LOW CARBON LIVING CRC

Knutsford Precinct - Renewable Energy Strategy

Authors	Bill Grace
Title	Knutsford Precinct - Renewable Energy Strategy
ISBN	
Date	June 2019
Keywords	Renewable energy, Local utilities
Publisher	CRC LCL
Preferred citation	Grace, B (2019) Knutsord Precinct - Renewable Energy Strategy

Australian Government
Department of Industry, Innovation and Science

Business
Cooperative Research Centres Programme

Acknowledgements

All reports must contain the following acknowledgement phrase:

This research is funded by the CRC for Low Carbon Living Ltd supported by the Cooperative Research Centres program, an Australian Government initiative.

The project would not have been possible without the support from the project partners LandCorp and City of Fremantle.

Disclaimer

Any opinions expressed in this document are those of the authors. They do not purport to reflect the opinions or views of the CRCLCL or its partners, agents or employees.

The CRCLCL gives no warranty or assurance, and makes no representation as to the accuracy or reliability of any information or advice contained in this document, or that it is suitable for any intended use. The CRCLCL, its partners, agents and employees, disclaim any and all liability for any errors or omissions or in respect of anything or the consequences of anything done or omitted to be done in reliance upon the whole or any part of this document.

Peer Review Statement

The CRCLCL recognises the value of knowledge exchange and the importance of objective peer review. It is committed to encouraging and supporting its research teams in this regard.

The author(s) confirm(s) that this document has been reviewed and approved by the project's steering committee and by its program leader. These reviewers evaluated its:

- originality
- methodology
- rigour
- compliance with ethical guidelines
- conclusions against results
- conformity with the principles of the Australian Code for the Responsible Conduct of Research (NHMRC 2007),

and provided constructive feedback which was considered and addressed by the author(s).

© 2019 Cooperative Research for Low Carbon Living

Contents

List of Tables

List of Figures

Acronyms

EV - Electronic vehicle

SWIS - South West Interconnected System

PV - Photovoltaics

WGV - White Gum Valley

JBA - Josh Byrne and Associates

SWIN - South West Interconnected Network

BESS - Battery Energy Storage System

RAC - Royal Automobile Club

RET - Renewable Energy Target

CER - Clean Energy Regulator

STCs - Small-scale Technology Certificates

LGCs - Large-scale Technology Certificates

REBS - Renewable Energy Buyback Scheme

IRR - Internal Rate of Return

AEMO - Australian Energy Market Operator

MNI - National Meter Identifier WEM - Wholesale Electricity Market

PUO - Public Utilities Office

ERA - Economic Regulation Authority

LGC - large scale certificate

SEN - Smart Embedded Network

STGR - Strata Titles General Regulations 1996

Executive Summary

Background

The Knutsford precinct includes the landholdings of LandCorp, the City of Fremantle and Western Power, as well as private owners. The development area has potential for approximately 1,000 new dwellings and more than 2,000 new residents, and is guided by the Swanbourne Street and Knutsford Street East Structure Plans.

The scope of the study reported here is as follows:

- Develop an approximate electrical energy demand for the site;
- Develop a 'net zero carbon' concept for the precinct, based on renewable energy sources and battery storage;
- Explore potential governance arrangements for the strategy, including the commerciality for a service provider and costs to customers; and
- Recommend an implementation pathway.

The research reported here builds on the work carried out to date by Western Power and Balance Utility Solutions for Knutsford, reflects the previous studies by AUDRC and Kinesis, and incorporates the learnings from LandCorp's landmark renewable energy microgrid at the Peel Business Park.

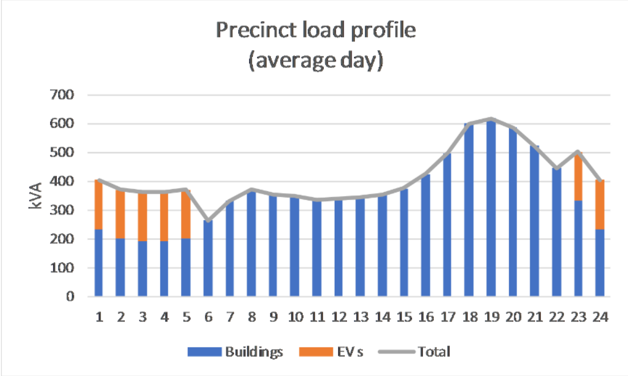
Electricity demand

The electricity demand for the precinct is very difficult to accurately predict, given that the yield and built form are indeterminate, and the penetration of electric vehicles is uncertain. Previous studies have resulted in a variety of approaches being adopted. Based on these studies and previous work by the author, approximate demands have been assumed in this study reflecting a yield of 400 single dwellings and 600 apartment dwellings. In addition to these loads, the charging of electric vehicles (EVs) has also been considered. It has been assumed that 30% of dwellings will have electric vehicles.

Table 1 Estimated annual demand

		Annual demand (MWh)
In-house demands	400 Townhouses	1,360
	600 Apartments	1,140
	Sub-total	2,800
Common areas		264
Electric vehicles		432
Total annual demand		3,496

Figure 1 Precinct load profile (average day)



Net Zero Carbon

A Net Zero Carbon objective relates only to stationary energy, i.e. that energy consumed in buildings and facilities, and does not include energy consumed in vehicles. In this study the objective has been set in the following terms:

- Electricity is the source of all stationary energy for the precinct, i.e. no natural gas;
- Sufficient renewable energy is generated within the precinct to meet the aggregate annual electricity demand;
- The precinct retains an electrical connection to the Western Power network, from which energy is imported when renewable sources are unavailable, and to which energy is exported when generation is excess to demand.

Under these arrangements, the amount of energy imported from the Western Power network, is completely offset by the amount of renewable energy exported, thereby substituting an equivalent amount of energy generated on the South West Interconnected System (SWIS). For the project to qualify as '*supplying all energy with renewables'* it would be necessary for energy imports from the SWIS to be 100% renewable by purchasing under the *GreenPower* scheme.

Renewable technologies

In this study it has been assumed that the form of renewable energy is rooftop solar PV. In order to reduce the quantity of energy imported from the SWIS during peak periods, battery storage has also been included as an element of the strategy. In order to generate sufficient energy to meet the annual demand of 3,500 MWh some 2,120 kW of rooftop solar PV would be required, i.e. 2.12 kW per dwelling on average.

The unit costs of solar PV and battery storage systems (BESS) have declined significantly over the recent past and are projected to continue to fall over the coming decades as volumes grow and economies of scale are realised. For the purposes of this study the following cost curves have been derived.

Figure 2 Solar PV cost curve

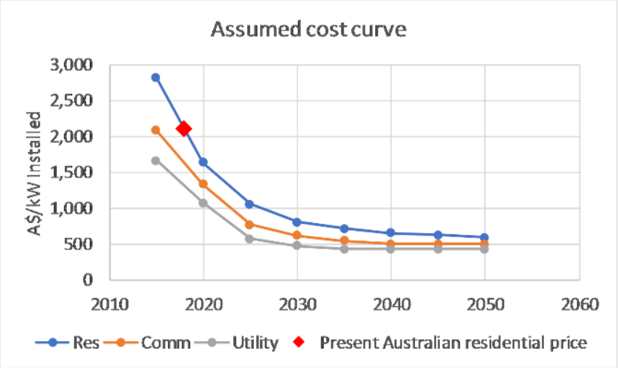
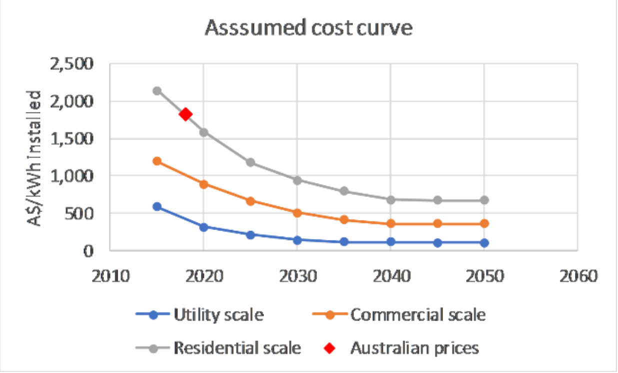


Figure 3 Battery storage system (BESS) cost curve



Scenarios considered

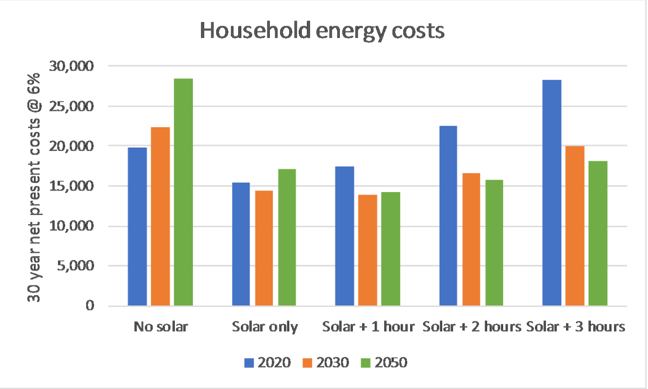
Two scenarios to implement a Net Zero Carbon precinct have been considered.

Customer self-supply scenario

The base case scenario assumes all dwellings, whether strata or green title, either purchase their own rooftop solar PV arrays or purchase dwellings in buildings with solar PV and battery storage installed as part of the development cost.

Presently, solar PV without energy storage is the cheapest option in life cycle cost terms, although 1 hour of storage is still economic in comparison to SWIS network supplied energy. However, after 2030, solar PV plus 1 hour of battery storage is likely to become the most economic option, with 2 hours of storage only marginally more expensive. By 2050, 1 and 3 hours of storage will be competitive with solar only.

Figure 4 Household energy cost

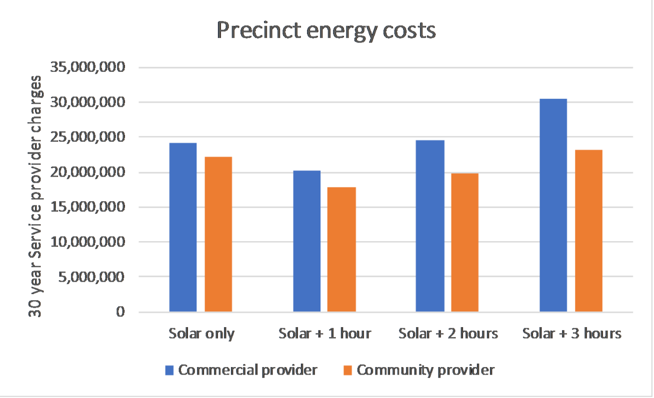


Service provider scenario

In this scenario, the same overall solar PV and BESS configurations are retained as in the Base case, but the precinct is serviced by a provider that invests in, and retains ownership of the equipment at each individual premise or strata complex.

Two variations have been applied to this scenario. In the first, the service provider is a commercial firm that requires a financial return from their operations. In the second scenario, it is assumed that the service is a community operated scheme, and accordingly is not required to make a financial return.

Figure 5 Precinct energy costs

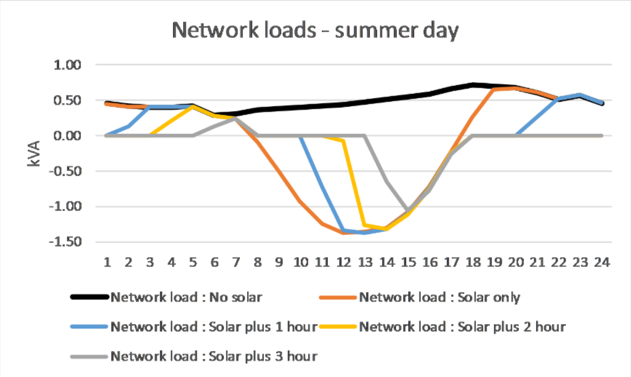


The analysis shows that there remains a significant benefit to householders in both of these cases, offering 35-50% savings (commercial provider), and 50-60% savings (community provider) over 30 years compared to purchasing energy from SWIS retailers. This is due essentially to the lower capital cost of equipment available at this scale. As in the Base case, battery storage between 1 and 2 hours x installed PV capacity offers the most financially attractive outcome.

Network loads

The deployment of solar PV without storage radically changes the overall network load profile, although has only a marginal impact on peak evening loads. Instead of importing power at all times, households export power to the SWIN during daylight hours. The export loads in this case exceed the normal import loads. The incorporation of storage reduces the magnitude of, but does not eliminate, the export load. Figure 6 illustrates the resulting network load for a single dwelling with and without solar and batteries for a typical summer day.

Figure 6 Network loads - summer day



Possible governance arrangements

Customer self-supply
The simplest way of delivering a net zero carbon precinct at Knutsford would be to mandate solar PV under the conditions of sale / design guidelines for all lots developed.

While this may be an option for the landholdings of LandCorp and the City of Fremantle, there are a number of private landholders who may not be prepared to sell sub-divided lots under such arrangements. Mandating the requirement generally across the precinct would require additional provisions to apply to the development application / approval process.

The Energy Village
The energy strategy developed by Josh Byrne and Associates (JBA) for Lot 1819 is a small grid-connected microgrid that resembles the Energy Village model described by Balance in a previous report. Owners of the 36 townhouses will own their own 5 kW solar PV systems (180 kW in total), which together with a commonly owned 670 kWh battery, will sit behind the Western Power meter. The strata company (body corporate) will act as the '*Energy Village Council'*, retail energy to building owners / occupiers and import energy from a SWIS retailer as required to supplement the on-site generation.

Assuming the strata company is an exempt retailer, it will be able to derive tariff arrangements for customers, subject to the requirement for prices not to exceed the equivalent Synergy tariff.

It is possible that other future land parcels at Knutsford intended for strata or community title could be developed in a similar way as proposed for Lot 1819. Again, there are a number of private landholders who may not be prepared to replicate these arrangements for strata or community title developments 'behind' a master meter on their land. It is also likely that the precinct will continue to contain freehold 'green title' lots, which under present regulation would need to be connected to the SWIS with energy supplied by Synergy.

Precinct-wide microgrid
It is electrically possible to isolate the entire precinct 'behind' a master meter and service that area under the *commercial provider* model. LandCorp is developing their Peel Business Park industrial development to operate in this way, the first in which a microgrid will service green-title landowners.

This project is showing that it is possible for a commercial service provider to provide renewable energy, supplemented by the SWIS, at a lower cost to the economy and the customer. The cost benefits derive from the lower cost of renewable generation and the avoidance of the Western Power network charges for distributing this power to customers.

However, the Knutsford precinct is already serviced by the Western Power network and is within the SWIS and accordingly, it is not viable to construct a private precinct-wide network. With Western Power involvement it would be possible to develop a 'virtual' network in which power generated within one development is notionally transported to another using peer-to-peer trading. This approach is currently being trialled under the RENeW Nexus project in Fremantle using Power Ledger's blockchain-enabled platform. In that case the residents are directly trading their solar energy with their neighbours, but this role could be undertaken by the strata company for such developments at Knutsford. The commerciality of a 'virtual' renewable energy microgrid at Knutsford would be dependent on the willingness of Western Power to participate, and the charges they would apply for transporting the energy.

Subject to the results of the RENeW Nexus trial in Fremantle, the virtual network solution should be further examined.

Recommendations

Swanbourne Street as a catalyst project
The Swanbourne Street structure plan area at the west of the Knutsford precinct has the largest lots in single ownership (by LandCorp). This site represents a unique opportunity for a commercial provider to develop the site with an embedded microgrid and realise the opportunities identified in this study for energy supply to the development to be both net zero carbon and cheaper than conventional supply. The developer and microgrid operator could either be the same entity, or two (or more) firms in partnership.

Although there are several options, the most likely model to be both financially viable for the developer / microgrid operator, and safe, reliable and cost effective for customers would be as follows. The developer would:

- Construct and retain ownership of the electricity distribution system 'behind' a Western Power master meter at the boundary of the site;
- Install and maintain solar rooftop solar PV which is capable of generating sufficient renewable energy to supply the annual energy needs of the site, importing from the SWIS as necessary;
- Install and maintain battery storage sufficient to optimise energy import and export from the site; and
- Act as a default electricity retailer to occupants.

It is recommended that a number of the proposed initiatives of the Peel Business Park are adopted to ensure competitiveness and customer protections by requiring the microgrid operator to:

- Obtain a distribution and retail licence (with appropriate exclusions) to ensure customers have the same rights and protections as SWIS connected customers;
- Facilitate customer purchases from SWIS retailers should they so desire; and
- Provide information to customers to compare their cost of electricity to the relevant Synergy regulated tariffs.

It is recommended that LandCorp include this scenario in the Expression of Interest documents.

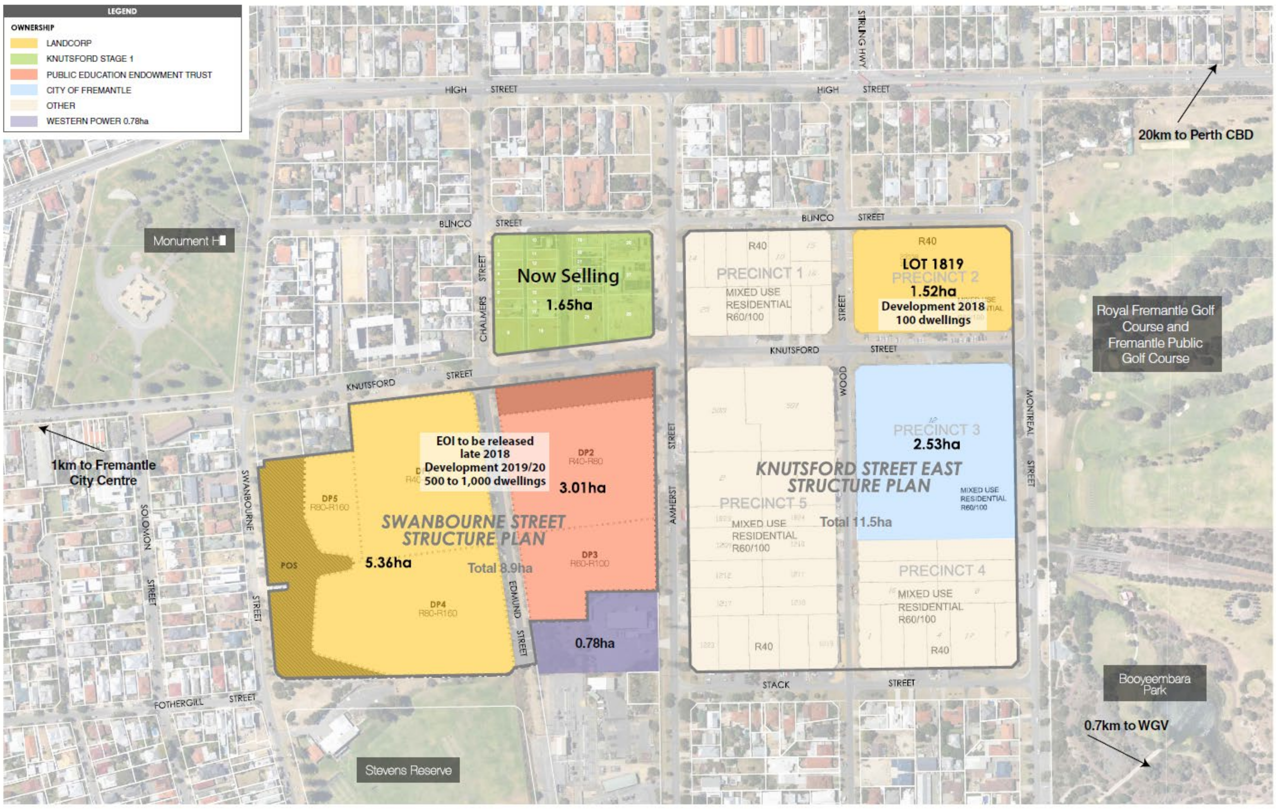
Beyond Swanbourne Street
Again, depending on the timing of development of the other Knutsford precinct sites and the willingness of landholders to participate, there are other potential ways the microgrid could expand.

1. The microgrid operator could replicate the arrangements on other landholdings in partnership with interested landowners intending to develop strata or community title developments, which offer 'behind-the-meter' opportunities.
2. The microgrid operator could facilitate peer-to-peer trading (either between microgrids, or between their microgrid and individual green title lots) using the Western Power network. These arrangements are subject to the learnings from the RENeW Nexus project in Fremantle, and the commerciality would be subject to Western Power's charges for this service.

1. Scope of Study

The Knutsford precinct (Figure 7) includes the landholdings of LandCorp, the City of Fremantle and Western Power, as well as other private owners. The development area has potential for approximately 1,000 new dwellings and more than 2,000 new residents, and is guided by the Swanbourne Street and Knutsford Street East Structure Plans. LandCorp's Lot 1354 is now selling and expressions of interest have been sought for Lot 1819 to construct up to 36 town homes. Expressions of interest for a master developer for the Swanbourne Street Precinct will be released in late 2019 with development able to commence on 8.3 hectares of vacant, remediated land by 2021. The vision for this development is for a high quality residential precinct with substantial new public open space along Swanbourne Street that responds to the City of Fremantle's Green Plan.

Figure 7 Knutsford precinct



LandCorp and the City of Fremantle intend to build on the sustainability features in the successful White Gum Valley (WGV) project, with initiatives including renewable energy, battery storage, peer-to-peer energy trading, electric vehicle fast charging, and a shared electric vehicle scheme, as well as water initiatives

This paper seeks to identify the most prospective technical and commercial solution to the provision of renewable electrical power to the Knutsford precinct, recognising the diverse land ownership and long development timelines. Renewable energy is also the key enabler for other potential initiatives such as a district energy system, wastewater recycling and electric vehicle charging. The scope of the study is as follows:

- Develop an approximate electrical energy demand for the site;
- Develop a 'net zero carbon' concept for the precinct, based on renewable energy sources and battery storage;
- Explore potential governance arrangements for the strategy, including the commerciality for a service provider and costs to customers; and
- Recommend an implementation pathway.

The research reported here builds on the work carried out to date by Western Power (2017) and Balance Utility Solutions (2018) for Knutsford, reflects the previous studies by AUDRC and Kinesis (2015), and incorporates the learnings from LandCorp's landmark renewable energy microgrid at the Peel Business Park.

In particular the potential for a major integrated master development at the Swanbourne Street precinct to catalyse the renewable energy project has been explored.

2. Electricity demand

The approximate electricity demand for the precinct is very difficult to accurately predict, given that the yield and built form are indeterminate, and the penetration of electric vehicles is uncertain. Previous studies have resulted in a variety of approaches being adopted.

The study for LandCorp and City of Fremantle for the proposed amalgamated site incorporating LandCorp's Lot 1819 and the City's depot site by Kinesis assumed the demands set out in Table 2[1].

Table 2 Estimated electricity demand - 294 dwellings (Kinesis)

per dwelling demands	**Electricity - kWh/year**	**Gas -MJ/year**	**All electric kWh/year**	
Hot water supply	-	6,564	548	
Space heating supply	323	-	323	
Space cooling supply	287	-	287	
Lighting	144	-	144	
Cooking equipment	128	861	199	
Fridge	316	-	316	
Dishwasher	170	-	170	
Clothes washer	284	-	284	
Clothes Dryer	738	-	738	
Ventilation	41	-	41	
Other (including plug-in loads)	663	-	663	
	3,094	7,425	3,714	
			10	units/day
for 294 dwellings				
Common area lighting	32			
Carpark lighting	79			
Carpark ventilation	160			
	271			

Balance Utility Solutions' demand assessment assumed 400 single dwellings and 600 apartment dwellings, utilising the unit demands set out in Table 3.

1 Kinesis assumed the lots were serviced by electricity and gas. The author has estimated equivalent 'all electric' demands.

Table 3 Estimated electricity demand (Balance)

	Single Dwellings		Apartment Buildings	
	kWh pa		kWh pa	
LED's	263		139	
Air Conditioner	383		319	
Fridge	246		110	
Computer	256		292	
Cook Top	365		365	
Hot Water	365		365	
Microwaves	164		164	
TVs	131		88	
Power Points	146		110	
	2,320		1,951	
	6.355	units/day	5.345	units/day
Common areas			438	

Josh Byrne and Associates (JBA) energy strategy for Lot 1819 made the following assumptions (Table 4) for the 36 townhouses, 12 guest suites and associated loads. The in-house demands (average 15 units/day) assumed by JBA are significantly higher than the previous studies.

Table 4 Estimated electricity demand (JBA)

	kWh pa				
Townhouses	197,100	5,475	kWh / dwelling	15	units/day
Guest suites	27,906	775	kWh / dwelling	2.1	units/day
Ext lighting	1,314				
Bore pump	1,680				
EV s	30,000				
	258,000				

Based on these studies and previous work by the author, the following approximate demands have been assumed in this study (Table 5), reflecting a yield of 400 single dwellings and 600 apartment dwellings as assumed by Balance.

Table 5 Estimated electricity demand for the present study

		no.
Townhouses		400
Apartments		600
		1,000
In-house demands	kWh pa	
Townhouses	3,400	1,360,000
Apartments	2,400	1,440,000
		2,800,000
Common areas	440	264,000
Total dwellings		3,064,000

In addition to these loads, the charging of electric vehicles (EVs) has also been considered. According to the Royal Automobile Club (RAC) the average annual travel for a passenger vehicle in Western Australia is 11,000 km[2]. Assuming some of this travel is for work (where charging may occur elsewhere), some for holidays and some for weekends, the electricity demand for the precinct is set out in Table 6, based on an average energy demand of 0.16 kWh/km (Wu 2013). It has been assumed that 30% of dwellings will have electric vehicles.

[2] https://rac.com.au/car-motoring/info/state_wa-transport-infographics

Table 6 Estimated electricity vehicle charging demand for the present study

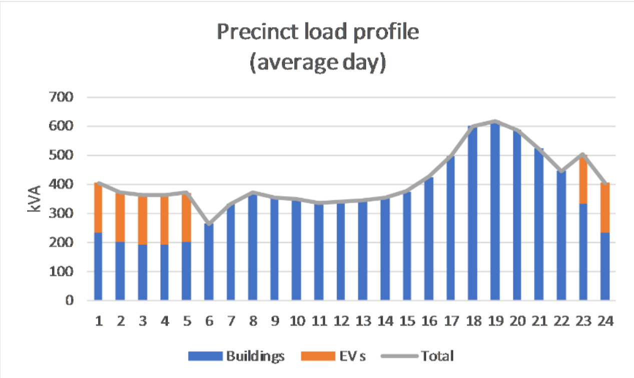
			km pa	kWh pa	kWh/day	
W/days	Assume 223 days/year @ 27km		6,021	626		35% charged elsewhere
Hols	Assume 28 days/year @ 100km		2,800	448		
W/ends	Assume 114 days/year @ 20km		2,280	365		
			11,101	1,439	3.94	
	30%	Penetration				
	1,000	dwellings	3,330,300	431,695	1,183	

For simplicity it has been further assumed that vehicles are charged overnight for 7 hours from 11pm to 5am.

Combining building and EV loads give an annual demand for the precinct of 3,608 MWh. It is stressed that this is a very approximate estimate and will need to be updated when further information is available on the nature of development.

Based on analysis of the load profiles from South West Interconnected System (SWIS) data for residential premises an approximate demand profile has been established for the precinct (see Figure 8).

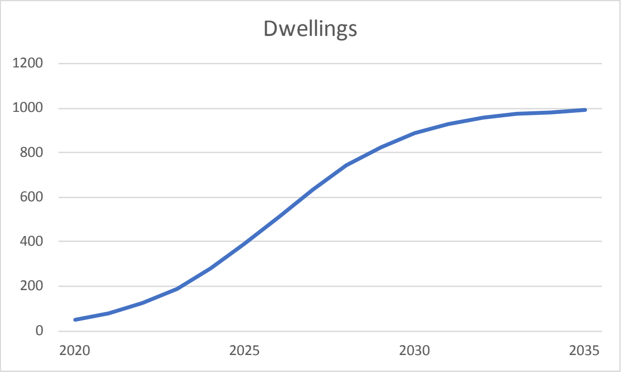
Figure 8 Precinct load profile (average day)



3. Development program

For the purposes of this study a development program has been assumed, and is shown in Figure 9. The timing of development is important to testing the commerciality of renewable energy scenarios as the cost of the technology will continue to reduce in the period to 2050.

Figure 9 Development timeline



4. Net Zero Carbon strategy

Devising an approach to net zero carbon for the precinct requires consideration of a number of issues. The One Planet Living framework[3] objective for their energy element is:

> *Zero carbon - Making buildings and manufacturing energy efficient and supplying all energy with renewables.*

It is important to note that this objective relates only to stationary energy, i.e. that energy consumed in buildings and facilities, and does not include energy consumed in vehicles. In this study the objective has been set in the following terms:

- Electricity is the source of all stationary energy for the precinct, i.e. no natural gas;
- Sufficient renewable energy is generated within the precinct to meet the aggregate annual electricity demand;
- The precinct retains an electrical connection to the Western Power network, from which energy is imported when renewable sources are unavailable, and to which energy is exported when generation is excess to demand.

Under these arrangements, the amount of energy imported from the Western Power network, is completely offset by the amount of renewable energy exported, thereby substituting an equivalent amount of energy generated on the South West Interconnected System (SWIS)[4]. The greenhouse gas emission factor for the SWIS is presently 0.7 kg CO_2-e/kWh (Department of the Environment and Energy 2018).

For the project to qualify as '*supplying all energy with renewables'* it would be necessary for energy imports from the SWIS to be 100% renewable by purchasing under the *GreenPower* scheme[5]. The current cost of purchasing Synergy's *Natural Power* product under this scheme is 7.0568 c/kWh.

However, it is important to note that under the Renewable Energy Target scheme, such an approach may not be considered as fully renewable depending on the treatment of certificates created under the scheme. This is discussed later in this paper.

---

[3] https://www.bioregional.com/oneplanetliving/
[4] In fact, as the SWIS sources include 3.7% of renewable generation, this approach is slightly carbon positive (AEMO 2018).
[5] https://www.greenpower.gov.au/

5. Renewable energy and storage

In this study it has been assumed that the form of renewable energy is rooftop solar PV. Supplementing rooftop solar with a ground mounted single axis tracking array and / or wind energy is also possible and may be viable depending on the implementation mechanism. In order to reduce the quantity of energy imported from the SWIS during peak periods, battery storage has also been included as an element of the strategy. It is noted that LandCorp's Lot 1819 development will include a 600 kWh battery.

5.1 Rooftop solar PV

The capacity factor for rooftop solar in the metropolitan area is around 18.3% (AEMO 2018) meaning that some 1,600 kWh pa is generated from each kW of installed nameplate capacity. In order to generate sufficient energy to meet the annual demand of 3,608 MWh some 2,250 kW of rooftop solar PV would be required, i.e. 2.25 kW per dwelling on average.

The daily generation and average monthly generation of the rooftop arrays is set out in Figure 10 and Figure 11.

Figure 10 Rooftop solar - daily generation

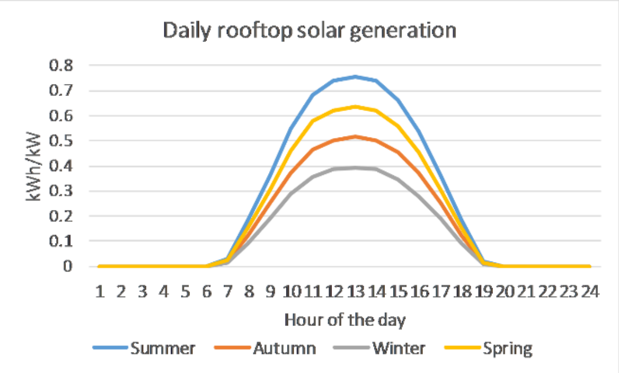
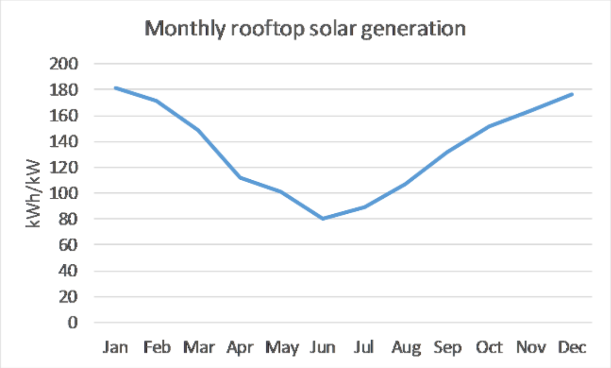


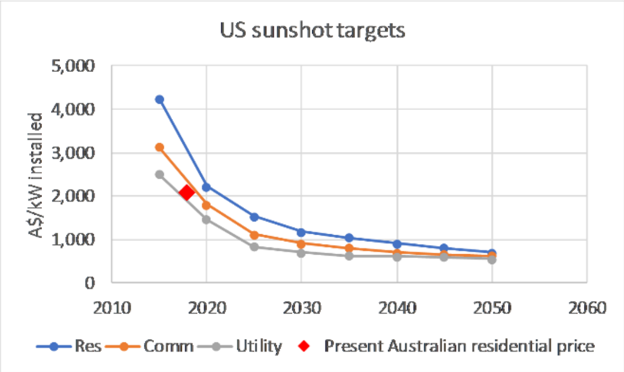
Figure 11Rooftop solar - monthly generation



5.2 Unit costs

The unit costs of solar PV and battery storage systems (BESS) have declined significantly over the recent past and are projected to continue to fall over the coming decades as volumes grow and economies of scale are realised. The assumptions on unit costs adopted in this study are derived from estimates from the U.S. National Renewable Research Laboratory (Cole et al 2017). Figure 12 illustrates the projections of the Sunshot program[6] converted to Australian dollars[7], and the present Australian prices[8]. This shows that Australian residential prices are somewhat lower than in the U.S., probably driven by the high uptake of residential solar PV in Australia. For the purposes of this study the cost curves in Figure 13 have been derived.

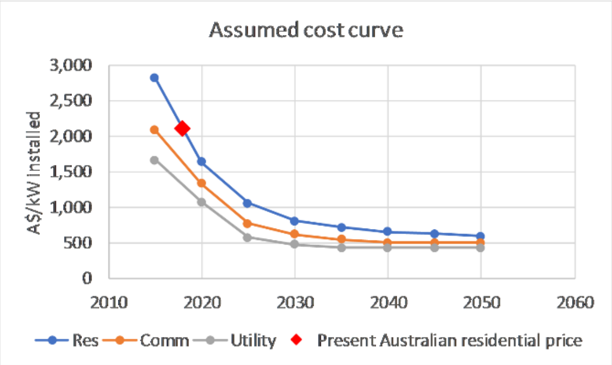
Figure 12 Unit cost of solar PV (US Sunshot program)



[6] https://www.energy.gov/eere/solar/sunshot-2030
7 At A$1.4/US$

8 https://www.solarchoice.net.au/blog/solar-power-system-prices (accessed 15/12/2018)

Figure 13 Assumed unit costs of solar PV



The Sunshot program projections for battery storage systems (BESS) include 'reference' and 'low' value estimates. As shown in Figure 14. Australian prices are tracking closer to the low values. Figure 15 shows the assumed cost curve adopted for this study.

Figure 14 Unit costs of BESS (US Sunshot program)

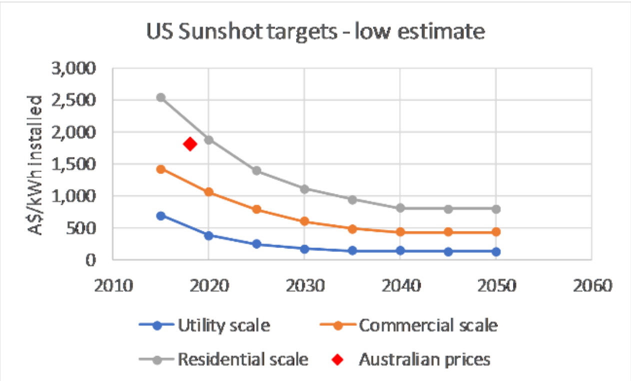
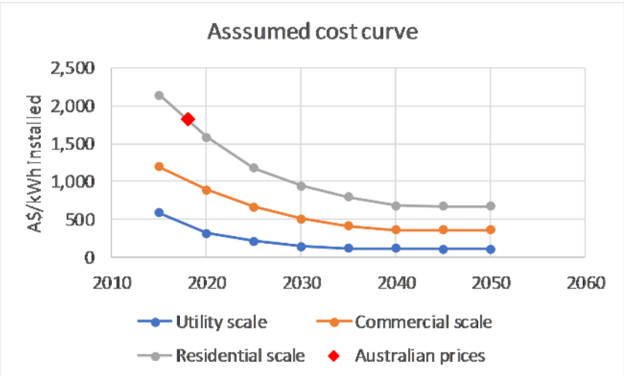


Figure 15 Assumed unit cost of BESS



9 Assuming the current market value of STCs around $34.50

5.3 Renewable energy target (RET) scheme

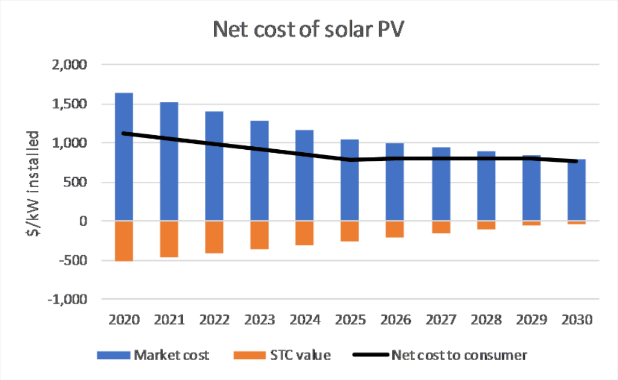
The federal government's RET scheme involves the creation of certificates representing 1 MWh of renewable energy generation. Liable retailers are required to acquit both small-scale and large scale certificates covering a percentage of the energy they sell to SWIS customers. The percentages are set each year by the Clean Energy Regulator (CER) based on their determination of the renewable generation required to achieve the RET, which is 33,000 gigawatt hours (nationally) of additional large scale renewable electricity generation by 2020. The scheme will continue to 2030.

5.3.1 Small scale technology certificates (STCs)

STCs support small-scale installations of solar photovoltaic (PV) panels, wind turbines, hydro systems, solar water heaters, and air source heat pumps. Household rooftop solar PV systems of no more than 100 kW are eligible. Purchasers of solar PV systems receive the benefit of multiple years of future generation which is set by the CER according to the location (i.e. solar generation potential) and the period to 2030. In Perth the number of certificates is equal to 1.382 x the deeming period, which will be 12 years in 2019, reducing to 1 year in 2030. The STC benefit in 2020 will be around $550[9], reducing the cost of solar PV from around $1,650 to $1,100 / kW. The financial benefit accrues to the customer and in most cases is deducted from the price at point of sale by the supplier. The supplier is then able to sell the certificates to liable energy retailers to cover their obligation to meet the annual 'small-scale technology percentage' of the energy they sell, 17.08% in 2018.

As the RET expires in 2030, the value of these certificates will reduce linearly over the intervening period, increasing the net purchase price of private rooftop solar PV. However, as the base cost of systems is also likely to reduce over the same time in line with Figure 13, the net installed cost to consumers is likely to continue to fall (see Figure 16).

Figure 16 Solar PV unit costs



5.3.2 Large scale technology certificates (LGCs)

The LGC market operates somewhat differently. Solar PV energy generators of more than 100 kW create LGCs for every 1 MWh of renewable generation. Liable retailers must acquit sufficient LGCs in each year to account for the renewable percentage set annually by the CER, 16.06% in 2018. The price of LGCs is set by the market, and is currently around $62.25.

6. Implementation scenarios

Two scenarios to implement a Net Zero Carbon precinct have been considered.

6.1 Customer self-supply scenario

The base case scenario assumes all dwellings, whether strata or green title, either purchase their own rooftop solar PV arrays or purchase dwellings in buildings with solar PV and battery storage are installed as part of the development cost. These cases represent the reference case against which commercial alternatives are considered.

The energy charges for each scenario are based on the 2018 regulated Synergy time of use tariff for households, summarised in Table 7 below. A time of use tariff yields lower charges for the demand profile in Figure 8 than the alternative flat (A1) tariff for customer owned solar PV.

Table 7 Synergy home tariffs

	Smart home[10] (time of use)
Supply charge (c/day)	101.5493
Energy charge (c/kWh)	
Energy charge – peak period	53.8714
Energy charge – shoulder period	28.2139
Energy charge – off-peak	14.8405

Applying this tariff to the energy demands set out in Table 7 establishes the annual costs to homeowners without solar PV.

Single dwellings	$1,533 pa
Apartment dwellings	$1,352 pa

Home owners are also eligible to receive a feed-in tariff under the Renewable Energy Buyback Scheme (REBS) which is currently 7.135 c/kWh of energy exported to the SWIS.

10 https://www.synergy.net.au/Your-home/Energy-plans/Smart-Home-Plan?tid=Energy-plans:side_nav:Smart%20Home%20Plan

6.1.1 Solar PV without energy storage

Assumed solar PV systems:

Single dwellings	2.40 kW
Apartment dwellings	2.04 kW

No battery storage is included in this scenario.

Under these arrangements it is assumed that the value of small-scale technology certificates (STCs) under the Renewable Energy Target (RET) scheme would be deducted from the purchase price at the time of sale.

6.1.2 Solar PV plus battery

This scenario assumes battery storage is incorporated in each single dwelling or shared in apartment buildings. As there are some losses involved in battery charging, the solar PV capacity has been increased slightly to ensure that energy exports continue to equal energy imports (in order to maintain carbon neutrality).

Various levels of BESS capacity have been considered under this scenario.

6.1.3 Customer self-supply modelling and analysis

In order to determine the quantity of energy that would be imported and exported from the precinct under the generation scenarios set out above, dynamic modelling was undertaken using a bespoke systems model using the Vensim software[11]. The model simulates energy demand and generation, battery charging and discharging for each hour of a typical day in each month. Each scenario was modelled with battery storage representing the solar capacity in kW, times 1, 2 and 3 hours of storage respectively.

The financial analysis period is 30 years and assumes that solar PV is replaced every 15 years and BESSs every 10 years. The analysis assumes:

- The import tariff and supply charge each increase by 1.5% pa; and
- The unit cost of solar PV and batteries follow the trajectories set out in Figure 13 and Figure 15 for residential scale equipment.

The full results of the Base case simulation runs are included in Appendix A and summarised in Table 8 and Figure 17 for single dwellings. The results for apartment dwellings are very similar.

The introduction of battery storage significantly reduces energy imports at peak times in the afternoon and evenings. However, the benefit is offset by the capital

11 https://vensim.com/

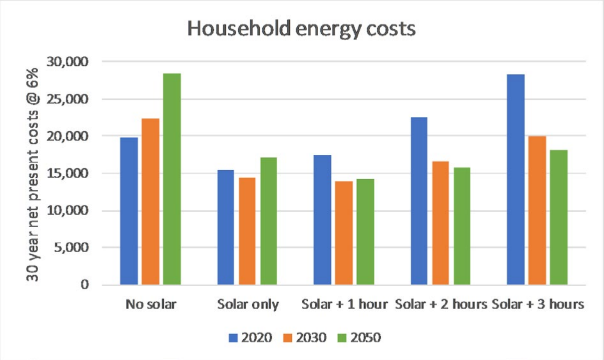
costs of storage. Accordingly, at present prices for solar PV and batteries, and with current tariffs, there remains a marginal business case for investment in battery technology. Presently, solar PV without energy storage is the cheapest option in life cycle cost terms, although 1 hour of storage is still economic in comparison to SWIS network supplied energy. However, after 2030, solar PV plus 1 hour of battery storage is likely to become the most economic option, with 2 hours of storage only marginally more expensive. By 2050, 1 and 3 hours of storage will be competitive with solar only.

Table 8 Customer self-supply analysis

				No solar	Solar only	Solar + 1 hour	Solar + 2 hours	Solar + 3 hours
						Imported kWh		
			Off-peak	1,331	1,331	1,285	721	361
			Weekday peak	1,011	562	75	19	13
			Weekday shoulder	775	104	104	103	66
			Weekend shoulder	714	266	71	49	32
			`	3,832	2,263	1,535	891	472
			Energy charge ($)	1,162	605	280	160	88
			Supply charge ($)	371	371	371	371	371
				1,533	975	651	530	459
Customer purchases in 2020								
1,633	$/kW	Solar	kW		2.39	2.39	2.43	2.48
1,585	$/kWh	Battery	kWh		0.00	2.39	4.87	7.44
		Solar	(15 yr replacement)		3,897	3,897	3,975	4,053
		Battery	(10 yr replacement)		0	3,782	7,715	11,799
			Capital ($)		3,897	7,679	11,690	15,852
			Annual costs ($)	1,533	975	651	530	459
7.135	c/kWh		REBS income	0	161	110	64	34
				1,533	814	542	467	425
			Annual savings ($)	0	719	992	1,066	1,108
2020 purchases			30 year costs ($)	45,993	32,890	35,104	43,828	53,953
			30 year NPC@6% ($)	19,908	15,386	17,528	22,558	28,243
			30 year savings (%)	0	28	24	5	-17
			LCOE (c/kWh)	40.01	30.92	35.23	45.34	56.76
2030 purchases			30 year costs ($)	51,592	32,133	29,505	34,162	40,326
			30 year NPC@6% ($)	22,332	14,445	13,950	16,644	20,016
			30 year savings (%)	0	38	43	34	22
			LCOE (c/kWh)	44.88	29.03	28.04	33.45	40.23
2050 purchases			30 year costs ($)	65,629	38,857	31,658	34,163	38,739
			30 year NPC@6% ($)	28,408	17,105	14,307	15,727	18,057
			30 year savings (%)	0	41	52	48	41
			LCOE (c/kWh)	57.09	34.38	28.75	31.61	36.29

The financial case for homeowners is illustrated graphically in Figure 17.

Figure 17 Customer self-supply analysis - 30 year household energy costs



6.2 Service provider scenario

In this scenario, the same overall solar PV and BESS configurations are retained as in the Base case, but the precinct is serviced by a provider that invests in, and retains ownership of the equipment at each individual premise or strata complex. The key differences in the assumptions for this scenario compared to the Base case are:

- Solar and BESS are installed as required as the precinct develops (in accordance with Figure 9);
- Equipment is purchased by the service provider at commercial unit prices instead of residential unit prices;
- Energy is not exported to the SWIS network so no revenue is obtained;
- Sub-meters are each dwelling are required;
- Equipment is owned, operated, maintained and replaced by the service provider;
- Customers are charged at a tariff and supply charge that recovers the capital and operating costs, including for energy imported from the SWIS network.
- Charges for energy and supply are increased annually, at the same rate as the applicable SWIS tariff, i.e. 1.5% pa.
- The service provider pays (4.5%) and receives interest (3.0%) depending on the account balance of the service.

It has been assumed that solar energy is produced and consumed 'behind the meter' and therefore SWIS based charges are incurred only for energy imported from the SWIS network. The same cost and rate increase as assumed in the Base case has been (conservatively) retained.

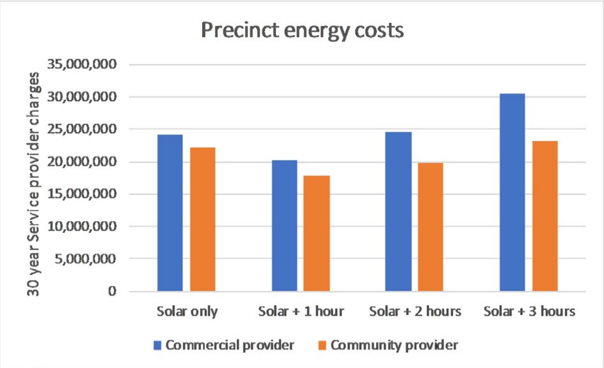
Two variations have been applied to this scenario. In the first, the service provider is a commercial firm that requires a financial return from their operations. It has been assumed that a 15% internal rate of return (IRR) applies to this case. In the second scenario, it is assumed that the service is a community operated scheme, and accordingly is not required to make a financial return. It has been assumed in this case that charges are sufficient to recover costs, i.e. that the Net Present Value of the cash flows is zero at a discount rate of 6%.

The results of the analysis are shown in Table 9 and Figure 18.

Table 9 Service provider case analysis

	Solar only	Solar + 1 hour	Solar + 2 hours	Solar + 3 hours
Commercial provider				
Initial tariff (c/kWh)	13.81	10.08	12.40	15.81
Initial service charge (c/day)	52.50	56.01	70.19	86.01
30 year NPV @ 6% ($)	1,000,002	1,170,862	2,340,314	3,509,897
30 year normal customer charges ($)	47,274,962	47,274,962	47,274,962	47,274,962
30 year service provider charges ($)	24,198,234	20,265,323	24,634,565	30,477,472
30 year customer savings ($)	23,076,728	27,009,639	22,640,397	16,797,490
	49%	57%	48%	36%
Community provider				
Initial tariff (c/kWh)	12.52	8.74	9.76	11.81
Initial service charge (c/day)	47.57	48.61	55.27	64.24
30 year NPV @ 6% ($)	0	0	0	0
30 year normal customer charges ($)	47,274,962	47,274,962	47,274,962	47,274,962
30 year service provider charges ($)	22,110,395	17,843,248	19,812,131	23,254,804
30 year customer savings ($)	25,164,567	29,431,714	27,462,831	24,020,158
	53%	62%	58%	51%

Figure 18 Service provider analysis - 30 year precinct energy costs

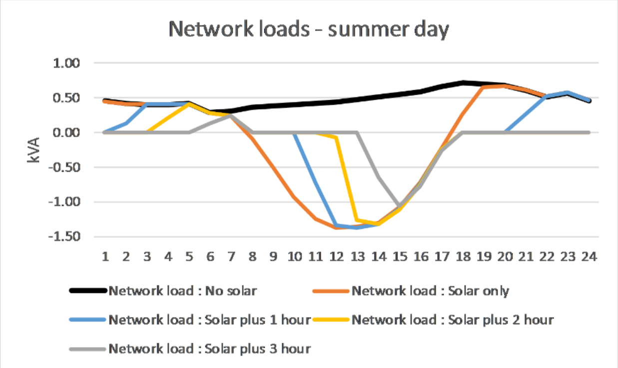


The analysis shows that there remains a significant benefit to householders in both of these cases, offering 35-50% savings (commercial provider), and 50-60% savings (community provider) over 30 years compared to purchasing energy from SWIS retailers. This is due essentially to the lower capital cost of equipment available at this scale (see Figure 13 and Figure 15). As in the Base case, battery storage between 1 and 2 hours x installed PV capacity offers the most financially attractive outcome.

6.3 Network loads

The deployment of solar PV without storage radically changes the overall network load profile, although has only a marginal impact on peak evening loads. Instead of importing power at all times, households export power to the SWIN during daylight hours. The export loads in this case exceed the normal import loads. The incorporation of storage reduces the magnitude of, but does not eliminate, the export load. Figure 19 illustrates the resulting network load for a single dwelling with and without solar and batteries for a typical summer day.

Figure 19 Customer self-supply analysis - network loads



It can be seen that at least two hours of storage are required to eliminate the evening peak load and hence provide the most beneficial outcome for reducing peak power on the SWIN. However, export loads are higher in all cases than import loads. At present, these negative network loads merely reduce the overall positive load in the local distribution network. However, when high penetrations of solar occur in a particular area, as proposed here, operation of the network will need to take this into account.

7. Regulatory issues

Each of the scenarios has implications for customers and Western Power, the network operator of the SWIS. In order to understand these, it is necessary to outline how the electricity industry is structured and regulated in Western Australia.

7.1 Electricity industry

The metropolitan region is part of the South West Interconnected System (SWIS) which is operated by the Australian Energy Market Operator (AEMO). Following disaggregation of the electricity industry in Western Australia in 2006, the system has three separate service elements:

- Generation;
- Transmission and distribution; and
- Retailing.

Generation and retailing are open to any licenced market participants but remain dominated by the state-owned Synergy who provide about half of the energy sold to the one million household and business customers in the SWIS.

The transmission and distribution network, known as the South West Interconnected Network (SWIN) is operated by the state-owned Western Power Corporation. Under conventional arrangements, Western Power install a meter with a unique National Meter Identifier (MNI) at the boundary of customers' properties. All transactions in the market utilise the data from these meters, which remain the property of Western Power.

The Wholesale Electricity Market (WEM) in the SWIS is operated by the AEMO under the WEM rules, controlled by the Minister for Energy who is advised by the Public Utilities Office (PUO). Generation, distribution and retail licences are granted and enforced by the Economic Regulation Authority (ERA). Generation and retail licences are awarded with conditions that require the licensee to operate according to a complex set of rules, aimed at ensuring:

- Safety and reliability;
- Competition between providers; and
- Customer protections are in place (including the Energy Ombudsman).

To supply electricity to homes or businesses on the SWIS, retailers must purchase electricity from a generator directly or indirectly through the Wholesale Electricity Market, which facilitates wholesale electricity sales within the SWIS between sellers (generators and demand side management facilities) and buyers (retailers and large users). Generators and retailers must operate within the WEM rules, and also comply with the Federal Government's RET scheme[12] (see Section 5.3 above).

Under the present arrangements, only Synergy can supply customers with an annual demand of no more than 50 MWh per annum. All other customers are 'contestable', i.e. they may purchase electricity from any retailer. There are also a range of protections offered to customers (residential or commercial) who consume no more than 160 MWh per annum under the *Code of Conduct for the Supply of Electricity to Small Use Customers*.

These arrangements have yet to be adapted to deal with the full consequences of private generation 'behind-the-meter'. The State parliament has instigated a Microgrid inquiry which is currently preparing its report. Proposals for precinct scale renewable energy at Knutsford must take this changing landscape into account.

7.2 Customer self-supply

Householders and businesses wishing to install private solar systems 'behind-the-meter' require permission from Western Power to ensure that the systems (particularly inverters) are technically suitable and, if energy export is intended, that the network upstream of premises is capable of transporting the power. Larger scale systems in commercial properties may require augmentation of the network at their cost, and this has constrained growth in larger systems to date. Without storage, solar systems of even medium size are likely to create higher instantaneous power demand on the network when exporting than a conventional import load (see Appendix A).

Subject to obtaining approval from Western Power, self-supply consumers take full responsibility for the electrical network inside their boundary, and any solar PV, inverters and batteries. They are also responsible for the financial implications of maintenance and replacement of their systems.

7.3 Embedded networks

The term 'embedded network' refers to a private network 'behind the (Western Power) meter' that services multiple customers, typically in apartment blocks, retirement villages, caravan parks and shopping centres. In traditional embedded networks the owner 'on-sells' electricity[13] from a retailer to customers. The customer may or may not have a separate sub-meter on their premises. In such cases the owner is usually exempt from holding a retail licence under the *Electricity Industry Exemption Order 2005*. Exemptions are granted by the

12 Generators create certificates under the scheme and retailers acquire and use those certificates to meet their obligations.

13 https://www.treasury.wa.gov.au/uploadedFiles/Site-content/Public_Utilities_Office/Licence_exemption_applications/On-supply-of-electricity-in-embedded-networks.pdf

PUO and the ERA plays no role in regulating the exempt retailer who is usually the owner or manager of the premises.

Under an exemption, residential customers in the SWIS cannot be charged more than the equivalent Synergy charges, but this restriction does not apply to commercial customers.

Customers who are serviced by an exempt retailer do not have the benefit of the range of protections offered by the requirements under which retailers hold licences issued by the ERA in the SWIS. Complaints or disputes cannot be referred to PUO, nor do customers have access to the Energy and Water Ombudsman scheme.

7.4 Microgrids

A microgrid can be described as an embedded network that also has distributed energy resources within it, i.e. generation and / or energy storage. Microgrids can either be electrically connected to the broader network and / or operate in island-mode. The operator of a microgrid is therefore not just on-selling and reticulating power from a retailer to a customer, it is also generating power for consumption onsite and often exporting power to the broader network.

8. Net Zero Carbon and the Renewable Energy Target

The RET scheme has slightly different requirements for small and large generation. For simplicity the large scale certificate (LGC) system is used here to explain the implications of the RET for the net zero carbon aspirations of the project.

Under the RET, renewable energy generators ‘create’ a certificate for every 1 MWh of power generated. In so doing they create monetary value equal to 1 MW x the market price of LGCs at any time (presently around $62 per LGC). Liable retailers are required to acquit LGCs to cover the renewable energy percentage of their sales for any given year (presently 16%), meaning that 16 LGCs must be acquitted for every 100 MWh of energy sold to customers. If a generator is also a retailer, they acquit a portion of the certificates they themselves have created. Otherwise, retailers have to buy the certificates from the market. The scheme effectively subsidises renewable energy through this process.

The financial analysis set out in Section 6 assumes that the certificates that are created are sold, either to the supplier of private owners of solar PV, or to the market in the case of a commercial or community provider. It has been argued that in such arrangements, the ‘renewable’ content of the energy has also been sold and is properly claimed by the purchaser rather than the seller, thus avoiding double-counting. An alternative would be to voluntarily surrender all certificates created in the precinct, thereby removing the certificates from the pool and effectively contributing to renewable energy beyond the RET. This in effect increases the cost of renewable energy, noting that the scheme is due to close in 2020, and the value of STCs will reduce (as noted in Section 5.3.1).

If certificates are sold, as assumed in this study, communications and marketing for the project should ensure that it is the net zero carbon objective that applies (i.e. supplying all energy with renewables), rather than making any claims under the RET.

9. Possible governance arrangements

9.1 Customer self-supply

The simplest way of delivering a net zero carbon precinct at Knutsford would be to mandate solar PV under the conditions of sale / design guidelines for all lots developed.

While this may be an option for the landholdings of LandCorp and the City of Fremantle, there are a number of private landholders who may not be prepared to sell sub-divided lots under such arrangements. Mandating the requirement generally across the precinct would require additional provisions to apply to the development application / approval process.

9.2 The Energy Village

Balance Utility Solutions have prepared a report entitled 'Beyond White Gum Valley' as a guide for precinct development. In this document Balance define a smart embedded network.

A 'smart embedded network' (SEN) has additionally ability to integrate, monitor and optimise (and potentially peer-to-peer trade) distributed energy, storage, load and demand, while maintaining interaction with the main grid.

Integrating battery energy storage with solar PV within the embedded network, either behind the customer meter (rooftop solar PV and household storage) or in front of the customer meter (embedded generation and central shared storage) means the embedded network's community can maximise full use of solar electricity surpluses, before drawing from the main grid.

Balance's 'Energy Village' concept is essentially a SEN controlled by the owners of the premises serviced by that SEN, effectively the customer self-supply scenario described in Section 6.1.

All the energy producers and consumers interconnected to the village's SEN are considered a 'villager' and the village is governed by specific energy rules, a 'Village Council'. The success of a village relies on the balance of power between the villagers; individual interest vs community interest. Its goal is to create and share a set of efficient, effective and affordable energy resources which benefit the individuals within the village and the village as a whole.

The energy strategy developed by JBA for Lot 1819 is a small grid-connected microgrid that resembles the Energy Village model described by Balance. Owners of the 36 townhouses will own their own 5 kW solar PV systems (180 kW in total), which together with a third party owned 6700 kWh battery, will sit behind the Western Power meter. The strata company (body corporate) will act as the 'Energy Village Council', retail energy to building owners / occupiers and import energy from a SWIS retailer as required to supplement the on-site generation. Although the system will at times have generation in excess of demand (from customers or the battery), it is not currently planned to export energy from the site.

Assuming the strata company is an exempt retailer, it will be able to derive tariff arrangements for customers, subject to the requirement for prices not to exceed the equivalent Synergy tariff.

As noted above, as this private network will not be controlled under ERA licences, a range of protections for customers will not apply. Accordingly, arrangements will need to be devised for:

- customers to procure, maintain and replace their PV systems / inverters (under conditions of sale);
- second and subsequent owners to be incorporated in the scheme;
- the strata company to safely operate, maintain and replace the internal electricity network, battery system and controls;
- the strata company to establish metering and tariff arrangements, including for peer-to-peer trading; and
- the strata company to handle dispute resolution (including initial and / or subsequent owners wishing to opt out of the scheme) and complaint handling.

Strata companies are governed by the Strata Titles Act 1985 as amended; and the Strata Titles General Regulations 1996 (STGR) as amended.

It is possible that other future land parcels at Knutsford intended for strata or community title could be developed in a similar way as proposed for Lot 1819. Again, while this may be a viable approach for the landholdings of LandCorp and the City of Fremantle, there are a number of private landholders who may not be prepared to replicate these arrangements for strata or community title developments 'behind' a master meter on their land. It is also likely that the precinct will continue to contain freehold 'green title' lots, which under present regulation would need to be connected to the SWIS with energy supplied by Synergy.

9.3 Precinct-wide microgrid

It is electrically possible to isolate the entire precinct 'behind' a master meter and service that area under the *commercial provider* model described in Section 7. LandCorp is developing their Peel Business Park industrial development to operate in this way, the first in which a microgrid will service green-title landowners. In summary, the characteristics of that scheme are as follows.

- The internal electricity network, generation and battery storage will be ‘behind-the-meter’ and owned and operated by a private service provider (the *commercial provider* model set out in Section 6.2).
- The operator will import energy from the SWIS as required, and potentially export energy to the SWIS (subject to upstream network constraints).
- The operator will either be licensed (distribution and retail) with the ERA with exclusions from various codes that are required in the SWIS, or provided with exemptions by the PUO with additional requirements appropriate for the microgrid.
- Customers will be free to provide their own on-site power with the ability to export to the local network, or procure electricity from a SWIS retailer.

This project is showing that it is possible for a commercial service provider to provide renewable energy, supplemented by the SWIS, at a lower cost to the economy and the customer. The cost benefits derive from the lower cost of renewable generation and the avoidance of the Western Power network charges for distributing this power to customers (noting that transmission and distribution makes up around 49% of SWIS customer costs (AEMC 2018)).

However, the Knutsford precinct is already serviced by the Western Power network and is within the SWIS and accordingly, it is not viable to construct a private precinct-wide network. With Western Power involvement it would be possible to develop a ‘virtual’ network in which power generated within one development is notionally transported to another using peer-to-peer trading. This approach is currently being trialled under the RENeW Nexus project in Fremantle using Power Ledger’s blockchain-enabled platform. In this trial Western Power is applying fixed daily supply charges, rather than the conventional distribution charges. In that case the residents are directly trading their solar energy with their neighbours, but this role could be undertaken by the strata company for such developments at Knutsford. The commerciality of a ‘virtual’ renewable energy microgrid at Knutsford would be dependent on the willingness of Western Power to participate, and the charges they would apply for transporting the energy.

Subject to the results of the RENeW Nexus trial in Fremantle, the virtual network solution should be further examined.

10. Recommendations

10.1 Swanbourne Street as a catalyst project

The Swanbourne Street structure plan area at the west of the Knutsford precinct has the largest lots (Lots 1356 and 1737) in single ownership (by LandCorp). Expressions of interest for a master developer for the Swanbourne Street Precinct will be released in late 2019. This site represents a unique opportunity for a commercial provider to develop the site with an embedded microgrid and realise the opportunities identified in this study for energy supply to the development to be both net zero carbon and cheaper than conventional supply. The developer and microgrid operator could either be the same entity, or two (or more) firms in partnership.

Although there are several options, the most likely model to be both financially viable for the developer / microgrid operator, and safe, reliable and cost effective for customers would be as follows. The developer would:

- construct and retain ownership of the electricity distribution system 'behind' a Western Power master meter at the boundary of the site;
- install and maintain solar PV on ground-mounted and / or rooftop solar PV which is capable of generating sufficient renewable energy to supply the annual energy needs of the site, importing from the SWIS as necessary;
- install and maintain battery storage sufficient to optimise energy import and export from the site;
- act as a default electricity retailer to occupants.

It is recommended that a number of the proposed initiatives of the Peel Business Park are adopted to ensure competitiveness and customer protections by requiring the microgrid operator to:

- obtain a distribution and retail licence (with appropriate exclusions) to ensure customers have the same rights and protections as SWIS connected customers;
- facilitate customer purchases from SWIS retailers should they so desire; and
- provide information to customers to compare their cost of electricity to the relevant Synergy regulated tariffs.

It is recommended that LandCorp include this scenario in the Expression of Interest documents.

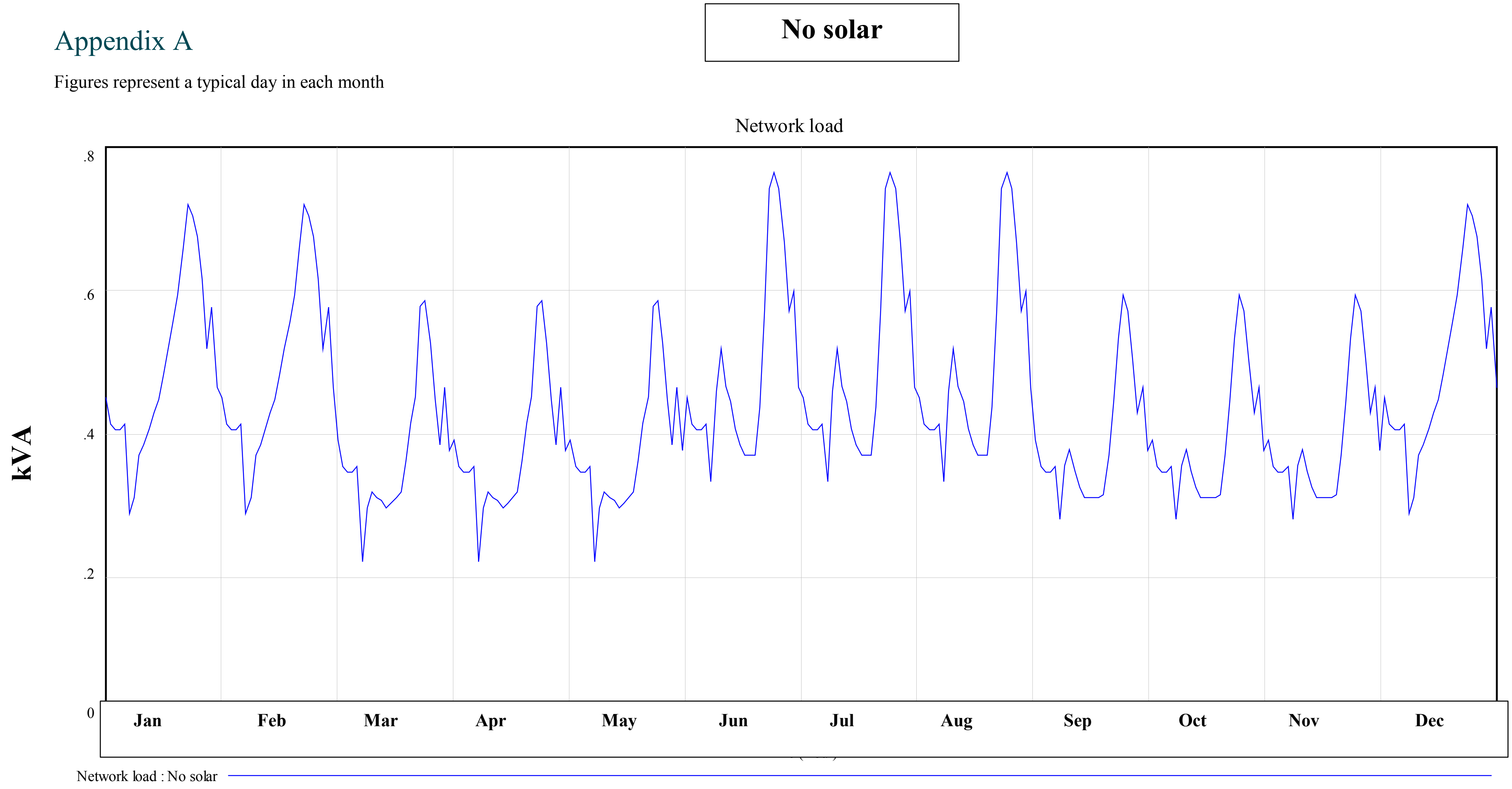
10.2 Beyond Swanbourne Street

1. The microgrid operator could replicate the arrangements on other landholdings in partnership with interested landowners intending to develop strata or community title developments, which offer 'behind-the-meter' opportunities.

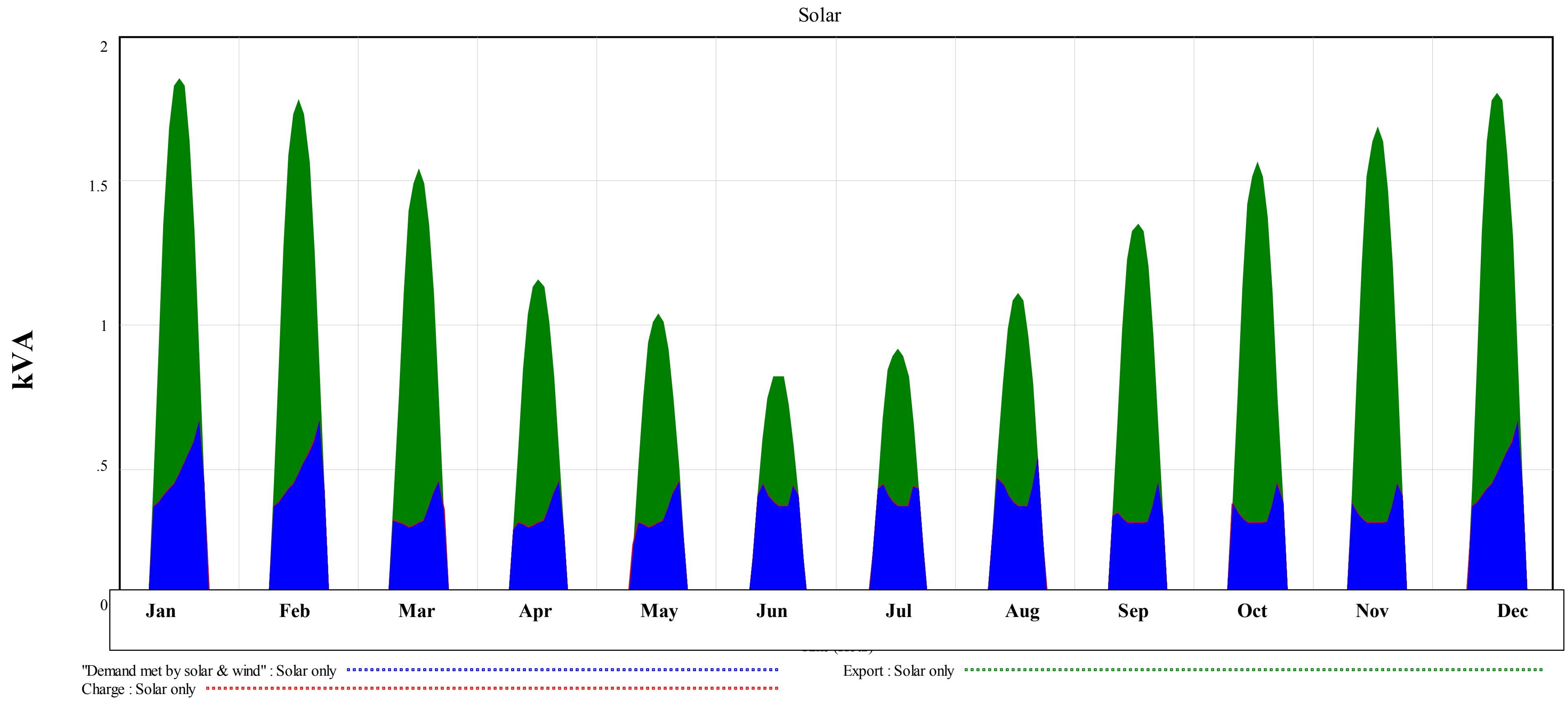
2. The microgrid operator could facilitate peer-to-peer trading (either between microgrids, or between their microgrid and individual green title lots) using the Western Power network. These arrangements are subject to the learnings from the RENeW Nexus project in Fremantle, and the commerciality would be subject to Western Power's charges for this service.

Appendix A

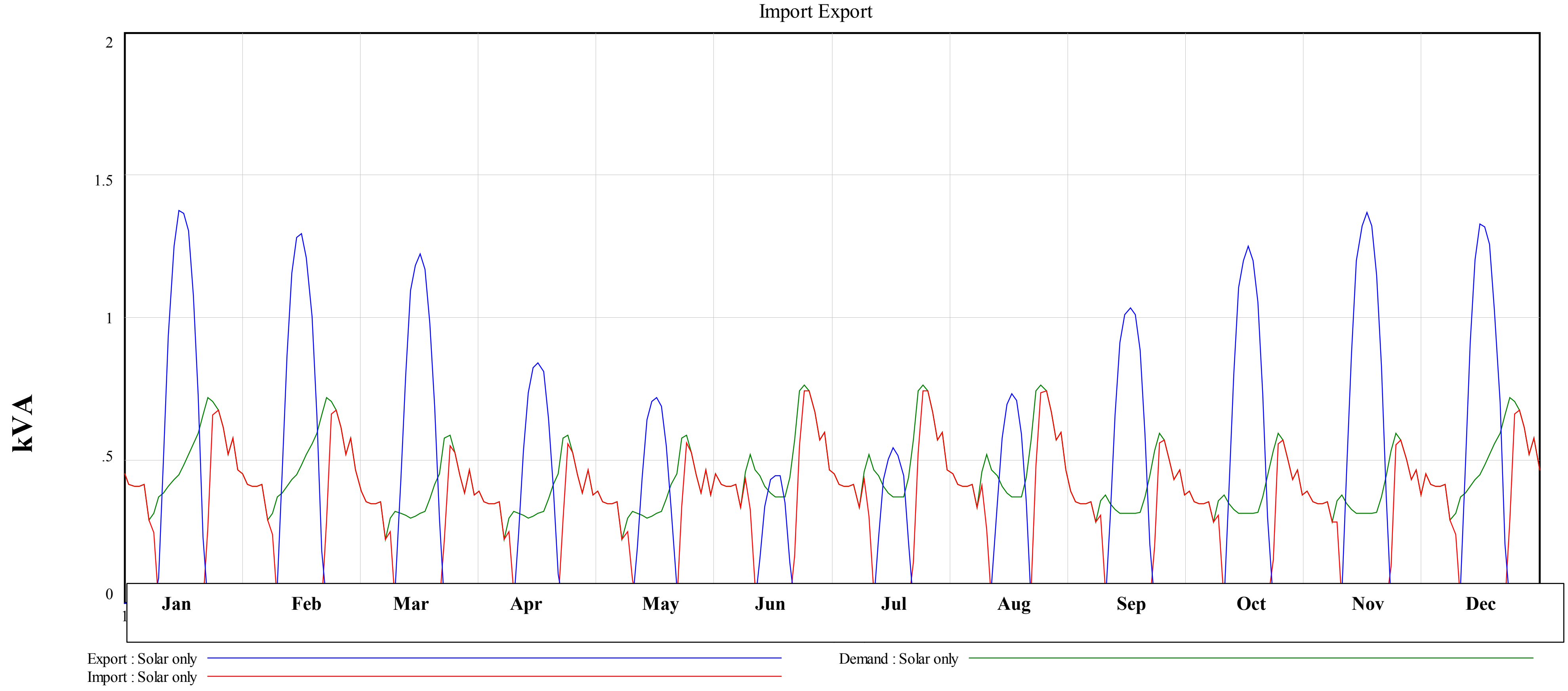
Figures represent a typical day in each month



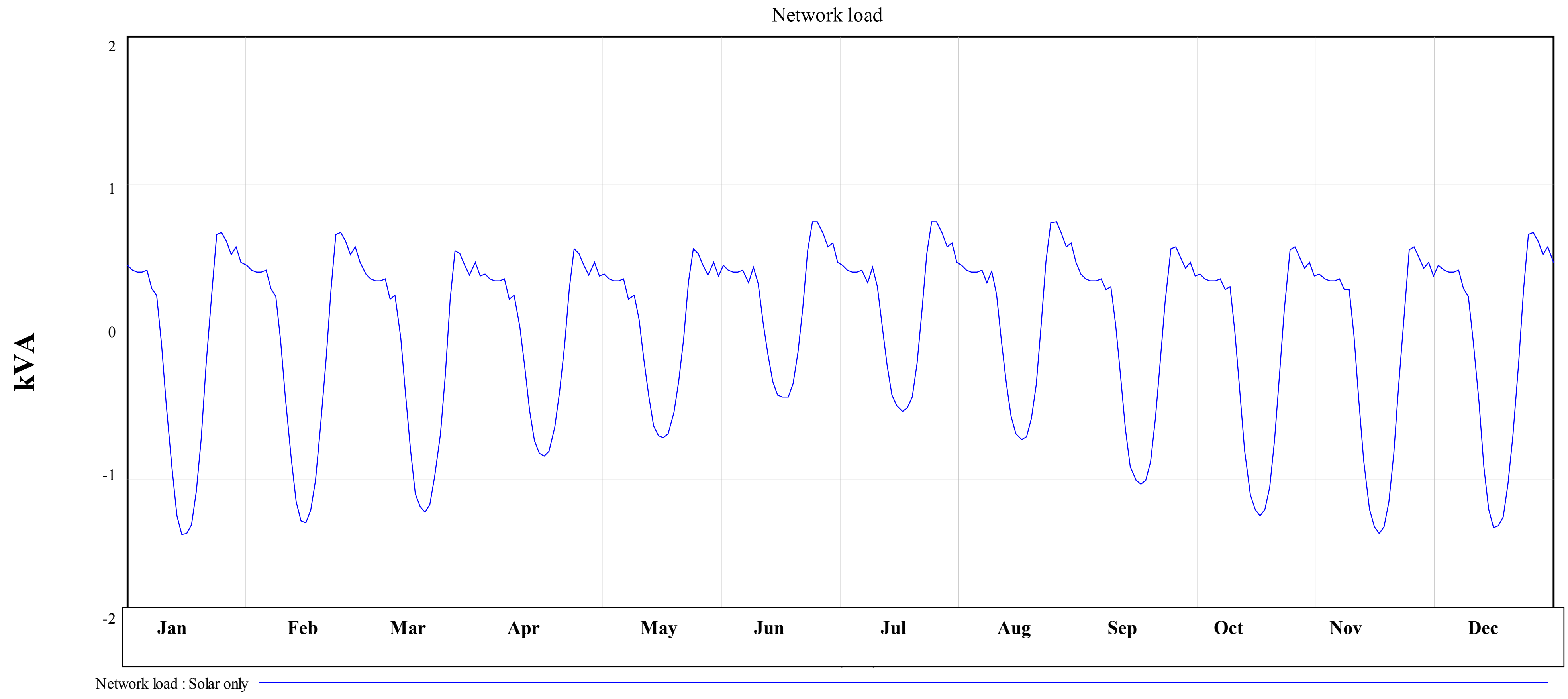
Solar without storage



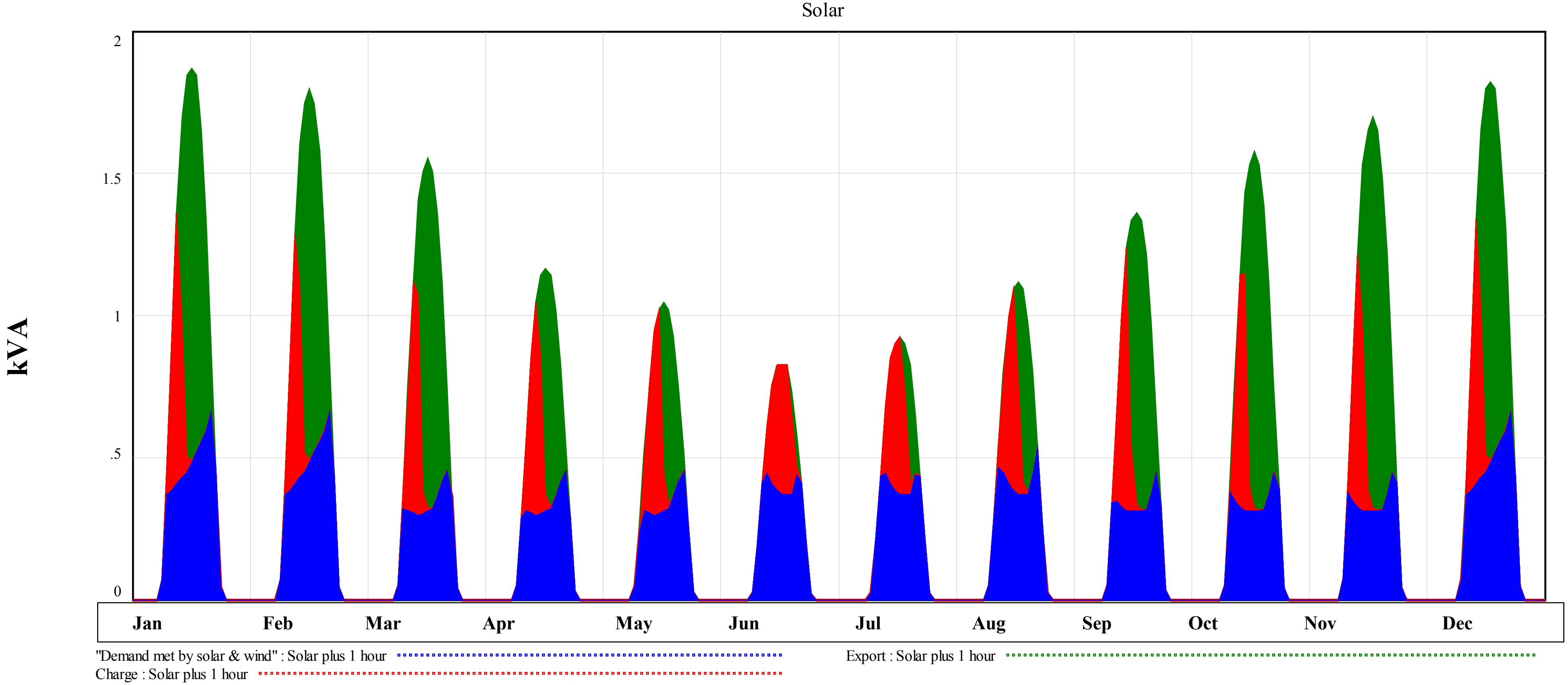
Solar without storage



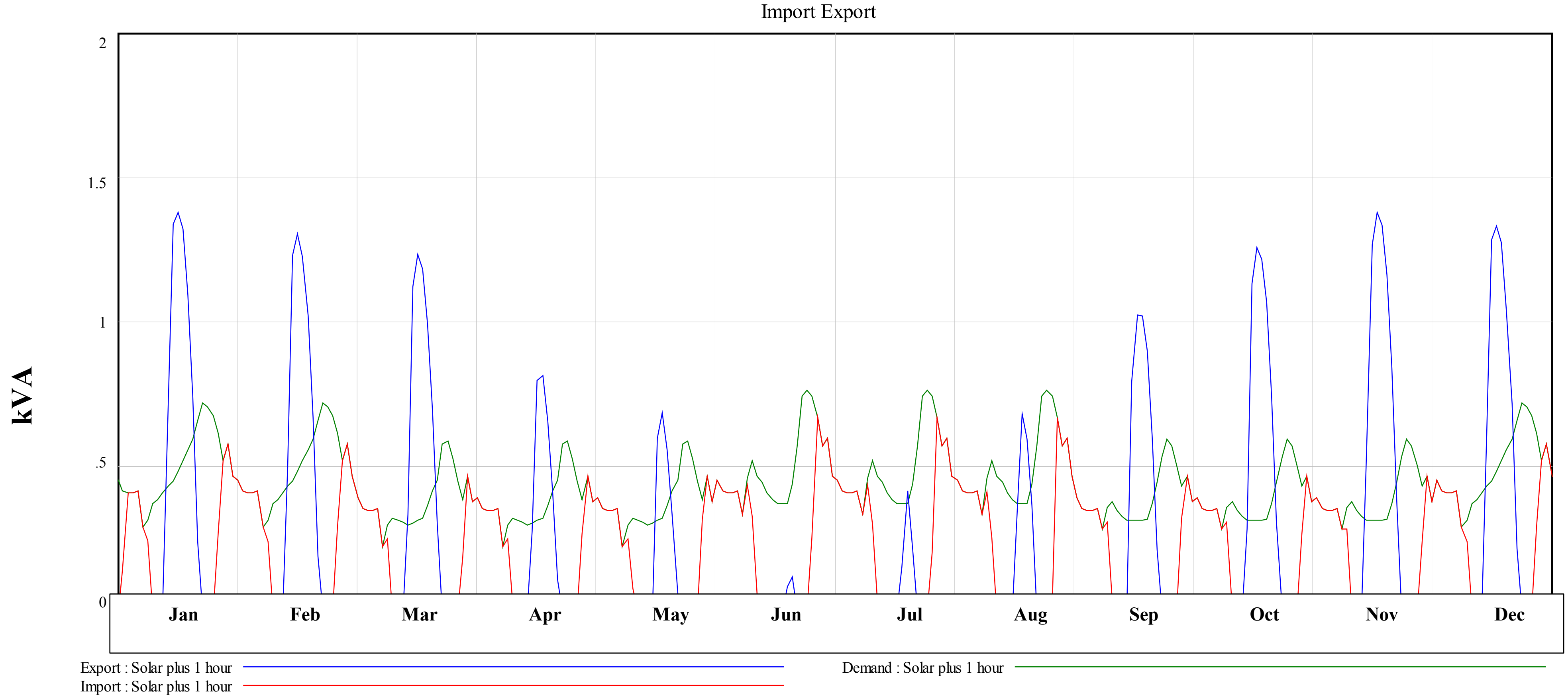
Solar without storage



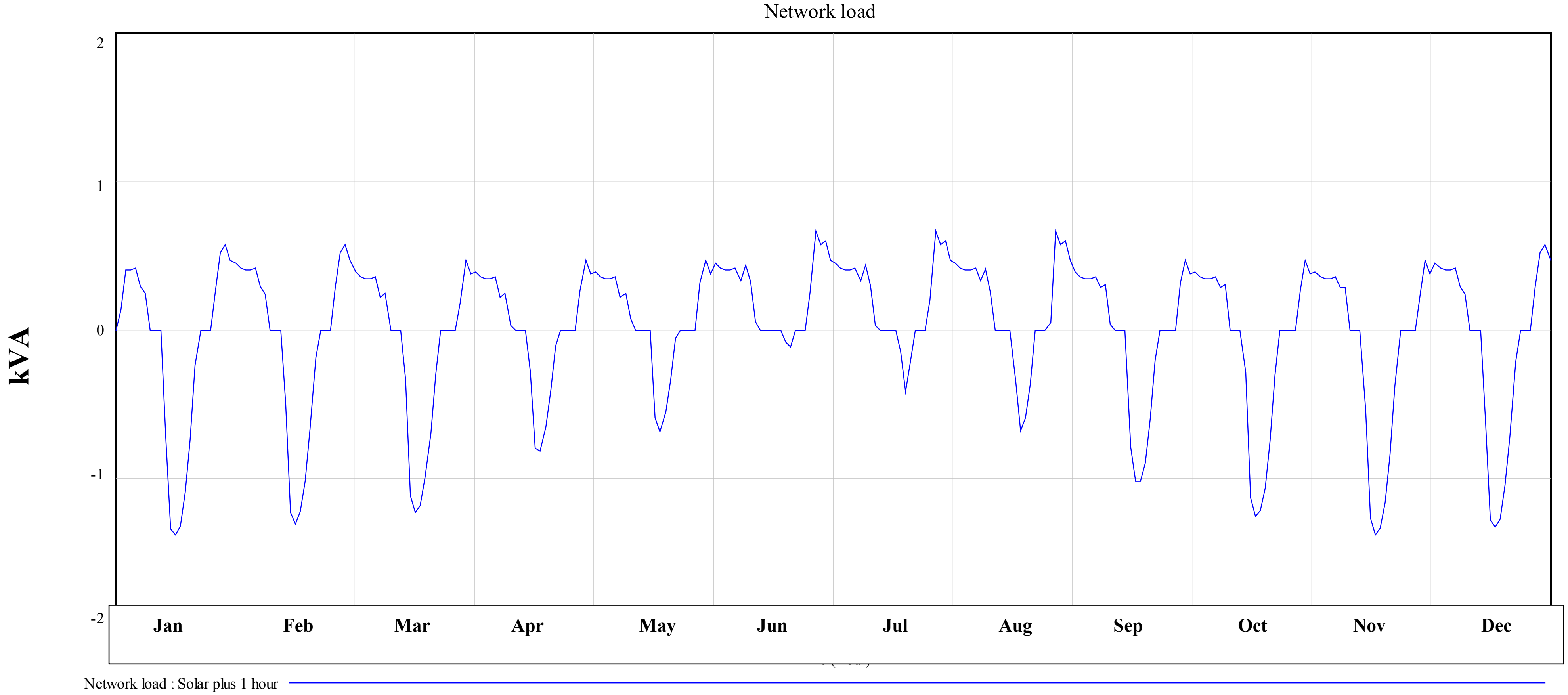
Solar with 1 hour of storage



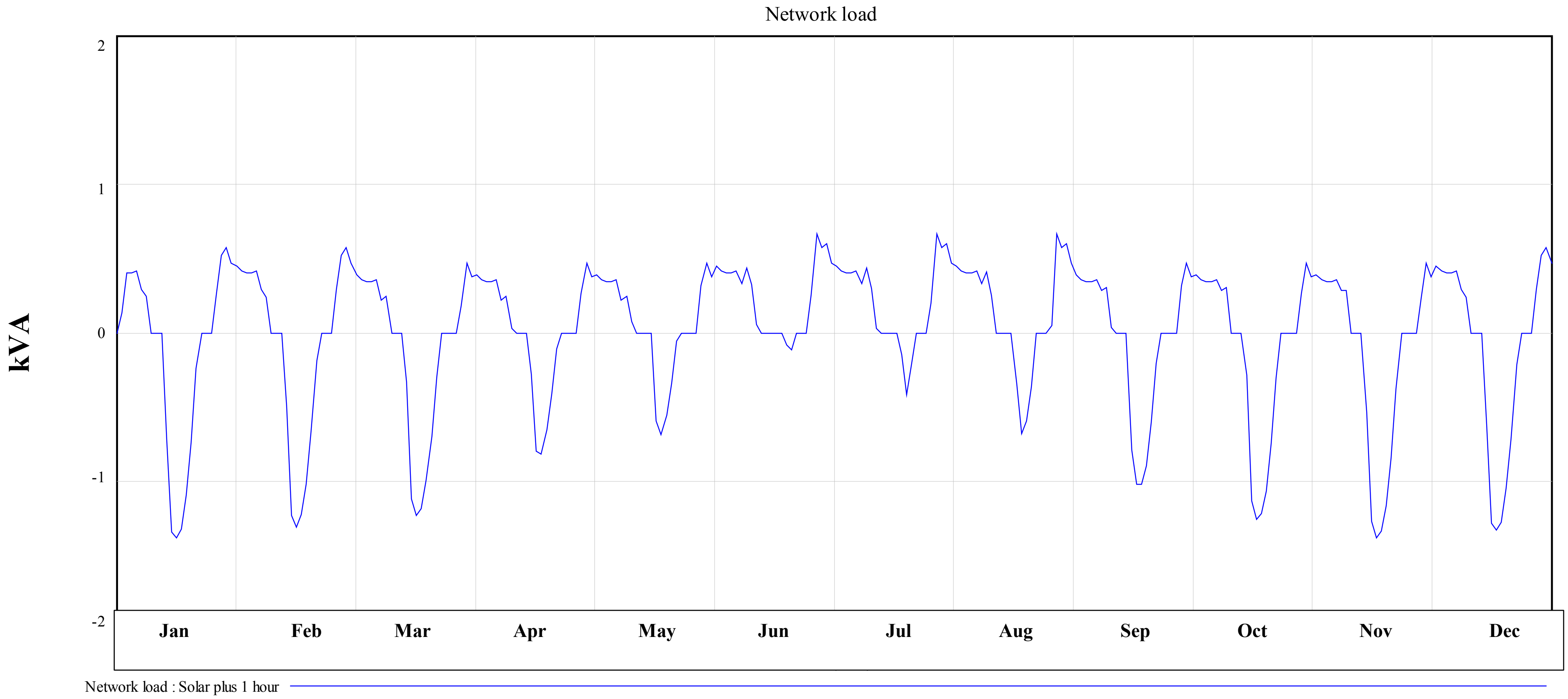
Solar with 1 hour of storage

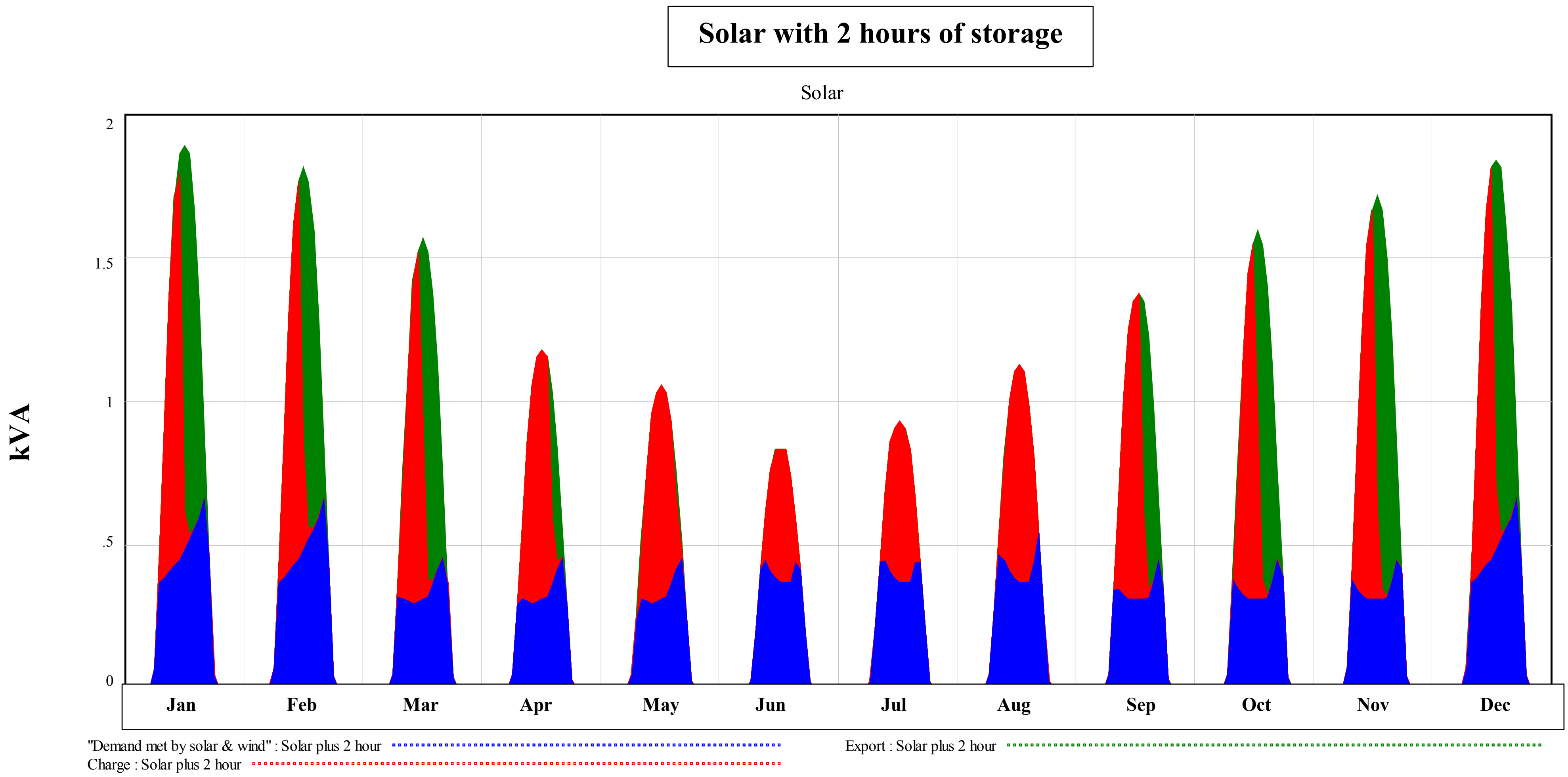


Solar with 1 hour of storage

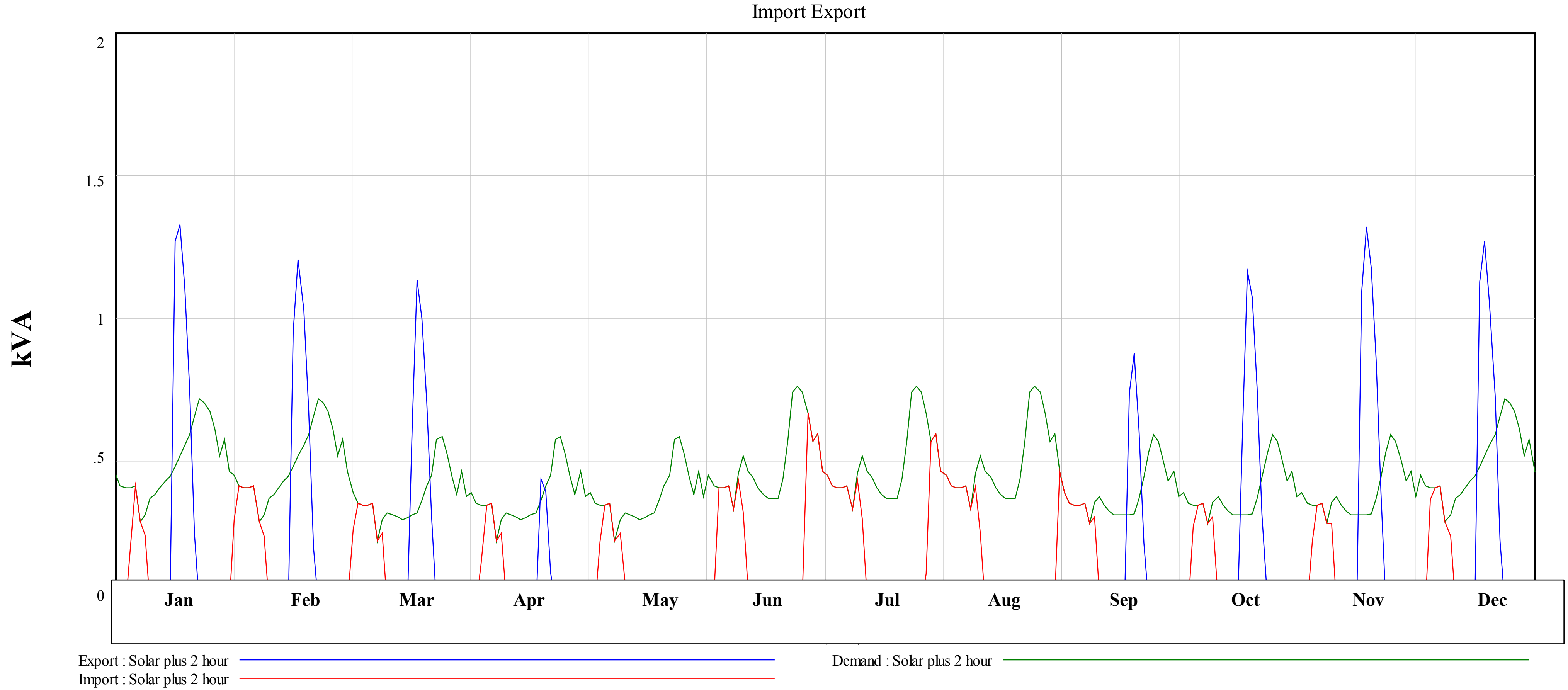


Solar with 1 hour of storage

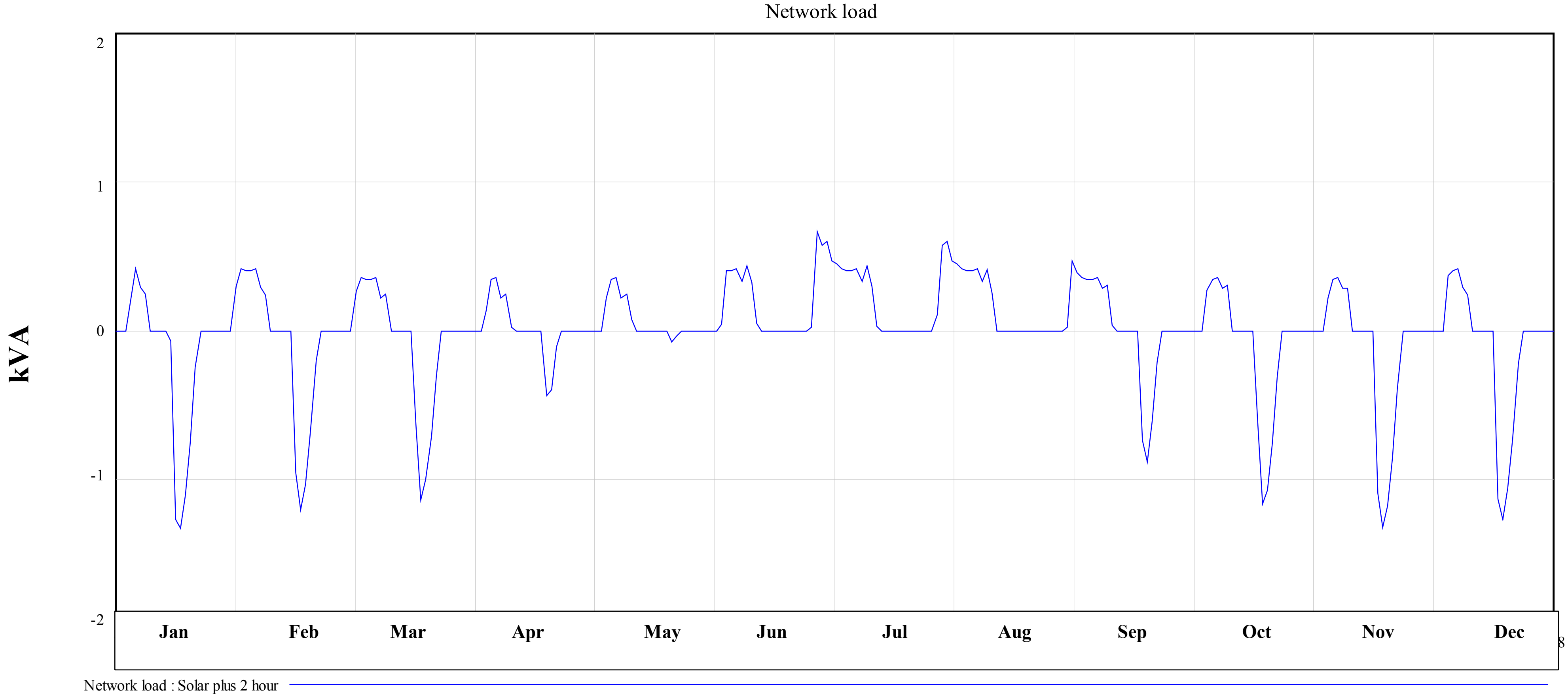


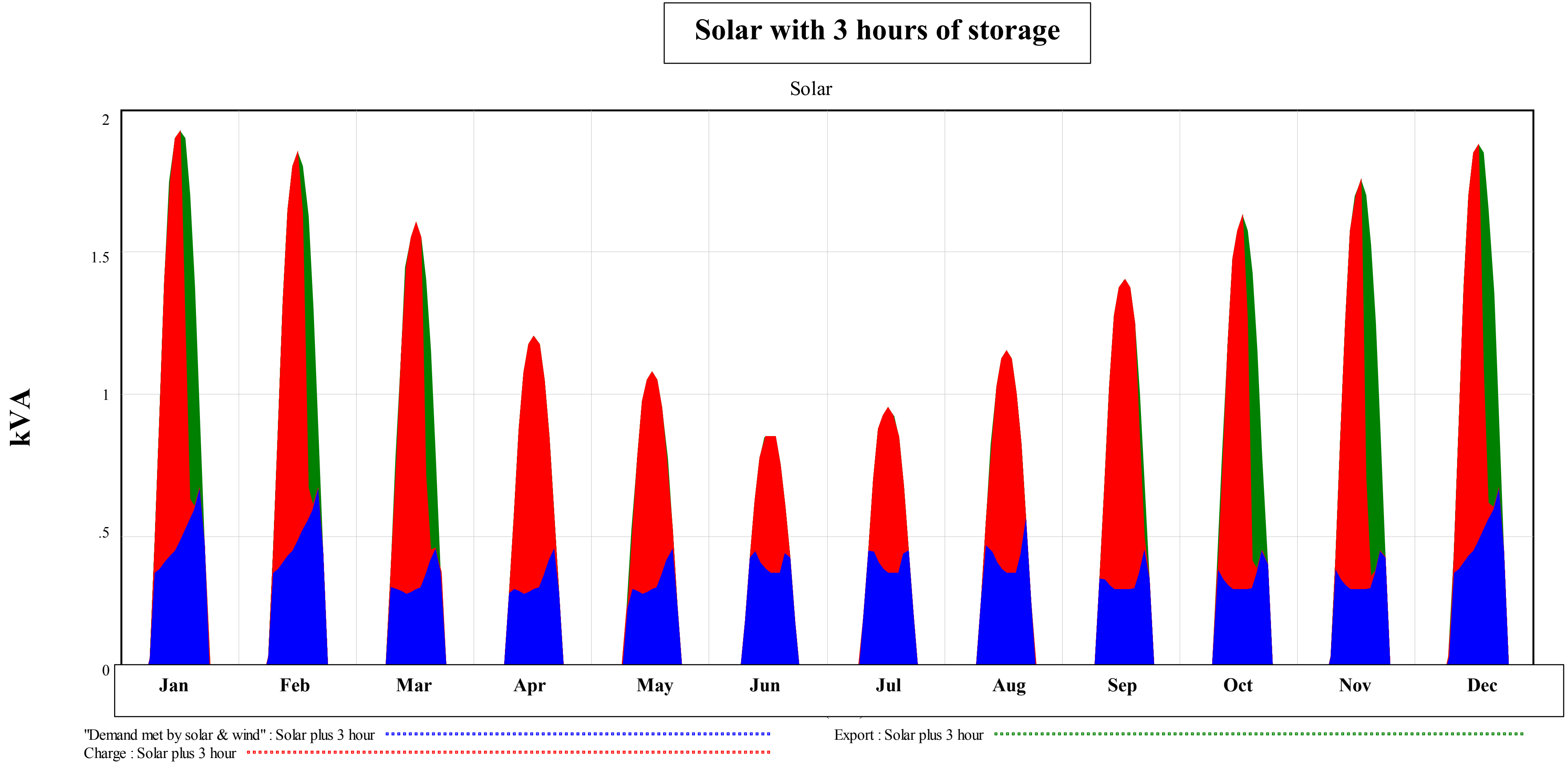

Solar with 2 hours of storage
Solar
kVA
2
1.5
1
.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
"Demand met by solar & wind" : Solar plus 2 hour
Export : Solar plus 2 hour
Charge : Solar plus 2 hour

Solar with 2 hours of storage

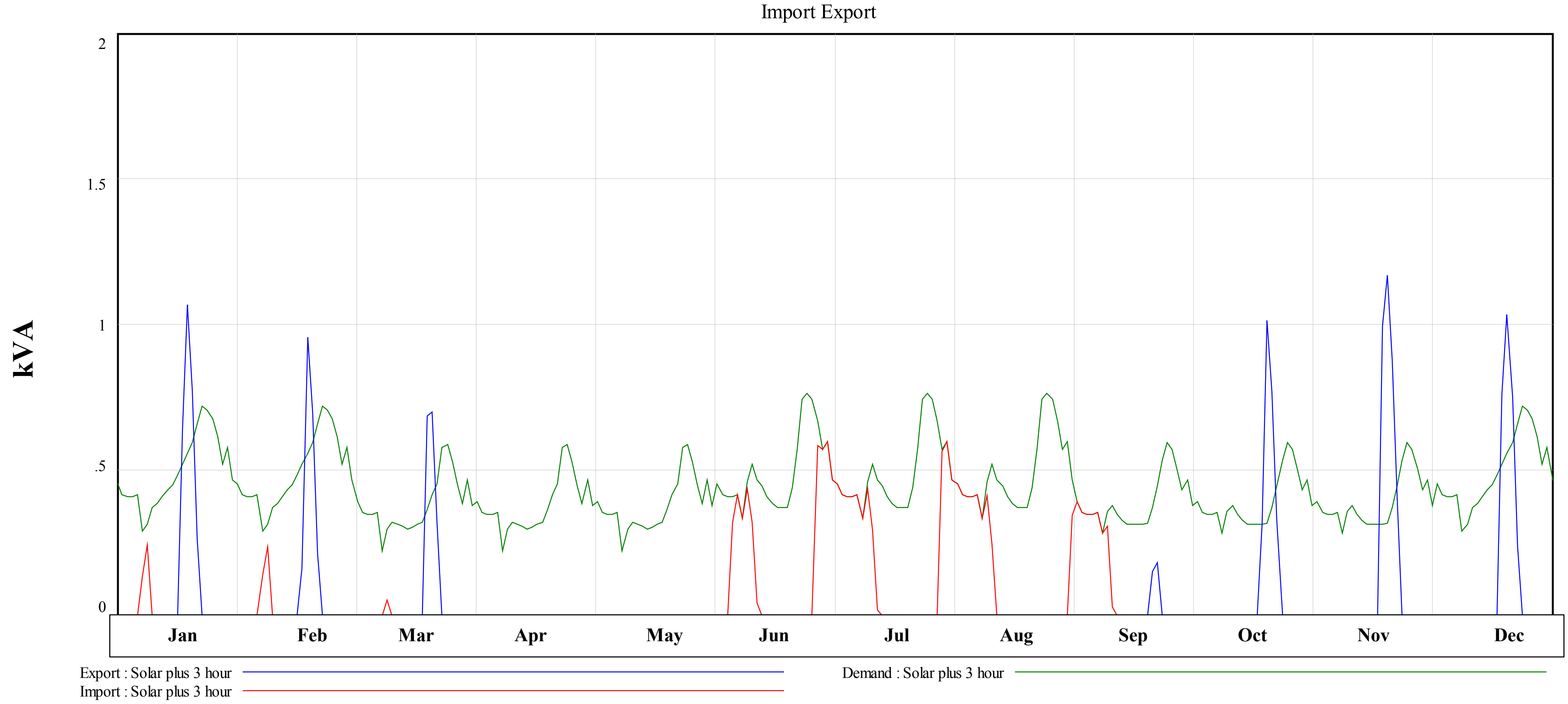


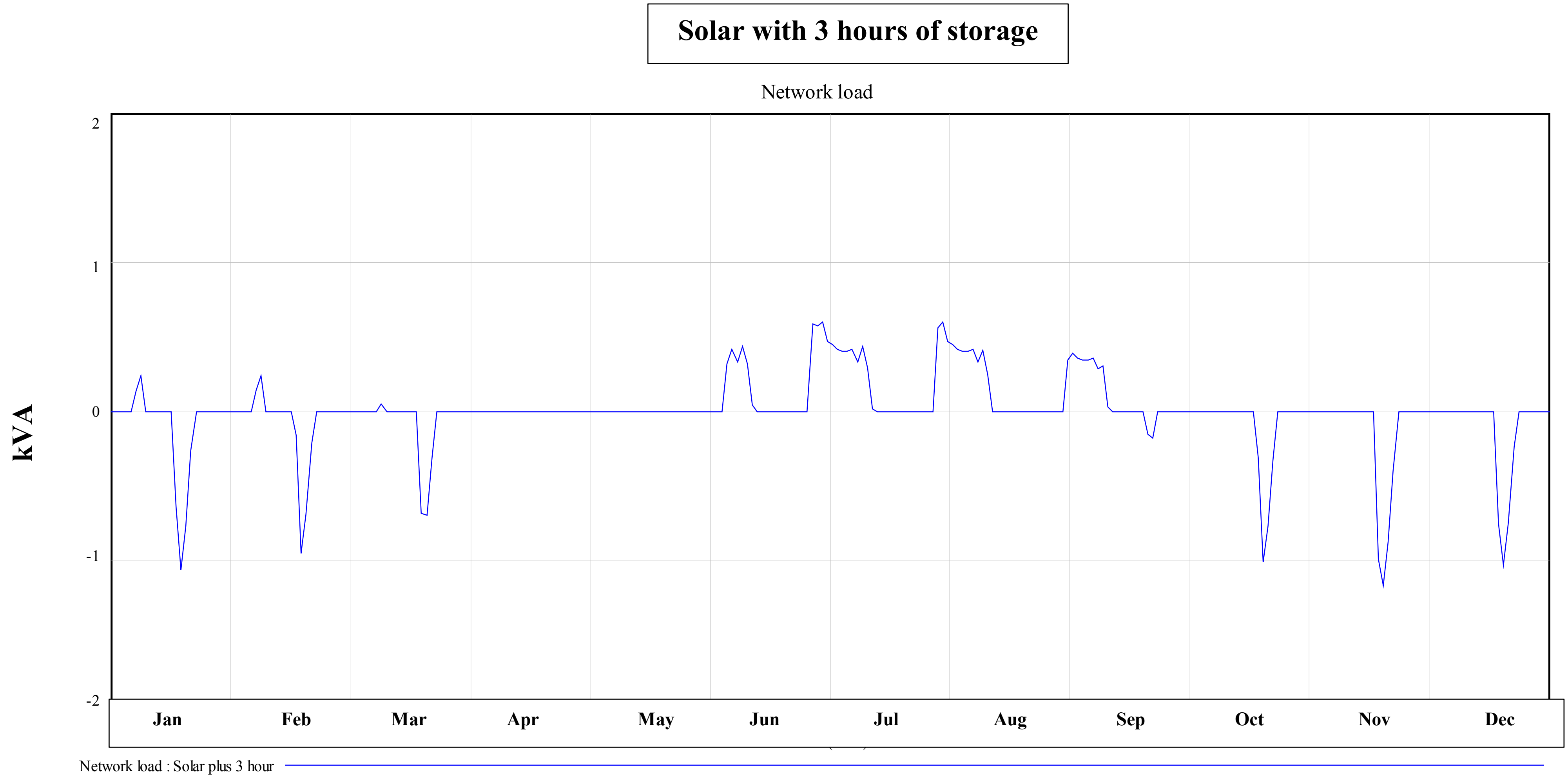
Solar with 2 hours of storage




Solar with 3 hours of storage
Solar
kVA
2
1.5
1
.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
"Demand met by solar & wind" : Solar plus 3 hour
Charge : Solar plus 3 hour
Export : Solar plus 3 hour

Solar with 3 hours of storage




Solar with 3 hours of storage
Network load
2
1
0
-1
-2
kVA
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Network load : Solar plus 3 hour

Reference

Australian Energy Market Commission (2018). Electricity Price Trends Report. Appendix H.

Australian Energy Market Operator (June 2018). Electricity Statement of Opportunities.

Balance Utility Solutions (2018). *Beyond White Gum Valley Precincts Guide.*

Cole, W., Bethany Frew, Pieter Gagnon, James Richards, Yinong Sun, Jarett Zuboy, and Robert Margolis (2017). *SunShot 2030 for Photovoltaics (PV): Envisioning a Low-cost PV Future*. National Renewable Energy Laboratory. Technical Report NREL/TP-6A20-68105.

Department of the Environment and Energy (2018). National Greenhouse Accounts Factors. http://www.environment.gov.au/climate-change/climate-science-data/greenhouse-gas-measurement/publications/national-greenhouse-accounts-factors-july-2018

Grace, W. (2015). *Knutsford Development – sustainable infrastructure study*. Australian Urban Design Research Centre report.

Western Power (2017). *'First Check' Feasibility Study: Beyond WGV (Knutsford)*. Western Power report.

Wu, Qiuwei. (2013). Grid Integration of Electric Vehicles in Open Electricity Markets: John Wiley & Sons.