacts.

Table 7.1 New Energy Compact – Draft guiding principles for enabling DER access and pricing and potential challenges associated with this Project

GUIDING PRINCIPLES	FEATURES AND JUSTIFICATION	RISKS AND CHALLENGES SPECIFIC TO THIS PROJECT
Meet the needs of energy users	Distributed Energy Resources should: — Benefit energy users — Support access to Distributed Energy Resources — Deliver DER services that energy users want at a price they are willing to pay — Enable investment in a wide range of energy service models to meet the diverse and changing needs of people, businesses and communities.	— Infrastructure planning and policies need to accommodate multiple energy users with competing priorities and energy preferences, and it may not be possible to meet the needs of all users at the desired price point. — Changing energy needs and profiles over time may result in different DER requirements. The system should therefore allow for flexibility to accommodate changing requirements.
Create greater fairness and equity	Distributed Energy Resources should: — Result in fair distribution of costs and benefits — Pay to use the system and are rewarded for the benefits to the system — Result in equitable access to shared network resources — Result in risks sitting with those best placed to manage them — Aim to reduce inequality between cohorts — Not leave future energy users with unreasonable costs — Ensure energy is affordable in all locations — Make the costs and benefits of DER services clear, so that policy makers and end users can respond appropriately.	— A fully inclusive, equitable, transparent and cost reflective DER arrangement may be complex and expensive to establish. — There are multiple stakeholders involved with competing priorities, and agreement on a suitable framework is expected to be a complicated process. — It may take time for the regulatory frameworks (e.g. OpEN Hybrid Framework) currently under development to be finalised. In the interim, there may be a lack of clarity on technical, regulatory and commercial arrangements associated with establishing and connecting DERs.

GUIDING PRINCIPLES	FEATURES AND JUSTIFICATION	RISKS AND CHALLENGES SPECIFIC TO THIS PROJECT
Be future focused and responsive	Distributed Energy Resources should be: — Flexible and responsive to support the innovation and growth in DER products and services — Clear and transparent.	— Driven by changes in climate, extreme weather events such as cycles, strong storms, intense rainfall, heatwaves, droughts and catastrophic bushfires are becoming more frequent and severe. — Infrastructure planning and energy demand forecasting should consider trends in climate, society, technology, and resources to ensure that the strategies adopted are resilient to a changing future.
Drive efficiency and reduce waste	Distributed Energy Resources should: — Lead to efficient network investment in short, medium and long-term — Incentivise uptake of DER products and services where it helps reduce costs to the energy system — Supports and complements the uptake of energy efficiency and demand management.	— DER strategies need to work hand-in-hand with overall energy efficiency and demand management interventions. — Emerging industries (such as electric vehicles) should be considered, as they may drastically change the local energy profile.
Contribute to reliability, security and resilience	Distributed Energy Resources should: — Support the secure operation of the grid with regard to frequency, voltage, and thermal constraints. — Support system reliability with regard to generation sufficiency and network outages. — Incentivise DER products and services where it helps to improve the resilience of homes and businesses in response to severe weather events and cyber-attacks.	— As DERs become an increasing focus of regulatory agencies, there may be more scrutiny on their compliance with network service providers' requirements. This may result in increase in connection costs and the time required to connect. — DERs plans should therefore take into consideration the changing regulatory environment.
Support the transition to zero emissions	Distributed Energy Resources should: — Support integration of more renewable and zero emissions energy — Incentivise DER products and services to accelerate the transition to zero emissions.	— Zero emission targets may be impacted by any reliance on grid-supplied electricity, which is unlikely to be net-zero in the short-medium term (see section 7.2.2 below).

7.2.2 OTHER SUPPORTING PLANS/STRATEGIES/TARGETS

In addition to the DER regulatory work discussed under section 7.2.1, there are also broader plans and targets in place relating to the decarbonisation of the energy sector, and a focus on improving the effectiveness of the electricity sector in general.

NSW NET ZERO PLAN

The NSW Government has committed to a goal of net zero emissions by 2050. As part of meeting this target, they released an interim Net Zero Plan for the period 2020 to 2030 in March 2020 [106]. This plan targets 35% emissions reductions in NSW compared to a 2005 baseline.

To achieve this, they have set out four main priorities:

1. "*Drive uptake of proven emissions reduction technologies that grow the economy, create new jobs or reduce the cost of living*
2. *Empower consumers and businesses to make sustainable choices*
3. *Invest in the next wave of emissions reduction innovation to ensure economic prosperity from decarbonisation beyond 2030*
4. *Ensure the NSW Government leads by example*"

NSW ELECTRICITY STRATEGY

The NSW Government has also issued the NSW Electricity Strategy "*to improve the efficiency and competitiveness of the NSW electricity market and encourage investment in new price-reducing generation and energy saving technology*" and "*support a competitive and low-cost energy market, and deliver more resilient electricity supplies*."

The Electricity Strategy includes the following overarching objectives:

- "*Making it easier to invest*
- *Reducing risk for investors*
- *Encourage clean and affordable technologies to take pressure off the grid*
- *Delivering more resilient electricity supplies*
- *Being prepared for an electricity emergency.*"

AUSTRALIAN NATIONAL HYDROGEN STRATEGY

Acknowledging the potential role that Hydrogen may have on the energy landscape, COAG Energy Council Hydrogen Working Group has published Australia's National Hydrogen Strategy in November 2019, which discusses the opportunity for building and demonstrating the local hydrogen sector [107].

Within NSW, the priorities identified within the Strategy include:

- developing the supporting infrastructure and capabilities
- planning approval and infrastructure development
- regulatory oversight
- support for business and R&D.

8 EMERGING INDUSTRIES

8.1 EMERGING INDUSTRIES AND INVESTMENT OPPORTUNITIES

While there are several well-developed and commercially available renewable energy technologies able to be easily deployed within the Snowy Mountains SAP, there are also other emerging technologies which would be complimentary to the renewables strategy. Early support for these emerging technologies will assist to future proof the precinct and which support a long term renewable energy strategy in the Snowy Mountains SAP. These opportunities for investment and support are discussed below.

8.1.1 ELECTRIC VEHICLE CHARGING STATIONS

In total, there are 19 electric vehicle (EV) charging stations in the Snowy Mountains SAP region. Ten of these stations are part of the Tesla network and can only be used by Tesla models. Of the remaining nine charging stations, which are usable by any car model, five are non-networked and four are part of the NRMA network. See Table 8.1 for a summary of the charging stations in the region [108].

Table 8.1 Summary of current EV charging stations in the Snowy Mountains SAP region

AREA	CHARGING NETWORK	STATION TYPE	NO. OF STATIONS	COMMENTS
Jindabyne	NRMA	Fast charge	4	Free for NRMA members. Fee for non-members.
	Telsa	Public/Guests only	5	Two of the stations are public and three are for hotel guests.
	Non-networked	Public	3	Free if hotel guest otherwise it is $0.3/kWh.
Bullocks Flat	Tesla	Public	2	
Thredbo	Tesla	Public/Guests only	2	One station is 7 kW guests only, the other is 22 kW and public.
Perisher	Tesla	Guests only	1	
	Non-networked	Guests only	2	

The NRMA charging stations are the only networked charging stations in the Snowy Mountains SAP region which are publicly available to anyone and usable by any car model. As the market share of EVs grows, there are opportunities to develop more charging stations to attract EV owning tourists. WSP was unable to locate any publicly available planned charging station data. Chargefox Australia operates the largest charging network in Australia and is currently adding four new stations in Cooma nearby. Jindabyne would be the next logical step in expanding their network and would be an extra incentive for tourists.

The expansion of the publicly accessible electric vehicle charging infrastructure in the precinct will be an important step forward in establishing the benchmarks and standards for the approach to sustainability within the precinct. The addition of additional charging stations led by the local governance authority and/or through industry partnerships will be an important measure for the precinct. It is likely that some additional precinct-led electrical vehicle infrastructure would be an important catalyst for expanding the uptake of these facilities across private infrastructure such as commercial, industrial and multiunit residential buildings. In order to overcome the present cost hurdles perceived with electric vehicle infrastructure it may be necessary to both showcase existing installations and to mandate installations within some larger new building developments.

A key part of the strategy to expedite electric vehicle charging infrastructure would be to facilitate planning measures and approvals to enable these types of public infrastructure to be deployed easily and in prominent accessible locations. A small number of Council-operated (as referring to the Snowy Monaro Council) free charging stations could be an important measure, these have been deployed by other councils in metropolitan cities. Ultimately it would be important to enable private operators to setup charging stations and derive income from their use, it is therefore likely better to work with commercial charging station operators rather than establishing too many free charging stations and stifling the business case for further charging infrastructure. Some subsidisation of electric charging station infrastructure may be necessary.

The development of further electric vehicle infrastructure within the precinct could bolster the local market for electric charging sales as well as the local industry selling and servicing electric vehicles.

8.1.2 GEOTHERMAL POTENTIAL

Geothermal resources in New South Wales have been used for tourist attractions and for heating and cooling systems in buildings as referenced in Section 3.6.2.3 of the Context Analysis report however, only a few instances have been developed near or within the Snowy Mountains SAP region.

The Yarrangobilly Caves Thermal pools in the Snowy Mountains region is the closest tourist attraction that utilises geothermal energy. The thermal pools take advantage of rainwater seeping approximately 760 m into the ground, which is heated and propagates back to the surface at a constant 27°C throughout the year, supplying the pools with warm water [109]. The pools are located near the Snowy Mountains SAP but are not included in the area, refer to Figure 8.1.

Buildings within the region and within the Snowy Mountains SAP have taken advantage of the geothermal resource via heat pumps as highlighted in the Context Analysis report. An example is the Snowy Region Visitor Centre, which uses the geothermal resource to heat and cool the building. This technology has been applied in other large commercial buildings in NSW near the Snowy Mountains SAP but not strictly included within the area such as the Riverina Highlands Building, which is fitted with a water to air vertical loop system that has a heating capacity of 175 kW_{th} [110].

Excluding the above mentioned cases and the smaller residential applications mentioned in Section 3.6.2.3 of the Context Analysis Report, WSP is not aware of any other attractions, resorts or buildings that are utilising the geothermal resource.

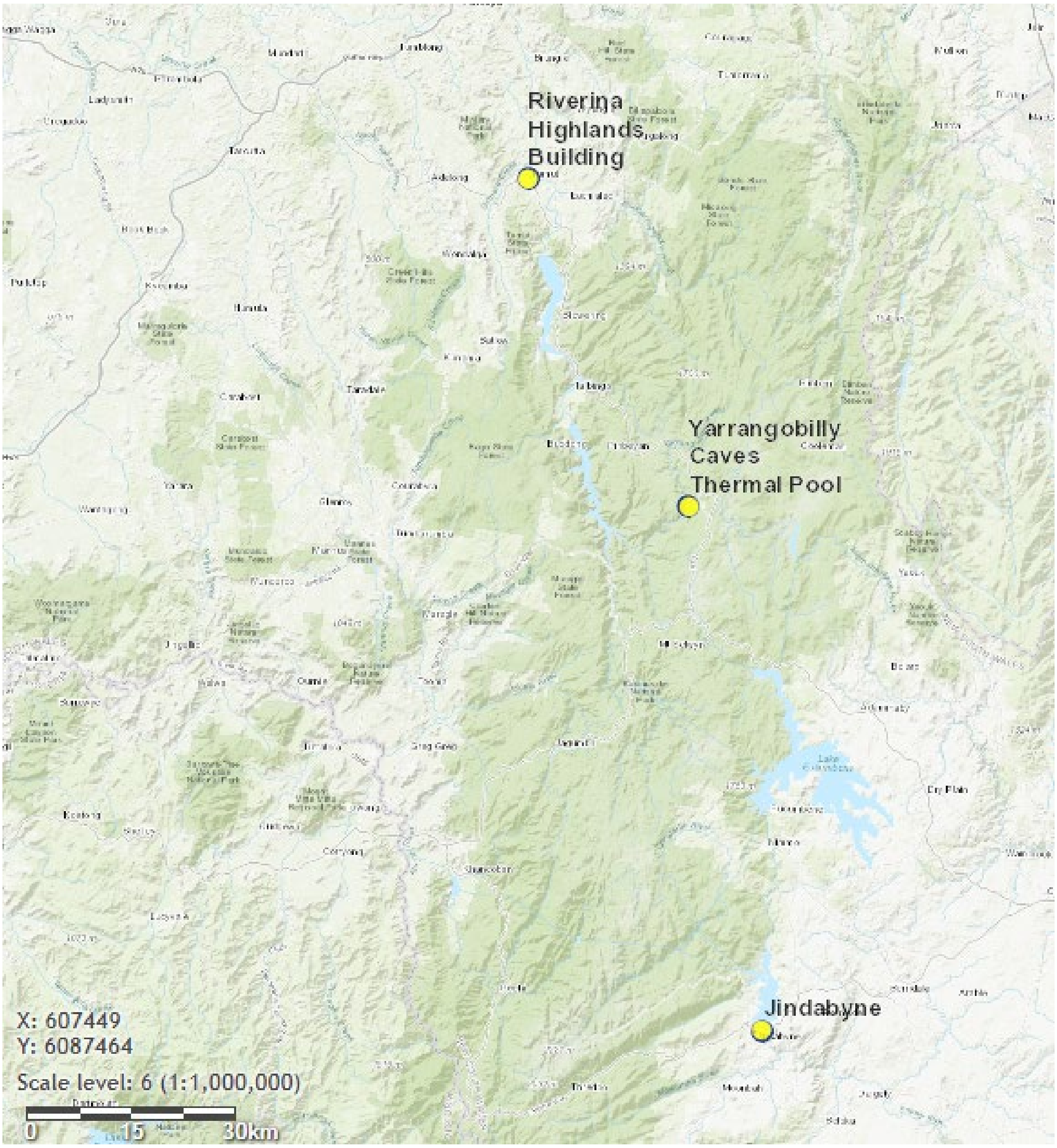

Figure 8.1 Location of Yarrangobilly Caves Thermal Pool and Riverina Highlands Building compared to Jindabyne

8.1.3 COMMUNITY-BASED VIRTUAL POWER PLANT (CVPP)

Opportunities identified in Section 5.2.2, 5.2.4 and 5.2.5 above can be integrated and optimised using emerging technologies such as community-based Virtual Power Plant (cVPP).

The implementation of emerging technologies is key to achieving the optimised internal utilisation of energy generated from renewable energy sources located within the Snowy Mountains SAP boundary, and in ensuring the real-time supply-demand balance of electrical energy. The solar PV systems may generate more power than the average demand load during peak generation hours. The generation from this excess solar PV capacity can either be fed onto the grid network or stored in energy storage systems to use when generation is lower than the average demand load.

Another method used to optimize demand-supply gaps, when there are multiple generators and multiple consumers, is the implementation of a community-based Virtual Power Plant (cVPP) network.

A cVPP is a portfolio of community-owned distributed energy resources aggregated and coordinated by an ICT-based control system, adopted by a (place-based, interest-based, virtual or sectoral) network of people (and/or organisations, who collectively perform a certain role in the energy system. What makes it community-based is not only the involvement of a community, but also the community-logic under which it operates [111].

A community-based Virtual Power Plant (cVPP) for the Snowy Mountains SAP could be a network of distributed solar photovoltaic (PV) generators and energy storage systems working together to generate and store energy, and feed energy into the grid. The installed solar PV and BESS provides electricity to the consumer at its installed location. The energy that is generated by the system but is not being used or stored by the initial consumer will be dispatched to the network either to be stored in a central BESS/Hydrogen production plant or to be used by a consumer who has lower generation capacity than their load (or energy storage capacity) at any moment.

A schematic arrangement of the functionality of cVPP for the Snowy Mountains SAP is shown in Figure 8.2 below:

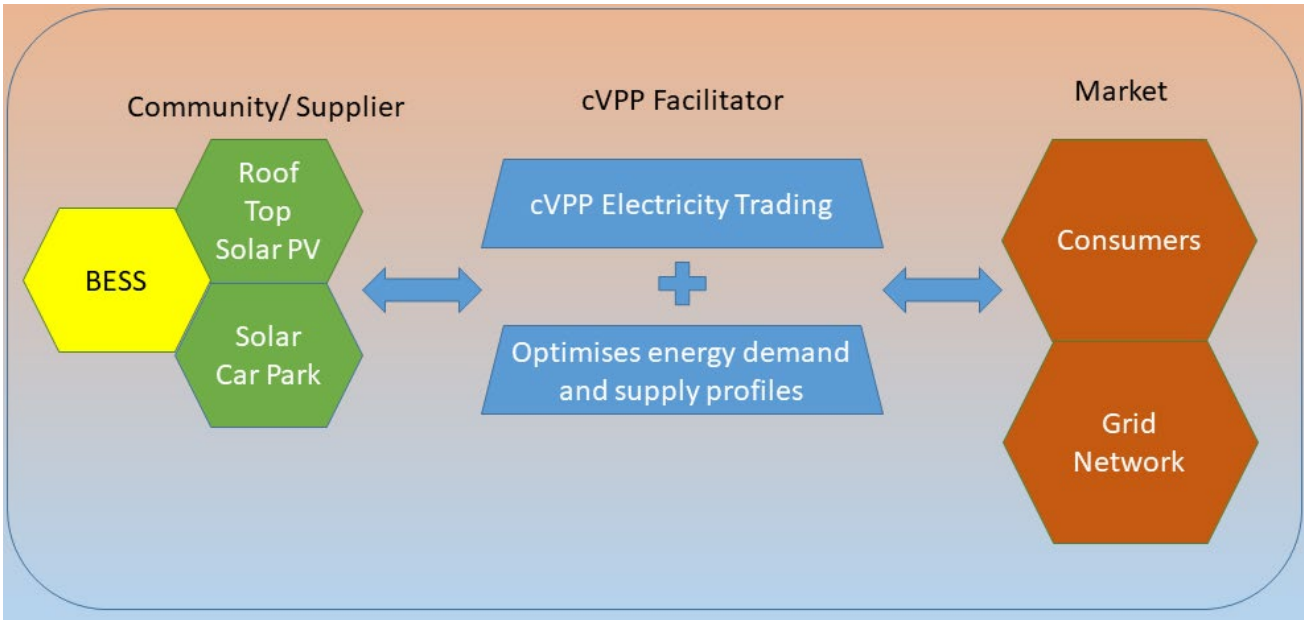

Figure 8.2 Schematic arrangements of functionality cVPP for Snowy Mountains SAP

The intermediate control unit which forwards operational data from the roof top solar PV power plants and receives online instructions from the cVPP Facilitator (cVPP Control Centre) can manage power dispatch in line with real-time market demands.

The cVPP Facilitator (VPP Control Centre) can have direct data connection not only with the control system of the small-scale power plants, but also with multiple market segments, enabling it to ensure a balance between production and consumption at all times. The intermediate control unit would be equipped with a Programmable Logic Controller (PLC) and Uninterruptible Power Supply (UPS) to increase transparency and reliability.

8.1.3.1 POWER TRADING WITHIN CVPP

To maximize the revenue for the generators from excess energy dispatched through the cVPP, various business and energy transaction models can be developed. The following two emerging energy trading models can potentially be implemented for the VPP within the users of the Snowy Mountains SAP in order to achieve i) revenue optimization through energy dispatch per NEM electricity prices for the generators, and ii) maximum utilization of Snowy Mountains SAP generated renewable electrical energy within the Snowy Mountains SAP.

SINGLE AGENT MODEL:

In this model, generators sell their excess energy at a feed-in tariff rate to a single company which provides the energy back to the consumers within the Snowy Mountains SAP with a reasonable fixed operational margin on the feed-in tariff rate.

An example of the single agent model is the Byron Bay micro-grid in the Northern Rivers area of NSW, where the small retail company named Enova Energy has implemented a mini-grid system, and 40% of its energy supply in that area is being generated behind the meter through solar rooftop installations[25].

The residents of Byron Bay sell their excess energy to Enova Energy and earn revenue at Enova Energy's feed-in tariff rate. The purchased energy is then provided to the residents requiring energy within the network.

PEER TO PEER TRANSACTION MODEL

This model provides an opportunity for one party to sell their excess power directly to another party in need of it in real time, with the use of blockchain technology.

Figure 8.3 Peer to Peer energy trading[26]

As an example, a company named Power Ledger has created a trading platform that uses anonymised and historical customer data and blockchain processes to explore how an exchange would work across a regulated network. In Fremantle, Western Australia, under the project named RENew Nexus, the households are using Power Ledger's platform to trade excess energy generated from their rooftop solar panels with their neighbours[27].

The blockchain technology creates a record of energy generation and consumption, allowing consumers to trade energy with their sellers within the cVPP automatically. The process works as clearing mechanism between parties to decide at what price and to whom they want to sell their excess energy.

Overall, through the effective implementation of a cVPP concept, the Snowy Mountains SAP would be expected to be able to achieve the utilisation of 100% of the renewable electrical energy produced from the Snowy Mountains SAP.

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[25] Source: https://www.smh.com.au/business/the-economy/australian-towns-going-off-the-grid-20171219-p4yxvv.html

[26] Image Source: https://100percentrenewables.com.au/peer-to-peer-energy-trading/

[27] Source: https://www.powerledger.io/project/renew-nexus/

9 DELIVERY CONSIDERATIONS

A discussion of the delivery considerations for the identified renewable energy technologies is provided below. In this section, commentary is provided on the strategies to attract investment, targeting specific technology deployment opportunities. The opportunities to attract a broader range of energy opportunities and development within the precinct is also discussed.

9.1 SMALL SCALE SOLAR

Solar energy is proposed to be delivered at various capacities from small scale residential and commercial systems through to larger scale solar farms up to 10 MW. Many households and smaller buildings within the Snowy Mountains SAP will have the ability to install small scale PV systems on their home however we note also there may be circumstances where PV cannot be installed on some homes including:

- houses under rental agreement
- excessive overshadowing
- south facing roofs
- roofs with structural limitations
- households with insufficient means to invest in solar.

With these constraints in mind it is necessary to set realistic targets for the quantity of solar PV that can be installed on individual households within the Snowy Mountains SAP.

For households who are willing to invest in solar PV but cannot install solar on their own residences for technical reasons, these households will benefit from aggregated investment and support programs within the Snowy Mountains SAP. These can include solar bulk buy programs or to create the ability for householders to invest in larger scale solar projects such as community investment projects.

The following delivery considerations are identified for small scale solar PV installations including for residential dwellings in the Snowy Mountains SAP.

- Small scale installations would be likely to benefit from a pre-approval process for systems up to 10 kW in size. The application process for grid connection of small and medium scale solar can be streamlined by working with the local network authority to pre-approve residential installations up to 10 kW. The Snowy Mountains SAP could assist by engaging with local utilities and local retailers to discuss any grid/economic constraints for connection and to assist small residential installers in understanding the connection application process.
- A solar power feed-in tariff is a payment that is available from electricity retailers for each unit of electricity a PV solar system exports to the grid (usually <100 kW). Some clarification with local retailers on the standard solar feed-in tariff offered within the Snowy Mountains SAP would be of benefit so this information can be demystified for small end users.
- Establishing project exemplars for small scale installations within the region would be an important method of engaging the residential market to install solar PV on their homes within the Snowy Mountains SAP. It would be beneficial to establish some specific local projects with full disclosure of their costs, financial returns and system outputs so that potential buyers can understand the likely project outcomes for their own site.
- Solar PV systems don't generate electricity all the time, so battery storage is required for constant energy supply. The support for the deployment of small-scale batteries within the Snowy Mountains SAP will be an important element in developing the market for small scale solar. Battery technology at the residential scale is in relative infancy and the Snowy Mountains SAP Governance structure could support small-scale battery deployment by establishing a show case project and working with solar PV suppliers to secure bulk buy programs for batteries.
- Undertake high level engagement with energy retailers located near the Snowy Mountains SAP to provide assistance to negotiate favourable feed-in tariffs.
- Identify any local banking organisations providing low cost loans for solar power installations for commercial businesses.

9.2 LARGE SCALE SOLAR

The following delivery considerations are identified for large scale solar PV installations applicable to commercial and industrial end users in the Snowy Mountains SAP. Large scale solar are typically considered as systems of greater than 1 MW.

- Grid connectivity can be an issue for some large scale solar – it is necessary to work with the Distributed Network Service Provider (DNSP) to identify any limitations in the grid and to increase the minimum pre-approved connected capacity so that detailed network studies can be prioritized for larger systems. Grid connectivity for larger scale solar PV installations can be less certain than for small scale residential and commercial systems. The Snowy Mountains SAP governance authority could assist by engaging with local utilities and local retailers to discuss any grid/economic constraints for connection and to assist small residential installers in understanding the connection application process.
- Facilitating opportunities for diverse investment from community groups or third-party investors in larger solar projects including those at commercial scale (1–2 MW) or sub-utility scale (1 MW–5 MW).
- Investors in PV systems greater than 100 kW can take advantage of the large-scale renewable energy certificates eligible for creation through the renewable energy target (RET) legislation. These can be created based on the amount of electricity the renewable generator produces and can be on sold to entities with liabilities under the RET (mainly electricity retailers) to meet their compliance obligations.
- A solar power feed-in tariff is a payment that is available from electricity retailers for each unit of electricity a PV solar system exports to the grid (usually <100 kW). For systems >100 kW it may be necessary to negotiate a feed-in tariff with a retailer however it is expected a similar figure to the standard feed-in tariff would be provided for systems of 100–300 kW. Alternatively, energy generation from larger scale solar power plants could be sold through power purchase agreements with larger end users.
- The investment in large scale renewable energy power plants in the region is likely to benefit from the establishment of financial support through committed power purchase agreements. These substantially alleviate the risk for developers of larger PV systems. Establishing support mechanisms in the Snowy Mountains SAP to aggregate investors and to facilitate power purchase agreements between consumers and solar developers will significantly expedite the deployment of larger scale systems in the region. Snowy Hydro is already working towards backing some additional renewable energy power plants in the region.
- Marginal loss factors (a coefficient applied to generation exports on the NEM) for exporting solar have been declining in recent times making the return on investment less attractive for utility scale solar farms that deliver power via the grid infrastructure. For smaller scale systems where exports are a necessary part of the system there may also be marginal loss factors applied to specific parts of the grid. The Snowy Mountains SAP governance authority would need to work with local network authorities to ensure grid infrastructure does not suffer loss factors which inhibit the financial economics based on transmission of solar power in the region.
- Some preliminary mapping of the local grid infrastructure within the Snowy Mountains SAP including existing and proposed infrastructure would be an important element in facilitating larger scale solar installations and assisting developers to evaluate appropriate sites for larger scale solar systems.
- Commercial scale solar energy offers significant opportunity for the Snowy Mountains SAP to expand the jobs market as these types of solar PV installations can require a degree of consulting, equipment suppliers, logistics, installers, electricians, certifiers, and ongoing jobs in system maintenance.
- Solar PV systems don't generate electricity all the time, so battery storage is required for constant energy supply. Consideration for larger scale solar development may also need to include provision for battery storage.

- Solar PV systems naturally produce more energy in summer months than winter months. Within the Snowy Mountains SAP there is an opportunity to utilise the Snowy Hydro scheme as a seasonal storage mechanism for all renewables in the Snowy Mountains SAP.
- Undertake high level engagement with energy retailers located near the Snowy Mountains SAP to provide assistance to negotiate favourable feed-in tariffs and supply off-take agreements.
- Identify any local banking organisations providing low cost loans for solar power installations for commercial businesses.
- Consider methods of assisting businesses to engage with local PV suppliers and installers. This would not necessarily require the Snowy Mountains SAP Governance to evaluate, endorse and publicise solar installers but it could include the provision of help guides to assist residents and businesses to ask the right questions and seek the right advice in regard to larger scale solar installations.
- Facilitation of information sessions by independent advisors (e.g. Solar NSW, Sustainability NSW, Alternative Technology Association, the Australia Industry Group) for local residents and industry on the procurement and installation of solar PV systems. This would not necessarily involve identifying or approving suppliers but could include methods to assist businesses in finding suppliers or putting them in contact with others who have completed a similar installation.
- Consider the zoning boundaries within the shire and how these would affect the location of a utility scale or commercial scale solar farm.
- The Snowy Mountains SAP Governance team should work with State and local government to evaluate the extent of environmental no-go zones and define more specific opportunity boundaries.

9.3 GEOTHERMAL HEATING

Information about the Snowy Mountains SAP region's geothermal resources is limited and because the resource is found deep underground, exploration can be expensive and the process difficult to carry out.

Given the small number of existing geothermal resource projects established within the region, a geothermal energy plant is unlikely to be viable within the Snowy Mountains SAP.

If, however further geothermal projects are to be pursued, some delivery considerations for geothermal systems are as follows:

- Conducting of a geotechnical study to locate potentially viable site/s for a geothermal energy source.
- Aggregating a geothermal resource across multiple end users to improve the financial viability of this type of system. An example is Portland, Victoria in which the shire's police station, hospital, library, arts centre, municipal offices, civic hall, public swimming pool, Maritime Discovery Centre and History House were among premises to benefit. It was estimated to have saved approximately $300,000 annually for the operation of these buildings collectively. For such a scheme to be viable, a suitable geothermal resource is required, however.

The integrity of geothermal aquifer bores is crucial to their long-term success and continued operation. It is important that engineering on these systems is undertaken by experienced professionals with proven track record of successfully completed projects with long term operation. One of the key important steps in evaluating the resource for the region could be to engage with specialist suppliers of geothermal boring and heat pump systems to define the potential for these systems in the region.

9.4 HYDROGEN

In order to be considered a renewable energy resource, hydrogen fuel cell technology would have to be coupled with a renewable energy power source such as solar or wind to provide the energy required to power an electrolyser to split water into its component elements, oxygen and hydrogen.

Hydrogen storage will complement the highly intermittent energy generating capabilities associated with solar generation and will ensure that there are minimal GHG emissions over the life cycle, as compared with conventional storage options such as lithium batteries. Hydrogen production has a small GHG impact associated with the fugitive loss of hydrogen from the plant into the atmosphere which can increase the content of methane and ozone in the atmosphere.

When comparing hydrogen fuel cells as a method of energy storage to the more conventional lithium ion battery technology, for the same quantity of manufacturing energy input, hydrogen storage provides more energy dispatched from storage than a typical lithium ion battery over the lifetime of the facility. On the other hand, energy storage in hydrogen has a much lower overall efficiency than batteries (30% vs 75–90%), resulting in significant energy losses during operation. The round-trip efficiency of hydrogen fuel cell energy storage must improve dramatically before it can offer the same overall energy efficiency as batteries.

Some of the key considerations in allowing for the future development of hydrogen in the Snowy Mountains SAP include the following:

- The economic viability of large-scale hydrogen production is likely to be contingent upon the supply of sufficiently sized renewable energy systems including additional large scale solar farms in the Snowy Mountains SAP.
- Locally produced hydrogen could enable the transition to a clean vehicle fleet within the Snowy Mountains SAP serving the transport logistics network.
- A hydrogen production plant could enable major research and development opportunities, creating jobs growth in the Snowy Mountains SAP.
- Hydrogen technology is highly scalable and could initially be implemented as a small-scale trial.
- Access to technical and financial support from state and federal government is likely to be necessary to progress the prospects for hydrogen in the Snowy Mountains SAP.
- Hydrogen power plants offer significant jobs growth potential as the industry is in its infancy in Australia. The design, construction and maintenance of a plant would be a significant undertaking involving a large stakeholder and design team.
- This technology provides significant environmental advantages over other forms of long-term energy storage such as batteries which use precious resources in limited supply.
- Hydrogen is likely to be strongly supported from all renewable energy sectors including solar and biomass.
- Electrolysis and steam reforming, the two main processes of hydrogen extraction, are currently relatively expensive. This is a key reason it’s not heavily used across the world. Today, hydrogen energy is primarily used to power hybrid fuel cell vehicles.
- The development of a hydrogen fuel production plant in the Snowy Mountains SAP represents a longer-term proposal for which a significant amount of work is still required to realise the potential in the region.
- The interest in hydrogen technology around the country is very strong and Snowy Mountains SAP would be in competition with other major cities around the Country to establish themselves as a hydrogen hub.

9.5 BATTERY ENERGY STORAGE SYSTEMS

Electrical battery energy storage is discussed here as a separate initiative to the potential for pumped hydro storage opportunities (e.g. via Snowy Hydro). Electrical energy storage can be delivered through a variety of mechanisms including large scale battery deployment and/or the aggregation of multiple smaller batteries through a network. It is likely that both of these solutions will form part of the strategy for Snowy Mountains SAP and both require market support and testing of the business case.

The cost of large-scale batteries makes their deployment less viable than solar power photovoltaic systems alone and their implementation is typically made more viable when combined with renewable energy systems. However, the inclusion of battery storage systems can turn renewable energy plants into reliable dispatchable power plants and such storage technologies may require additional incentive and support within the Snowy Mountains SAP. It is also noted that the cost of battery systems is decreasing, and they are becoming more cost competitive.

Large scale on-grid battery storage is capable of being delivered by private development consortia who are capable of operating dispatchable energy supplies to the grid. This approach is likely to be integrated with a large renewable energy plant such as a solar farm. Some recent precedents have also shown delivery of large scale on-grid battery projects being delivered through network operators with the assistance of government funding streams such as from ARENA.

Storage is a crucial element of grid system management and will likely rely on the local network operators to support and drive the installation of this infrastructure utilizing investment partners who can profit from the storage and on-demand supply of energy. A major element of the economics of battery storage is the ability to deliver supply during peak demand periods when energy market pool prices are high.

The emergence and increased use of electric vehicles and associated charging infrastructure could represent a significant change to the energy usage profile within the Snowy Mountains SAP over the coming decade. This may change the pricing dynamics of renewable energy and the business case for small scale and large-scale solar power systems along with on-demand stored energy. Ongoing evaluation of the up-take of electric vehicles in the region is necessary to adequately respond and develop the required changes to the Snowy Mountains SAP renewable energy strategy.

9.6 VIRTUAL POWER PLANTS

Virtual power plants within the Snowy Mountains SAP can follow a variety of implementation pathways. Typically, these virtual power plants would consist of an aggregation of smaller individual power generation and supply devices.

There are existing regulatory frameworks which enable the implementation of virtual power plants in the National Energy Market and as a result their implementation is un-encumbered by regulation or grid reform.

A host of third-party providers offer the ability to aggregate energy supplies from disparate sources. One of the key requirements for this type of system however is the ability to provide dispatchable power to consumers through the use of batteries.

Within the Snowy Mountains SAP it is possible to support enabling infrastructure for Virtual Power Plants such as support for organizations providing block chain technology and smart gateways.

One of the key ways Snowy Mountains SAP governance can provide support for Virtual Power Plant implementation is to support knowledge sharing of the technology amongst potential customers.

The economics of operating a Virtual Power Plant are very similar to those of larger scale batteries, these systems would typically rely on the business case for providing dispatchable power at times of peak demand, targeting times when energy pool prices are high.

Virtual Power Plant operation is an important element in the spectrum of renewable energy generation and their application in the Snowy Mountains SAP should be supported through local policy settings.

Th establishment of Virtual Power Plants can improve the stability of the grid by creating incentive for consumers to incorporate local storage, reduce the incidence of uncontrolled export to the grid and participate in the operation of a Virtual Power Plant.

Virtual Power Plants have the benefit of increasing grid asset utilisation and this can reduce system loses. There is a degree of market incentive for grid infrastructure asset operators to support the growth of virtual power plants within the Snowy Mountains SAP.

In the coming decade the installed capacity of solar PV and other renewables could surpass the total demand in the network and as a result the challenge in meeting demand with the available supply will be reliant on aggregating and dispatching those supplies.

Virtual Power Plants can be established at a fraction of the cost of larger scale convention generation technologies and as a result there is strong incentive for a range of parties including grid operators, retail, and household generators to support their implementation.

However, prices of energy storage systems are generally expected to drop by approximately 50% over the next five years, which would support VPPs becoming commercially viable without subsidy and provide consumers with commercially rational purchasing decision when purchasing a battery.

One key consideration for the application of virtual networks is maintaining the option for participants to have contestability of suppliers and retailers in the market without being locked in to a supply agreement either contractually or technically.

9.7 RENEWABLE POWER PURCHASE AGREEMENTS

The Sydney City Council has committed to a power purchase agreement worth $60 million for procurement of wind and solar power to meet its energy needs over the next 10 years. The commitment is the biggest of its kind in Australia and sets a strong precedent for demand for renewable energy in the State of NSW. The energy contract includes supply from the 120 MW Boman Solar farm near Snowy Mountains SAP as well as the 270 MW Sapphire wind farm near Glenn Innes and a not-for-profit community owned solar scheme near Nowra. The procurement process provides a useful reference when considering the acquisition of large-scale energy take-off agreements from both major solar farms or aggregated virtual solar farms.

Similarly, the City of Melbourne instigated a market-wide request for offers from renewable energy generators and “shovel ready” projects for the supply of 88,000 MWh of renewable energy to supply a consortium including Melbourne City Council and businesses within the City of Melbourne. An additional example of this type of large-scale procurement of renewable energy has been undertaken by a consortium of 13 Victorian water Authorities.

These examples of large-scale energy supply procurement by local government and infrastructure authorities show the opportunities that will be available for Snowy Mountains SAP. In order to attract this type of investment it may be necessary to develop mechanisms of aggregating smaller scale solar PV installations into a Virtual Power plant supply so that larger scale supply agreements can be met.

9.8 OTHER SUPPORTING INITIATIVES

In combination with the above technology strategies, other renewable energy support strategies are likely to compliment the strategy for the Snowy Mountains SAP and act to support the initiative based on land and grid infrastructure. These are discussed below.

- Energy efficiency strategies are highly complementary to the deployment of renewable energy technology and in most cases, it is important to ensure energy is used efficiently prior to switching to a clean supply. The benefit gained from energy efficiency can offset the need for additional renewable supplies. Within the Snowy Mountains SAP governance structure, it will be important to set strong mandates for efficient energy utilisation across the precinct, this can include energy performance criteria for new and existing buildings. It would also be beneficial to support consultants and providers of energy efficiency technology to operate effectively within the Snowy Mountains SAP. These can include support opportunities for building improvement technologies such as air sealing, insulation, specialist technologies, and energy tracking.
- Alternative energy retailing structures within the national Energy Market are likely to be helpful to facilitate broader uptake of renewable energy within the Snowy Mountains SAP. These may include retailers and suppliers who are able to aggregate supplies from multiple sources such as through a virtual power plant.
- Monitoring and tracking of the success of the renewable energy strategy within the Snowy Mountains SAP is important and this may entail a degree of infrastructure or governance to ensure the right monitoring is in place to verify baseline conditions and the specific renewable energy outcomes within the Snowy Mountains SAP boundary are being followed and met. Initial investigations of the large-scale electrical infrastructure and the extent to which renewable energy utilisation can be recorded and tracked would be necessary at the master planning stage.
- Facilitating education for small business and residences on opportunities to participate in virtual power plants such as making their battery systems available for peak load supply would be an important method of assistance for renewable energy deployment.
- The Snowy Hydro scheme provides a method of pumped hydro storage and any storage strategy within the Snowy Mountains SAP would need to consider the financial and technical opportunities presented by Snowy Hydro to store renewable energy.

10 LIMITATIONS

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APPENDIX A

LIST OF PREMISES AND INDICATIVE PV INSTALLATION CAPACITY

Table A.1 List of premises and indicative installation capacity

#	PROPERTY	MEASURED AREA (SQ.MTR)	AVAILABLE AND USABLE AREA (SQ.MTR)	INDICATIVE CAPACITY (KWP)
1	JE Resort	3424	856	142.7
2	Highland Lodge Farmstay	715	178.75	29.8
3	Rivergum Lodge	482	120.5	20.1
4	Mowamba River Lodge	423	105.75	17.6
5	Frost Creek Lodge	154	38.5	6.4
6	The Station	298	74.5	12.4
7	Ski Rider Hotel	3420	855	142.5
8	-36.348951, 148.528535	987	246.75	41.1
9	Sponars Chalet	844	211	35.2
10	Royal Coachman Ski Lodge	470	117.5	19.6
11	Snowy Gums Chalet	864	216	36.0
12	The Lodge	337	84.25	14.0
13	The Aspen Chalet	476	119	19.8
14	Smiggins Hotel & Chalet Apartments	1890	472.5	78.8
15	Southern Cross Alpine Lodge	178	44.5	7.4
16	Perisher Fire Station	701	175.25	29.2
17	Man From Snowy River Hotel	2184	546	91.0
18	Stables Resort	1502	375.5	62.6
19	Valhalla Lodge Perisher	400	100	16.7
20	Narraburra Ski Club Co-Op	146	36.5	6.1
21	Barina Milpara Lodge	240	60	10.0
22	Ski Tube Perisher Station	2375	593.75	99.0
23	Perisher Centre - Perisher Valley Hotel	2716	679	113.2
24	Perisher Manor	1437	359.25	59.9
25	Eiger Chalet	646	161.5	26.9
26	Matterhorn Ski Lodge	752	188	31.3
27	Marritz Alpine Inn	440	110	18.3
28	Swagman Chalet	249	62.25	10.4
29	Mawabu Ski Lodge	192	48	8.0
30	Chalet Sonnenhof	472	118	19.7

#	PROPERTY	MEASURED AREA (SQ.MTR)	AVAILABLE AND USABLE AREA (SQ.MTR)	INDICATIVE CAPACITY (KWP)
31	Sundeck Hotel	1035	258.75	43.1
32	Wirruna Lodge	245	61.25	10.2
33	Yalara Alpine Ski Lodge	240	60	10.0
34	Barrakee Lodge	518	129.5	21.6
35	Blue Cow Skitube station	1432	358	59.7
36	Guthega Ski Centre	302	75.5	12.6
37	Guthega Alpine Inn	375	93.75	15.6
38	Burning Lodge Restaurant	390	97.5	16.3
39	Perisher Midstation café	677	169.25	28.2
40	Kosciuszko Chalet Hotel	789	197.25	32.9
41	Charlotte Pass Ski Resort	350	87.5	14.6
42	Stillwell lodge	493	123.25	20.5
43	Elouera Ski Club	289	72.25	12.0
44	Arlberg Lodge	599	149.75	25.0
45	Andrea's White House	210	52.5	8.8
46	Mia creek	354	88.5	14.8
47	Wildbrumpy Schnapps Distillery	325	81.25	13.5
48	Altitude 1260	704	176	29.3
49	Silvertop snowy mountain retreat lodge	337	84.25	14.0

APPENDIX B

ROOFTOP SOLAR PV – JINDABYNE PROJECTED GROWTH AREA

Table B.1 Rooftop solar PV – Jindabyne projected growth area

SNOWY MOUNTAINS SAP GROWTH OPPORTUNITIES	LAND PARCEL	NET DEVELOPABLE AREA (HA)	ACTUAL ROOF AREA OF DEVELOPMENT AREA (M^2)	AREA AVAILABLE FOR PV (M^2)	PV ARRAY SIZE (KW)	REMARK
Town centre	MU8 – B.P. Inn overflow car parking	0.30	1,500.00	375	75.3	
	MU10 – additional car park	0.23	1,150.00	288	57.7	
	MU13 – car park	0.14	675.00	169	33.9	
	TA5 – McLure Circuit	0.36	1,800	450	90.4	
South Jindabyne (Growth Area 2)	Residential Neighbourhood (Area 2A)	11.19	39,150	9,788	1,631.3	174 houses with 450 m^2 site size
	Residential Lifestyle – Larger suburban Lots	8.03	28,000	7,000	1,166.7	56 houses with 1000 m^2 site size
	Residential Neighbourhood (Area 2B)	1.72	6,075	1,519	253.1	27 houses with 450 m^2 site size
West Jindabyne (Growth Area 3)	Residential Neighbourhood	60.19	210,600	52,650	8,775.0	351 houses with 600 m^2 site size and 468 houses with 450 m^2 site size
	Residential Lifestyle – Green Ridge	11.24	46,500	11,625	1,937.5	93 houses with 1000 m^2 site size
	Slope 1 in 4	8.02	104,000	26,000	4,333.3	208 houses with 800–1200 m^2 site size

SNOWY MOUNTAINS SAP GROWTH OPPORTUNITIES	LAND PARCEL	NET DEVELOPABLE AREA (HA)	ACTUAL ROOF AREA OF DEVELOPMENT AREA (M^2)	AREA AVAILABLE FOR PV (M^2)	PV ARRAY SIZE (KW)	REMARK
East Jindabyne (Growth Area 4)	Residential Neighbourhood (Area 4A)	17.68	61,820	15,455	2,575.8	37X1000 m^2, 62X600 m^2, 110X450 m^2 houses
	Residential Choice – Medium Density (Area 4A)	4.05	91,155	22,789	3,798.1	84X1000 m^2, 72X1350 m^2 houses
	Residential Neighbourhood (Area 4B)	2.75	9,555	2,389	398.1	16X600 m^2, 21X450 m^2 houses
	Residential Lifestyle – Larger Suburban Lots (Area 4B)	2.38	8,500	2,125	354.2	17 houses with 1000 m^2 site size
Lake Jindabyne Village/ Rabbit Corner (Growth Area 5)	Residential Neighbourhood (tourist accommodation assumed)	4.46	15,525	3,881	646.9	69 houses with 450 m^2 site size
	Residential Choice (Medium Density)	3.23	63,000	15,750	2,625.0	126 houses with 800–1200 m^2 site size
Leesville (Industry) (Growth Area 6)	Industry (Area 6A)	5.77	28,850	7,213	1,202.1	
	Industry (Area 6B)	4.48	22,400	5,600	933.3	
	Industry (Area 6C)	6.57	32,850	8,213	1,365.8	
Total		**152.79**	**773,105**	**193,279**	**32253.5**	

APPENDIX C

ENERGY YIELD MODELLING
ASSUMPTIONS

APPENDIX C-1
LARGE SCALE SOLAR – PVSYST ASSUMPTIONS

Grid-Connected System: Simulation parameters

Project : **Snowy SAP**

Geographical Site	**Ciawood**		Country	**Australia**
Situation	Latitude	-36.53° S	Longitude	148.67° E
Time defined as	Legal Time	Time zone UT+10	Altitude	1216 m
	Albedo	0.20		
Meteo data:	**Ciawood**	Meteonorm 7.3 (1990-2008), Sat=52% - Synthetic		

Simulation variant : **Snowy_12.5MW**

Simulation date 08/04/21 17h16

Simulation parameters	System type	**Trackers single array, with backtracking**		
Tracking plane, tilted axis	Axis Tilt	0°	Axis azimuth	0°
Rotation Limitations	Minimum Phi	-60°	Maximum Phi	60°
	Tracking algorithm	Irradiance optimization		
Backtracking strategy	Nb. of trackers	538	Single array	
	Tracker Spacing	7.00 m	Collector width	2.31 m
Inactive band	Left	0.02 m	Right	0.02 m
Backtracking limit angle	Phi limits	+/- 70.3°	Ground Cov. Ratio (GCR)	32.9%
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
			Circumsolar	separate
Horizon	Free Horizon			
Near Shadings	Linear shadings			
User's needs :	Unlimited load (grid)			

PV Array Characteristics				
PV module Si-mono	Model	**LR5-72 HPH 540 M**		
Original PVsyst database	Manufacturer	Longi Solar		
Number of PV modules	In series	27 modules	In parallel	1005 strings
Total number of PV modules	nb. modules	27135	Unit Nom. Power	540 Wp
Array global power	Nominal (STC)	**14653 kWp**	At operating cond.	13394 kWp (50°C)
Array operating characteristics (50°C)	U mpp	1008 V	I mpp	13289 A
Total area	Module area	**69358 m²**	Cell area	62910 m²
Inverter	Model	**Sunny Central 2500-EV**		
Original PVsyst database	Manufacturer	SMA		
Characteristics	Unit Nom. Power	**2500 kWac**	Oper. Voltage	850-1425 V
Inverter pack	Total power	**12500 kWac**	Pnom ratio	1.17
	Nb. of inverters	5 units		
Total	Total power	**12500 kWac**	Pnom ratio	1.17

PV Array loss factors

Array Soiling Losses			Loss Fraction	1.5 %
Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	1.3 m• •	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	2.0 %
Module Quality Loss			Loss Fraction	-0.4 %
Module mismatch losses			Loss Fraction	2.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Grid-Connected System: Main results

Project : **Snowy SAP**

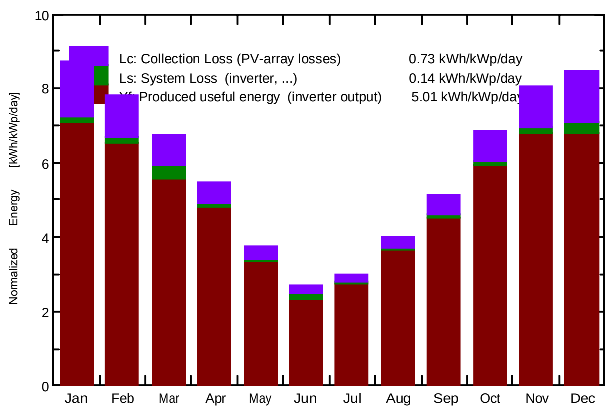
Simulation variant : **Snowy_12.5MW**

Main system parameters	System type	**Trackers single array, with backtracking**		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis azimuth	0°
PV modules	Model	LR5-72 HPH 540 M	Pnom	540 Wp
PV Array	Nb. of modules	27135	Pnom total	**14653 kWp**
Inverter	Model	Sunny Central 2500-EV	Pnom	2500 kW ac
Inverter pack	Nb. of units	5.0	Pnom total	**12500 kW ac**
User's needs	Unlimited load (grid)			

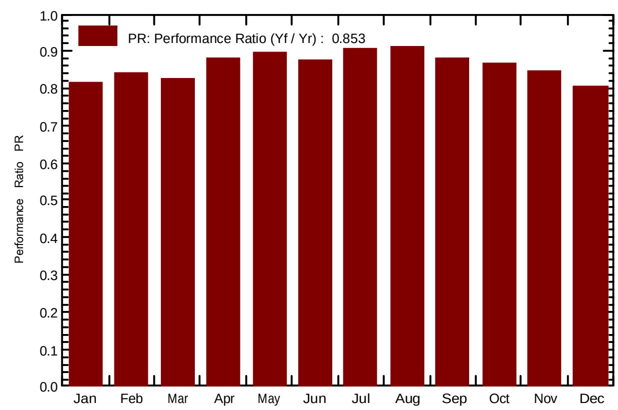
Main simulation results

System Production	**Produced Energy**	**26815 MWh/year**	Specific prod.	1830 kWh/kWp/year
	Performance Ratio PR	85.26 %		

Normalized productions (per installed kWp): Nominal power 14653 kWp



Performance Ratio PR



Snowy_12.5MW

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	205.4	75.83	17.50	270.0	259.7	3297	3231	0.817
February	164.7	68.11	16.77	218.0	209.4	2744	2690	0.842
March	155.1	60.73	14.18	209.1	200.7	2684	2536	0.827
April	117.7	35.91	9.79	164.1	157.5	2164	2122	0.882
May	81.5	28.19	6.31	116.0	110.1	1552	1521	0.895
June	59.5	27.88	3.39	80.5	75.9	1090	1036	0.878
July	67.7	31.53	1.96	93.3	88.1	1267	1242	0.908
August	91.9	38.42	2.97	124.6	118.9	1695	1662	0.910
September	116.4	51.14	5.85	154.3	147.7	2033	1991	0.881
October	161.8	77.61	8.68	212.5	203.5	2752	2698	0.866
November	185.9	75.66	12.70	241.9	232.6	3052	2991	0.844
December	200.8	79.78	14.83	262.2	251.7	3215	3096	0.806
Year	1608.5	650.81	9.54	2146.5	2056.0	27547	26815	0.853

Legends:				
GlobHor	Global horizontal irradiation		GlobEff	Effective Global, corr. for IAM and shadings
DiffHor	Horizontal diffuse irradiation		EArray	Effective energy at the output of the array
T_Amb	T amb.		E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane		PR	Performance Ratio

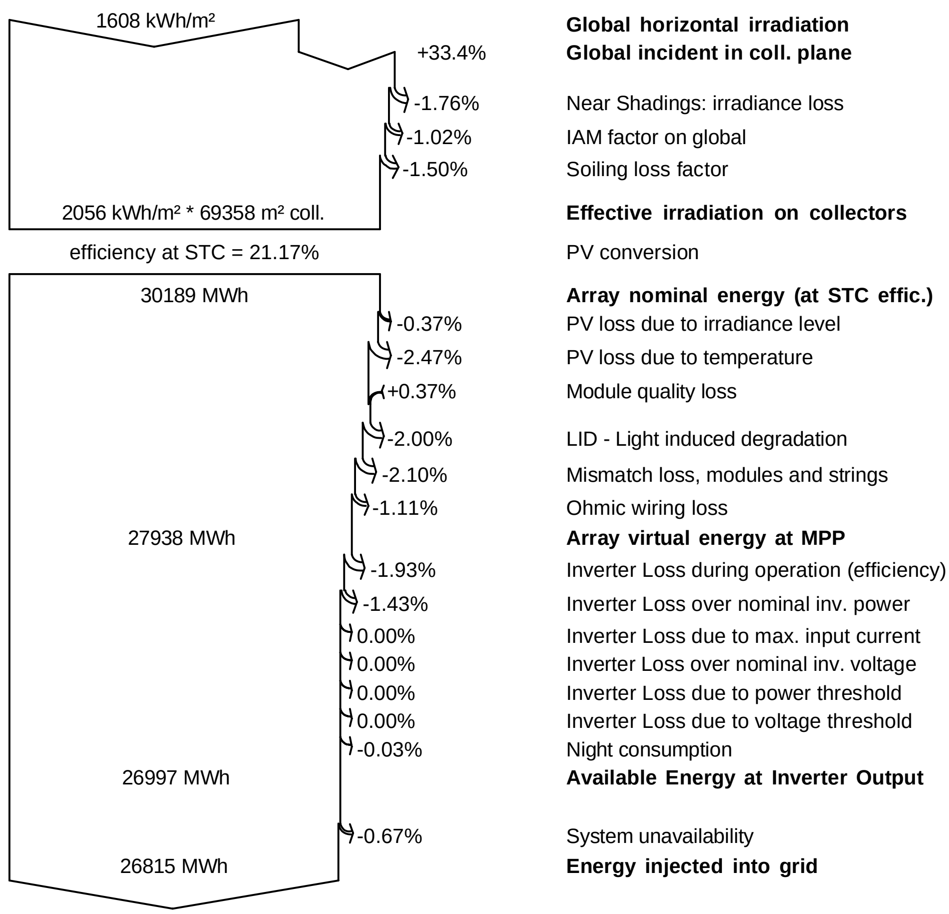
Grid-Connected System: Loss diagram

Project : **Snowy SAP**

Simulation variant : **Snowy_12.5MW**

Main system parameters	System type	**Trackers single array, with backtracking**		
Near Shadings	Linear shadings			
PV Field Orientation	tracking, tilted axis, Axis Tilt	0°	Axis azimuth	0°
PV modules	Model	LR5-72 HPH 540 M	Pnom	540 Wp
PV Array	Nb. of modules	27135	Pnom total	**14653 kWp**
Inverter	Model	Sunny Central 2500-EV	Pnom	2500 kW ac
Inverter pack	Nb. of units	5.0	Pnom total	**12500 kW ac**
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



APPENDIX C-2
CAR PARK SOLAR – PVSYST ASSUMPTIONS

Grid-Connected System: Simulation parameters

Project : **Snowy SAP_Car Parking**

Geographical Site		**Jindabyne**	Country	**Australia**
Situation	Latitude	-36.43° S	Longitude	148.60° E
Time defined as	Legal Time	Time zone UT+10	Altitude	1020 m
	Albedo	0.20		
Meteo data:	**Jindabyne**	Meteonorm 7.3 (1990-2008), Sat=22% - Synthetic		

Simulation variant : **Snowy SAP_Car Park**

Simulation date 08/04/21 16h34

Simulation parameters	System type	**No 3D scene defined, no shadings**		
Collector Plane Orientation	Tilt	20°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
			Circumsolar	separate
Horizon	Free Horizon			
Near Shadings	No Shadings			
User's needs :	Unlimited load (grid)			

PV Array Characteristics

PV module Si-mono	Model	**LR5-72 HPH 540 M**		
Original PVsyst database	Manufacturer	Longi Solar		
Number of PV modules	In series	18 modules	In parallel	122 strings
Total number of PV modules	nb. modules	2196	Unit Nom. Power	540 Wp
Array global power	Nominal (STC)	**1186 kWp**	At operating cond.	1084 kWp (50°C)
Array operating characteristics (50°C)	U mpp	672 V	I mpp	1613 A
Total area	Module area	**5613 m²**	Cell area	5091 m²

Inverter	Model	**Sunny Central-990CP-KR**		
Original PVsyst database	Manufacturer	SMA		
Characteristics	Unit Nom. Power	**990 kWac**	Oper. Voltage	596-850 V
Inverter pack	Total power	**990 kWac**	Pnom ratio	1.20
	Nb. of inverters	1 units		
Total	Total power	**990 kWac**	Pnom ratio	1.20

PV Array loss factors

Array Soiling Losses			Loss Fraction	1.0 %
Thermal Loss factor	Uc (const)	29.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	6.9 m• •	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	2.0 %
Module Quality Loss			Loss Fraction	-0.4 %
Module mismatch losses			Loss Fraction	2.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Incidence effect (IAM): User defined profile

0°	25°	45°	60°	65°	70°	75°	80°	90°
1.000	1.000	0.995	0.962	0.936	0.903	0.851	0.754	0.000

Grid-Connected System: Main results

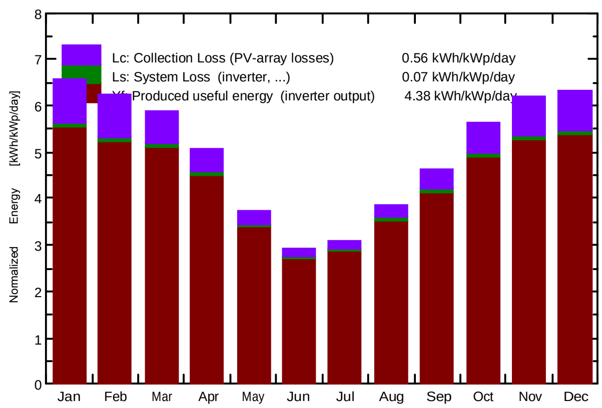
Project : **Snowy SAP_Car Parking**

Simulation variant : **Snowy SAP_Car Park**

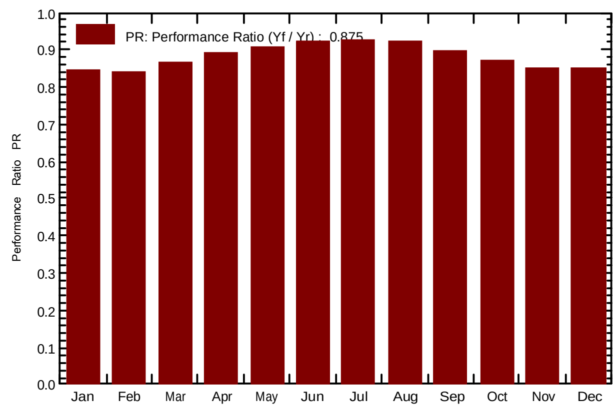
Main system parameters	System type	**No 3D scene defined, no shadings**		
PV Field Orientation	tilt	20°	azimuth	0°
PV modules	Model	LR5-72 HPH 540 M	Pnom	540 Wp
PV Array	Nb. of modules	2196	Pnom total	**1186 kWp**
Inverter	Model	Sunny Central-990CP-KR	Pnom	990 kW ac
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**1898 MWh/year**	Specific prod.	1600 kWh/kWp/year
	Performance Ratio PR	87.49 %		

Normalized productions (per installed kWp): Nominal power 1186 kWp



Performance Ratio PR



Snowy SAP_Car Park

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	206.7	86.44	19.03	204.0	197.6	207.3	204.2	0.844
February	167.3	60.32	18.28	174.8	169.3	176.7	174.0	0.840
March	159.1	55.22	15.92	182.8	177.6	190.5	187.5	0.865
April	119.1	39.45	11.64	151.9	147.6	163.3	160.9	0.893
May	82.9	27.43	8.06	116.2	112.7	127.1	125.1	0.908
June	61.0	23.77	5.29	88.3	85.7	98.3	96.6	0.922
July	68.4	28.72	4.12	96.1	93.0	107.3	105.5	0.927
August	92.9	39.97	5.31	119.3	115.8	132.4	130.3	0.921
September	118.3	48.56	8.00	138.5	134.6	149.6	147.2	0.896
October	163.1	58.99	10.89	175.2	169.7	183.7	180.8	0.870
November	185.0	72.35	14.57	186.2	180.4	191.0	188.0	0.852
December	202.9	83.17	16.61	196.0	190.0	200.8	197.7	0.850
Year	1626.9	624.39	11.44	1829.4	1774.0	1928.1	1897.9	0.875

Legends:				
GlobHor	Global horizontal irradiation		GlobEff	Effective Global, corr. for IAM and shadings
DiffHor	Horizontal diffuse irradiation		EArray	Effective energy at the output of the array
T_Amb	T amb.		E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane		PR	Performance Ratio

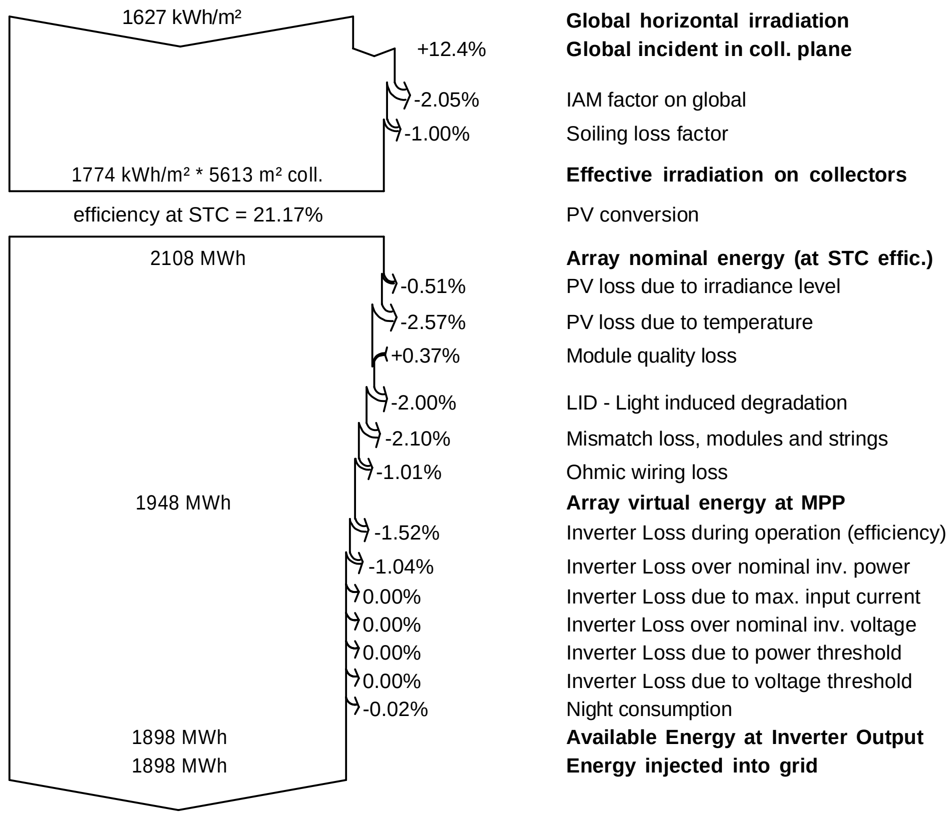
Grid-Connected System: Loss diagram

Project : **Snowy SAP_Car Parking**

Simulation variant : **Snowy SAP_Car Park**

Main system parameters	System type	**No 3D scene defined, no shadings**		
PV Field Orientation	tilt	20°	azimuth	0°
PV modules	Model	LR5-72 HPH 540 M	Pnom	540 Wp
PV Array	Nb. of modules	2196	Pnom total	**1186 kWp**
Inverter	Model	Sunny Central-990CP-KR	Pnom	990 kW ac
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



APPENDIX C-3
ROOFTOP SOLAR – PVSYST ASSUMPTIONS

Grid-Connected System: Simulation parameters

Project : **Snowy SAP_Rooftop**

Geographical Site	**Jindabyne**		Country	**Australia**
Situation	Latitude	-36.43° S	Longitude	148.60° E
Time defined as	Legal Time	Time zone UT+10	Altitude	1020 m
	Albedo	0.20		
Meteo data:	**Jindabyne**	Meteonorm 7.3 (1990-2008), Sat=22% - Synthetic		

Simulation variant : **New simulation variant_Final**

Simulation date 08/04/21 16h32

Simulation parameters	System type	**Unlimited sheds**		
Collector Plane Orientation	Tilt	10°	Azimuth	0°
Sheds configuration	Nb. of sheds	5	Unlimited sheds	
	Sheds spacing	2.50 m	Collector width	2.06 m
Inactive band	Top	0.02 m	Bottom	0.02 m
Shading limit angle	Limit profile angle	38.4°	Ground Cov. Ratio (GCR)	82.2%
Models used	Transposition	Perez	Diffuse	Perez, Meteonorm
			Circumsolar	separate
Horizon	Free Horizon			
Near Shadings	Mutual shadings of sheds			
User's needs :	Unlimited load (grid)			

PV Array Characteristics

PV module Si-mono	Model	**LR5-72 HPH 540 M**		
Original PVsyst database	Manufacturer	Longi Solar		
Number of PV modules	In series	11 modules	In parallel	2 strings
Total number of PV modules	nb. modules	22	Unit Nom. Power	540 Wp
Array global power	Nominal (STC)	**11.88 kWp**	At operating cond.	10.86 kWp (50°C)
Array operating characteristics (50°C)	U mpp	411 V	I mpp	26 A
Total area	Module area	**56.2 m²**	Cell area	51.0 m²
Inverter	Model	**Sunny Tripower 10000TLEE-JP-11**		
Original PVsyst database	Manufacturer	SMA		
Characteristics	Unit Nom. Power	**9.90 kWac**	Oper. Voltage	300-590 V
Inverter pack	Total power	**9.9 kWac**	Pnom ratio	1.20
	Nb. of inverters	1 units		
Total	Total power	**9.9 kWac**	Pnom ratio	1.20

PV Array loss factors

Array Soiling Losses			Loss Fraction	1.5 %
Thermal Loss factor	Uc (const)	20.0 W/m²K	Uv (wind)	0.0 W/m²K / m/s
Wiring Ohmic Loss	Global array res.	257 m• •	Loss Fraction	1.5 % at STC
LID - Light Induced Degradation			Loss Fraction	2.0 %
Module Quality Loss			Loss Fraction	-0.4 %
Module mismatch losses			Loss Fraction	2.0 % at MPP
Strings Mismatch loss			Loss Fraction	0.10 %

Grid-Connected System: Main results

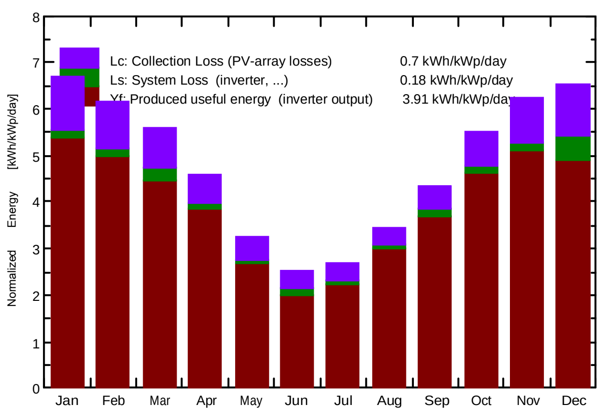
Project : **Snowy SAP_Rooftop**

Simulation variant : **New simulation variant_Final**

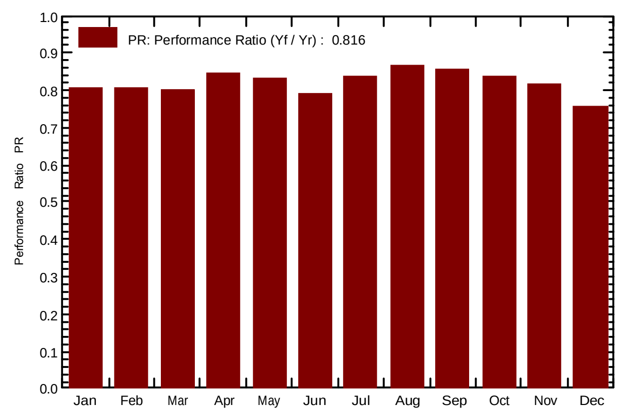
Main system parameters	System type	**Unlimited sheds**		
PV Field Orientation	Sheds disposition, tilt	10°	azimuth	0°
PV modules	Model	LR5-72 HPH 540 M	Pnom	540 Wp
PV Array	Nb. of modules	22	Pnom total	**11.88 kWp**
Inverter		Sunny Tripower 10000TLEE-JP-11	Pnom	9.90 kW ac
User's needs	Unlimited load (grid)			

Main simulation results				
System Production	**Produced Energy**	**16.95 MWh/year**	Specific prod.	1427 kWh/kWp/year
	Performance Ratio PR	81.60 %		

Normalized productions (per installed kWp): Nominal power 11.88 kWp



Performance Ratio PR



New simulation variant_Final

Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR ratio
January	206.7	86.44	19.03	207.7	198.8	2.052	1.984	0.804
February	167.3	60.32	18.28	173.1	165.7	1.717	1.659	0.807
March	159.1	55.22	15.92	173.1	165.9	1.753	1.647	0.801
April	119.1	39.45	11.64	137.2	130.3	1.422	1.376	0.844
May	82.9	27.43	8.06	100.8	91.8	1.025	0.992	0.828
June	61.0	23.77	5.29	75.6	67.1	0.763	0.709	0.790
July	68.4	28.72	4.12	83.2	74.5	0.852	0.825	0.835
August	92.9	39.97	5.31	107.3	100.6	1.137	1.101	0.864
September	118.3	48.56	8.00	129.9	124.1	1.369	1.323	0.857
October	163.1	58.99	10.89	171.2	163.8	1.762	1.702	0.837
November	185.0	72.35	14.57	187.8	179.9	1.883	1.819	0.815
December	202.9	83.17	16.61	201.7	192.7	2.005	1.813	0.757
Year	1626.9	624.39	11.44	1748.5	1655.0	17.739	16.951	0.816

Legends:				
	GlobHor	Global horizontal irradiation	GlobEff	Effective Global, corr. for IAM and shadings
	DiffHor	Horizontal diffuse irradiation	EArray	Effective energy at the output of the array
	T_Amb	T amb.	E_Grid	Energy injected into grid
	GlobInc	Global incident in coll. plane	PR	Performance Ratio

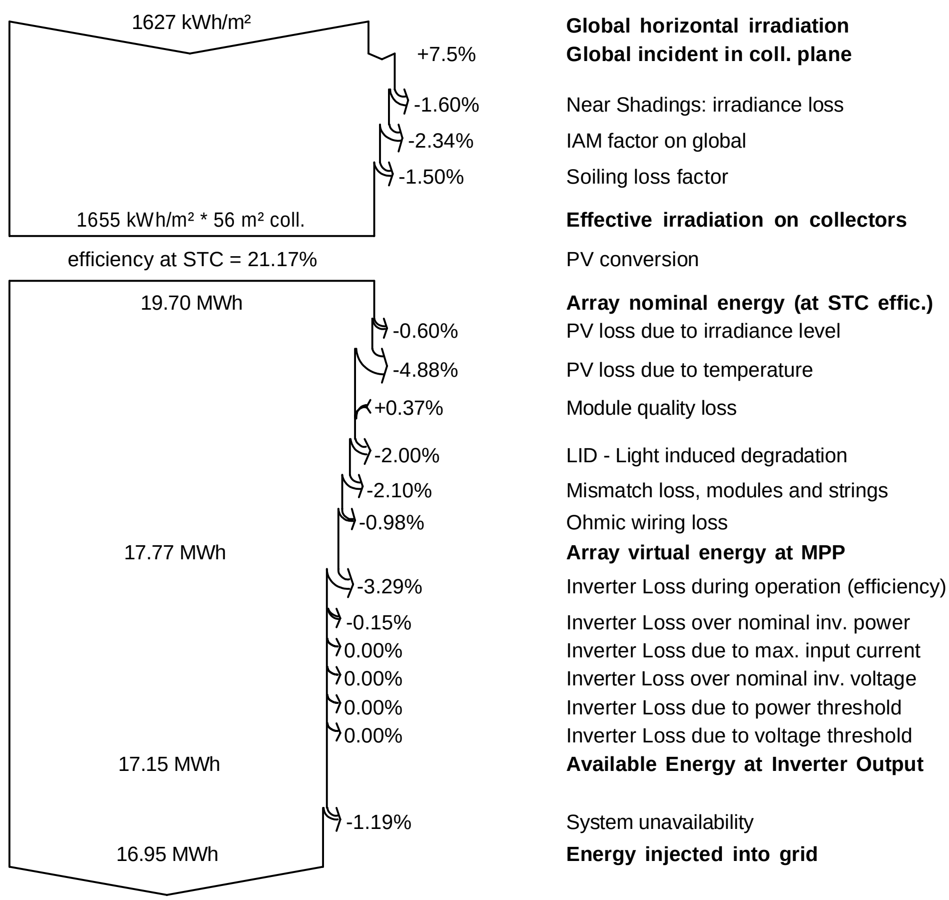
Grid-Connected System: Loss diagram

Project : **Snowy SAP_Rooftop**

Simulation variant : **New simulation variant_Final**

Main system parameters	System type	**Unlimited sheds**		
PV Field Orientation	Sheds disposition, tilt	10°	azimuth	0°
PV modules	Model	LR5-72 HPH 540 M	Pnom	540 Wp
PV Array	Nb. of modules	22	Pnom total	**11.88 kWp**
Inverter		Sunny Tripower 10000TLEE-JP-11	Pnom	9.90 kW ac
User's needs	Unlimited load (grid)			

Loss diagram over the whole year



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