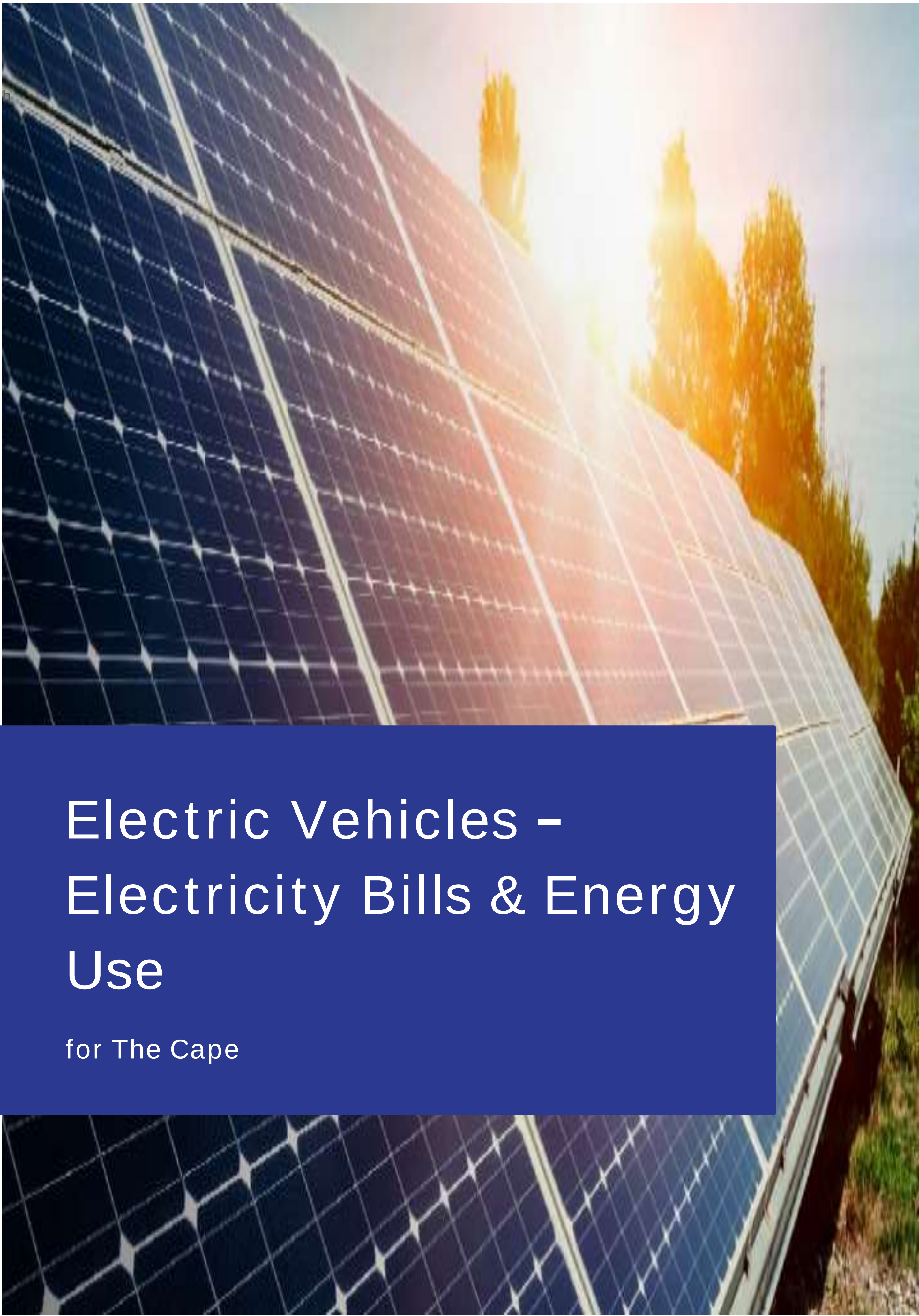

Electric Vehicles – Electricity Bills & Energy Use

for The Cape

Document information

DOCUMENT VERSION	DATE	PREPARED BY	REVIEWED BY	COMMENTS
The Cape EV Modelling_v01 DRAFT	29th July 2019	Damien Moyse – Policy & Research Manager		Initial Version – submitted for client feedback
The Cape EV Modelling_v02 DRAFT	19th Aug 2019	Damien Moyse – Policy & Research Manager		Second draft – incorporating client feedback
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Prepared for The Cape

ATA Energy Projects Team
Prepared by: Damien Moyse
Cover photograph:

[Company]
Level 1, 39 Little Collins St, Melbourne VIC 3000
+61 3 9639 1500
+61 3 9639 5814
www.ata.org.au

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Executive Summary

Electric Vehicles are emerging in Australia. This study seeks to explore the potential impact of electric vehicles on household energy usage and electricity bills, and to explore the abilty of solar photovoltaic technology, coupled with household energy storage, to offset both grid energy usage and cost.

The Cape is an environmentally friendly housing development, comprising 230 new homes at Cape Paterson, on Victoria's south-east coast[1].

The purpose of this analysis has been to explore optimal solar PV and battery system sizes at The Cape, for a range of home sizes and driving characteristics, in order to achieve:

- zero stationary energy bills and zero transport energy bills; and
- net zero energy and carbon for both stationary energy transport energy.

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[1] https://www.liveatthecape.com.au/

Renew modelled a range of different household sizes, different solar and battery system sizes, different EV charging patterns and different annual kilometres travelled, in order to capture a range of results that can be explored, with the original purpose in mind.

The modelling was structured to accommodate the following key variables:

- A small and a large-sized home (i.e. 135 m^2 and 195m^2);
- A medium and a large-sized solar PV system (i.e. 5kW & 10kW);
- A small and a large household battery size (i.e. 5kWh & 13.5kWh); and
- A low and a high annual driving distance (i.e. 15,000 km per annum & 40,000 km p.a.).

Findings

The general findings from this study are:

1. It is relatively achievable to reduce electricity bills to near or beyond zero, particularly for the smaller annual loads for both stationary and transport energy load;

2. It is also relatively achievable to reduce carbon emissions to net zero (or positive), again particularly for the smaller annual loads (but also the higher annual load almost achieved net zero carbon where 10 kW of solar was installed);

3. It is very difficult to reduce imports from the grid to near zero for any level of energy consumption, when combining both the stationary and transport energy loads from electricity. Even where household energy use and annual mileage are low, a very and expensive large solar and battery system is required to reduce grid imports to near zero (15 kW solar & 27 kWh batteries at an installed cost of approximately $40,000).

   However, reducing imports from the grid to zero is not a particularly worthwhile objective where a grid connection is available.

4. The charging profile of the EV does have a material impact on the value of the solar and/or solar-battery system, as well as on the ability of the solar-battery system to reduce grid imports closer to zero.

   Sensitivity Tests 2 and 4 demonstrate that by undertaking most EV charging during solar generation times, thousands of dollars of additional value can be created over 20 years, and grid imports can be reduced down to only a few kWh per day (dependent on solar-battery system size).

   Sensitivity Tests 2 and 4 should be thought about as "Best Case" scenarios with regards to EV charging profiles. In reality however, it is unlikely that an EV owner will be able to delay full re-charging until the daytime of the following day after a lengthy trip, every time.

   As the original modelling for Scenarios 1 and 2 include EV charging predominately occurring overnight, the Scenario 1 and 2 results, and the Sensitivity Tests 2 and 4, can be considered a "Worst" and "Best Case" for the purposes of this study.

Contents

1. Introduction

Electric Vehicles are emerging in Australia. This study seeks to explore the potential impact of electric vehicles on household energy usage and electricity bills, and to explore the abilty of solar photovoltaic technology, coupled with household energy storage, to offset both grid energy usage and cost.

The Cape is an environmentally friendly housing development, comprising 230 new homes at Cape Paterson, on Victoria's south-east coast[2]. The development includes:

- a minimum 7.5 Star energy efficiency requirement for all new homes;
- a mandatory requirement of a minimum 2.5 kilowatts (kW) of grid connected solar photovoltaic (PV) for each home (current installations are averaging approximately 5.0 kW);
- the use of all-electric appliances (i.e. no gas provided to the estate);
- the use of high efficiency heat pump technology for heating, cooling and hot water;
- a mandatory requirement for LED lighting;
- a mandatory minimum 10,000 Litres of rainwater storage per home; and
- the encouragement of on-site home energy storage as well as use of electric vehicles (EVs).
-

1.1. Purpose

The purpose of this analysis has been to explore optimal solar PV and battery system sizes at The Cape, for a range of home sizes and driving characteristics, in order to achieve:

- zero stationary energy bills and zero transport energy bills; and
- net zero energy and carbon for both stationary energy transport energy.

In order to deliver on this purpose, Renew has undertaken modelling of the energy use and electricity cost of a range of different home sizes and driving characteristics for residents of The Cape.

As agreed with the client:

[2] https://www.liveatthecape.com.au/

- All homes modelled as part of this analysis have been designed to a minimum 8.0 Star energy performance[3], as defined under NatHERS[4] (as this is the average performance of currently built homes at The Cape);
- All homes modelled will have a minimum 5 kW of solar PV installed (slightly less than the average for Cape homes built in 2018); and
- The heating, cooling and hot water loads of all homes modelled are supplied by heat pump technology only.

1.2. Methodology

Different homes will vary with regard to their stationary energy[5] and transport energy[6] characteristics, and in particular:

- their overall energy usage (either daily, seasonally, or annually) and their daily load profile;
- the specific size of any solar and/or battery system that they may install (even though there may be a minimum requirement);
- the type of EV they may purchase; and
- their driving patterns.

Renew's approach has been to model a range of different household sizes, different solar and battery system sizes, different EV charging patterns and different annual kilometres travelled, in order to capture a range of results that can be explored, with the original purpose in mind.

[3] As this is what the majority of homes are achieving to date at The Cape
[4] The Nationwide House Energy Rating Scheme: http://www.nathers.gov.au/
[5] Energy used for stationary appliances and loads.
[6] Energy used in transportation.

On this basis, the modelling has been structured to accommodate the following key variables:

- A small and a large-sized home (i.e. 135 m^2 and 195m^2);
- A medium and a large-sized solar PV system (i.e. 5kW & 10kW);
- A small and a large household battery size (i.e. 5kWh & 13.5kWh); and
- A low and a high annual driving distance (i.e. 15,000 km per annum & 40,000 km p.a.).

This approach allows the consideration of a variety of results and provides an overview of the key factors involved in trying to limit energy use and cost associated with stationary and transport energy for high efficiency homes and EVs at The Cape.

2. Scenario 1: Small Home, Low Mileage

Scenario 1 included the following key parameters:

- A new, 8 Star all-electric home;
- 135m2 home size; and
- Annual mileage of 15,000 km.

The electricity usage of this home, on an average daily and annual basis, was modelled as follows:

	Average Daily Usage (kWh)	Annual Usage (kWh)
Stationary Energy	11.45	4,179
Transport Energy	7.6	2,774
Total Electricity	19.05	6,953

Table 1 Daily & Annual Electricity Usage - Scenario 1 Home

To put this in context, a typical Victorian existing dual fuel home (i.e. one that uses electricity and gas) and of low thermal performance (e.g. 3 Stars or less) uses in the order of 4,000 kWh p.a. (with additional gas energy usage). The Scenario 1 home uses around the same amount of electricity annually for stationary energy, but for all end uses (including heating, hot water and cooking)[7]. The transport energy use for Scenario 1 is a relatively small additional electricity load.

2.1. Electricity Usage Profile

The average daily electricity usage profile of the combined stationary energy and transport energy loads is contained in Figure 1 below. It should be noted that this profile is the average of all days throughout the year – on any individual days, electricity usage associated with EV charging, heating/cooling or hot water may be larger or smaller, depending on the usage on that day. But Figure 1 broadly shows:

- the switching on of the heat pump hot water system each day from 11am;
- patterns of EV charging that occurs overnight and for short periods in the middle of the day (from midday);
- a typical residential "hump" (albeit smaller than a typical existing Victorian home) in the late afternoon / early evening.

[7] Whereas a typical dual fuel home will supply some or all of those three end uses with gas and thereby use an additional 20 GJ to 50GJ or more of gas on top of the electricity usage).

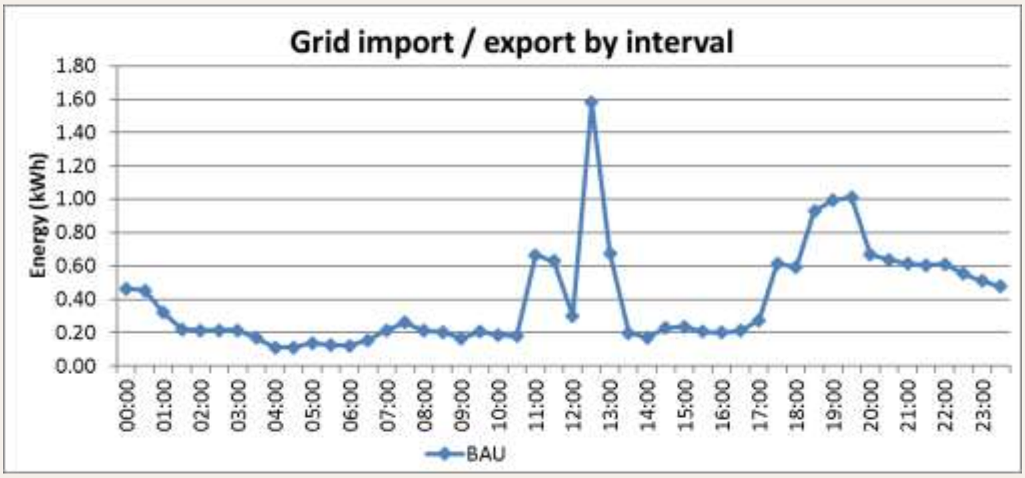

Figure 1: Average Daily Electricity Usage Profile, Scenario 1 Home

To gain a better understanding of the profile on specific days, the following two charts show the electricity usage on a day where significant EV charging occurs (overnight), and another day where the EV is not charged at all:

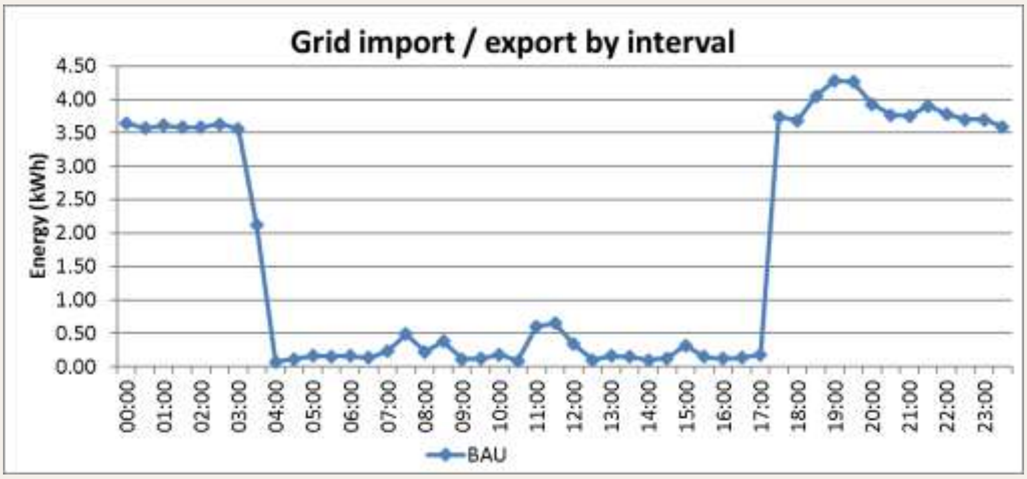

Figure 2: Electricity Usage Profile, Sunday 15th September, Scenario 1 Home (Overnight EV charge)

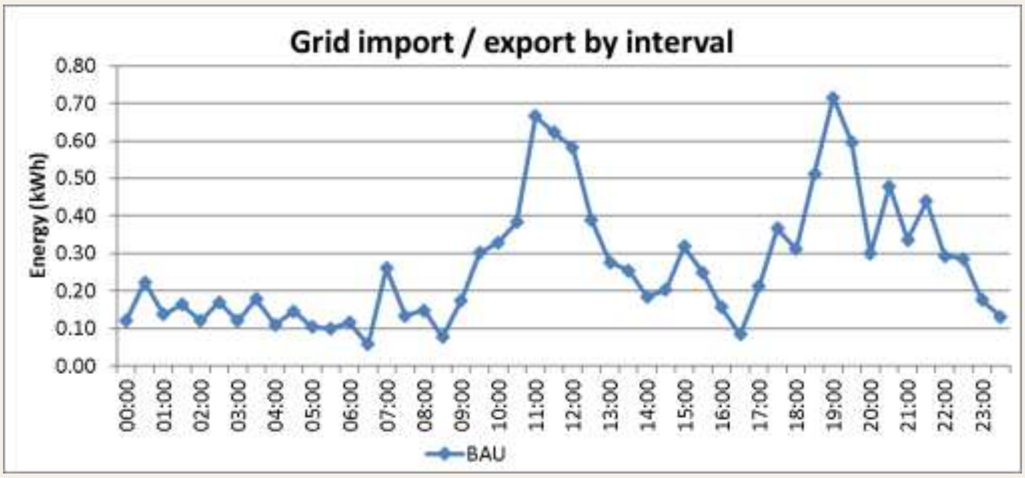

Figure 3: Electricity Usage Profile, Saturday 21st September, Scenario 1 Home (No EV charge)

2.2. EV Charging Profile

Considering the 15,000 km annual mileage for the EV, Renew developed a separate model of driving patterns and subsequently an EV charge electricity profile, that fed into the overall electricity usage profile above.

LABEL	DRIVING PATTERN NAME	TRIPS PER WEEK	KM PER TRIP	KWH CONSUMPTION PER 100KM	KWH CHARGE REQUIRED
A	Local Trip A	1	20	18	3.6
B	Local Trip B	1	40	18	7.2
C	Trip to Melbourne	0.5[8]	300	18	54
D	Monthly Regional Trip	0.25[9]	400	18	72
E	No EV Travel Day	-	-	-	0

Table 2 Weekly Driving Patterns, Scenario 1 Home

When applied annually, and assuming a four (4) week holiday per year, during which no EV driving occurred, the driving patterns above resulted in an annual mileage of 15,440km.

A charging profile was then developed for each of these driving days, assuming a 7kW max (i.e. 32 Amp) EV charger. The key parameters of this profile were as follows:

LABEL	DRIVING PATTERN NAME	KWH CHARGE REQUIRED	CHARGE PATTERN
A	Local Trip A	3.6	A 40-minute charge from midday that day
B	Local Trip B	7.2	A 75-minute charge from midday that day
C	Trip to Melbourne	54	An 8-hour charge from 5pm that day (upon arriving home)
D	Monthly Regional Trip	72	A 10-hour charge from 5pm that day (upon arriving home)
E	No EV Travel Day	0	No charge

Table 3 EV Charging Profile, Scenario 1 Home

2.3. Tariffs

A simple approach to tariff selection was undertake for the modelling. Renew reviewed available electricity tariffs for the Cape Paterson postcode[10] and selected a mid-level, basic flat tariff structure (all prices include GST):

- $0.30 per kWh for energy;
- $1.10 per day fixed charge; and
- $0.12 per kWh feed-in tariff.

[8] i.e. fortnightly
[9] i.e. once per month
[10] https://compare.energy.vic.gov.au/

2.4. Solar-Battery Analysis

Renew modelled a range of solar PV and solar-battery systems against that annual load, to test the ability of each system configuration to meet the annual and daily load for the Scenario 1 home. The modelling was done on a 30-minute basis so an accurate picture of on-site usage of the solar and battery energy, versus export to, and import from, the grid could be determined. System sizes and configurations modelled were:

- BAU – i.e. no solar/battery, simply to understand the load characteristics and the annual electricity bill;
- 5 kW solar PV only (no battery);
- 10 kW solar PV only (no battery);
- 5 kW solar PV with a 5 kWh (small) battery;
- 5 kW solar PV with a 13.5 kWh (large) battery;
- 10 kW solar PV with a 13.5 kWh (large) battery.

The following table captures a range of environmental, economic and energy results from the model:

	BAU	5KW	10KW	5KW+5KWH	5KW+13.5KWH	10KW+13.5KWH
Environment Results						
Annual Co2 Saved (T)	-	7.1	14.2	6.9	6.8	13.9
Annual Net Carbon (T)[11]	8.07	0.97	- 6.13[12]	1.17	1.27	- 5.83
System sizing statistics						
Self-consumption of Solar		29%	17%	59%	73%	39%
Solar Export %		71%	83%	41%	27%	61%
Average Battery Utilisation		0%	0%	100%	56%	58%
Export to grid (kWh/day)[13]		13.78	32.36	8.00	5.24	23.55
Import from grid (kWh/day)	19.05	13.38	12.53	8.14	5.65	4.54
Financial stats						
Solar/Battery Cost[14]		$6,500	$12,000	$13,500	$17,000	$22,000
Annual Electricity Bill	$2,487	$1,264	$356	$942	$791	-$133
Annual Maintenance Cost		$50	$100	$100	$100	$130
Annual Total Cost	$2,487	$1,314	$456	$1,042	$891	-$3
Annual Bill Saving		$1,173	$2,031	$1,445	$1,596	$2,490
Net Present Value (20 yrs)[15]		$9,434	$15,440	$3,968	$1,550	$8,688
Simple Payback (yrs)		6	6	10	16	9
Return on Investment		15.9%	14.6%	5.7%	3.5%	6.7%

Table 4 Solar & Battery System Performance, Scenario 1 Home

[11] Assumes July 2018 NGA Factors: https://www.environment.gov.au/system/files/resources/80f603e7-175b-4f97-8a9b-2d207f46594a/files/national-greenhouse-accounts-factors-july-2018.pdf
[12] A negative figure denotes a carbon positive impact.
[13] The model assumes a 10kW export limit.
[14] Prices do not include the Solar Victoria rebate.
[15] Future benefits discounted at 2.5% real.

The key points of note from the table above are:

- With no solar or battery, the annual electricity bill of the Scenario 1 home would be $2,487 per year;
- Just adding a 5 kW solar-only system reduces this bill to $1,264 per year – a saving of $1,173 with a simple payback of 6 years:
    - However, the 5 kW solar-only system only reduces grid imports by 5.67 kWh/day – or around 30%. The home still requires an average 13.38 kWh/day from the grid;
- The 10kW solar-only system reduces the annual electricity bill to only $356. Even allowing for maintenance costs, the annual savings from this system are over $2,000:
    - However, with a 10 kW solar-only system, the home still requires an average 12.53 kWh/day from the grid – reducing grid imports by around 35%;
- The only system that reduces the use of grid electricity to near zero is the largest solar and battery system modelled – i.e. the 10 kW & 13.5 kWh system:
    - This system reduces grid imports to an average 4.54 kWh/day – a 76% reduction;
    - This system's installed cost is $22,000, annual savings are $2,490, and simple payback is 9 years;
    - The 13.5 kWh battery is only 58% utilised (on an average daily basis). This means that for some days of the year, the load is relatively small and the battery is only partially discharged; whilst on other days (where significant EV charging occurs – e.g. the 54kWh or 72kWh charge days), the battery cannot sufficiently supply the requisite energy and grid imports are required.
- From a net-carbon perspective, the systems involving 5 kW of solar (either solar-only or solar and battery) do not quite achieve zero-net carbon – each of these scenarios result in around one tonne of emissions per year:
    - However, the 10 kW solar systems (either solar-only or solar and battery) achieve a carbon net-positive result (meaning the emissions reduced from these solar or solar-battery systems is larger than the emissions associated with the stationary and transport energy loads from the grid.

2.5. Sensitivity Test 1: Large Solar, Large Batteries

In order to see how much further grid imports could be reduced for the Scenario 1 home, Renew tested two larger solar-battery systems:

- 10 kW solar PV with a 20 kWh battery; and
- 15 kW solar PV with a 27 kWh battery[16].

The high-level costs, benefits and energy characteristics of these larger systems sizes were as follows:

	BAU	10KW+20KWH	15KW+27KWH
Annual Co2 Saved (T)		13.9	20.9
Annual Net Carbon (T)[17]		- 5.83	- 12.83
Average Battery Utilisation		43%	33%
Import from grid	19.05	3.74	2.83
Financial stats			
Solar/Battery Cost		$28,500	$40,000
Annual Total Cost	$2,487	-$31	-$905
Annual Bill Saving		$2,518	$3,392
Net Present Value (20 yrs)		$5,853	-$988
Simple Payback (yrs)		14	17

Table 5 Larger Solar & Battery System Performance, Scenario 1 Home

As can be seen:

- Increasing the battery to 20 kWh still results in an average 3.74 kWh per day imported from the grid;
- Increasing the solar to 15 kW and the battery to 27 kWh further reduces grid import by 0.9 kWh per day (to 2.83 kWh) – but this comes at a significant cost ($40,000 upfront);
- Both of these systems result in a negative annual electricity bill; and
- Both systems are easily net carbon positive.

[16] e.g. 2x Tesla Powerwalls
[17] Assumes July 2018 NGA Factors: https://www.environment.gov.au/system/files/resources/80f603e7-175b-4f97-8a9b-2d207f46594a/files/national-greenhouse-accounts-factors-july-2018.pdf

2.6. Sensitivity Test 2: Charge EV from Solar

Given the difficulty of reducing the grid imports to zero even with the larger solar and battery systems, Renew modelled an alternative scenario whereby the majority of the EV charging occurred during solar generation times.

This was achieved by changing the times for the most significant two charging profiles for Scenario 1 – i.e. Labels C and D in the table below:

LABEL	DRIVING PATTERN NAME	KWH CHARGE REQUIRED	CHARGE PATTERN
A	Local Trip A	3.6	A 40-minute charge from midday that day
B	Local Trip B	7.2	A 75-minute charge from midday that day
C	Trip to Melbourne	54	An 8-hour charge from 10am the following day
D	Monthly Regional Trip	72	A 10-hour charge from 10am the following day
E	No EV Travel Day	0	No charge

Table 6 EV Charging Profile, Scenario 1 Home

The average daily electricity usage profile of the combined stationary energy and transport energy loads involving the daytime EV charging is presented below. It should be noted that this profile is the average of all days throughout the year – on any individual days, electricity usage associated with EV charging, heating/cooling or hot water may be larger or smaller, depending on the usage on that day:

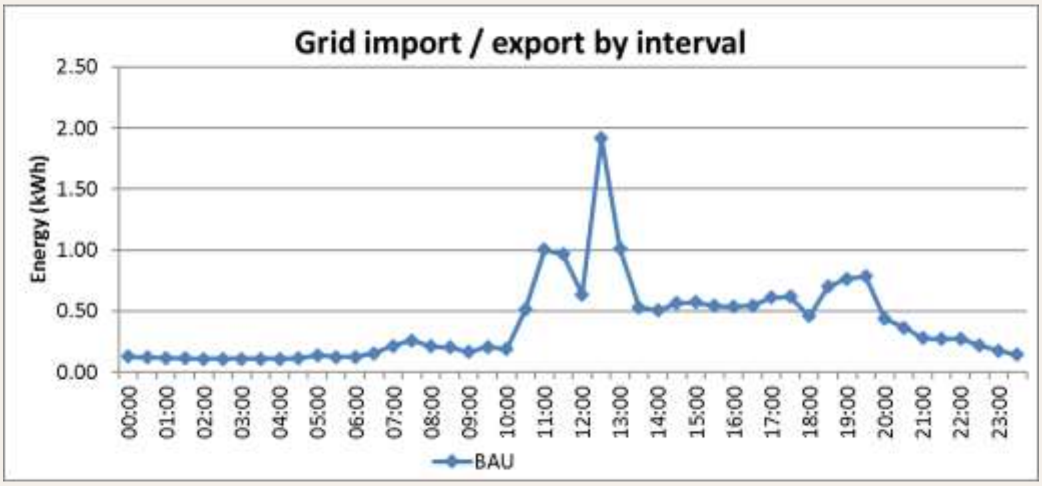

Figure 4: Average Daily Electricity Usage Profile, Scenario 1 Home, Day Time EV Charging

It should be noted that delaying such significant charges to the following day may be somewhat unrealistic in that the EV then becomes unusable following a trip to Melbourne or a regional trip. In reality, an EV owner may wish to use the car the following day and therefore require it to be partially or fully charged by the following morning.

There will of course be times throughout a year where charging the EV will be possible during solar generation hours. As such, this sensitivity test could be considered a "Best Case" for EV charging; whilst the original Scenario 1 results could be considered more a "Worst Case" end of results.

The high-level costs, benefits and energy characteristics of changing the EV charging pattern to better match solar generation were as follows:

	BAU	10KW+13KWH	15KW+27KWH
Annual Co2 Saved (T)		13.9	20.9
Annual Net Carbon (T)[18]		- 5.83	- 12.83
Average Battery Utilisation		53%	28%
Import from grid	19.05	2.72	0.71
Financial stats			
Solar/Battery Cost		$22,000	$40,000
Annual Total Cost	$2,487	- $125	- $1,051
Annual Bill Saving		$2,613	$3,538
Net Present Value (20 yrs)		$10,840	$1,152
Simple Payback (yrs)		9	17

Table 7 Large Solar & Battery System Performance, Scenario 1 Home, Day Time EV Charging

As can be seen, by changing the EV charging profile:

- With the 10 kW & 13.5 kWh solar-battery system, import from the grid is reduced from 4.54 kWh/day to 2.72 kWh/day;
- With the larger 15 kW & 27 kWh solar-battery system, import from the grid is reduced from 2.83 kWh/day to 0.71 kWh/day. This system and charging profile almost achieves zero use of grid-supplied electricity.

[18] Assumes July 2018 NGA Factors: https://www.environment.gov.au/system/files/resources/80f603e7-175b-4f97-8a9b-2d207f46594a/files/national-greenhouse-accounts-factors-july-2018.pdf

3. Scenario 2: Large Home, High Mileage

Scenario 2 included the following key parameters:

- A new, 8 Star all-electric home;
- 195m2 home size; and
- Annual mileage of 40,000 km.

The electricity usage of this home, on an average daily and annual basis, was modelled as follows:

	Average Daily Usage (kWh)	Annual Usage (kWh)
Stationary Energy	19.12	6,979
Transport Energy	19.24	7,023
Total Electricity	38.36	14,001

Table 8 Daily & Annual Electricity Usage - Scenario 2 Home

To put this in context, both the stationary energy and transport energy loads of the Scenario 2 home are larger than for Scenario 1. This is due to:

- the additional home size (the Scenario 2 home is 44% larger), and therefore the additional heating and cooling required;
- the additional number of occupants (4 people instead of 2), and therefore the additional hot water demand in particular; and
- an annual mileage that is more than double that of Scenario 1.

3.1. Electricity Usage Profile

The average daily electricity usage profile of the combined stationary energy and transport energy loads is contained in Figure 4 below. It should be noted that this profile is the average of all days throughout the year – on any individual days, electricity usage associated with EV charging, heating/cooling or hot water may be larger or smaller, depending on the usage on that day. But Figure 1 broadly shows:

- the switching on of the heat pump hot water system each day from 11am;
- patterns of EV charging that occurs overnight and for short periods in the middle of the day (from midday);
- a typical residential "hump" (albeit smaller than a typical existing Victorian home) in the late afternoon / early evening.

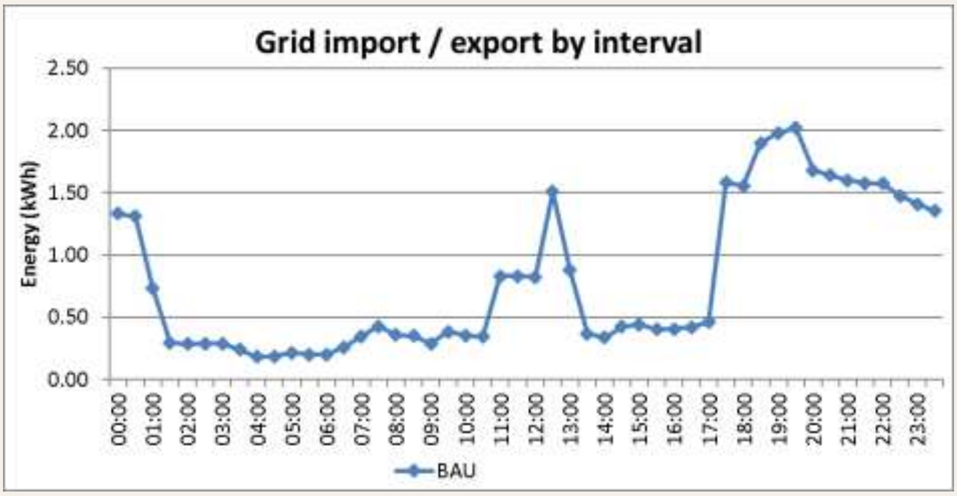

Figure 5: Average Daily Electricity Usage Profile, Scenario 2 Home

To better understand the profile on specific days, the following two charts show the electricity usage on a day where significant EV charging occurs (overnight), and another day where the EV is not charged at all:

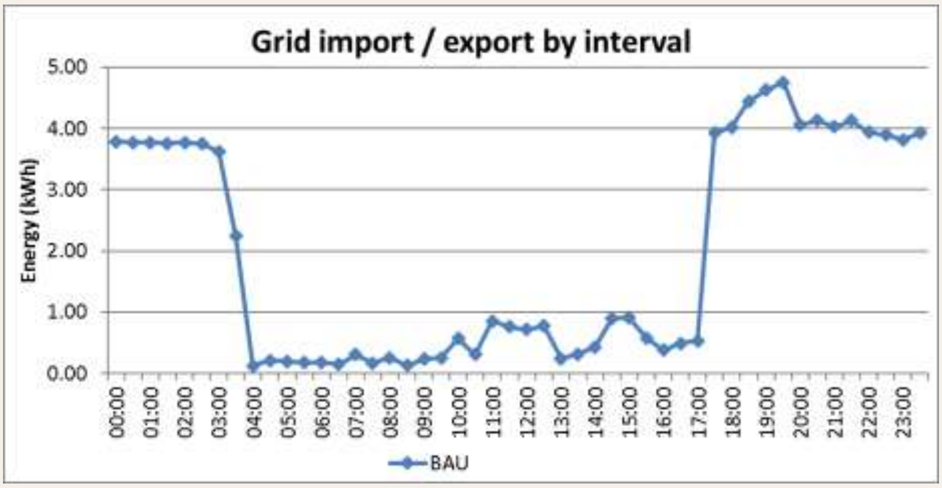

Figure 6: Electricity Usage Profile, Saturday 18th May, Scenario 2 Home (Overnight EV charge)

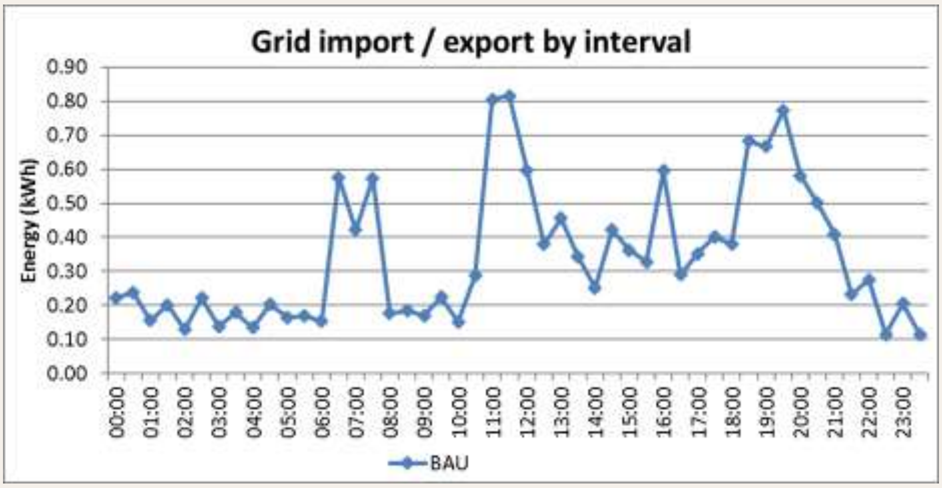

Figure 7: Electricity Usage Profile, Wednesday 6th February, Scenario 2 Home (No EV charge)

3.2. EV Charging Profile

Considering the 40,000 km annual mileage for the EV, Renew developed a separate model of driving patterns and subsequently an EV charge electricity profile, that fed into the overall electricity usage profile above.

LABEL	DRIVING PATTERN NAME	TRIPS PER WEEK	KM PER TRIP	KWH CONSUMPTION PER 100KM	KWH CHARGE REQUIRED
A	Local Trip A	1	20	18	3.6
B	Local Trip B	1	40	18	7.2
C	Trip to Melbourne	2	300	18	54
D	Monthly Regional Trip	0.25[19]	400	18	72
E	No EV Travel Day	-	-	-	0

Table 9 Weekly Driving Patterns, Scenario 2 Home

When applied annually, the driving patterns above resulted in an annual mileage of 39,120km.

A charging profile was then developed for each of these driving days, assuming a 7kW max (i.e. 32 Amp) EV charger. The key parameters of this profile were as follows:

LABEL	DRIVING PATTERN NAME	KWH CHARGE REQUIRED	CHARGE PATTERN
A	Local Trip A	3.6	A 40-minute charge from midday that day
B	Local Trip B	7.2	A 75-minute charge from midday that day
C	Trip to Melbourne	54	An 8-hour charge from 5pm that day (upon arriving home)
D	Monthly Regional Trip	72	A 10-hour charge from 5pm that day (upon arriving home)
E	No EV Travel Day	0	No charge

Table 10 EV Charging Profile, Scenario 2 Home

3.3. Tariffs

A simple approach to tariff selection was undertake for the modelling. Renew reviewed available electricity tariffs for the Cape Paterson postcode[20] and selected a mid-level, basic flat tariff structure (all prices include GST):

- $0.30 per kWh for energy;
- $1.10 per day fixe charge; and
- $0.12 per kWh feed-in tariff.

[19] i.e. once per month
[20] https://compare.energy.vic.gov.au/

3.4. Solar-Battery Analysis

Renew modelled the same range of solar PV and solar-battery systems against that annual load, to test the ability of each system configuration to meet the annual and daily load for the Scenario 2 home. The modelling was done on a 30-minute basis so an accurate picture of on-site usage of the solar and battery energy, versus export to, and import from, the grid could be determined. System sizes and configurations modelled were:

- BAU – i.e. no solar/battery, simply to understand the load characteristics and the annual electricity bill;
- 5 kW solar PV only (no battery);
- 10 kW solar PV only (no battery);
- 5 kW solar PV with a 5 kWh (small) battery;
- 5 kW solar PV with a 13.5 kWh (large) battery;
- 10 kW solar PV with a 13.5 kWh (large) battery.

The following table captures a range of environmental, economic and energy results from the model:

	BAU	5KW	10KW	5KW+5KWH	5KW+13.5KWH	10KW+13.5KWH
Environment Results						
Annual Co2 Saved (T)		7.1	14.2	6.9	6.8	13.9
Annual Net Carbon (T)[21]	16.24	9.14	2.04	9.34	9.44	2.34
System sizing statistics						
Self-consumption of Solar		45%	26%	73%	92%	59%
Solar Export %		55%	74%	27%	8%	41%
Average Battery Utilisation		0%	0%	94%	60%	85%
Export to grid (kWh/day)[22]		10.72	28.82	5.24	1.51	15.89
Import from grid (kWh/day)	38.36	29.63	28.30	24.65	21.26	16.56
Financial stats						
Solar/Battery Cost[23]		$6,500	$12,000	$13,500	$17,000	$22,000
Annual Electricity Bill	$4,602	$3,177	$2,238	$2,871	$2,663	$1,519
Annual Maintenance Cost		$50	$100	$100	$100	$130
Annual Total Cost	$4,602	$3,227	$2,338	$2,971	$2,763	$1,649
Annual Bill Saving		$1,375	$2,264	$1,631	$1,838	$2,953
Net Present Value (20 yrs)[24]		$12,367	$18,833	$6,681	$5,041	$15,364
Simple Payback (yrs)		5	6	9	10	8
Return on Investment		19.5%	16.9%	7.7%	5.7%	9.6%

Table 11 Solar & Battery System Performance, Scenario 2 Home

[21] Assumes July 2018 NGA Factors: https://www.environment.gov.au/system/files/resources/80f603e7-175b-4f97-8a9b-2d207f46594a/files/national-greenhouse-accounts-factors-july-2018.pdf
[22] The model assumes a 10kW export limit.
[23] Prices do not include the Solar Victoria rebate.
[24] Future benefits discounted at 2.5% real.

The key points of note from the table above are:

- With no solar or battery, the annual electricity bill of the Scenario 2 home would be $4,602 per year;
- Just adding a 5 kW solar-only system reduces this bill to $3,177 per year – a saving of $1,375 with a simple payback of 5 years:
    - However, the 5 kW solar-only system only reduces grid imports by 8.73 kWh/day – or around 23%. The home still requires an average 29.63 kWh/day from the grid;
- The 10kW solar-only system reduces the annual electricity bill to only $2,238. Even allowing for maintenance costs, the annual savings from this system are over $2,200:
    - However, with a 10 kW solar-only system, the home still requires an average 28.3 kWh/day from the grid – reducing grid imports by around 26%;
- Even the largest 10 kW & 13.5 kWh system only reduces the annual electricity bill to $1,519 and still requires an average 16.56 kWh per day from the grid (a 57% reduction):
    - This system's installed cost is $22,000, annual savings are $2,953, and simple payback is 8 years;
    - The average battery utilisation for the largest system is now 85% - meaning that the 13.5 kWh battery is well utilised given the increased electricity usage. However, given the requirement for an average 16.56 kWh per day of imports from the grid, this battery size still cannot adequately charge the EV in significant charge days.
- From a net-carbon perspective, and given the larger electricity load, the systems involving 5 kW of solar (either solar-only or solar and battery) still result in around nine tonnes of emissions per year (reduced from over 16 tonnes in the BAU load):
    - The 10 kW solar systems (either solar-only or solar and battery) reduce this down to just over two tonnes per year, not quite achieving the goal of carbon neutrality for both stationary and transport energy loads.

3.5. Sensitivity Test 3: Large Solar, Large Batteries

In order to see how much further grid imports could be reduced for the Scenario 2 home, Renew tested two larger solar-battery systems:

- 10 kW solar PV with a 20 kWh battery; and
- 15 kW solar PV with a 27 kWh battery[25].

The high-level costs, benefits and energy characteristics of these larger systems sizes were as follows:

	BAU	10KW+20KWH	15KW+27KWH
Annual Co2 Saved (T)		13.7	20.6
Annual Net Carbon (T)[26]		2.54	- 4.36
Average Battery Utilisation		69%	61%
Import from grid	38.36	14.30	10.93
Financial stats			
Solar/Battery Cost		$28,500	$40,000
Annual Total Cost	$4,602	$1,530	$499
Annual Bill Saving		$3,072	$4,103
Net Present Value (20 yrs)		$11,062	$12,548
Simple Payback (yrs)		10	13

Table 12 Larger Solar & Battery System Performance, Scenario 2 Home

As can be seen:

- Increasing the battery to 20 kWh still results in an average 14.30 kWh per day imported from the grid;
- Increasing the solar to 15 kW and the battery to 27 kWh further reduces grid import by just over 3.0 kWh per day (to 10.93 kWh) – but this comes at a significant cost ($40,000 upfront);
- Both of these systems still result in a positive annual electricity bill (the larger system reduces the bill to $499 per year); and
- The larger system becomes achieves carbon neutrality (indeed is carbon positive on an annual basis).

[25] e.g. 2x Tesla Powerwalls

[26] Assumes July 2018 NGA Factors: https://www.environment.gov.au/system/files/resources/80f603e7-175b-4f97-8a9b-2d207f46594a/files/national-greenhouse-accounts-factors-july-2018.pdf

3.6. Sensitivity Test 4: Charge EV from Solar

Given the difficulty of reducing the grid imports to zero, Renew again modelled an alternative for Scenario 2, whereby the majority of the EV charging occurred during solar generation times.

This was achieved by changing the times for the most significant two charging profiles for Scenario 2 – i.e. Labels C and D in the table below:

LABEL	DRIVING PATTERN NAME	KWH CHARGE REQUIRED	CHARGE PATTERN
A	Local Trip A	3.6	A 40-minute charge from midday that day
B	Local Trip B	7.2	A 75-minute charge from midday that day
C	Trip to Melbourne	54	An 8-hour charge from 10am the following day
D	Monthly Regional Trip	72	A 10-hour charge from 10am the following day
E	No EV Travel Day	0	No charge

Table 13 EV Charging Profile, Scenario 2 Home

The average daily electricity usage profile of the combined stationary energy and transport energy loads involving the daytime EV charging is presented below. It should be noted that this profile is again the average of all days throughout the year – on any individual days, electricity usage associated with EV charging, heating/cooling or hot water may be larger or smaller, depending on the usage on that day:

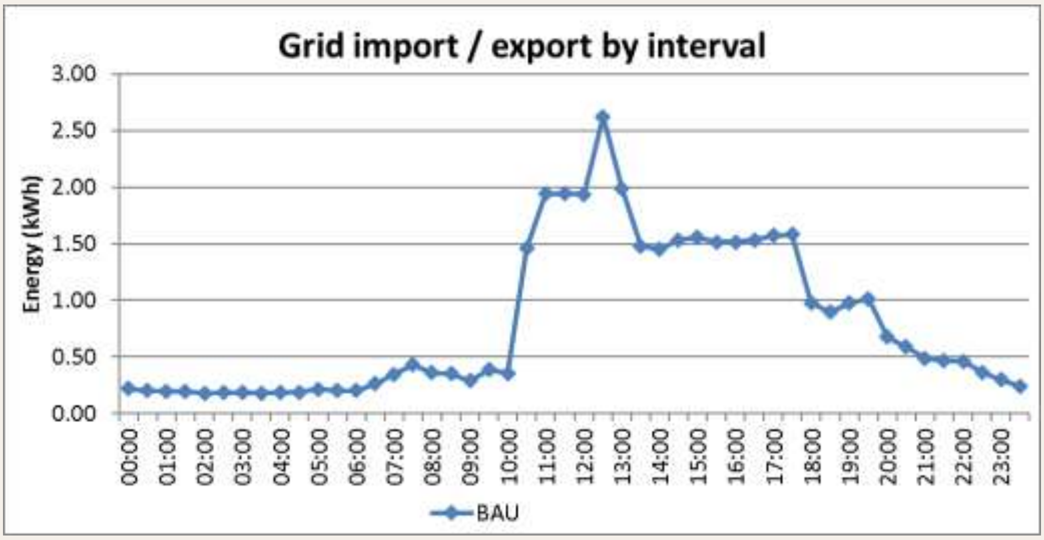

Figure 8: Average Daily Electricity Usage Profile, Scenario 2 Home, Day Time EV Charging

The high-level costs, benefits and energy characteristics of changing the EV charging pattern to better match solar generation were as follows:

	BAU	10KW+13KWH	15KW+27KWH
Annual Co2 Saved (T)		13.8	20.8
Annual Net Carbon (T)[27]		2.44	- 4.56
Average Battery Utilisation		69%	48%
Import from grid	38.36	12.07	4.42
Financial stats			
Solar/Battery Cost		$22,000	$40,000
Annual Total Cost	$4,602	$1,343	$55
Annual Bill Saving		$3,258	$4,546
Net Present Value (20 yrs)		$19,832	$19,098
Simple Payback (yrs)		7	9

Table 14 Large Solar & Battery System Performance, Scenario 2 Home, Day Time EV Charging

As can be seen, by changing the EV charging profile:

- With the 10 kW & 13.5 kWh solar-battery system, import from the grid is reduced from 16.56 kWh/day to 12.07 kWh/day;
- With the larger 15 kW & 27 kWh solar-battery system, import from the grid is reduced from 10.93 kWh/day to 4.42 kWh/day. This system and charging profile achieve the closest of any system for the Scenario 2 home to zero use of grid-supplied electricity.

[27] Assumes July 2018 NGA Factors: https://www.environment.gov.au/system/files/resources/80f603e7-175b-4f97-8a9b-2d207f46594a/files/national-greenhouse-accounts-factors-july-2018.pdf

4. Findings

As can be seen, the general findings from this study are:

1. It is relatively achievable to reduce electricity bills to near or beyond zero, particularly for the smaller annual loads for both stationary and transport energy load;

2. It is also relatively achievable to reduce carbon emissions to net zero (or positive), again particularly for the smaller annual loads (but also the higher annual load almost achieved net zero carbon where 10 kW of solar was installed);

3. It is very difficult to reduce imports from the grid to near zero for any level of energy consumption, when combining both the stationary and transport energy loads from electricity. Even where household energy use and annual mileage are low, a very and expensive large solar and battery system is required to reduce grid imports to near zero (15 kW solar & 27 kWh batteries at an installed cost of approximately $40,000).

   However, reducing imports from the grid to zero is not a particularly worthwhile objective where a grid connection is available:

   - Reducing grid imports to zero essentially means being able to operate independently of, or "off grid";
   - Off grid systems waste significant amounts of renewable energy, as they over generate in summer and have no network thru which to share exceeds supply;
   - Being grid connected means that excess solar generation can be used by others in the network, whilst the grid can be relied on at times of low solar resource.

4. The charging profile of the EV does have a material impact on the value of the solar and/or solar-battery system, as well as on the ability of the solar-battery system to reduce grid imports closer to zero.

   Sensitivity Tests 2 and 4 demonstrate that by undertaking most EV charging during solar generation times, thousands of dollars of additional value can be created over 20 years, and grid imports can be reduced down to only a few kWh per day (dependent on solar-battery system size).

   Sensitivity Tests 2 and 4 should be thought about as "Best Case" scenarios with regards to EV charging profiles. In reality however, it is unlikely that an EV owner will be able to delay full re-charging until the daytime of the following day after a lengthy trip, every time.

   As the original modelling for Scenarios 1 and 2 include EV charging predominately occurring overnight, the Scenario 1 and 2 results, and the Sensitivity Tests 2 and 4, can be considered a "Worst" and "Best Case" for the purposes of this study.

4.1. Further Work

Obviously, this is a preliminary piece of analysis that attempts to understand the bill, energy use and carbon impacts of high efficiency homes and EVs for one location in Australia. Significant work is required to expand this type of analysis to accommodate greater variability in (amongst other things) project location and EV annual mileage and charging regime.

Renew will seek to work with relevant project partners across government and the housing and transport industries to expand this work to provide greater guidance to consumers, and particularly retailers and electricity network businesses in the future.

renew.

ABN 57 533 056 318
Reg No. A0017411T

L1, 39 Little Collins St.
Melbourne VIC 3000
61 (3) 9639 1500
renew.org.au