Life after FiTs

Final Report for the Total Environment Centre

June 2016

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Promoting Renewable Energy, Energy Efficiency and Water Conservation since 1980

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Contents

Executive Summary

The Total Environment Centre (TEC) commissioned the Alternative Technology Association (ATA) to provide guidance to existing New South Wales, Victorian and South Australian solar feed-in tariff (FiT) customers as to:

- The financial impact of the closure of the respective 'premium' FiT schemes in each state – i.e:
  - the NSW Solar Bonus Scheme and the Victorian Transitional Feed-in Tariff at the end of 2016; and
  - the South Australian Feed-in Scheme at the end of September 2016; and
- The opportunities for these FiT customers going forward, using a combination of different complementary technologies (e.g. batteries) and/or retail strategies, and the related technical considerations that each option may have (e.g. metering changes).

More than 275,000 solar customers across these three states, will be impacted by the closure of these scheme at or towards the end of 2016. The breakdown by state is as follows:

Table 0.1: No. of Solar Customers for whom Premium FiTs are closing in 2016

State	Current tariff	End date	Feed in tariff rate for 2017	No. affected
NSW	The Solar Bonus Scheme: - a FiT of 20 cents per kWh or 60 c/kWh for all solar generation	Dec 31, 2016 (started 2010)	No mandated FiT for NSW. IPART determines a 'benchmark range' (in 2015-16: 5.5-7.2 c/kWh) but up to retailer to decide the FiT offer.	146,000
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TOTAL AFFECTED				**275,902**

The key question for many of these existing FiT customers is – *how do I mitigate the financial impact of the closure of these schemes*?

There are a number of different technology and related considerations for these solar customers to consider before embarking on any purchase decisions or other energy management strategies. This Executive Summary highlights the main findings of this report in a "Decision Tree" type structure, in order to assist these solar customers to work through the various issues that need to be considered to mitigate the economic impact of the scheme closures going forward.

Step 1: Ensure the Correct Metering

With FiTs reducing to relatively low levels, it is imperative that from an economic perspective, those customers are able to use their solar-generated electricity to directly power their household or business appliances.

The Victorian and South Australian schemes were 'net' schemes. Net metering recognises the use of solar electricity on-site to reduce purchases from the grid. As such, solar customers in these jurisdictions will not need to change their metering configuration.

The NSW Solar Bonus Scheme offered a 'gross' FiT. Gross metering separately measures the solar generation from household use – i.e. it does not offset electricity purchases from the grid. Those NSW customers will need to enable net metering at their site in order to maximise the financial benefit of their system.

Overall, the technical solutions for switching from gross to net metering for Solar Bonus Scheme customers are somewhat difficult to navigate at this time. Costs differ greatly and there are differences depending on the local distribution business[1]:

- Customers in the Endeavour distribution area wishing to change to net metering at this point in time will be required to install a new meter. The suggested cost of a new distributor installed meter is around $600. The total cost of allowing a retailer to install the meter is unclear at this time.
- Customers in the Essential Energy area may have the additional possibility of utilising their existing solar meter. This requires a minor wiring adjustment to change the meter from gross to net with an estimated cost of $150. At the time of writing Essential Energy have not clarified if they will accept this solution.
- Customers in the Ausgrid area have the possibility of utilising their existing solar meter after a minor wiring adjustment to change the meter from gross to net (cost estimated to be around $150). At the time of writing Ausgrid have confirmed they will allow this option.
- As a further option for Ausgrid customers, Ausgrid have also suggested they are prepared to use the data from the two existing gross meters to calculate net energy flows. While this is does not require any meter changes, at the time of writing it is unclear if retailers intend to accept this option.

Whether the solution ends up being the replacement of any meter, re-wiring or changes to billing arrangements, if these solutions are being offered through an energy retailer, then the customer must ensure they understand the full implications of agreeing to any particular solution – as this may have implications for that customer's retail tariff or other related considerations.

ATA advise a cautious approach in dealing with both distribution businesses and retailers regarding metering changes. The Solar Bonus Scheme will continue to the end of 2016 and consumers should attempt to maximise the benefits they receive under the existing scheme. At the closure of the Scheme, customers in the Ausgrid and Essential Energy areas should explore zero or low cost options.

[1] To find out which distribution area you are in, go to: https://www.agl.com.au/residential/help-and-support/emergencies-and-outages/electricity-distributor-lookup-tool

Consumers should also carefully evaluate the various retailer tariffs, including those offering a subsidised (net) smart meter.

As of June 2016, ATA understands there are around six retail offers in existence involving free or cheap meters in NSW. The only way for any individual customer at this point in time to calculate if one of those offers is their best approach to enabling net metering, is to:

- calculate an annual bill based on the fixed and kWh rates of that specific retail offer, and using their net consumption (after on site solar use); and then compare this to:

- the distributor charge for re-wiring or the net billing option (e.g. $150) and add this to the calculation of an annual bill for the best retail deal they can find in the market (again using their net consumption).

Given that all retailers will cost recover the meters thru their charges in one way or another (and given the history of NSW solar customers facing somewhat higher retail charges and tariffs that other non-solar customers do not typically face), it is not clear at this point in time which is the better path for any individual customer.

At this point, the last resort should be to request the local distributor to install a net meter. This option will likely incur a high upfront cost and the customer needs to still compare available retail tariffs.

Rather than rushing into the meter upgrade it is suggested customers wait a few weeks or even months after the closure of the Scheme to give time to compare the various options.

Step 2: Use your Solar Electricity

With FiTs being reduced, there is significantly greater value in using your solar electricity on-site – rather than export it to the grid for a low feed-in credit.

Most households, even those with relatively small solar PV systems (e.g. 1.0 – 2.0kW), do not use much of their solar electricity during the day time[2]. Even people who stay at home regularly often run little more than the fridge, a computer or audio-visual equipment, and maybe the washing machine or dishwasher once every few days, during solar generation hours.

The opportunity is to shift more of your appliances to run during the day – and be directly powered by solar. And the biggest two appliances you can shift is your water heating; or your space heating & cooling – to maximise the use of that free solar electricity.

Electric water heating for homes is broadly done in two ways:

- by utilising a traditional electric storage hot water (ESHW) system – which uses single or multiple resistive electric elements in a tank to heat and store water; or

[2] As an example, a 1.5kW PV system in Sydney will generate around 10kWh between 9am and 5pm in summer; and around 5-7kWh in autumn/spring. Most homes consume not much more than 2kWh between breakfast and dinner – meaning even this small system has a relatively export rate to the grid.

- using a heat pump – which involves the compression and expansion of ambient air through a heat exchanger to extract heat, which combined with electricity creates multiple units of heat output for heating water stored in a tank.

Both of these systems use electricity as an input to the system and can be powered directly from solar PV – provided:

- the home or business is configured for net metering;
- the ESHW or heat pump is connected the main electrical circuit (e.g. not a separate, dedicated circuit established for off-peak hot water); and
- the ESHW or heat pump operates during the day (i.e. when the solar system is generating electricity).

ATA modelled the cost and benefits of purchasing and installing a new ESHW system versus a new heat pump hot water system – for a Sydney home with existing solar PV and about to lose their gross FiT (**Section 5.0** of this report).

The analysis suggests that for the majority of existing solar PV customers about to lose their premium FiT, irrespective of PV system size, they would either be better off, or no worse off, over 10 years by choosing to install a heat pump hot water system instead of an ESHW system.

Besides hot water, as the other major (and usually larger) residential load, space heating and cooling is a key opportunity. Where this is electric, these can be programmed to at least partially run during the day time to soak up excess solar energy; whilst at the same time ensuring less electricity is required for temperature control after solar-generation hours.

Pre-heating or pre-cooling takes advantage of excess solar electricity during the daytime by programming the electric heating/cooling appliance to switch on earlier (e.g. 2pm), but at a relatively conservative setting (e.g. 16-18 degrees in winter; or 28-30 degrees in summer).

A key factor in the potential success of a pre-heating / pre-cooling strategy is the thermal performance of the building itself. Any householder attempting to use this strategy should ensure decent levels of ceiling insulation (and potentially wall and floor insulation if undertaking a renovation project) within the building.

And for those solar customers that heat or cool during the day, provided they have net metering and their PV system has sufficient capacity, they will use solar electricity to heat/cool their homes.

Finally, a number of existing solar homes are considering adding more panels to their existing solar system once their premium FiT ends. Provided those solar customers are not looking for the most economic approach to mitigating their loss of FiT income, then this is a great way to add more renewable energy into the grid.

However, if mitigating the economic impact is a key driver, then this will make a difficult situation worse – as not only will the customer lose significant annual revenue through the FiT, they will pay (likely) thousands of additional dollars to add panels to the existing system, and which will likely require the replacement of the existing inverter (as it will likely be matched with the rated capacity of the existing panels).

Ultimately, the majority of the additional generation from the newly expanded system will also be exported to the grid, for very low FiT price.

Step 3: Get Off Gas

With space heating and hot water generally comprising somewhere between 50% and 70% of a home's stationery energy needs, it is difficult to maximise the use of solar PV without using it to power one or both of these major loads.

For some NSW, Victorian and SA solar customers, they will run one or both of these appliances using mains or bottled gas.

For gas-connected solar customers, switching away from gas is imperative to achieving the best economic return possible for their existing (and any upgraded) solar PV system.

This strategy will largely involve considering the kind of electric hot water and space heating solutions canvassed above.
Designed and implemented well, transitioning away from gas will allow most NSW, Victorian and SA customers to reduce their annual stationery energy bills to no more (and potentially less) than $1,000 per year. This is in the context of the majority of NSW, Victorian and South Australian homes currently paying in the order of $2,000-$3,000 per year for stationery energy (i.e. electricity or electricity and gas)[3].

Given the rise of distributed solar energy, most Australian homes now have three clear choices with regards to their stationery energy requirements, those being:

- Electricity from the electricity grid;
- Electricity from their own solar system; and/or
- Gas from the gas grid or bottled (LPG).

From an economic perspective, it makes no sense to rely on all three - ultimately households do not consume such significant amounts of stationery energy as to necessitate three separate input fuel sources.

Going forward, Australian households are facing a clear choice with regards to keeping their energy bills low:

1. either remain dual fuel and rely on both the electricity and gas grids; or
2. become (or remain) all electric – purchasing some electricity from the grid, and some from their own solar PV system.

Increasingly, option 2 is the more economic. And with falling costs of renewable energy and some efficient electric technologies; the increasing efficiency of electric water and space heating technologies; and slow to steadily rising gas prices (due to linkage of the gas price with the international export market), the future trend is clearly in favour of option 2.

[3] http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4670.0main+features132012

Step 4: Get the Best Retail Deal

ATA conducted an analysis of available retail FiT offers, including their associated consumption tariffs, in NSW, Victoria and SA. This analysis informed the modelling undertaken for the project.

Currently in Victoria, every retailer with 5,000 or more retail customers must offer a mandatory minimum FiT payment to any new solar customer. SA takes the same mandatory minimum approach as Victoria – with regulators in each jurisdiction setting a minimum FiT rate each year.

In NSW, there is no mandatory minimum FiT rate that must be offered by retailers to any new solar customer under the current NSW legislation. Retailers can choose whether or not to offer a FiT at all.

The tables in **Section 6.0** aggregates the results from a review of 52 solar FiT retail offers; and 28 non-solar retail offers; in the NSW, Victorian and SA markets. The ranges and averages/medians of FiT rates, as well as rates for consumption (be those as part of flat or time of use offers) and any pay-on-time discounts, are presented[4].

In considering solar offers versus non-solar offers, ATA did not find material differences in the consumption rates (whether they were as part of flat tariff offers or time of use) for retail offers to solar customers as compared with non-solar customers, across the three jurisdictions.

In addition, a mix of one, two and three year market contracts; as well as 'Ongoing' offers were present in both retail offers to solar customers and non-solar customers.

The only material distinction ATA could find with respect to solar offers versus non-solar offers was the relatively lower pay-on-time discounts that were offered to solar customers – particularly in NSW and SA. Non-solar customers in those markets were offered discounts that were on average 7% higher than for solar customers.

It should be noted that ATA's retail tariff analysis represents only a subset of available offers in each of the three markets; and offers may differ more widely across the full range of available offers.

Irrespective of how solar and non-solar offers play out across these markets, our advice to existing and new solar customers is the same – shop around to get the best overall deal taking into account FiT rate[5], consumption rates and supply charge, discounts and other relevant offer elements.

Step 5: What about Batteries?

ATA conducted modelling to understand the value of installing new lithium-based storage to homes with existing solar PV systems in Sydney, Adelaide and Melbourne.

The modelling considers investment (i.e. battery and inverter purchase and install), at the start of 2017 and in 2020; and takes account of reducing component capital (and operating) costs over time.

[4] It should be noted that this analysis can only be considered accurate at the time of writing. Retail offers in the NEM change on a 6-12 month basis (depending on jurisdiction and offer type). These tariffs are unlikely to be completely accurate at the time of the premium FiTs ending toward the end of 2016.

[5] Bearing in mind that the retail offer with the highest FiT rate may not necessarily be the best retail offer overall for any individual solar customer.

ATA modelled four different system configurations, in order to find the most economic cases:

- 1.5kW solar PV + 3.0kWh storage;
- 4.0kWh solar PV + 3.0kWh storage;
- 1.5kW solar PV + 7.0kWh storage; and
- 4.0kW solar PV + 7.0kWh storage.

The modelling results (**Section 4.3**) demonstrate that retro-fitting energy storage to solar is not cost effective for existing solar PV customers prior to 2020 – with some scenarios remaining unfavourable after 2020 (particularly those associated with the larger battery).

The results can be broadly interpreted as suggesting that:

- systems with smaller batteries, that have more chance of being fully utilised over the course of the year, are likely to be economic in these three (and likely other) jurisdictions by 2020;

- systems with larger batteries, that have less chance of being fully utilised over the course of a year, may remain uneconomic in these three jurisdictions in 2020 and potentially beyond. A key influencing factor will be the future declining cost of storage technology;

- That Adelaide offers better economics than Sydney or Melbourne – largely due to:
    - higher electricity retail tariffs (approx. 30% higher than Sydney/Melbourne); and
    - higher solar insolation levels in Adelaide on an annual basis.

Step 6: Am I Battery Ready?

There are multiple ways that batteries can be added to an existing solar PV system – involving different component configurations which ultimately influence different overall system capabilities.

The majority of NSW, Victorian and SA solar customers will have somewhat older inverters, with the technology likely being installed between the beginning of 2010 and the end of 2013. In terms of functionality, these inverters will not have the full capabilities of many of the inverters available in the Australian market in 2016 – and many of the inverters required for hybrid solar-battery systems.

Given the poor economics of storage in 2016, it is advisable to wait with regards to battery investment and instead, ensure Steps 1-4 above are fully implemented, by:

- ensuring the correct metering;
- maximising your existing solar electricity by shifting major appliances to the day time;
- implementing a plan to get off gas; and
- getting the best possible feed-in tariff offer;

Steps 2 & 3 will likely take one to three years to implement, by which time batteries will have reduced in cost; and your existing inverter may be coming close to needing replacement anyway (a necessary step for existing solar customers moving to a solar-battery system).

Following these steps, and with battery prices low enough around 2020, it should be eminently achievable for most solar homes to be consuming the majority of their own solar electricity whilst at the same time reducing their annual stationery energy bills to below $500 per annum (a reduction of around 75%-83% on what most Australian households currently pay per year).

1.0 Introduction

The Total Environment Centre (TEC) commissioned the Alternative Technology Association (ATA) to provide guidance to existing NSW, Victorian and South Australian solar feed-in tariff (FiT) customers as to both:

- the financial impact of the closure of the respective 'premium' FiT schemes in each state – i.e:
  - the NSW Solar Bonus Scheme (SBS) and the Victorian Transitional Feed-in Tariff (TFiT) at the end of 2016; and
  - the South Australian Feed-in Scheme (FiS) at the end of September 2016; and
- the opportunities for these FiT customers going forward, using a combination of different complementary technologies (e.g. batteries) and/or retail strategies, and the related technical considerations that each option may have (e.g. metering changes).

More than 275,000 solar customers across these three states, will be impacted by the closure of these scheme at or towards the end of 2016. The breakdown by state is as follows:

Table 1.1: No. of Solar Customers for whom Premium FiTs are closing in 2016

State	Current tariff	End date	Feed in tariff rate for 2017	No. affected
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In order to satisfy these requirements, ATA has undertaken the following tasks – the results of which are detailed in the following chapters of this report:

- Modelling of the economics of different types of battery installations and management strategies for FiT customers post-2016;
- A product review of the latest home energy management systems and devices that allow better utilisation of solar energy in homes; and
- A brief review of the retail energy market in NSW, Victoria and SA for FiTs, including any implications for consumption tariffs (where these exist) for solar customers.

This document is the Final Report. It outlines the literature review, modeling and related investigations undertaken by the ATA and includes recommendations for these specific solar customers going forward.

ATA wishes to thank TEC for the opportunity to work on this highly interesting project.

2.0 Metering

With premium FiTs reducing for some solar customers, it is imperative that from an economic perspective, those customers are able to use their solar-generated electricity on-site and avoid paying a retail peak or day-time tariff – as this economic benefit will be greater than any new FiT they may receive.

The Victorian and South Australian premium FiT scheme only offered a premium for exported electricity in excess of household use. Participants in these schemes installed 'net' meters (sometimes referred to as "import/export" metering).

Solar customers in these jurisdictions will not need or be required to change their metering configuration[6]. These customers are able to increase the financial benefits they receive from their solar system by increasing the amount of solar electricity they self-consume.

The NSW Solar Bonus Scheme (SBS) offered a 'gross' FiT. Under the gross FiT, a credit of either 60c/kWh or 20c/kWh (depending on when the household joined the scheme) is applied to the total output of the solar system. The majority of participants in the SBS therefore chose to install a gross meter configuration separately measuring the solar system output and household use.

The NSW SBS ends midnight 31st December 2016. Those customers who have installed gross metering will need to enable net metering to continue to enjoy the financial benefits of their system.

2.1 SA & Victoria

The FiT schemes in South Australia and Victoria both used net metering – as such, there is no need to change the utility metering.

While there is no need for the utility meter to be changed, there may be some benefits to installing a meter able to show the amount of electricity being produced by the solar system and used by the household. This is particularly important when the household is on a time of use tariff with a high peak rate during daylight hours.

In this case, household electricity use should not exceed the output of the solar system. Any metering able to provide a guide to how much electricity to use during daylight hours will help maximise the financial benefits for these customers.

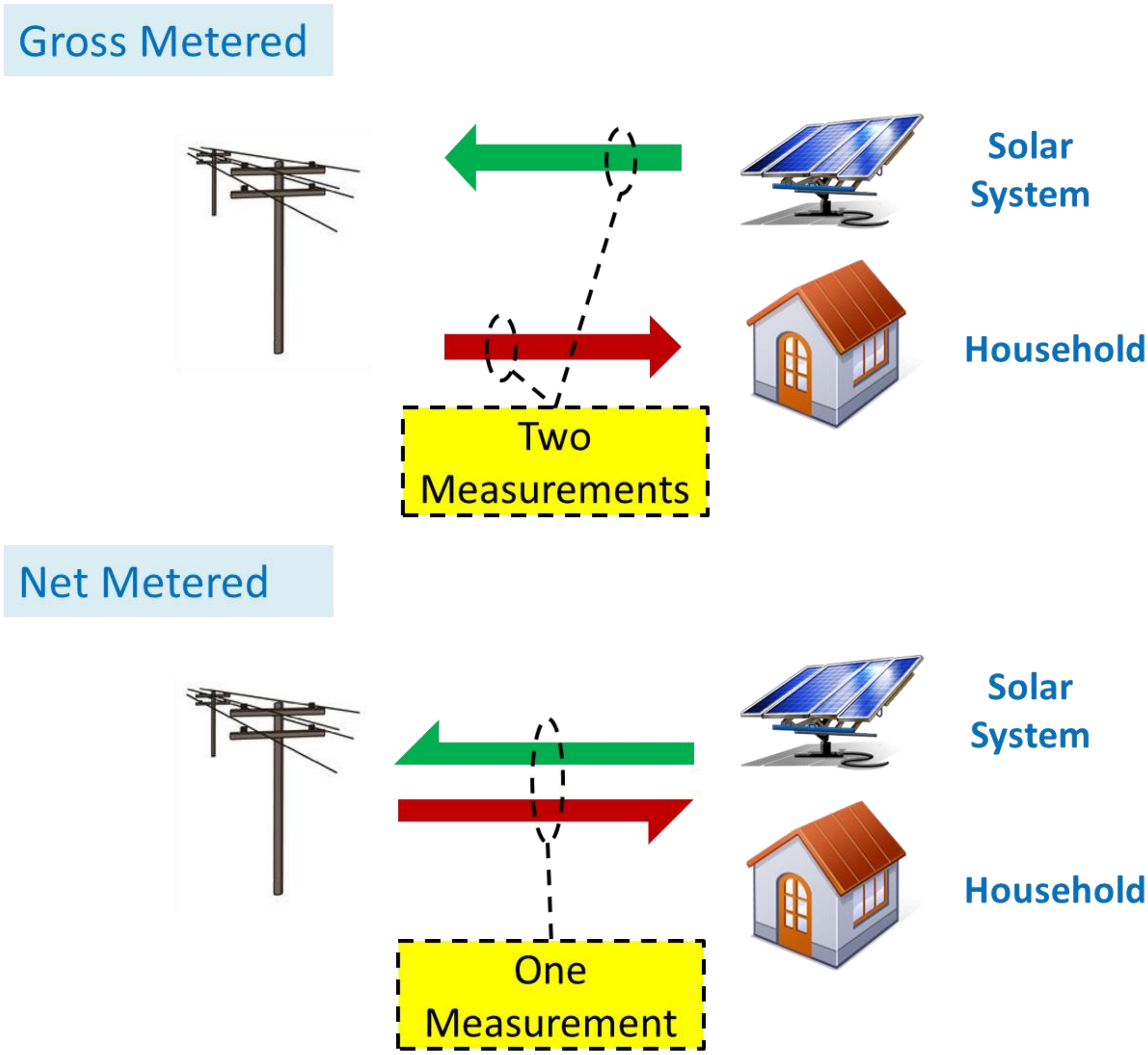
2.2 NSW: Gross to Net

Figure 3.1 on the following page depicts the difference between the existing gross metering configuration and the required net metering configuration for NSW SBS customers. The figure shows the gross metering configuration uses two separate measurements, one of household use and the other of solar system output. The two separate measurements mean household use does not affect the solar credits the household receives for electricity produced by their solar system.

[6] Indeed all small [<160MWh p.a.] customers in Victoria have net metering via the smart meters deployed under the Victorian Government's Advanced Metering Infrastructure [AMI] Program.

In the net metered configuration only one measurement is made – in this case the meter records the difference between household use and solar system output. Solar credits are earned for electricity produced by the solar system in excess of household use.

Figure 3.1: Gross & Net Metering Configurations



2.2.1 NSW Distribution Network Differences

The existing metering configuration of NSW SBS customers may be dependent on which distribution network the customer is situated in. In NSW, this can be either Ausgrid, Endeavour Energy or Essential Energy:

- The solar meter for Endeavour customers was typically a uni-directional meter measuring only electricity produced by the solar system;
- The solar meter for Essential Energy customers was typically a bi-directional meter measuring the net energy flow to and from the solar system (solar inverters are electronic devices and use standby power at night);
- The solar meter for Ausgrid customers was typically a bi-directional 'type 5' (interval) meter measuring the net energy flow to and from the solar system.

2.2.2 Required Changes

Discussion within the industry and on various consumer forums have focussed on the need for existing gross metered NSW SBS customers to purchase and install a new, bi-directional meter configured for net metering[7]. The cost to purchase and install the new meter is estimated to be $600[8].

While it may be possible for existing SBS customers to have their retailer install a smart meter the cost of this option is currently not available. This is discussed in greater detail in **Section 2.3** (below). However, ATA conversations with some metering experts have raised the possibility of two potential solutions that would not require the purchase of a new meter:

2.2.3 Ausgrid & Essential Energy Customers

The existing solar meter is already configured as a net meter. A suitably authorised electrician can connect the household to the existing solar meter. This meter is already measuring bi-directional net energy flows so the modification results in the net metered solution shown above.

For most households this is a simple change of one wire on the switchboard. The cost of this modification is estimated to be less than $150.

2.2.4 Ausgrid Customers

Net energy flow is the difference between household use and solar system output. It is therefore possible to calculate net energy flow provided the gross measurements are sufficiently regular.

In the Ausgrid area, the existing 'type 5' interval meters measure household use and solar system output every 30 minutes. Discussions with the Australian Energy Market Operator suggest this is sufficiently regular to meet market requirements. The advantage of this method is no metering changes are required.

A number of metering experts consulted by ATA are firmly of the view that both solutions above are technically possible and the second option for Ausgrid is legally permitted under AEMO (Australian Energy Market Operator) regulations.

Further a recent news article has validated both approaches[9] are being considered in the Ausgrid area. At this time it is unclear if Essential Energy customers will be allowed to utilise their existing solar meter or if retailers will accept these alternatives.

2.2.5 Endeavour Energy Customers

Existing meters in Endeavour Energy's network will need to be replaced with a net meter.

[7] It should be noted that it is not a requirement for any NSW SBS customer to change to net metering; and indeed some NSW solar customers already have net metering enabled.

[8] http://www.smh.com.au/nsw/households-face-buying-600-smart-meter-to-avoid-electricity-bill-shock-20160308-gndf37.html

[9] http://www.smh.com.au/nsw/solar-panel-households-told-smart-meters-not-compulsory-as-bonus-scheme-ends-20160402-gnwr1k.html

2.3 Metering Rules & Regulations

At the time of publication of this report, the regulatory landscape for metering is shifting and the likely impact on the NSW metering market is difficult to determine.

2.3.1 National Regulatory Changes

On 26 November 2015, the Australian Energy Market Commission (AEMC) made a Final Rule that will open up competition in metering services and will give consumers more opportunities to access a wider range of metering-related services.

Improved access to the services enabled by advanced meters may provide consumers with opportunities to better understand and take control of their electricity consumption and costs.

The new arrangements, which will commence on 1 December 2017, have required changes to the National Electricity Rules (NER) and the National Energy Retail Rules (NERR).

Under the new Rule, retailers will be required to appoint a Metering Coordinator for their retail customers. Customers will have a choice of which retailer will provide their meter. Customers may wish to install a smart meter to enable access to new tariff structures (e.g. time of use, demand [kW] tariffs or critical peak pricing) or to enable net metering.

Ultimately, responsibility for supplying meters will be passed from distribution businesses to electricity retailers who may engage a third party energy service business to provide the service. This may have an impact on the upfront cost of a new meter – as some retailers may choose to offer new meters to customers as part of a new retail contract or related energy service.

Critically, ATA understands that from 1 December 2017, all new and replacement meters will have to be provided by retailers and retailers only. How a NSW customer acquires a low cost metering solution (as per the Ausgrid/Essential Energy solutions canvassed above) is ambiguous in this context. Potentially this may mean that a window may exists between 1 Jan and 1 Dec 2017 to ensure that either Ausgrid or Essential can facilitate one of these options.

The meters offered by retailers may not have as extensive functionality as may otherwise have been required by distribution businesses – but have the basics including remote read, remote de-energise/re-energise and the necessary additional function/s to allow the retailer/third party to offer their respective service[10]. Simplifying the meter functionality may reduce the upfront cost of the new meter, but at this time retailers have not published prices so this cannot be confirmed.

In changing to a new meter, customers may need to sign up to a new tariff structure – this will depend on whether the customer agrees to a new meter as part of a new retail electricity plan. This could be with either their existing retailer or a new retailer and is something affected customers should consider carefully to understand the full consumer implications of accepting a new meter and tariff.

[10] This compares with the Victorian AMI meters that had over 20 functions included within the minimum functional specification.

As of May 2016, a number of retailers in the NSW market are offering existing Solar Bonus Scheme customers to install a net meter free of charge at the beginning of 2017, provided they sign up to a retail contract or offer with that retailer. These include Powershop[11], Origin Energy[12], Diamond Energy[13] and Mojo[14]. It is advisable for NSW customers to wait to see the full detail of offers before signing up to any of these offers.

An unanswered question is whether existing SBS customers can continue with their gross metering configuration. While retailers will continue to offer net solar tariffs there does not appear to be a similar obligation to offer a gross metered tariff. This may result in the customer not receiving any financial benefit from their solar system.

2.3.2 NSW Regulatory Changes

The new national regulations relating to metering will not take effect until 11 months after the conclusion of the NSW SBS and it is anticipated that the vast majority of NSW SBS customers will seek to switch to net metering as soon as their gross FiT ends.

In anticipation of a potential bottleneck, the NSW Government is seeking to urgently pass legislation to ease regulatory restrictions on the timely uptake of metering changes.

This will likely be done in two ways. Firstly, the new legislation will lift the restrictions on who is qualified to remove and install a meter. It will no longer be restricted to Level 2 electricians but will be opened up to other electricians who have the requisite training and accreditation.

The NSW Office of Fair Trading (as opposed to distribution businesses) will become responsible for the future program of metering installation safety, compliance audits and inspections. It is anticipated that this will increase the number of available technicians for meter replacement/ reconfiguration[15].

2.4 What to do?

South Australian and Victorian customers in premium FiT schemes coming to an end are not required to make any metering changes. They may wish to adjust their electricity use to maximise the financial benefits they receive. At the time of writing, it is unclear if ‘doing nothing’ is a valid response for NSW customers on the Solar Bonus Scheme (SBS).

Overall the technical solutions for switching from gross to net metering for NSW SBS customers are somewhat difficult to navigate at this time. Costs differ greatly and there are differences depending on the local distribution business:

- Customers in the Endeavour distribution area wishing to change to net metering will be required to install a new meter. The suggested cost of a new distributor installed meter is around $600. The total cost allowing a retailer to install the meter is unclear at this time.

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11 http://www.powershop.com.au/solarnsw/

12 https://www.originenergy.com.au/for-home/solar/plans-offers/nsw-solar-bonus.html

13 https://diamondenergy.com.au/solarbonusnsw/

14 http://www.mojopower.com.au/solarbonus/. Mojo does not specifically state that the meter will be provided with no upfront cost.

15 http://neca.asn.au/nsw/content/major-changes-proposed-smart-meter-installations

- Customers in the Essential Energy area may have the additional possibility of utilising their existing (net) solar meter. This requires a minor wiring change with an estimated cost of $150. At the time of writing Essential Energy have not clarified if they will accept this solution.
- Customers in the Ausgrid area have the possibility of utilising their existing (net) solar meter after a minor wiring change (cost estimated to be around $150). At the time of writing Ausgrid have confirmed they will allow this option.
- As a further option for Ausgrid SBS customers, Ausgrid have also suggested they are prepared to use the data from the two existing gross meters to calculate net energy flows. While this is does not require any meter changes, at the time of writing it is unclear if retailers intend to accept this option.

Whether the solution ends up being the replacement of any meter, re-wiring or changes to billing arrangements, if any of these or other solutions are being offered through an energy retailer, then the SBS customer must ensure they understand the full implications of agreeing to any particular solution – as this may have implications for that customer's retail tariff or other related considerations.

Following conversations with some metering specialists and the review of online consumer commentary, it is also apparent that customers are finding it difficult to get specific advice tailored to their distribution network area and existing metering configuration.

ATA advise a cautious approach in dealing with both distribution businesses and retailers regarding metering changes. The SBS will continue to the end of 2016 and consumers should attempt to maximise the benefits they receive under the existing scheme. At the closure of the SBS, customers in the Ausgrid and Essential Energy areas should explore zero or low cost options.

The next option is to carefully evaluate the various retailer tariffs including a subsidised (net) smart meter. While ultimately the consumer pays for the new meter through energy (kWh), fixed or other charges, there is likely to be no or lower upfront fees.

As of June 2016, ATA understands there are around six retail offers in existence involving free or cheap meters in NSW. The only way for any individual customer at this point in time to calculate if one of those offers is their best approach to enabling net metering, is to:

- calculate an annual bill based on the fixed and kWh rates of that specific retail offer, and using their net consumption (after on site solar use); and then compare this to:
- the distributor charge for re-wiring or the net billing option (e.g. $150) and add this to the calculation of an annual bill for the best retail deal they can find in the market (again using their net consumption).

Given that all retailers will cost recover the meters thru their charges in one way or another (and given the history of NSW solar customers facing somewhat higher retail charges and tariffs that other non-solar customers do not typically face), it is not clear at this point in time which is the better path for any individual customer.

The option of last resort should be to request the local distributor to install a net meter. This option will likely incur a high upfront cost and the customer should still compare available retail tariffs.

Rather than rushing into the meter upgrade it is suggested customers wait a few weeks or even months after the closure of the SBS scheme to give time to compare the various options.

3.0 Storage: Battery Readiness

With the price of storage falling, many existing solar customers are wondering whether their system is 'battery ready'.

The majority of NSW SBS, Victorian TFiT and relevant SA FiS customers will have somewhat older inverters, with the technology likely being installed between the beginning of 2010 and the end of 2013. In terms of functionality, these inverters will not have the full capabilities of some of the inverters available in the Australian market in 2016.

So what does it mean to be 'battery ready'? There are multiple ways that batteries can be added to an existing solar PV system – involving different component configurations which ultimately influence different overall system capabilities.

At a very high level, there are two main options: referred to as 'AC' or 'DC coupling'. 'Coupling' in this context broadly refers to where within the system the batteries are connected.

3.1 DC Coupling

DC coupling involves siting the battery on the DC side of (or indeed plugging it directly into) the existing grid connect solar inverter. The wires on this side of the solar inverter carry DC electricity, and the solar-generated electricity can be used to charge the battery prior to it being converted to AC for household/on-site consumption or export to the grid.

The diagram on the following page outlines a typical DC coupled solar-battery system. There are a few key points of note.

Firstly, is the isolation switch. This sits on the grid side of the solar inverter's connection to the switchboard and allows the solar-battery system to be used as a back-up system in the event of a blackout[16][17].

It should be noted that whilst DC coupling may be the more common approach to retro-fitting (and new) solar-battery systems, **grid isolation switches are not at all common** – either in existing grid connect solar PV systems or in new solar or solar-battery systems. **This means that the majority of solar-battery systems are not able to operate when a power failure on the grid occurs**.

Should a solar-battery customer want to be able to use their system for back-up power, they will need to specifically request this from their provider/installer – and pay the additional cost for the switch and its installation.

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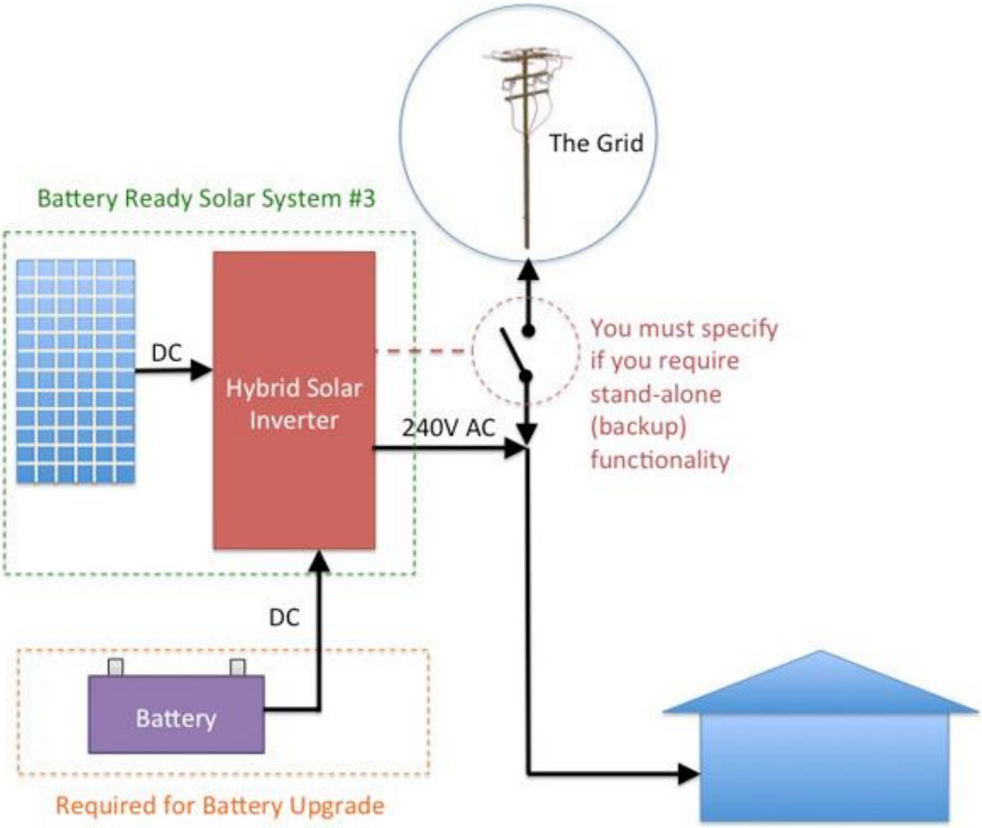
[16] The isolation switch ensures that power does not flow to the grid during a blackout event, thereby protecting any linesman or other technician who may be trying to rectify the network fault.

[17] There are other systems that can operate without this switch (or have it internally). This involves two output lines in the battery: for Normal loads and Critical Loads. The latter will be supplied by the battery in case of grid failure automatically (however it may not have the switching time of an Uninterruptible Power Supply). This needs to be specified by the customer to the installer and may imply changes to the switchboard with associated costs. Furthermore, the amount of load must be low enough for the battery to support it for an appropriate time (e.g. led lights and fridge). If the grid outage extends to the following day, if there is enough sunshine the solar panels will recharge the battery again and allow it to continue supporting the critical loads.

The other key aspect of a DC coupled solar-battery system is the 'hybrid' solar inverter. The hybrid inverter has a higher level of functionality than traditional string, grid connect inverters for solar systems.

Figure 3.1: DC Coupled Battery with Isolation Switch[18]



The hybrid inverter converts both the panels' and the batteries' DC power to AC and takes care of the required battery control and switching functions. Given this increased functionality, hybrid inverters are more expensive than traditional string inverters (in the order of $1,000-$2,000 more for the equivalent rated capacity).

Examples of hybrid solar inverters include the Sungrow SH5K[19], the SolarEdge DC-optimised inverter[20], the Redback Smart Hybrid System[21] and the Fronius Symo[22].

Given the age of their systems, the majority of NSW SBS, Victorian TFiT and SA FiS customers will not have hybrid inverters. As such, these will either need to be replaced, or additonal battery control and switching systems will need to be retro-fitted to the existing system.

Hybrid inverters in the Australian market currently start at around $1.00 per watt (non-installed) – e.g. $5,000 for a 5kW hybrid inverter. This is in additon to the cost of the battery and installation costs.

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18 http://onestepoffthegrid.com.au/the-truth-about-battery-ready-solar-systems/
19 http://en.sungrowpower.com/index.php/products/storage-system/4-6-sh5k
20 http://www.solaredge.com/groups/products/storedge
21 http://www.redbacktech.com/smart-hybrid-system/
22 http://www.fronius.com/cps/rde/xchg/fronius_international/hs.xsl/83_35246_ENG_HTML.htm

3.1.1 Inverter now – Battery later

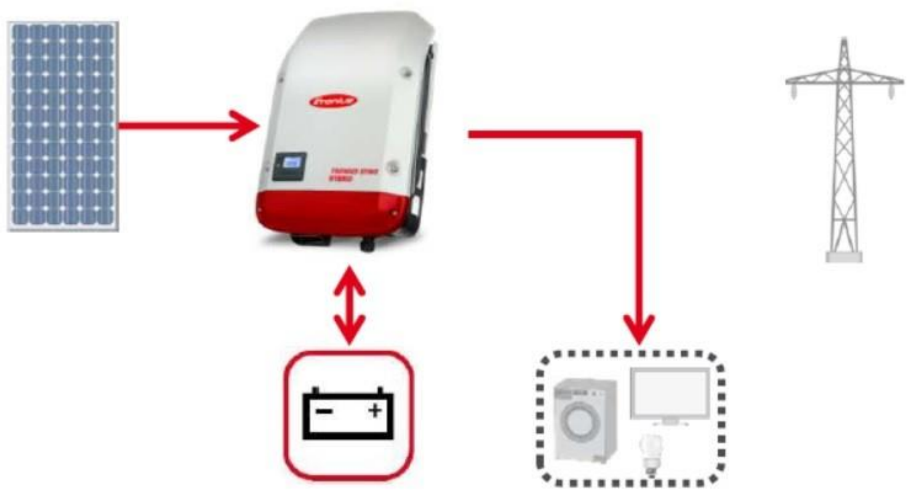
Some existing or new solar customers are considering the purchase of a solar-hybrid inverter in readiness for adding batteries later on. This is a risk and requires proper consideration.

ATA's analysis of the economics of storage in **Section 4.0** suggests that for many Australian homes, batteries won't be economic until around 2020. Installing a solar hybrid inverter now, up to three of four years before the actual addition of storage, runs the risk of storage technology evolving and the hybrid inverter being obsolete or sub-optimal at the time the batteries are purchased.

On this basis, ATA would advise against purchasing and installing a new hybrid inverter in the near term without knowing when; and which battery system; is going to be retro-fitted to the overall system.

Figure 3.2: Examples of Hybrid Solar Inverters

The Sungrow SH5K (left) and the Redback Smart Hybrid System (right).



The Fronius Symo Hybrid Inverter.

3.2 AC Coupling

AC coupling involves the battery being sited on the AC side (or the grid or household side) of the solar inverter – meaning the wires connecting the battery to the solar system are 240V AC.

Given all batteries operate in DC, AC coupling requires a second battery-dedicated inverter (and battery charge controller) – significantly adding to the cost of the overall system. Typically referred to as inverter-chargers, these:

- convert the batteries' DC to a household/grid compatible AC;
- convert the solar inverter's AC output to DC in order to charge the battery;
- control the charging so that the battery is not damaged;
- can charge the battery with solar electricity or electricity from the grid – e.g. during cheaper off-peak times; and
- only discharge the battery when the household/site requires it – and not back to the grid[23].

AC coupled inverter-chargers can only perform these last two tasks if they know what the site's power consumption and solar generation is at any given time. The inverter-charger therefore needs to talk to a power-monitor (or current transformer) that attach to the wires coming both out of the solar inverter and into the site.

3.2.1 No Back-up

Once again, the operation of the system during a blackout is an important consideration.

Should a solar customer not require the system to provide back-up power during a power failure, then little else is needed – and an AC coupled battery with dedicated inverter-charger and power monitor can be retro-fitted to virtually any existing solar PV system.

The inverter-charger and the solar inverter do not need to talk to each other as the solar generation does not need controlling during blackout events – the entire system will simply be switched off. As such, the system is not dependent upon the functionality of the existing grid connect solar inverter – any existing solar inverter is compatible.

The following diagram outlines this simple AC coupled system.

Examples of inverter-chargers that can be used in this type of system include the SMA Sunny Boy Storage[24] and the micro inverters in the Enphase AC battery[25]. Pricing again starts at around $1.00 per watt (non-installed) – e.g. $5,000 for a 5kW simple inverter-charger – which is in additon to the cost of the battery and installation costs.

The Enphase battery is currently priced at around $1,150/kWh – competitive with other lithium-basd batteries emerging in the Australian market.

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[23] This is unless you have a system enabled to sell electricity directly from your batteries to the wholesale energy market when wholesale energy prices are high – such as offered by Reposit Power: http://www.repositpower.com/. The Reposit controller and required software costs in the order of $800.

[24] http://www.sma.de/fileadmin/user_upload/SBS25-DEN1604-V10web.pdf

[25] https://enphase.com/en-us/products-and-services/storage/our-system

Figure 3.3: AC Coupled Battery – no Back-up Power[26]

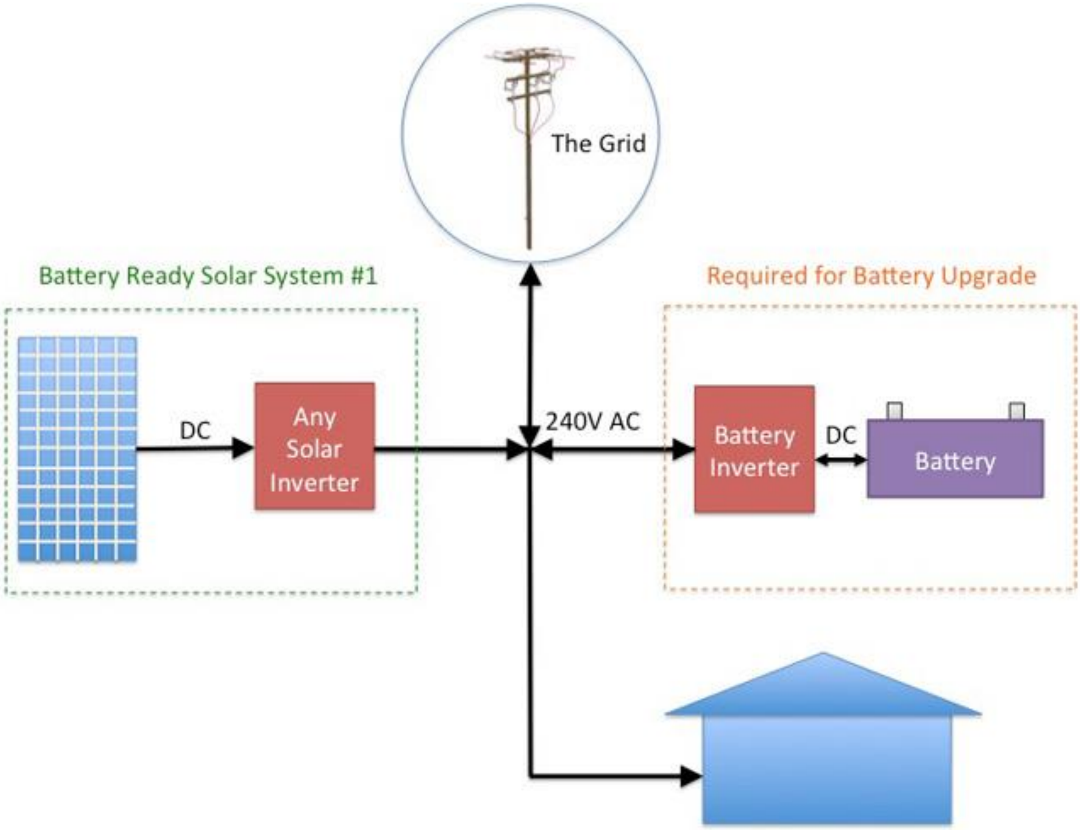


Figure 3.4: Examples of Inverter-Chargers for AC Coupling without Back-up Power

The SMA Sunny Boy Storage (left) and the Enphase AC battery (right).

[26] http://onestepoffthegrid.com.au/the-truth-about-battery-ready-solar-systems/

3.2.2 Back-up

Should the solar customer want to use the retro-fit solar-battery system for backup power during a blackout, then two additional smarts are required.

Firstly, the system requires an isolation switch. Secondly, the new inverter-charger (for the battery) and the grid connect solar inverter need to talk to each other – specifically the inverter-charger needs to be able to communicate to the solar inverter regarding the level of its AC power output. If the battery is full and the household load is being supplied, the AC output from the solar inverter needs to be 'throttled'.

Once again, this has implications for the functionality and cost of a new inverter-charger – and potentially a new solar inverter. There are different communication systems by which electronic devices can talk to each other, but one of the most common is called 'MODBUS'. If an existing solar inverter is MODBUS enabled, then it may be able to retro-fitted with AC coupled batteries that can provide power in a grid islanded situation.

In addition, AC coupled batteries that can provide back-up power also typically require some re-wiring within the home or site to ensure that essential loads/appliances are connected to a separate circuit from non-essential loads – in the same way as for DC coupling discussed above. This further adds to the installation cost.

Examples of inverter-chargers available in Australia with MODBUS communications include the Selectronic SP Pro[27] (Australian-manufactured, and one of the most popular and best quality inverter chargers for off-grid type systems) and the SMA Sunny Island[28]. Pricing for these higher functioning inverter-chargers starts at around $1.50 per watt (non-installed) – e.g. $7,500 for a 5kW unit. This is in additon to the cost of the battery.

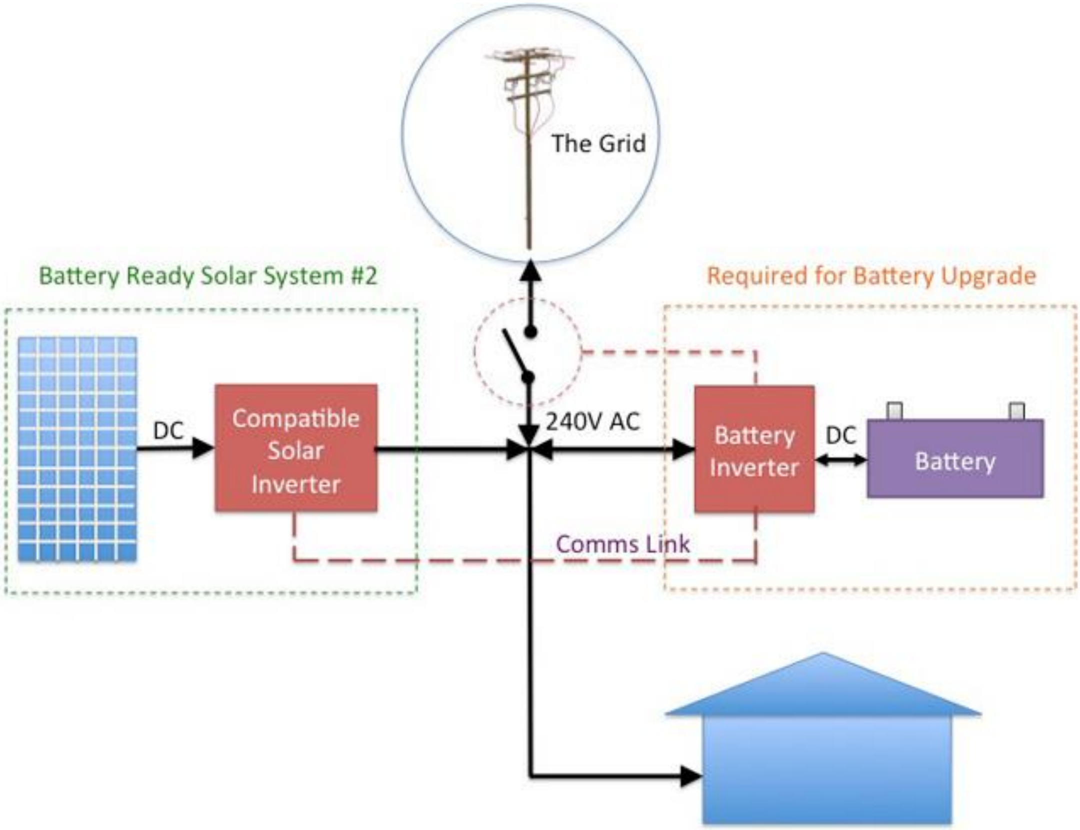
The following diagram outlines an AC coupled system with the ability to provide power islanded from the grid.

Figure 3.6: Examples of Comms-enabled Inverter-Chargers for Back-up Power

The SMA Sunny Island (left) and the Selectronic SP Pro (right).

[27] http://www.selectronic.com.au/sppro/models.htm
[28] http://www.sma-australia.com.au/products/battery-inverters/sunny-island-30m-44m.html

Figure 3.5: AC Coupled Battery – with Back-up Power[29]



3.3 What to do?

For existing NSW SBS, Victorian TFiT and relevant SA FiS solar customers considering retrofitting batteries to their existing system, the following should provide some guidance.

Firstly, irrespective of whether you want the new system to be able to provide power in a blackout, you will need to invest in both a new battery/s and a new inverter – appropriate to your desired system needs. In 2016/17, it will be difficult to achieve this for less than $10,000 installed.

Next, you will need to consider whether you want your retro-fit solar-battery system to provide power in a blackout. If yes – then you may need an isolation switch installed, and an inverter and/or communications system that can handle system operation in a network failure event (not all hybrid inverters can operate in a grid-islanded situation).

Next, you need to investigate if changing the inverter and including a battery will require a new connection agreement with your distributor. You are advised to consult your distributor or your installer to assess your options and their implications from a connection perspective.

[29] http://onestepoffthegrid.com.au/the-truth-about-battery-ready-solar-systems/

They can range from being straightforward (e.g. replacing an inverter by an hybrid inverter of the same rating) to being problematic (e.g. adding an AC coupled inverter and exceeding the single phase connection limitation imposed by your distributor).

The outcome of this investigation will guide you in terms of what is possible as well as associated costs and technical/operational impacts.

Consumption monitoring should be connected at the initial install for these systems – in order to control the battery charging from the solar inverter. Even prior to installing storage, monitoring can provide useful information regarding major appliance loads or the potential for load shifting or energy efficiency.

You also need to consider whether you want the system to be able to charge from the grid. If so, you will required an AC coupled system. If not, a DC coupled arrangement will work. Given the higher upfront cost of AC coupled retro-fit (or new) solar-battery systems, it is unlikely that these will offer significantly better economics than the DC coupled systems modelled in **Section 4.0** of this report.

Should you be considering a new inverter as part of the system, find out whether it (or other inverters) have energy management relays. These are switches that enable you to switch on or control loads when you have excess or insufficient solar (see **Section 5.1.3** of this report.) Designed and operated well, these inverters can reduce the need for more expensive chemical energy storage in the future.

Finally, given the rapid evolution of storage and related technologies, it is advisable to make your decisions regarding the batteries and any new inverter at the same time. The risk of installing a new, solar hybrid inverter in 2017, and batteries later, are relatively high with respect to battery technology evolution. Plus solar hybrid inverters are likely to be cheaper again by 2020.

4.0 Storage Economics

In 2016, the most common storage chemistry used in household storage systems in Australia remains the lead-acid battery. As demand for more advanced energy storage grows, there is an increasing focus on lithium-based batteries.

For household systems, lithium has seen considerable advancements in recent years and a steady decrease in cost as manufacturing scale has increased. Going forward, lithium is likely to remain the preferred chemistry for household stationery energy storage for the foreseeable future – for a range of technical reasons and global influences.

As of 2016, lithium technology is being used globally on a much larger scale in the automotive industry than in the stationery energy sector – that is, in the development and manufacturing of plug-in hybrid (PHEV) and battery electric vehicles (BEV).

For a variety of reasons, lithium is the preferred storage technology for the automotive industry and is the basis for the majority of research, development and commercialisation in relation to PHEVs and BEVs.

A strong indicator of this is that all global price forecasts for storage for 2025 are presented specifically in regards to lithium-based chemistries – and most in the context of wholesale prices to the automotive industry. For a more detailed overview of the current state of different storage chemistries and technologies, please refer to **Appendix A**.

4.1 Economics of Battery Chemistries

In order to understand the true economic value of storage, a metric must be used that can effectively be compared across different chemistries.

Storage costs are typically presented in dollars per kilowatt hour ($/kWh). Whilst somewhat useful, this metric is limited in comparing the relative costs and value to the end user of different battery chemistries. This is because different battery chemistries contain different properties with regards to 'useable' energy capacity.

In the same way that the end user is interested in the 'life-cycle' costs and value of demand-side energy technologies such as solar photovoltaic (PV), it is life-cycle costs and value that must be properly analysed when considering the utilisation of storage in either a hybrid (grid-connect) or off-grid scenario.

The relative costs and value of storage to the end user are a function of:

- capital cost;
- any required maintenance costs;
- the 'useable' energy capacity – largely determined by the optimal depth of discharge employed in ongoing operation;
- the battery capacity at a given charge/discharge rate – known as the 'C-rate'; and
- asset life (which is typically a function of the number of cycles at a given depth of discharge and varies significantly between batteries as a function of the quality of manufacture).

The discharge rate is the time – usually expressed in hours, our parts of an hour - it takes to discharge a battery before it is fully discharged. Where the battery is discharged at a constant rate over a number of hours, this is referred to as the 'C' rate[30].

The capacity of some batteries (specifically lead acid-based technologies) is reduced if the battery is discharged over a shorter period. In the case of lead acid, C10 to C20 – discharging over 10 to 20 hours - tends to be the highest level of discharge without significantly reducing the capacity of the battery).

At these discharge rates the energy output capacity is reduced as well as the asset life, expressed as an absolute number of charge cycles before the battery fails or suffers depletion of capacity. This is an important consideration for households or businesses who may wish to access the energy stored in a battery relatively quickly (e.g. a daytime or evening peak).

Newer lithium-based technologies do not suffer from these charge/discharge constraints in the same way – improving their effective operation. Hence the discharge rate of lithium batteries can comfortably exceed C1, with the capacity of other components typically being the limiting factor, not the battery.

The following table provides qualitative guidance as to the strengths and weaknesses of different battery chemistries in relation to the five properties listed above:

Table 4.1: Strengths & Weaknesses of Different Battery Chemistries

	Flooded Lead Acid	Gel Lead Acid	AGM Lead Acid	Lithium
Capital Cost	Low	Medium	Medium	Medium-High
Maintenance Costs	High	Low	Low	Very Low
Useable Energy Capacity	Low	Low - Medium	Low - Medium	High
Lifetime Cycles at High DoD	Very Low	Low	Low	High
Capacity at High Discharge Rate	Low	Low	Low	High

A specific example of the correct economic valuation of two different battery chemistries is presented below – that of conventional lead acid (e.g. absorbed glass mat [AGM] or sealed gel) versus lithium-iron phosphate (LiFePO4), which is one type of Lithium battery. These numbers are indicative only and it should be noted they do not take account of the additional potential charge/discharge constraint on the conventional lead-acid batteries:

[30] As an example, many small batteries are rated at the 'C20' rate – meaning they will deliver that amp hour capacity if discharged over 20 hours. The types of batteries in standalone power systems are rated at the 'C100' rate which means that they are rated assuming discharge over 100 hours or 4 days.

Table 4.2: Relevant Economics for Comparing Battery Chemistries

	AGM/Gel	LiFePO4
Amp-hours	260	300
Voltage	12	3.2
kWh – 'Nameplate' Capacity (per Cycle)	3.12	0.96
Capital Cost	$459	$540
Maintenance Cost (per annum)	-	-
$/kWh – 'Nameplate' Capacity	$147	$563
Cycles (10 Years)	3650	3650
Recommended Depth of Discharge for 3650 Cycles (10 years)	15%	70%
kWh – 'Useable' Capacity (per Cycle)	0.468	0.67
$/kWh – 'Useable' Capacity	$981	$804
$/kWh/Cycle – 'Useable' Capacity, 10 year basis	$0.27	$0.22

4.1.1 Storage Prices

As of late 2015, there are now prices for packaged solutions involving lithium batteries in the Australian market. ATA analysed a range of different retail storage offers, in order to ascertain input pricing for the modelling exercise for this project[31]. These included:

- The **Tesla Powerwall**: a 6.4kWh lithium-ion battery. Natural Solar currently quote $9,500 installed if compatible inverter already in place. The price for a Powerwall combined with a Fronius hybrid inverter is $13,990. **($1,357 per kWh)**

- **Sunverge:** an 11.6kWh lithium-ion battery. AGL offer the Sunverge 11.6kWh system for $14,990 and the 19.4kWh system for $19,990 (both installed and including hybrid inverter). **($1,292 per kWh)**

- **Enphase Energy: a** 1.2kWh lithium-ion modular DC 'plug and play' battery. Combined with the Enphase Home Energy Management System, the system is designed to help households to store and manage their rooftop solar energy supply and control their overall household energy use on a single platform. Will be sold to Australian installers for **$1,150 per kWh** (non-installed).

- **LG Chem:** a 6.4kWh lithium-ion battery. $6,898 (not installed) through wholesaler Solar Juice. **$1078 per kWh** (non-installed).

[31] A comprehensive list of battery storage options can be found at the following site (most do not yet have pricing information available: http://onestepoffthegrid.com.au/battery-storage-whats-on-offer-and-by-whom/

Given its competitive price and inclusion of hybrid inverter and installation costs, ATA used the Sunverge/AGL price of $1,292/kWh as the input price/capital cost for the modelling for 2015. To calculate a 2017 and 2020 capital cost, ATA reduced the $1,292/kWh price annually by 9%. This is in line with international forecasts of storage prices going out to 2025.

This resulted in the following capital costs for the different retro-fit battery-inverter system sizes for 2017 and 2020:

- 3kWh (2017): $3,210
- 3kWh (2020): $2,419
- 7kWh (2017): $7,489
- 7kWh (2020): $5,644

4.2 Modelling

Grid connected solar/battery system design attempts to capture a range of economic benefits, including:

- the increased utilisation of renewable energy (which provides electricity for on-site consumption or battery charging at significantly lower cost than peak grid tariffs[32]); and
- the potential of also charging the batteries from off-peak grid tariffs. This requires a more expensive AC coupled system, but can offer increased bill savings in the system is designed to only ever buy electricity from the grid during off-peak[33]).

ATA conducted modelling to understand the value proposition of installing new lithium-based storage to homes with existing solar PV systems in Sydney, Adelaide and Melbourne. The modelling considers investment (i.e. battery and inverter purchase and install), at the start of 2017 and 2020.

All scenarios considered involve remaining grid-connected and involved the more cost effective DC coupled systems. The model takes account of reducing component capital (and operating) costs over time.

The modelling defined 10 year Net Present Values (NPVs) in 2017 and 2020 dollars (depending upon the year of installation of the system). Cash flows were discounted by 2.5% - indicative of the real cost of current household mortgage finance.

Discounted payback periods were also calculated taking into account replacement of the inverter and batteries at the end of their asset life (batteries in Year 11; inverters in Year 12) – however given asset replacement did not occur until after year 10, these replacement costs did not impact the 10 year NPVs.

The modelling also accounted for reducing panel generation over time (due to panel degradation; 0.5% per annum was assumed[34]).

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[32] For most Australian locations, the levelised cost of electricity from a solar PV system without storage is roughly equivalent to an off-peak tariff (i.e. ~$0.10/kWh).

[33] For environmentally conscious consumers, this needs to be considered as the majority of overnight electricity generation comes from coal-fired generators in NSW, Vic and SA.

[34] Anecdotal evidence supplied to ATA is that in NSW, system degradation from early solar systems installed under the SBS may indeed be higher than this – i.e. around 8%. If real, this would slightly extend the payback times/worsen the NPVs of ATA's results.

Two different load (consumption) sizes were modelled – that of 10kWh per day ('working couple' - medium usage customer) and 35 kWh per day ('stay at home family' - high usage customer).

4.2.1 System Design

As the grid remains available for back-up (or even primary energy source) in a grid-connected scenario, system size and configuration must be optimised to maximise economic return.

To do this, ATA modelled four different system sizes and configurations, in order to find the most economic cases. The following components form the basis of the on grid system designs modelled:

- Existing solar PV modules with associated framing, mounts, wiring, connections;
- New hybrid solar DC to AC (string) inverter; and
- Lithium battery bank with battery management system.

Given the federal incentive that was targeted at 1.5kW systems early in the premium FiT era (the 'Solar Credits' scheme); and the later trend toward larger PV systems, ATA used a 1.5kW and a 4kW solar system for the modelling.

For the battery, given its availability now in the Australian market, ATA used the 7kWh daily cycle PowerWall; as well as a smaller 3kWh lithium battery. As such, the following systems were modelled for each location:

- 1.5kW solar PV + 3.0kWh storage;
- 4.0kWh solar PV + 3.0kWh storage;
- 1.5kW solar PV + 7.0kWh storage; and
- 4.0kW solar PV + 7.0kWh storage.

The solar customer's existing PV system was considered a sunk (i.e. zero) cost in the modelling.

4.2.2 System Prices & Tariffs

A range of tariffs (both consumption tariff and feed-in tariff) were used for the different locations. The tariffs chosen were based on ATA's retail tariff analysis undertaken for this project (and documented in **Section 5.0** of this report).

ATA reviewed seven currently available (April, 2016) retail tariff offers (that included a feed-in rate) for each jurisdiction (NSW, Vic and SA). The median consumption tariff rate was then chosen for use in the modelling. All consumption tariffs (for energy [i.e. kWh] and fixed) were indexed at +1% per annum. This approach led to the following consumption and feed-in rates for each location:

Table 4.3: Consumption & Feed-in Rates – ATA Storage Modelling

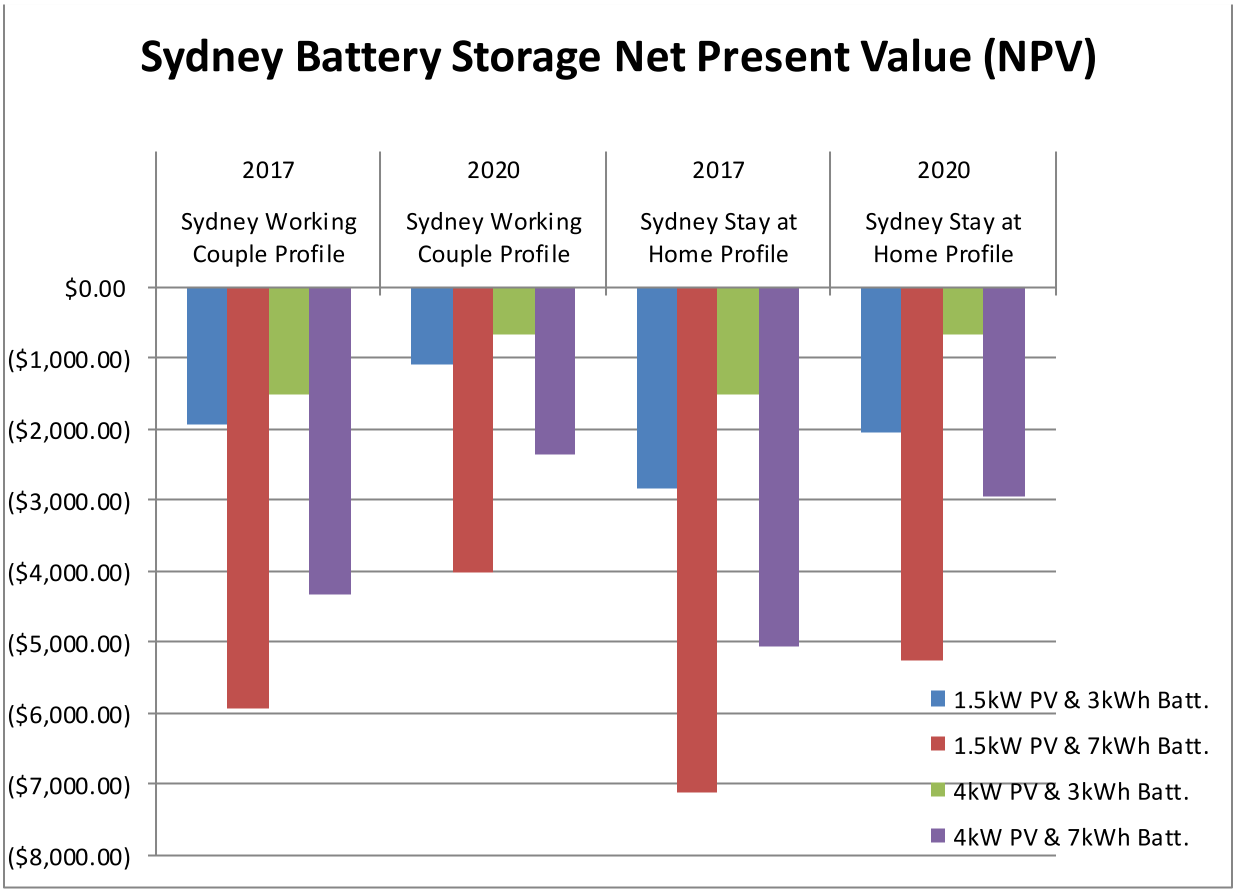
Jurisdiction	Consumption Tariff Type	Consumption Tariff Rate	Fixed Daily Charge	Feed-in Tariff Rate
NSW	Flat	$0.2194/kWh	$1.05	$0.05/kWh
Vic	Flat	$0.2258/kWh	$1.05	$0.05/kWh
SA	Flat	$0.3088/kWh	$1.05	$0.05/kWh

4.3 Modelling Results

The modelling results for each system size per location/configuration are presented below. The modelling was undertaken using ATA's 'Sunulator' solar-battery simulation model.

Each scenario has been simulated on a half hourly basis, with regards to energy flows and economic costs/benefits. This takes into account real world variability in both solar resource and consumption and is a key difference between this and much of the publically available analysis on the customer side economics of storage. For an overview of how the model works, please refer to **Appendix B**.

Figure 4.1: 10 Year NPV – Retro-Fit Battery Investment, Sydney



The figure above shows the 10 year NPV of:

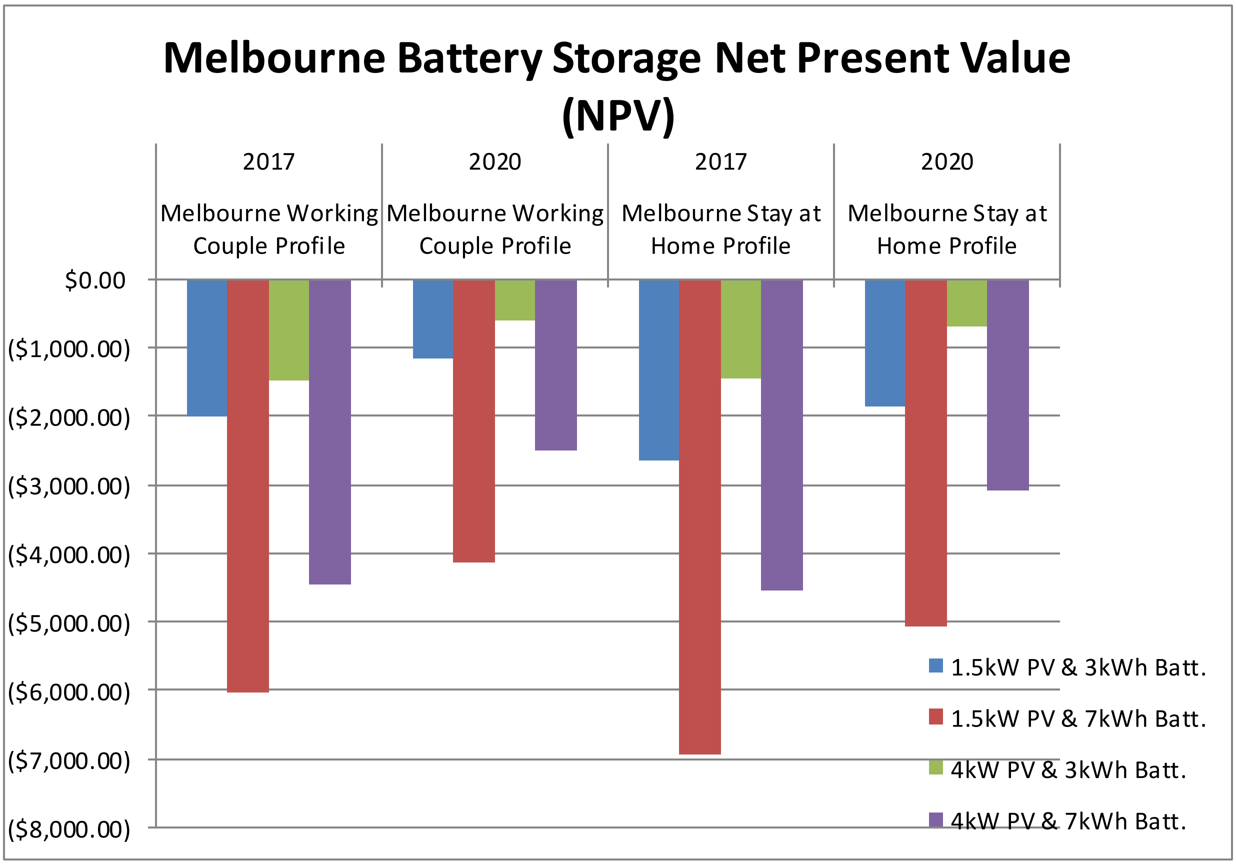
- two different Sydney households (with lower and higher annual electricity consumption);
- with an existing 1.5kW or 4.0kW PV system;
- investing in either a 3kWh or a 7kWh battery; and
- either in 2017 or in 2020.

The analysis demonstrates that:

- In all scenarios, the Sydney solar household is worse off over 10 years as compared with no investment in storage;
- Assuming investment in 2017, the Sydney household would be between $7,000 and $1,500 worse off over 10 years, dependent upon annual consumption and solar-battery system size;
- By 2020, a number of scenarios fall within $1,000 of breaking even (specifically, the 1.5kW + 3kWh system for the Working Couple; and the 4kW + 3kWh system for both the Working Couple and Stay at Home Family). Given the margin of error for a modelling exercise such as this, these scenarios can be considered to be broadly 'economic' in terms of return on investment.

The modelling results for Melbourne were relatively similar to those for Sydney, albeit slightly worse:

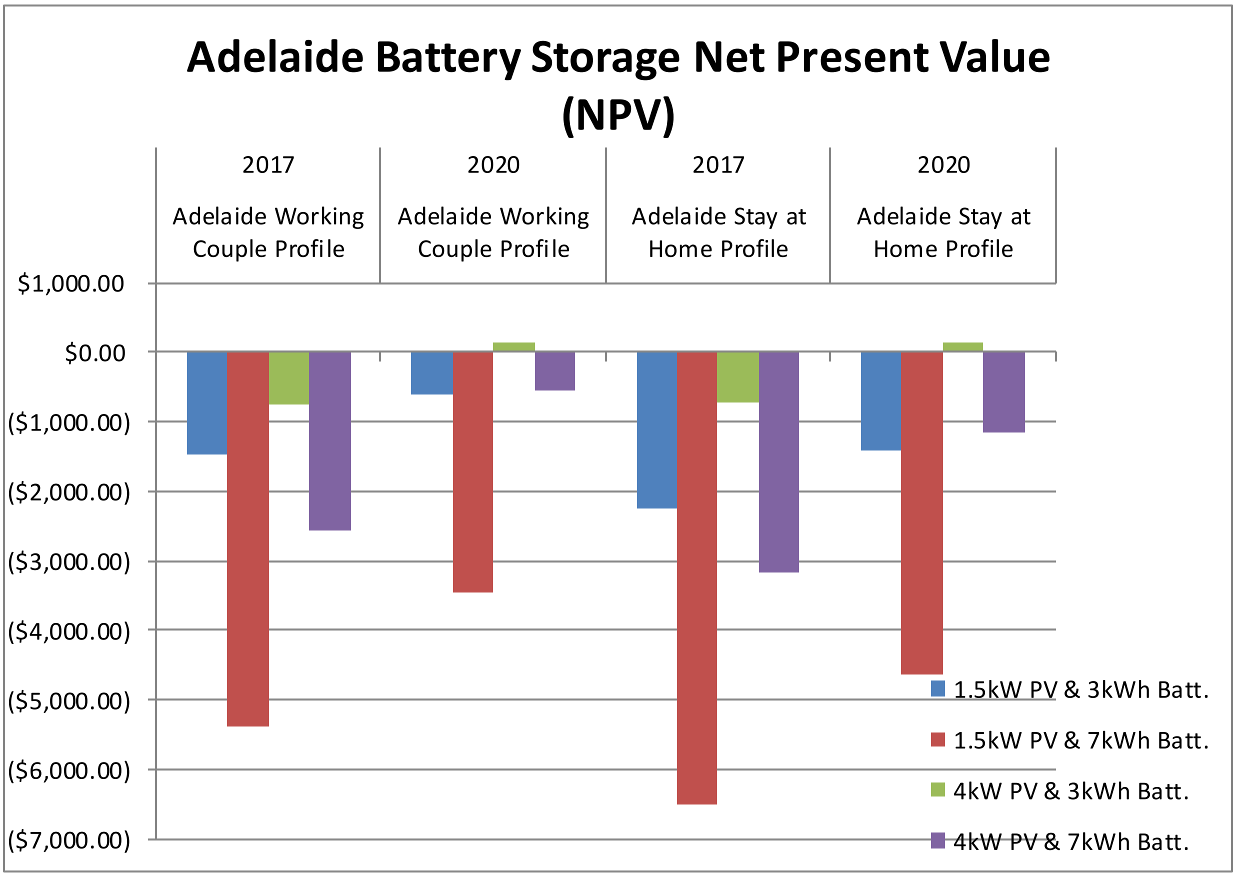
Figure 4.2: 10 Year NPV – Retro-Fit Battery Investment, Melbourne



As can be seen, the same scenarios achieve the best NPVs in 2020 for Melbourne. These similar results are largely due to the fact that the retail tariffs used for Sydney and Melbourne were similar; and the fact that Sydney and Melbourne's solar insolation levels, on an annual basis, aren't dissimilar.

The modelling results for Adelaide were again similar in trend, but somewhat improved in absolute terms from those of Sydney and Melbourne:

Figure 4.3: 10 Year NPV – Retro-Fit Battery Investment, Adelaide



As can be seen, the same scenarios achieve the best NPVs in 2020 for Adelaide (as compared with Sydney and Melbourne); however the 4kW + 3kWh system for both the Working Couple and the Stay at Home Family achieves a positive NPV within 10 years assuming investment in 2020.

The main two factors improving the results for Adelaide are the higher electricity retail tariffs (approx. 30% higher than for Sydney/Melbourne) and the higher solar insolation levels in Adelaide across the year.

4.4 Discussion

As can be seen, the modelling results are relatively poor with regards to investment by existing solar PV customers in storage prior to 2020 – with some scenarios remaining unfavourable in 2020 (particularly those associated with the larger battery).

The definition of 'economic' (versus 'non-economic') in this context is a key point for consideration.

In financial terms, ATA would consider 'economic' to be a payback of upfront and ongoing costs within about 10 years – as this will mean costs have been fully recovered before the batteries need replacement (incurring further material expense). Also, for many households, 5 to 10 years is considered a suitable investment timeframe.

The results can be broadly interpreted as suggesting that:

- solar-battery system with smaller batteries, that have more chance of being fully utilised over the course of the year, are likely to be economic in these three (and likely other) jurisdictions by 2020;
- solar-battery system with larger batteries, that have less chance of being fully utilised over the course of the year, may remain uneconomic in these three (and likely other) jurisdictions in 2020 and potentially beyond. A key influencing factor will be the future declining cost of storage technology.

Of course, the experience of solar PV in Australia demonstrates that many households will install systems with longer paybacks than this. Material solar PV uptake occurred from 2009 in Victoria for example, even when for many consumers, particularly those who over-sized systems after premium feed-in tariffs were closed to new entrants, payback was often no better than 15 years. Indeed, this can still be the case.

Of course, the majority of energy consumers do not undertake detailed economic analysis as part of a technology purchase decision. At best, the majority may rely on some form of independent consumer guidance through various media, forums or trusted organisations.

5.0 Storage: Other

The current capital cost of energy storage in batteries is likely to remain too high in the short to medium term (i.e. prior to 2020 and potentially after) for many solar customers – and in particular those losing premium FiTs at the end of 2016.

Given the typical load patterns/profiles of residential customers, when FiTs are low, some type of storage is critical to enabling more economic use of solar-generated electricity on-site.

The good news is that in the hiatus from now until whenever chemical energy storage becomes economic for the mass market, there exists other ways to store renewable energy – cheaper and just as effectively as using a battery.

Thermal energy storage (for example, as heat in water) is a concept that has been around for a long time – however in the context of renewable energy, it has until recently only been associated with solar hot water or with large generation projects (e.g. energy storage in molten salt for large solar generation plants).

With the falling cost of solar photovoltaic panels and the reduction in premium FiTs leading to the need for more cost effective storage, many solar PV customers are turning to their hot water systems and heating/cooling systems to provide a solution.

5.1 Hot Water Storage

Electric heating and storage of water for domestic (i.e. residential) consumption is broadly done in two ways[35]:

- by utilising a traditional electric storage hot water (ESHW) system – which uses single or multiple resistive electric elements in a tank to heat and store water; or
- using a heat pump – which involves the compression and expansion of ambient air through a heat exchanger to extract heat, which combined with electricity creates multiple units of heat output for heating water stored in a tank.

Both of these systems use electricity as an input to the system and can be powered directly from solar PV – provided:

- the home or business is configured for net metering;
- the ESHW or heat pump is connected the main electrical circuit (e.g. not a separate, dedicated circuit established for off-peak hot water); and
- the ESHW or heat pump operates during the day (i.e. when the solar system is generating electricity).

[35] Solar hot water systems can also use electricity to provide power to the boost system – i.e. that part of the overall system that is largely relied upon in winter and other low-solar resource times to heat the water. SHW has not been modelled as an alternative to ESHW or heat pumps as their primary energy source cannot be PV-provided electricity; their performance is low when solar PV performance is low (making the two technologies not particularly compatible) and the higher upfront cost of SHW (as compared with heat pump systems) means that over time (e.g. 10 years), their economics does not play out as well.

ESHW and heat pump systems offer the potential for existing (and new) solar customers to maximise the usage of their solar-generated electricity, rather than feeding it back to the grid for little economic return.

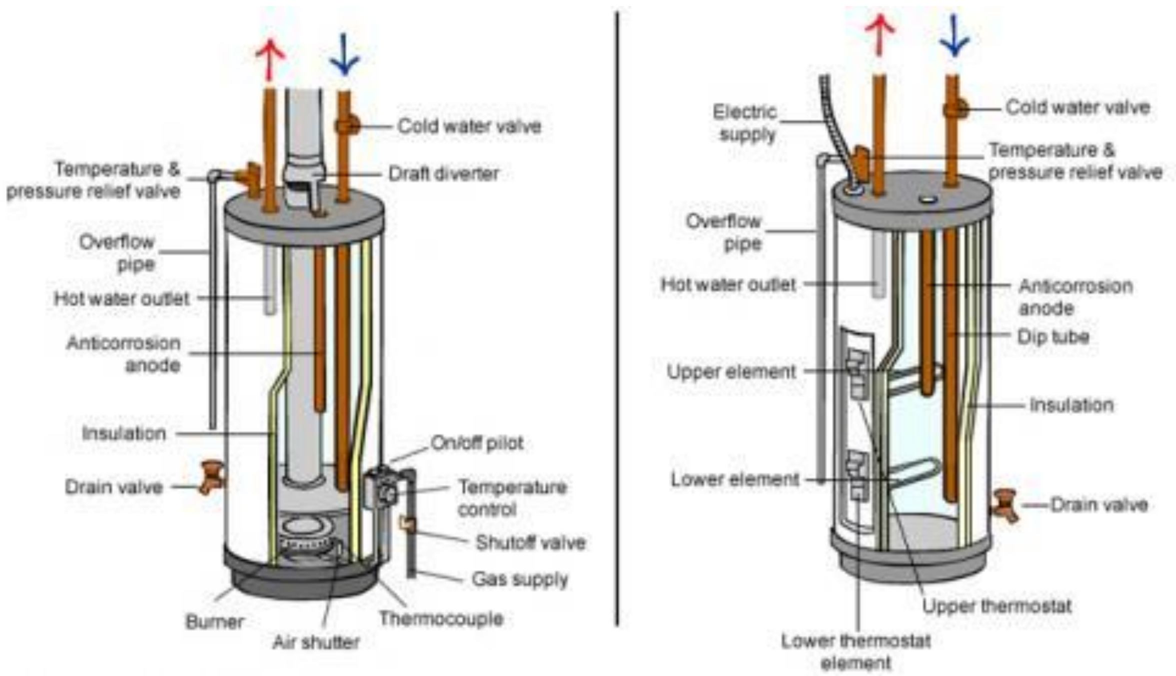
5.1.1 Electric Storage Hot Water

Across NSW, almost 66% of existing homes use electricity for water heating[36] – with the majority of these systems comprising electric (resistance) storage water tanks[37]. On this basis, it can be assumed that a material number of the 146,000 NSW SBS customers[38] will have existing ESHW systems.

In SA, 44% of existing homes use electricity for hot water[39] – again with the majority being ESHW.

In Victoria, the picture is a little different. Due to the expansive roll out of the reticulated gas network across the state over the past 40 years, over 80% of Victorian homes are connected to the mains gas network. Despite this, 28% of Victorian homes still use electricity for water heating[40].

Figure 5.1: Cross Section of a typical Electric Storage HW System



For any solar customer about to lose their premium FiT and who have an existing ESHW system, the opportunity is relatively straight forward. That is, ensure that the existing ESHW system is configured to run directly (or as a priority) from solar PV. This can largely be achieved in two ways:

[36] http://www.abs.gov.au/ausstats/abs@.nsf/mf/4602.0.55.001

[37] The ABS data treats solar HW system separately – with 8.5% of NSW homes heating their water with solar technology in 2014.

[38] http://www.resourcesandenergy.nsw.gov.au/energy-consumers/solar/solar-bonus-scheme/solar-bonus-scheme

[39] http://www.abs.gov.au/ausstats/abs@.nsf/mf/4602.0.55.001

[40] http://www.abs.gov.au/ausstats/abs@.nsf/mf/4602.0.55.001

1. Changing the timing of the ESHW unit so that it begins its heating cycle during daylight hours (e.g. between 10am and 4pm; and preferably shorter – i.e. between 11am and 3pm. The system will utilise the solar-electricity for its heating element and any shortfall will be taken from the grid.

   Ultimately this requires the solar customer to estimate the 'peak daylight hours[41] based on their location, season and any shading.

   Some existing ESHW systems will have in-built or added-on timers which can be adjusted to day time hours. For those that don't, a new timer can be installed at relatively low cost by any local electrician.

2. By using a dedicated solar or energy 'diverter'. An emerging technology, these devices detect the precise amount of electricity being generated by a solar PV system and match that against the amount needed by a particular appliance.

   In the case of ESHW, the solar is matched directly to the water heater's element and can in some cases, 'dial up' or 'dial down' that element to match precisely the level of excess solar generation. This ensures no additional electricity is purchased from the grid; and reduces the chance of grid export.

5.1.2 Diverters

There are a small number of products currently available which fit the second category above (i.e. 'diverters').

One of these, the *Powerdiverter*[42], has recently been introduced to the Australian market. The Powerdiverter has the ability to supply electricity to heating elements of multiple different sizes. Currently, the Powerdiverter acts only to divert solar electricity to a home's water heater, however the next generation will allow users to also shift their solar power to various other appliances based on a prioritised list of preferences.

Figure 5.2: The Powerdiverter

ATA understands that the cost of the first generation Powerdiverter unit to be available in Australia is in the order of $1,000 (fully installed).

[41] http://www.bom.gov.au/watl/sunshine/ or http://www.yourhome.gov.au/energy/photovoltaic-systems
[42] http://www.powerdiverter.com.au/

There are two other diverter-type devices on the market in Australia - and which perform a similar function to the Powerdiverter.

The *immerSUN*[43] is currently distributed by RFI and comes with a three year warranty. It is limited to 3kW which can be a problem as many ESHW systems have a 3.6kW element. Immersun units may also be able to use excess solar to charge an electric vehicle[44]. ATA understands that immerSUN units can be purchased and installed for approximately $1,100.

The *Sunnymate* has the same warranty but is capable of supplying a 3.6kW element. ATA understands that Sunnymate units can also be purchased and installed for approximately $1,100.

Figure 5.3: The ImmerSUN & Sunnymate

Around $1,000 installed is relatively expensive for these diverter products – particularly when compared with installing a simple timer, which will *almost* achieve the same outcome. It is anticipated however that the market for diverter devices may proliferate – and with increased market penetration and manufacturer competition, prices should come down.

As such, it is suggested that existing premium FiT solar customers with the ability to store their solar electricity as heat in hot water systems monitor this product over the coming year or two.

5.1.3 Inverters with Energy Management Relays

Similar in concept to the diverters above, some modern inverters also come with energy management relays that can switch on or off, and control certain loads (like hot water) to match excess solar generation[45]. Given their packaged nature as part of the inverter, it is unlikely that these will add such significant cost (i.e. ~$1,000) to an otherwise standard string inverter.

[43] http://www.solarquotes.com.au/blog/divert-excess-solar-pv-hot-water-cylinder/
[44] https://sway.com/CpaWPJYHRNUDMRAG
[45] For example: http://www.fronius.com/cps/rde/xchg/fronius_international/hs.xsl/83_24230_ENG_HTML.htm#.Vxbnhvl96Ht

However, for the solar customer with an existing PV system (and existing inverter), consideration must be given to whether simply to replace (potentially early) an otherwise well-functioning inverter; and future plans regarding the potential addition of batteries. (See **Section 3.1.1** of this report).

5.1.4 Hot Water Temperature Control

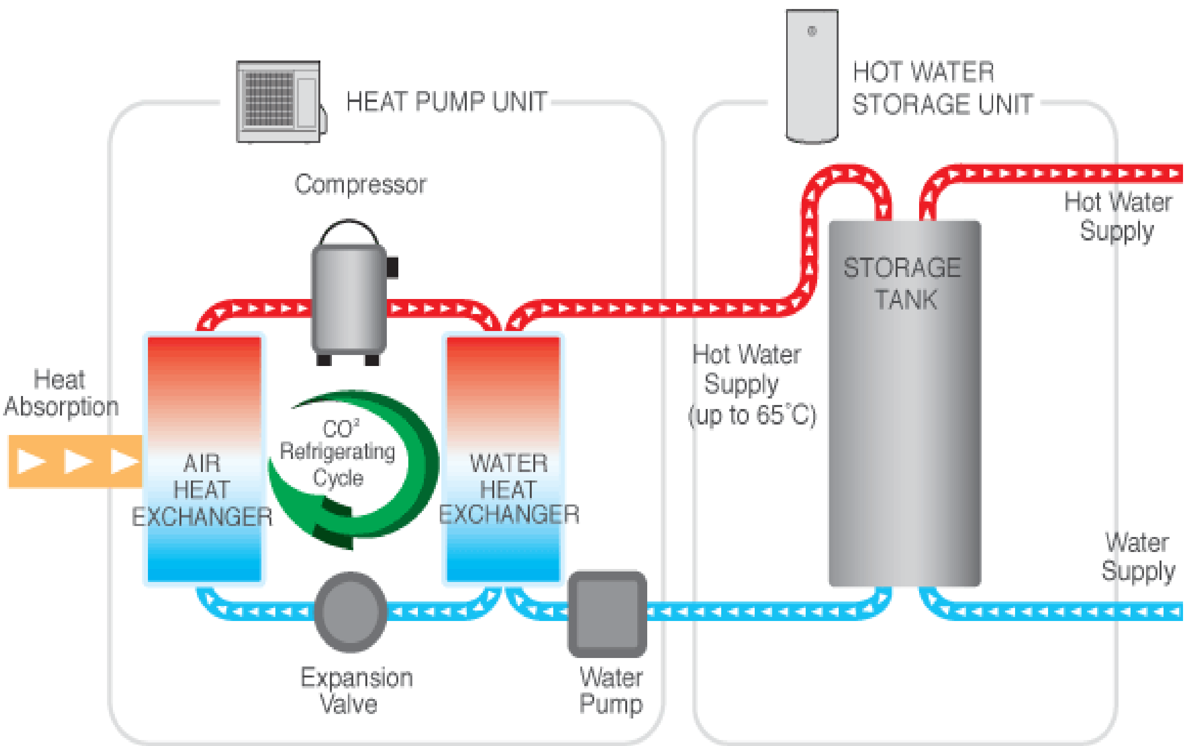
Should you choose to use solar-generated electricity to heat water, you can increase the efficiency of the energy saving by increasing the tank's temperature (e.g. to 90 degrees, instead of 50 degrees).

When doing this, you will need to ensure that you have a tempering valve installed at the water heater outlet or close to the fixture. If tempering valves are not installed then this will add to the cost of using the solar diverter or timer option.

5.1.5 Heat Pumps

Heat pump hot water systems are both more efficient and more expensive (upfront) than ESHW systems. Higher quality heat pumps create up to four units of heat for every single unit (e.g. kWh) of electricity input into the system. This means that heat pumps require les operational energy (and have lower running costs) than ESHW systems.

Figure 5.4: Basic Operation of a Heat Pump Hot Water Unit



Many solar PV system sizes in NSW and SA (and potentially some in Victoria) will be able to directly supply an ESHW system's total daily electricity demand in summer; whilst likely supplying its majority in autumn and spring. However in winter, when the energy use associated with water heating is at its highest, even a 5kW solar PV system is likely to fall well short of the daily demand required by an ESHW[46].

A heat pump, given its higher efficiency and therefore lower daily electricity demand – will be able to be supplied solely from most solar PV systems year round in NSW and SA – somewhat less so in Victoria.

Solar owners of course must be aware of their pre-existing daily electricity demand when considering whether their existing solar PV system will be able to meet the energy requirements of a new heat pump unit.

Heat pump hot water systems are a relatively modern technology – having only been in the Australian market for the past decade or so – with the newer and better quality models having completely dealt with some of the noise, reliability and cold climate efficacy issues of models past.

In addition, modern heat pumps are electronic, fully controllable and can be programmed to operate at specific times – perfect for matching to solar PV-generation times.

5.1.6 Gas versus Electric Hot Water

In 2014, ATA conducted detailed research and modelling[47] into the economics of using gas versus efficient electric appliances for space heating, water heating and cooking. The research modelled six different household types, and compared the 10-year costs of installing and running gas appliances, as compared with efficient electric appliances, in existing and new homes.

For details of the research methodology and results, which inform our view above that it is economic to replace existing gas hot water systems near the end of their asset life with electric, please refer to **Section 6.0** of this report, or to the source report.

5.2 Modelling: ESHW versus Heat Pump

Heat pump hot water systems are three to four times more expensive to purchase and install than ESHW systems. However heat pumps have significantly lower running costs, using around four times less electricity input.

For existing solar customers shortly to lose their premium FiT, the main trade off is the higher upfront cost of the heat pump versus the fact that a solar PV-backed heat pump unit is unlikely to use any electricity from the grid year round – whilst a solar PV-backed ESHW system will use significant amounts of grid-purchased electricity during at least winter; and potentially autumn/ spring.

[46] In winter, ESHW systems can easily use in the order of 15-20 kWh per day. This is in addition to other day time loads a solar customer may have.

[47] http://www.ata.org.au/wp-content/projects/CAP_Gas_Research_Final_Report_251114_v2.0.pdf

To properly consider this trade off, ATA modelled the cost and benefits of each option – as relevant to NSW/SA/Vic solar customers about to lose their FiT arrangements. However to begin with, a key question for any NSW/SA/Vic solar customer to consider is:

What is my existing hot water system?

Should an ESHW system or heat pump unit already be in place, then the decision is easy – do nothing. Provided the system is in good working order, it makes no sense to replace it with a new electric hot water system. The only thing to ensure is that the unit is timed/controlled to operate during the day time and net metering is in place.

Should an existing gas hot water system (storage or instantaneous) be in place, then provided that unit is coming toward the end of its useful life (typically somewhere between 10 and 20 years), then it will make economic sense to replace it with either an ESHW system or a heat pump.

5.2.1 Working Couple – Small Consumption

ATA modelled the cost and benefits of purchasing and installing a new ESHW system versus a new heat pump hot water system – for a Sydney home with existing solar PV and about to lose their gross FiT.

Given its closer proximity to the average annual electricity usage for a NSW home, ATA used the 10kWh per day, 'Working Couple' profile from the storage modelling in **Section 4.0**.

To this profile, ATA added a consumption profile for both:

- an ESHW system (~4.1 MWh p.a.); and separately
- for a heat pump hot water system (~1.67 MWh p.a.).

Both units were timed to operate during the daytime only – i.e. to run during solar-generation times. However dependent on the existing PV system size (1.5kW or 4.0kW), the solar system was able to either fully or only partly supply to hot water system load with any additional requirement coming from the grid (e.g. the ESHW system, with a much higher energy usage particularly during winter).

The modelling was conducted in Sunulator, which simulates generation, on-site consumption and grid export on a half hourly basis and projects out the results annually for a maximum 30 years.

The aim of the modelling was to understand how soon the additional purchase and installation cost of the heat pump (assumed to be $4,500 fully installed) versus the ESHW system (assumed to be $1,500 fully installed) would take to payback in the form of energy bill savings – taking into account that lower running cost of the heat pump; and the ability of the existing solar to part-power both systems.

The key inputs to, and outputs from, the modelling were as follows:

Table 5.1: Modelling Inputs & Outputs, ESHW v Heat Pump, Working Couple, Sydney

Modelling Inputs & Outputs	1.5kW	4.0kW	Unit
Capital Cost – ESHW	$1,500	$1,500	
Capital Cost – Heat Pump	$4,500	$4,500	
Pre-existing Annual Usage	3,915	3,915	kWh p.a.
Pre-existing Grid Import	2,921	2,580	kWh p.a.
New Annual Usage with ESHW	6,445	4,604	kWh p.a.
New Annual Usage with Heat Pump	4,093	3,022	kWh p.a.
New Grid Import for ESHW	3,524	2,024	kWh p.a.
New Grid Import for Heat Pump	1,172	442	kWh p.a.
ESHW Running Cost (@ $0.2194/kWh)	773	444	$ p.a.
Heat Pump Running Cost (@ $0.2194/kWh)	257	97	$ p.a.
Heat Pump Annual Saving versus ESHW	516	347	$ p.a.

With the annual savings of the heat pump (as compared with the ESHW unit) discounted at 2.5% p.a. [48], the net present value in each year over 10 years of investment in the heat pump, as an alternative to the ESHW system was as follows:

Table 5.2: NPV of Heat Pump v ESHW, Working Couple, Sydney

Year	1.5kW	4.0kW
0	-$3,000.00	-$3,000.00
1	-$2,435.65	-$2,596.49
2	-$1,956.45	-$2,274.20
3	-$1,488.94	-$1,959.78
4	-$1,032.83	-$1,653.03
5	-$587.85	-$1,353.76
6	-$153.72	-$1,061.78
7	$269.82	-$776.93
8	$683.03	-$499.03
9	$1,086.17	-$227.90
10	$1,479.47	$36.61

[48] Reflecting the upper end of the current cost of household mortgage finance.

What the above table demonstrates is that for the smaller PV system size, a quicker payback is achieved (~six years) by investing in a heat pump system instead of an ESHW unit. This is because the smaller PV system can't supply enough power to the ESHW system (particularly in winter, and to a lesser extent autumn/spring) and as such, grid purchases are relatively high. Over 10 years, this 1.5kW solar customer is ~$1,500 better off by choosing the heat pump.

But for a household with a larger PV system (i.e. around 4.0kW), this system is better able to supply the ESHW system over the course of the year – meaning the annual savings aren't as great for this customer choosing a heat pump. Over 10 years, it is relatively immaterial whether a 4.0kW PV household chooses a heat pump or an ESHW system.

5.2.2 Stay at Home Family – High Consumption

ATA also considered this analysis for the larger customer – i.e. the Stay at Home Family (~35kWh per day average). To this profile, ATA added the same ESHW and heat pump consumption profiles. Both units were again timed to operate during solar-generation times.

The key inputs to, and outputs from, the modelling were as follows:

Table 5.3: Modelling Inputs & Outputs, ESHW v Heat Pump, Stay at Home Family, Sydney

Modelling Inputs & Outputs	1.5kW	4.0kW	Unit
Capital Cost – ESHW	$1,500	$1,500	
Capital Cost – Heat Pump	$4,500	$4,500	
Pre-existing Annual Usage	12,572	12,572	kWh p.a.
Pre-existing Grid Import	10,472	8,789	kWh p.a.
New Annual Usage with ESHW	14,763	12,015	kWh p.a.
New Annual Usage with Heat Pump	12,290	9,801	kWh p.a.
New Grid Import for ESHW	4,021	3,226	kWh p.a.
New Grid Import for Heat Pump	1,548	1,012	kWh p.a.
ESHW Running Cost (@ $0.2194/kWh)	882	708	$ p.a.
Heat Pump Running Cost (@ $0.2194/kWh)	340	222	$ p.a.
Heat Pump Annual Saving versus ESHW	543	486	$ p.a.

With the annual savings of the heat pump (as compared with the ESHW unit) discounted at 2.5% p.a. [49], the net present value in each year over 10 years of investment in the heat pump, as an alternative to the ESHW system is as follows:

[49] Reflecting the upper end of the current cost of household mortgage finance.

Table 5.4: NPV of Heat Pump v ESHW, Stay at Home Family, Sydney

Year	1.5kW	4.0kW
0	-$3,000.00	-$3,000.00
1	-$2,410.34	-$2,464.49
2	-$1,906.46	-$2,013.43
3	-$1,414.86	-$1,573.36
4	-$935.25	-$1,144.03
5	-$467.34	-$725.18
6	-$10.85	-$316.54
7	$434.52	$82.14
8	$869.02	$471.09
9	$1,292.92	$850.55
10	$1,706.48	$1,220.76

The above table demonstrates that for the larger annual electricity usage profile, irrespective of PV system size, the heat pump is a better economic choice than the ESHW system – both with payback times of around six years. Over 10 years, both solar customers are more than $1,000 better off.

The reason for this is given the higher pre-existing load, the existing PV system (whether 1.5kW or 4.0kW) has insufficient spare generation to power the new ESHW load. The more efficient heat pump really comes into its own here, requiring only about one third of the electricity input of the ESHW, which the solar PV is able to at least partially supply.

This analysis suggests that for the majority of existing solar PV customers about to lose their premium FiT, irrespective of PV system size, they would either be better off, or no worse off, over 10 years by choosing to install a heat pump hot water system instead of an ESHW system.

Should either be preferred, the consumer should ensure:

- the system's tank comes with a decent warranty (ATA recommends minimum 10 years);
- the heat pump, where this is favoured:
  - offers a high degree of efficiency (ATA suggests a minimum co-efficient of performance of 3.5);
  - can operate in low temperature conditions; and
  - has low operational noise.

5.3 Heating & Cooling

There are also options with regards to space heating and cooling, and maximising the use of your solar PV electricity.

5.3.1 Heat Banks

Heat banks[50] are an electrical heaters that store thermal energy for release at a later time. Traditionally, these units have been used as a way of using cheaper, off-peak (overnight) electricity and releasing that energy as heat during the day time – however solar PV provides a different opportunity for their cost effective utilisation.

Heat banks for residential application are typically composed of clay bricks, concrete or other ceramic materials. Electric heating elements are embedded in these materials, which can be switched on to heat the storage medium and thus store the energy.

The stored heat is then given off continuously (typically via radiation and convection). To speed up heat transfer, heat banks may come with mechanical fans.

Whilst heat banks cannot claim to be as efficient as heat pumps or reverse cycle air conditioners, the ability to store the solar electricity as thermal energy is a big advantage. Heat banks are relatively easy to ramp up and down as clouds pass over, and to soak up excess solar that would otherwise be exported to the grid.

5.3.2 Pre-Heating & Pre-Cooling

If the solar customer does not have an electric hot water system, it may be possible to schedule the operation of other appliances to occur during solar generation times. Some examples include: washing machines, clothes dryers, dishwashers and space heating and cooling.

Some appliances have timing functions built-in as a feature (e.g. reverse cycle air conditioners). Others may require a dedicated timer used at the outlet to turn on their power at the desired time of day.

Besides hot water, as the other major (and usually larger) residential load, space heating and cooling is a key opportunity in this regard.

Where this is electric (e.g. split system air conditioner; ducted reverse cycle; more efficient panel heaters or heat pump-backed hydronic systems), these can be programmed to at least partially run during the day time to soak up excess solar energy; whilst at the same time ensuring less electricity is required for temperature control after solar-generation hours.
Many households will primarily heat, and to a lesser extent cool, during the evenings (and outside of solar generation times). Often the householder will wait until the middle to late afternoon (e.g. when arriving home from work) to switch on their electric heating or cooling in an attempt to shift the temperature within the building/room by more than 10 or even 15 degrees.

[50] For example: http://www.derbyheatbanks.com.au/cheap_off_peak_storage_heat

Pre-heating or pre-cooling takes advantage of excess solar electricity during the daytime by programming the electric heating/cooling appliance to switch on earlier (e.g. 2pm), but at a relatively conservative setting (e.g. 16-18 degrees in winter; or 28-30 degrees in summer).

Efficient air conditioners or hydronic systems will not use significant amounts of electricity to shift the building/room's temperature to these conservative levels.

Once the householder arrives home, or decides that they require a more comfortable temperature setting, they can dial up or down the system's thermostat as required. However, given the pre-existing building/room temperature (achieved through the use of 'free' electricity from their solar system), the air conditioning system does not have to work as hard to reach the desired temperature.

For example, 20 degrees may be the desired room temperature, however given the solar pre-heating, the system only has to 'drag' the temperature up from 16 degrees – i.e. a 4 degree temperature change.

Without the solar pre-heating, the building/room temperature may have been only 10 degrees or less – meaning that at the end of the day, the air conditioning system has to achieve a 10+ degree temperature shift – requiring significantly more electricity (from the grid) to do so.

The same principle can work at the other end of the temperature scale in summer – i.e. trying to shift the temperature from only 28 degrees to 24 degrees – instead of from 35 degrees, which may be the building/room temperature by the end of the day without solar pre-cooling.

A key factor in the potential success of a pre-heating / pre-cooling strategy is the thermal performance of the building itself. By international standards, Australian homes are relatively poor at retaining, or keeping out, heat.

As such, any householder attempting to use pre-heating / pre-cooling to soak up excess solar electricity should ensure decent levels of ceiling insulation within the building. Should insulation be old or non-existent, then investing in new ceiling insulation (and potentially wall and floor insulation if undertaking a renovation project) will retain building/room temperatures for longer.

And for those solar customers that heat or cool during the daytime, provided they have net metering in place and their PV system is of sufficient capacity, they will directly use solar electricity to heat and cool their homes.

5.4 Home Energy Management Systems (HEMS)

A more comprehensive energy management strategy can be employed by utilising a home energy management system (HEMS).

HEMS are typically cloud-based software systems which monitor the consumption and generation of electricity in the home and allow the resident a degree of autonomy in managing how their electricity is utilised.

For example, a user can remotely check the real-time generation of their PV system and, if it is exceeding the house's current demand, allocate the surplus to their AC unit to cool the house before they get home. Battery systems and certain inverters have their own HEMS software included but there are relatively few stand-alone 'off the shelf' products currently on the Australian market.

HEMS can help to facilitate the most efficient management of solar PV and battery storage combinations. In this way, their value is most effectively realised in homes with battery storage installed.
In addition, to make the most efficient use of the software, houses may need some alterations to wiring or meter boxes to allow the HEMS to measure and manage the consumption and allocation of electricity to different appliances. The cost of doing this would depend on the system.

Off-the-shelf HEMS include:

- The Smappee: https://forums.whirlpool.net.au/forum-replies.cfm?t=2464840
- The Efergy Solar Kit: http://efergy.com/au/products/engage-solar#.VUsSaiGeDGc/
- Rainforest Automation: http://rainforestautomation.com/

All of the above systems are 'monitoring' systems and not 'management' systems. They allow greater transparency for the household by showing real-time usage and generation data. They do not currently allow the user to actively manage household consumption by controlling the activity of home appliances.

The Smappee claims to be able to identify specific appliances by their energy use signature but feedback from customers indicates that this feature is unreliable. The Smappee also has the ability to use remote plugs on key appliances to measure their usage and to turn them off/on remotely to maximise the houses overall energy efficiency. These plugs are not yet available in Australia.

6.0 Retail Tariff Analysis

ATA conducted an analysis of available retail FiT offers, including their associated consumption tariffs, in NSW, Victoria and SA as part of this project. This analysis informed the modelling undertaken for the project.

In NSW and SA, ATA utilised the Australian Energy Regulator retail tariff comparator website, *Energy Made Easy*[51].

As a state/jurisdiction that has not yet signed up to the *National Energy Customer Framework*[52], Victoria has its own retail tariff comparator – called *Victorian Energy Compare*[53]. ATA used this website for the tariff analysis.

Another key difference of note between the states/jurisdictions is their relevant feed-in tariff legislation.

Currently in Victoria, every retailer with 5,000 or more retail customers must offer a mandatory minimum FiT payment to any new solar customer – the rate for which is advised annually by the Essential Services Commission (the regulator in Victoria). Retailers can choose to offer above this legislated minimum[54] (and some do).

South Australia takes the same mandatory minimum approach as Victoria – with the Essential Services Commission of South Australia setting a minimum FiT rate each year.

In NSW, there is no mandatory minimum FiT rate that must be offered by retailers to any new solar customer under the current NSW legislation. Retailers can choose whether or not to offer a FiT at all (and some don't).

The tables below summarise the range of retail FiT offers, with their associated consumption tariffs, for each state/jurisdiction. All figures are ex GST[55].

It should be noted that this analysis can only be considered accurate at the time of writing. Retail offers in the NEM change on a 6-12 month basis (depending on jurisdiction and offer type). These tariffs are unlikely to be completely accurate at the time of the premium FiTs ending toward the end of 2016.

51 https://www.energymadeeasy.gov.au/
52 https://www.aer.gov.au/retail-markets
53 https://compare.switchon.vic.gov.au/
54 The legislation does not control the price or structure of any associated consumption tariff.
55 It should be noted that GST is not credited back to the solar customer on the FIT rate in any jurisdiction.

6.1 New South Wales

The table below aggregates the results from a review of 23 solar FiT retail offers; and 12 non-solar retail offers; in the NSW market. The ranges and averages/medians of FiT rates, as well as rates for consumption (be those as part of flat or time of use offers) and any pay-on-time discounts, are presented.

Table 6.1: Retail Tariff Analysis, NSW (ex GST)

Solar Offers	*FiT c/kWh*	*Supply c/day*	*Flat Rate c/kWh*	*Flat Rate (Bal) c/kWh*	*TOU Peak c/kWh*	*TOU Off-peak c/kWh*	*TOU Should c/kWh*	*Discount*
No. offers	23							
Max	10.00	134.75	23.90	24.06	49.56	12.38	19.91	20%
Min	5.00	66.00	20.22	19.68	37.19	9.11	13.97	0%
Average	6.70	82.94	21.93	22.20	43.12	10.40	16.87	7%
Median	6.00	79.56	21.66	22.23	42.49	9.99	16.80	7%
Non-Solar Offers								
No. offers	12							
Max		104.90	23.00	22.50	46.48	11.50	17.87	20%
Min		57.50	19.72	19.72	38.74	9.74	14.55	0%
Average		78.16	21.11	20.98	43.36	10.47	16.67	14%
Median		75.61	21.21	20.68	43.49	10.16	17.13	16%
Difference between Solar & Non-Solar Offers								
Max		29.85	0.90	1.56	3.08	0.88	2.04	0%
Min		8.50	0.50	-0.04	-1.55	-0.63	-0.58	0%
Average		4.77	0.82	1.22	-0.23	-0.07	0.21	7%
Median		3.95	0.45	1.55	-0.99	-0.17	-0.32	9%

As can be seen, FiT rates (where offered) range between 5 and 10 cents per kWh.

In considering solar offers versus non-solar offers, ATA did not find material differences in the consumption rates (whether they were as part of flat tariff offers or time of use) for retail offers to solar customers as compared with non-solar customers. Average/median differences were within 1.55 cents per kWh.

In addition, a mix of one, two and three year contracts; as well as 'Ongoing' offers were present in both retail offers to solar customers and non-solar customers.

The only material difference ATA could find in this sample and with respect to solar offers versus non-solar offers was the relatively lower pay-on-time discounts that were offered to solar customers.

Of the 12 non-solar retail offers reviewed, only three offered discounts (those being 20%, 16% and 16% respectively).

However ATA also utilised the Tariff Tracker database, as managed by St Vincent de Paul [56], to understand the broader suite of discounts available for market contracts in NSW.

The Tariff Tracker highlighted 15 non-solar market offers, with 12 of those including a pay-on-time discount. Whilst the highest (20%) and lowest (0%) remained the same, the average/median across this sample was 14%/16% - materially higher than the average/median for solar customer discounts (7%/7%).

It should be noted that this analysis represents only a subset of available offers in the NSW market, and offers may differ across the three NSW network more substantially. Irrespective of how solar and non-solar offers play out across the market, the advice to existing and new solar customers is the same – shop around to get the best overall deal.

Of the solar offers available, the top five currently available in New South Wales, where the associated consumption tariffs and supply charge did not materially differ from the better non-solar offers in the market, were as follows:

Table 6.2: Best FiT Retail Offers, NSW

Retailer	Urth Energy	Urth Energy	Click Energy	Click Energy	Diamond Energy Pty Ltd
Plan ID	URT126204MR	URT126201MR	CLI141008MR	CLI141003MR	DIA101946MR
Rate Type	Single Rate	TOU	Single rate	TOU	Single rate
Contract Term	3 years	3 years	Ongoing	Ongoing	2 year
Supply Charge c/day	80.5	82.6	81.86	91.6	75.15
Flat Rate (First) c/kWh	23.9		23.08		21.35
Flat Rate (Bal) c/kWh	21.5		24.06		23.95
ToU Peak c/kWh		46.1		49.56	
ToU Off Peak c/kWh		11.5		11.42	
ToU Shoulder c/kWh		18.7		19.91	
FiT Rate	10	10	10	10	8
Pay on Time Discount	10%	10%	7%	15%	3%

6.2 Victoria

The table below aggregates the results from a review of 16 solar FiT retail offers; and 7 non-solar retail offers; in the Victorian market. The ranges and averages/medians of FiT rates, as well as rates for consumption (be those as part of flat or time of use offers) and any pay-on-time discounts, are presented.

[56] https://www.vinnies.org.au/page/Our_Impact/Incomes_Support_Cost_of_Living/Energy/

Table 6.3: Retail Tariff Analysis, Victoria (ex GST)

Solar Offers	FiT c/kWh	Supply c/day	Flat Rate c/kWh	Flat Rate (Bal) c/kWh	TOU Peak c/kWh	TOU Off-peak c/kWh	TOU Should c/kWh	Discount
No. offers	16							
Max	10.00	112.75	22.64	24.64	29.96	14.55	22.59	30%
Min	5.00	71.50	14.71	17.33	21.10	11.00	18.70	0%
Average	6.81	98.30	18.76	21.19	25.91	12.96	20.28	19%
Median	6.50	102.40	18.85	21.40	27.00	12.89	19.55	7%
Non-Solar Offers								
No. offers	7							
Max		112.75	21.35	22.49	28.40	14.18	19.55	30%
Min		71.50	14.71	16.20	22.67	12.01	9.71	0%
Average		95.93	17.22	18.66	25.86	12.99	14.30	17%
Median		102.00	16.40	17.88	26.08	12.89	13.63	2%
Difference between Solar & Non-Solar Offers								
Max		0.00	1.29	2.15	1.56	0.37	3.04	0%
Min		0.00	0.00	1.13	-1.57	-1.01	8.99	0%
Average		2.38	1.55	2.53	0.05	-0.04	5.98	2%
Median		0.40	2.45	3.52	0.92	0.00	5.92	5%

As with NSW, current FiT rates in Victoria range between 5 and 10 cents per kWh. Also in line with NSW, ATA did not find material differences in the consumption rates (whether they were as part of flat tariff offers or time of use) for retail offers to solar customers as compared with non-solar customers. Average/ median differences for flat or peak rates were between 1.55 and 3.52 cents per kWh.

Again, a mix of one, two and three year market contracts; as well as 'Ongoing' offers were present in both retail offers to solar customers and non-solar customers.

The difference in available discounts to solar customers in Victoria, as compared with non-solar customers, was slightly less than the difference in discounts for NSW. Across the sample above, only a 2% difference in average, and 5% difference in the median, was found between solar offers and non-solar offers in relation to discounts.

Again using the Vinnies Tariff Tracker database[57], 16 current non-solar offers had an average discount of 23.75% - approximately 4% higher than for solar offers.

Of the solar offers available, the top five currently available in Victoria, where the associated consumption tariffs and supply charge did not materially differ from the better non-solar offers in the market, were as follows:

[57] https://www.vinnies.org.au/page/Our_Impact/Incomes_Support_Cost_of_Living/Energy/

Table 6.4: Best FiT Retail Offers, Victoria

Retailer	Next Business Energy Pty Ltd	Click Energy	Diamond Energy Pty Ltd	Powerdirect	People Energy
Plan ID	NEX42694SR	CLI42065MR	DIA41880MR	POW39833MR	PEO42453MR
Rate Type	Single rate	Single rate	Flex pricing	Single rate	TOU
Contract Term	Ongoing	Ongoing	2 year	Ongoing	Ongoing
Supply Charge c/day	71.5	104	109.95	109.77	108.88
Flat Rate (First) c/kWh	16.5				
Flat Rate (Bal) c/kWh	18	21.4		21.1	
ToU Peak c/kWh			29.5		29.96
ToU Off Peak c/kWh			12.98		12.73
ToU Shoulder c/kWh			19.55		
FiT Rate	10	10	8	8	8
Pay on Time Discount	0%	7%	7%	30%	20%

6.3 South Australia

The table below aggregates the results from a review of 13 solar FiT retail offers; and 9 non-solar retail offers; in SA. The ranges and averages/medians of FiT rates, as well as rates for consumption (be those as part of flat or time of use offers) and any pay-on-time discounts, are presented.

Table 6.5: Retail Tariff Analysis, SA (ex GST)

Solar Offers	*FiT c/kWh*	*Supply c/day*	*Flat Rate c/kWh*	*Flat Rate (Bal) c/kWh*	*TOU Peak c/kWh*	*TOU Off-peak c/kWh*	*TOU Should c/kWh*	*Discount*
No. offers	13							
Max	8.00	78.75	30.23	36.85	24.33	18.24	N/A	17%
Min	5.00	63.79	24.80	28.74	24.33	18.24	N/A	0%
Average	6.74	70.25	28.06	32.33	24.33	18.24	N/A	6%
Median	6.80	69.50	28.29	31.97	24.33	18.24	N/A	3%
Non-Solar Offers								
No. offers	9							
Max		78.12	32.79	37.89	24.33	18.24	N/A	20%
Min		63.79	24.80	28.74	24.33	18.24	N/A	0%
Average		70.93	28.17	32.02	24.33	18.24	N/A	13%
Median		71.70	28.08	31.00	24.33	18.24	N/A	14%
Difference between Solar & Non-Solar Offers								
Max		0.63	-2.56	-1.04	0.00	0.00	N/A	-3%
Min		0.00	0.00	0.00	0.00	0.00	N/A	0%
Average		-0.68	-0.11	0.31	0.00	0.00	N/A	7%

Median	-2.20	0.20	0.97	0.00	0.00	N/A	11%

Current FiT rates in South Australia range between 5 and 8 cents per kWh. Again, ATA did not find material differences in the consumption rates for retail offers to solar customers as compared with non-solar customers. Average/ median differences for flat or peak rates were between just below zero (i.e. the solar consumption tariff was better) and 0.97 cents per kWh.

ATA only found one 2-part time-of-use offer, with the same consumption charges for peak / off-peak for solar customers as for non-solar customers. ATA did not find any 3-part (i.e. with shoulder) tariffs available.

A mix of fixed term, non-fixed term and 'Ongoing' market offers were present in both retail offers to solar customers and non-solar customers.

Using the Vinnies Tariff Tracker database[58], 13 current non-solar offers had an average/median discount of 13%/14% - approximately 7%/11% higher than for solar offers. This was a more material difference in line with the disadvantage experienced by NSW solar customers.

Of the solar offers available, the top five currently available in South Australia, where the associated consumption tariffs and supply charge did not materially differ from the better non-solar offers in the market, were as follows:

Table 6.6: Best FiT Retail Offers, SA

Retailer	Diamond Energy	Powerdirect	Click Energy	Lumo Energy	Commander Energy
Plan ID	DIA109361MR	POW147719MR	CLI141057MR	LUM96873MR	M2E130605MR
Rate Type	Single rate	Single rate	Single rate	Single rate	Single rate
Contract Term	2 year	Ongoing	Ongoing	2 year	Ongoing
Supply Charge c/day	71.80	68.68	78.75	77.57	67.35
Flat Rate (First) c/kWh	24.8	28.08	30.04	26.47	28.49
Flat Rate (Bal) c/kWh	29.95	28.74		31.97	34.99
FiT Rate	8	8	8	7	7
Pay on Time Discount	3%	9%	17%	12%	0%

58 https://www.vinnies.org.au/page/Our_Impact/Incomes_Support_Cost_of_Living/Energy/

7.0 The Key Opportunity: Gas

As outlined above, in 2014, ATA conducted detailed research and modelling[59] into the economics of using gas versus efficient electric appliances for space heating, water heating and cooking.

ATA's methodology for the research modelled six different household types, and compared the 10-year costs of installing and running gas, as compared with efficient electric appliances in existing and new homes.

Different replacement cases took into account whether the existing gas appliance/s were near the end of their asset life, or not. The analysis was conducted across 26 different gas pricing zones (eight in NSW) and took into account the impact of different climate conditions.

For details of the ATA methodology, please refer to **Appendix C** or to the source report.

7.1 Changing Technology & Economics

Space heating and water heating are the two most energy intensive activities that residential energy consumers typically use reticulated gas for, particularly in cold and temperate climates. Cooking is the third – albeit significantly lower end use – for residential gas.

Electrical technology used to heat air and water is becoming increasingly efficient. Residential scale reverse cycle air-conditioners (for space heating) are reaching co-efficients of performance (CoP) of 5.0 and over – which means that for every 1 unit of energy input to the system, 5 units are generated to heat air. CoPs for the most efficient electric heat pumps (for water heating) now exceed 4.0.

Compared with the most efficient equivalent gas appliance that have a CoP of around 0.8 – 0.9, an efficient air-conditioner or electric water heater now uses 1/7th to 1/5th of the input energy for the same end use. While CoPs for electric appliances may continue to improve, gas appliances are forever limited to 0.9 at best.

In addition, induction cook tops, that offer high efficiency and similar (or greater) amenity to gas cook tops, have become increasingly affordable in recent years and continue to drop in price as they gain popularity as a mass market product.

At the same time, wholesale gas prices are increasing across Eastern Australia as a result of the expansion of Australian gas exports. These two trends (increasing gas prices and improved electric performance) are changing the customer economics of gas versus electricity.

7.1.1 Consumer Purchasing Behaviour

Approximately 7% of all Australian households replace their gas hot water systems each year, in keeping with a typical asset life of 10 to 15 years. Space heaters tend to have slightly longer asset lives.

59 http://www.ata.org.au/wp-content/projects/CAP_Gas_Research_Final_Report_251114_v2.0.pdf

When faced with this decision, according to industry data, the majority choose a 'like for like' replacement. This common approach ignores the impact of running cost, determined by technology efficiency and future energy prices, on the total cost of purchasing, owning and operating the appliance over the life of the system.

In addition, for a NSW SBS, Victorian TFiT or SA FiS solar customer, supplying their space and water heating requirements electrically, and from solar PV, offers the best opportunity available for maximising solar PV use and its economic benefit.

7.2 2014 Modelling Results

The economic results for each Household Scenario in the ATA research included the following capital cost assumptions for each case:

Table 7.1: Capital Cost Assumptions by Replacement Case

No.	Replacement Case	Capital Cost Assumptions
1	Switching a gas appliance, within 5 years of end of life, staying on gas network	Gas & Electric
2	Switching a gas appliance, not within 5 years of end of life, staying on gas network	Electric Only
3	Switching one gas appliance, of any age, disconnecting from gas network	Electric Only
4	Switching two gas appliances, at least one is within 5 years of end of life, disconnecting from gas network	1 Gas & 2 Electric
5	New & existing homes, not currently gas connected, choosing efficient electric instead of gas	3 Gas & 3 Electric
6	All gas appliances switched: one is within 5 years of end of asset life, avoiding $2,000 replacement capex	1 Gas & 3 Electric

Economic results assumed a discount rate of 5.5% - reflective of the upper end of the cost of residential mortgages - an appropriate time cost of money for household investment.

Results were presented by appliance type (i.e. space heating, water heating, cooking) and replacement case for each Household Scenario; with Net Present Values (NPV) defined over a ten year period.

The payback time of the efficient electric alternative/s to equivalent gas appliance/s based on discounted cash flows were indicated as per below, along with ATA's advice:

Table 7.2: Explanation of Results Table

Colour	Economic Result	ATA Advice
$NPV	A positive NPV with payback time of 5 years or less	Definitely choose efficient electric over gas: any extra up-front cost will be recouped through savings within five years
$NPV	A positive NPV with payback time of between 6 and 10 years	Consider choosing efficient electric over gas: any extra up-front cost will be recouped through savings within ten years
- $NPV	A negative NPV over 10 years	Choosing electricity over gas is unlikely to save any money: any extra up-front cost will not be recouped within ten years

The economic results for metropolitan Sydney were as follows:

Table 7.3: Economic Results, Gas versus Efficient Electric, Metropolitan Sydney

Gas Zone: Jemena/AGL Greater Sydney				Electricity Zone: Ausgrid		
Example Location: Hurstville, 2220, NSW				**Climate Zone: Balanced Moderate Demand**		
Household Scenario	Ref home	Small home	Large home	Public housing	LPG home	New build
Switching a gas appliance, within 5 years of end of life, staying on gas network.						
Space Heating	$1,345	$1,166	$1,284	$1,847	$1,688	$2,114
Hot Water	$342	-$471	$519	-$123	$2,195	$740
Cooking	-$259	-$102	-$348	-$259	n/a	-$348
Switching a gas appliance, not within 5 years of end of life, staying on gas network						
Space Heating	-$1,455	-$1,034	-$2,116	-$1,153	$72	n/a
Hot Water	-$1,158	-$1,671	-$1,281	-$1,323	$636	n/a
Cooking	-$2,059	-$1,902	-$2,148	-$2,059	n/a	n/a
Switching one gas appliance, of any age, disconnecting from gas network						
Space Heating	$936	$1,256	$320	$1,163	n/a	n/a
Hot Water	$1,416	$596	$1,429	$1,177	n/a	n/a
Cooking	-$236	-$286	-$185	-$236	n/a	n/a
Switching two gas appliances, at least one is within 5 years of end of life, disconnecting from gas network						
Space Heating + Cooking	$1,954	$1,623	$1,988	$2,381	n/a	n/a
Hot Water+ Cooking	$1,134	-$36	$1,497	$595	n/a	n/a
New & existing homes, not currently gas connected, choosing efficient electric instead of gas*						
All Heating & Cooking	$6,416	$4,868	$7,029	$6,378	$6,838	$7,519
All gas appliances switched: one is within 5 years of end of asset life, avoiding $2,000 replacement capex.						
All Heating & Cooking	-$96	-$293	-$833	-$33	$3,888	-$493

** Assumes full CAPEX on both electric and gas sides.*

The economic results for metropolitan Adelaide were as follows:

Table 7.4: Economic Results, Gas versus Efficient Electric, Metropolitan Adelaide

Gas Zone: Envestra Adelaide			Electricity Zone: SA Power Networks			
Example Location: Marion, 5034, SA			**Climate Zone: Balanced Moderate Demand**			
Household Scenario	Ref home	Small home	Large home	Public housing	LPG home	New build
Switching a gas appliance, within 5 years of end of life, staying on gas network.						
Space Heating	$863	$1,346	$687	$1,548	$2,050	$1,844
Hot Water	-$1,107	-$1,314	-$1,895	-$906	$1,190	-$1,597
Cooking	-$462	-$182	-$680	-$441	n/a	-$680
Switching a gas appliance, not within 5 years of end of life, staying on gas network						
Space Heating	-$1,937	-$854	-$2,713	-$1,452	$550	n/a
Hot Water	-$2,607	-$2,514	-$3,695	-$2,106	-$10	n/a
Cooking	-$2,262	-$1,982	-$2,480	-$2,241	n/a	n/a
Switching one gas appliance, of any age, disconnecting from gas network						
Space Heating	$2,303	$2,548	$1,593	$2,458	n/a	n/a
Hot Water	$1,796	$884	$911	$2,070	n/a	n/a
Cooking	$246	$244	$247	$246	n/a	n/a
Switching two gas appliances, at least one is within 5 years of end of life, disconnecting from gas network						
Space Heating + Cooking	$3,223	$2,867	$3,114	$3,578	n/a	n/a
Hot Water+ Cooking	$1,416	$203	$833	$1,390	n/a	n/a
New & existing homes, not currently gas connected, choosing efficient electric instead of gas*						
All Heating & Cooking	$6,040	$5,224	$5,494	$6,742	$6,202	$6,310
All gas appliances switched: one is within 5 years of end of asset life, avoiding $2,000 replacement capex.						
All Heating & Cooking	-$385	$149	-$2,281	$417	$3,252	-$1,615

** Assumes full CAPEX on both electric and gas sides.*

The economic results for metropolitan Melbourne were as follows:

Table 7.5: Economic Results, Gas versus Efficient Electric, Metropolitan Melbourne

Gas Zone: Envestra Central 2			Electricity Zone: Citipower			
Example Location: Richmond, 3121, VIC			**Climate Zone: Heating Dominated**			
Household Scenario	Ref home	Small home	Large home	Public housing	LPG home	New build
Switching a gas appliance, within 5 years of end of life, staying on gas network.						
Space Heating	$628	$514	$1,507	-$343	$2,925	$1,395
Hot Water	-$1,511	-$1,810	-$1,731	-$1,691	$2,904	-$1,556
Cooking	-$335	-$199	-$460	-$268	n/a	-$460
Switching a gas appliance, not within 5 years of end of life, staying on gas network						
Space Heating	-$2,172	-$1,686	-$1,893	-$3,343	$1,111	n/a
Hot Water	-$3,011	-$3,010	-$3,531	-$2,891	$1,296	n/a
Cooking	-$2,135	-$1,999	-$2,260	-$2,068	n/a	n/a
Switching one gas appliance, of any age, disconnecting from gas network						
Space Heating	$622	$872	$981	-$1,136	n/a	n/a
Hot Water	-$155	-$475	-$623	-$579	n/a	n/a
Cooking	-$80	-$22	-$137	-$324	n/a	n/a
Switching two gas appliances, at least one is within 5 years of end of life, disconnecting from gas network						
Space Heating + Cooking	$1,424	$1,132	$2,326	-$79	n/a	n/a
Hot Water+ Cooking	-$652	-$1,215	-$878	-$1,323	n/a	n/a
New & existing homes, not currently gas connected, choosing efficient electric instead of gas*						
All Heating & Cooking	$3,959	$2,958	$4,994	$1,494	$8,273	$4,276
All gas appliances switched: one is within 5 years of end of asset life, avoiding $2,000 replacement capex.						
All Heating & Cooking	-$2,461	-$2,112	-$2,776	-$4,376	$5,773	-$3,413

** Assumes full CAPEX on both electric and gas sides.*

Of note:

- switching space heating to efficient electric, when the existing gas heater was within five years of the end of its asset life, involved considerable economic gain in most scenarios;
- switching hot water to efficient electric, where an existing gas hot water system is near the end of its asset life, is at least comparable with a new gas hot water system; and is significantly better where it involves disconnecting from the gas network (either as the last gas appliance, or in combination with cooking).
- switching all three gas appliances over to efficient electric, where only one is near the end of its asset life, is broadly equivalent (in terms of 10 year cost) to staying with gas in Sydney and Adelaide.

7.3 Discussion

A critical issue with the 2014 modelling in the context of this report is that typical peak retail electricity tariffs (i.e. in the order of $0.20 - $0.30/kWh) were used as the basis for the running cost of the efficient electric appliances in each location.

Given current solar PV installed prices, the cost of electricity from a solar system over its asset life in Australia is in the order of $0.10/kWh – or less than half that of most peak/daytime retail tariffs. This means that the economics of switching from gas to efficient electric, for those installing new solar PV systems, will be better than as presented in the three tables above.

Sensitivity analysis was undertaken in the 2014 research to test the results against a range of forecast gas prices for NSW; as well as the use of solar PV to power hot water appliances. The sensitivity analysis found that:

- the modelling results were not particularly sensitive to different gas price trajectories – whilst they changed the magnitude of the numbers; they largely did not change an uneconomic investment into an economic one (or vice versa); and

- running efficient electric hot water systems on off-peak tariffs or solar PV significantly improved the economics.

But even more so, for NSW SBS, Victorian TFiT and SA FiS solar customers, who have existing solar PV systems, the running cost of efficient electric space and water heating systems will be zero – for when they are run during the daytime and there is sufficient solar generation capacity.

With space heating and hot water comprising more than 50% of a home's energy needs in most locations, it is difficult to maximise the use of solar PV without using it to power one or both of these major loads.

For NSW SBS, Victorian TFiT and SA FiS solar customers, switching away from gas is imperative to achieving the best economic return possible for their existing (and any upgraded) solar PV system.

This strategy will largely involve considering the kind of electric hot water and space heating solutions canvassed in **Section 5.0** of this report.

Designed and implemented well, transitioning away from gas will allow most NSW, Victorian and SA customers to reduce their annual stationery energy bills to no more (and potentially less) than $1,000 per year. This is in the context of the majority of NSW, Victorian and South Australian homes currently paying in the order of $2,000-$3,000 per year for stationery energy (i.e. electricity or electricity and gas)[60].

Given the rise of distributed solar energy, most Australian homes now have three clear choices with regards to their stationery energy requirements, those being:

- Electricity from the electricity grid;
- Electricity form their own solar system; and/or
- Gas from the gas grid or bottled (LPG).

[60] http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4670.0main+features132012

From an economic perspective, it makes no sense to rely on all three - ultimately households do not consume such significant amounts of stationery energy as to necessitate three separate input fuel sources.

Going forward, Australian households are facing a clear choice with regards to keeping their energy bills low:

- either remain dual fuel and rely on both the electricity and gas grids; or
- become (or remain) all electric – purchasing some electricity from the grid, and some from their own solar PV system.

Increasingly, option 2 is the more economic. And with falling costs of renewable energy and some efficient electric technologies; the increasing efficiency of electric water and space heating technologies; and slow to steadily rising gas prices (due to international exports), the future trend is clearly in favour of option 2.

8.0 Appendix A: Storage Chemistries

8.1.1 Lead-Acid

Lead-acid batteries consist of lead and lead-sulphate plates suspended in a sulphuric acid electrolyte. They are a reliable and well-understood chemistry that is relatively forgiving to mild overcharging, although over-discharging can impact lifespan considerably.

In years past, the most common type of lead-acid batteries in household-scale stationary power systems were flooded cell types. In more recent times there has been a trend towards prioritising safety and lowering maintenance requirements, resulting in a shift from flooded to sealed lead-acid batteries that have no risk of acid spillage or need to check cell electrolyte levels or check for internal corrosion.

Sealed lead-acid batteries come in two main designs—AGM (absorbent glass mat) and gel cell.

Gel cells have their electrolyte as a gel to prevent spillage and stratification (where the acid density of the electrolyte varies from the bottom to the top of the cells), while AGM batteries have liquid electrolyte, like flooded-cell batteries, but it is absorbed into fibreglass separators between the cells to provide the same benefits as the gel type.

Because both gel and AGM have the electrolyte effectively immobilised, they are safe and no longer need equalising charging; thus they don't need to be topped up with distilled water like flooded cells do.

The main failure mode of lead-acid batteries is corrosion – typically accelerated by higher temperatures. Lead-acid batteries are also constrained by what's known as the 'Peukert effect' – which expresses the capacity of a battery in terms of the rate at which it is discharged. As the rate increases, the battery's available capacity decreases.

As a result of this property, in applications where long life is and frequent discharge is required, researchers from the CSIRO state that lead-acid batteries shouldn't be discharged faster than a 10 C10 rate ('C' being the reference to the charge/discharge time and is a unit published by battery manufacturer's as part of the product specifications). This is equivalent to discharging at one-tenth of the rated capacity of the battery in any hour.

This is a limitation of lead-acid technology for those users who wish to utilise a significant proportion of a battery's capacity in a relatively short time period (e.g. during typical residential evening peaks).

8.1.2 Lithium

Lithium offers considerable advantages over lead-acid. Lithium iron phosphate ($LiFePO_4$) batteries have higher storage densities (more energy can be stored in a battery of a given volume), greater power densities (batteries can produce far greater instantaneous power outputs without damage), much better charging efficiency and longer life spans than any lead-acid formats.

They currently have higher capital costs but increasingly lower lifetime costs – with more 'useable' energy capacity and longer asset lives than lead-acid. This is likely to continue to improve as the global push for lower cost batteries for electric vehicles continues.

Lithium batteries are not constrained by the Peukert effect. According to the CSIRO, most lithium storage systems can be used at up to a 3C rate, (being 30 times higher than the C10 rate of LA batteries). Given that there are few applications that require such fast charge or discharge, there is effectively no practical limit on discharge rate and lithium manufacturers typically publish charging capacity at the 'C1' rate.

Their longer asset lives, higher charging and discharging efficiency and their ability to provide capacity over very short charge/discharge periods enables smaller capacity banks to be used as compared to lead-acid.

Lithium batteries must have an effective battery management system (BMS). This enables each cell in the battery bank to be individually monitored when charging and discharging. Overcharged cells and cells discharged below the minimum voltage point can fail.

Some batteries, particularly smaller format lithiums, are supplied with a fully integrated BMS. Larger format cells typically come with the BMS modules supplied separately—fitted once the bank is assembled in the final location; or may (as is the case with the new Tesla PowerWall) have the BMS integrated.

8.1.3 Other Chemistries

There are a variety of other storage chemistries that can be used for household energy storage – including existing nickel-cadmium; nickel-iron; nickel metal-hydride and flow batteries; as well as ultra-batteries, sodium and zinc (chemistries that are still in the R&D phase).

Compared with lithium, those alternative chemistries that are commercially available now:

- remain less efficient (with regards to charging); or
- have even higher upfront costs; or
- are unavailable in Australia; or
- are suited only to large format applications.

With regards to the emerging chemistries:

- the ultra-battery is essentially a lead-acid battery with capacitors added in to the electrolyte for enhanced performance. Like all lead-acids, ultra-batteries remain susceptible to corrosion and must be periodically charged to 100% to maintain their capacity (e.g. once per month). This requirement comes at an economic cost to the end user as the battery will not be available for normal use for a portion of the time.

  Ultra-batteries also have an effective limit on discharge rate in the range of a 'C1' rate. However according to the CSIRO, this is only achievable provided that the technology is only cycled between 50% and 80% state of charge (SoC) – effectively a significant limit on useable capacity. As yet, ultra-batteries are not widely commercially available.

- sodium batteries have relatively low discharge rates and low energy density - neither of which is necessarily a problem for suitably sized storage in a home renewable energy system. However this emerging technology still has high capital costs and high weight per battery.

- zinc-air storage is expected to become commercially available in 2016 – zinc-air batteries. Normally found as single use batteries in small devices such as hearing aids, this chemistry has been developed into rechargeable batteries in the US[61].

  Zinc-Air technology is rated as being capable of 10,000 cycles (DOD not specified) and a 30-year lifespan. Zinc-air chemistry, it is relatively non-toxic and low cost. Their first system is a 4 MWh battery storage system for grid stabilisation, but hopefully smaller systems for domestic use will be available in the near future.

  Other Air-based technology is in development including Aluminium-air technology, however none of these are approaching commercial viability at this time.

[61] By EOS Energy Storage (www.eosenergystorage.com)

9.0 Appendix B: The Sunulator

The 'Sunulator' is currently the most capable economic analysis tool for grid-connected solar and grid-connected solar-battery systems, available in Australia. The strengths of the Sunulator simulation model are as follows:

- To accurately inform generation, ATA integrated 19 years (1994-2013) of solar insolation data from the Bureau of Meteorology (BoM) into Sunulator. The data exists across five-kilometre grids for all of Australia and is the basis for the generation calculations within the model.
- Regarding consumption, Sunulator has the capability to:
  - directly accommodate interval data files of any time period (as Sunulator averages both generation & consumption back to a typical meteorological year and typical consumption year). For most accurate results, at least 12 months of data is preferable;
  - alternatively, a detailed consumption profile can be built based on relevant input assumptions regarding load patterns, including daily, weekly and seasonal variations; and other variables such as public and private holidays, weekends and standby loads.
- Regarding storage, Sunulator has the ability to analyse the energy flows and economic outcomes of different storage chemistries (e.g. lead acid versus lithium) with the ability to input specific battery charge/discharge rates and efficiencies. Battery storage strategies such as export minimisation, peak shaving and tariff arbitrage can be modelled by setting limits for charge/discharge rates at any time of the day.

Economic and energy results are based on netting off generation versus consumption data, specific to that location and user profile, for each 30 minute interval over a full year.

This takes account of climate variability and gives the most accurate picture of how much solar generation will be consumed on-site (and when); versus how much will be stored and discharged from the batteries and when (if of relevance); versus exported. System design and configuration can then be optimised to maximise the value of solar generation and minimise the cost of consumption from the grid.

Sunulator calculates the impact on the consumer's electricity bill (annually) and projects the savings over a 30-year time frame. Financial results include simple and discounted payback, net present value and return on investment (project internal rate of return). The carbon impact of the project is also automatically calculated.

10.0 Appendix C: ATA Gas Research Methodology

For six different household types, ATA estimated the 10-year costs of replacing gas appliances with like-for-like gas appliances or efficient electric alternatives. In a residential setting, an individual consumer may be considering:

- switching one or two gas appliances with electric appliances, but retaining an existing reticulated gas connection or LPG gas system for any gas appliance/s that remain;
- a complete switch from gas to electric appliances, with subsequent:
  - disconnection from the reticulated gas network; or
  - termination of the use of LPG; or
- establishing a new connection to the reticulated gas network, and purchase of new gas appliances, for:
  - an existing home without mains gas; or
  - a newly built home.

The economics of the gas and electric choices is sensitive to a wide range of interrelated factors, which include:

- whether or not an appliance is at or near the end of its asset life;
- whether the decision incurs the cost of a new connection or new fixed charges;
- whether the decision avoids the cost of existing fixed charges;
- current gas and electricity tariffs and tariff structures;
- forecast prices for electricity and gas;
- the annual input energy use of individual gas and/or electric appliances, which is itself influenced by:
  - building type, size and thermal performance;
  - the type and mix of existing appliances in the home;
  - climate zone (with particular reference to space and water heading loads and the performance of electric systems); and
  - consumer financial expectation, including the cost of capital and return on investment expectations for any individual consumer; and
  - consumer behaviour.

10.1.1 Household Scenarios

In line with the above, ATA developed six 'Household Scenarios' that could be applied to each location modelled.

The scenarios considered a range of housing types and sizes, with differing characteristics in terms of gas and electric appliance use and overall energy use. The exception to this is the newly built home scenario (*Scenario 6: New Build*). As there are no existing appliances in place, a consumer is assumed to choose between installing either gas or electric appliances as the initial appliance investment.

10.1.2 Replacing Gas Appliances in Existing Homes

Household Scenarios 1 to 5 consider cases where a decision to replace one or more existing gas appliance is made, either:

- at the point where it has failed, or is highly likely to require replacement within five years. In this case, replacing it with one appliance avoids the capital expense of another in the near to medium term, hence the up-front cost impact on the consumer will be the difference in capital cost between the two appliances; or
- while the existing appliance is still in good working order and unlikely to require replacement within five years. In this case, the decision does not lead to any avoided capital cost in the near term and up-front cost to the consumer will be the full capital cost of the new appliance.

The options are either to:

1. replace the gas appliance/s with a new, efficient gas appliance (this is considered the *Business as Usual* (BAU) case; or
2. replace the gas appliance/s with an efficient electric appliance/s.

Under option 2, there is also the case where a consumer replaces all gas appliances with efficient electric, avoiding the need for an existing gas supply. In this case, the consumer:

- avoids the ongoing fixed charge incurred by maintaining a gas connection; and
- usually incurs a charge for temporary or permanent isolation of the gas supply to their home.

10.1.3 Connecting Existing All-Electric Homes to Gas

Household Scenarios 1 to 5 also consider the case where an established all-electric home has the option to connect to an existing gas network and install gas appliances. The available options are to:

1. connect one or more efficient gas appliances to the gas network, with or without some number of efficient electric appliances. In this case, the use of any one appliance avoids the capital expense of another, hence the up-front cost impact on the consumer will be the difference in capital cost between the two appliances; or
2. install efficient electric appliance/s and not connect to the gas network. Under this option, the consumer also avoids any ongoing fixed charge incurred by maintaining a gas connection.

In option 1 above, there is also an establishment cost to connect the home to the gas network in the street, including the installation of a gas meter. On the advice of gas network businesses and in order to be conservative, ATA have not attributed this cost to the householder, as businesses are likely to subsidise this cost as an incentive to the consumer to connect to the network.

10.1.4 Choosing Appliances for New Homes

Household Scenario 6: *New Home* considers the case where a new home is built and either:

1. connects one or more efficient gas appliances to the gas network, with or without some number of efficient electric appliances. In this case, the use of any one appliance avoids the capital expense of another, hence the up-front cost impact on the consumer will be the difference in capital cost between the two appliances; or
2. installs efficient electric appliance/s and does not connect to the gas network. Under this option, the consumer also avoids any ongoing fixed supply charge.