CRC-P Integrated Smart Home Energy Management Technologies

Smart Home Energy Management Systems User Needs Report

FINAL REPORT
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EXECUTIVE SUMMARY

This report summarises the results and insights drawn from online surveys of Solar Analytics (SolA) customers and other energy consumers and prosumers with an interest in Smart Home Energy Management Systems (SHEMS), as well as in-depth, semi-structured interviews with 24 of the participants. The parent populations are not representative of energy consumers, with a strong bias towards highly-engaged solar owners and energy consumers, and the cohort is further self-selected for interest in, and potential early adoption of SHEMS. Nevertheless, a wide range of attitudes, experiences, understanding, motivations and needs is revealed.

Motivations

Although cost reduction is a primary motivator for energy management, motivations are complex and contradictory, with many people conflating financial and environmental drivers. Any strategy for engagement of prosumers with SHEMS should account for these multiple motivations and address environmental concerns and comfort needs together with financial benefits.

Automation

Attitudes to automation vary widely. Some prosumers see compelling benefits to automation, including added convenience, more optimal energy management or inherent value in automation itself. Even the most enthusiastic advocates of automation need the facility to override automated settings in response to changes in household occupancy, schedule or weather, or to deal with malfunction. Automation requires personalisation or training and may be constrained by different lifestyles and preferences of multiple household members.

Others prefer provision of real-time notifications that recommend potential actions for using excess solar generation ('notify and control'), which, for 'working-away' households, must be combined with the ability to control devices remotely. 'Notify and control' allows for greater complexity or irregularity of lifestyle and for user input to help facilitate intelligent decision-making. Both notifications and automation decisions must be evidence-based and linked to concrete benefits; information that conflicts with household realities or experience undermines trust.

These automation preferences do not correlate with daytime occupancy levels or with energy management requirements but seem to be related to more general attitudes to technology. However, the lifestyles of 'working-away' and 'stay-home' households have different constraints which require different approaches to home energy management.

Monitoring and load shifting

Solar Analytics is used for load monitoring as much as for solar monitoring; many SA customers use the app to help them manage their energy. Most commonly, solar owners shift appliance loads (mainly washing machines, dishwashers and pumps) to the daytime to maximise solar self-consumption, although 'working-away' households may focus on demand reduction as easier to achieve than load-shifting. Monitoring of separate load circuits is highly desired but is not provided by many of the monitoring and HEMS systems used by participants.

Despite describing cost-saving as a primary motivation, prosumers rarely quantify the energy or financial benefits of their demand reduction and load-shifting behaviours, and many would welcome accurate assessment of the savings due to specific behaviours.

For some households, energy services are non-negotiable, for reasons of health, comfort, lifestyle or convenience, which may preclude manual as well as automatic load shifting or demand reduction.

Appliances

In 'stay-at-home' households, appliance load-shifting is achieved manually, based on real-time information from the SolA dashboard or inverter, or from seeing that the sun is shining; in 'working-away' households, in-built appliance timers are more commonly used. Both remote control and automation of appliances face significant technical challenges to improving on manual operation or

built-in timers. These include the need for intelligent device communication (beyond power switching) and that minimum programme times could result in increased daytime import if appliances are switched on to use excess generation without accounting for future generation.

Around half of SolA users surveyed would like to control appliances from their dashboard or app, either directly or through automation to increase self-consumption. However, an additional barrier to automated or remote operation of appliances is the need for user input (pre-loading of washing machine, etc.). Effective load-shifting of appliances, whether automated or manual, may therefore require behaviour change from multiple household members; hence education is part of the role of SHEMS.

Although 'stay-at-home' households might have more flexibility around when appliances are used, their energy service or appliance needs may be constrained by personal preferences, including non-negotiable daytime comfort and convenience. They may therefore require greater flexibility and user-interaction in HEMS control. They are able to act on intelligent notifications to control a wider range of appliances, beyond those with remote programme control.

Conversely, the needs of working families are constrained by more regular schedules, so are better suited to automated time control of devices through built-in timers than manual control, while response to notifications about excess generation, whether manual or automated, requires direct programme control of appliances.

Hot water

Although there is interest in using hot water to increase self-consumption, gas and solar hot water preclude hot-water load shifting for many consumers (and perhaps for a greater proportion of solar owners?). Some users are unclear about their tariff arrangements or even whether they have controlled load and may see hot-water demand as beyond the scope of their energy management. Where controlled load tariff (including additional fixed charges) is less than feed-in tariff, there is no economic case for switching to general load and load shifting hot-water. However, a minority of users would accept occasional lack of hot water if they could see clear economic benefit to load-shifting, so any economic case for optimisation compared to a 'dumb' timer needs to be compelling. Of course, shower times and duration are the main driver of hot water needs, rather than daytime occupancy.

Air-conditioning and heating

Although many prosumers are interested in the potential for pre-heating and cooling, participant experience suggests that poor building insulation and thermal efficiency makes it ineffective for many households. Automation or remote operation of air-conditioning also requires user input (close windows, e.g.) or extensive household automation, and may therefore need education of multiple household members.

For 'stay-at-home' households, summer daytime air-conditioning use is more likely to be driven by daytime temperatures than by evening temperatures, with any pre-cooling effect a bonus, while pre-heating faces the additional challenge of lower winter solar generation.

Pool pumps

Pool pumps present an opportunity for load shifting without complex control, using existing timers, but may be subject to other constraints.

User needs and concerns

The most important feature of a SHEMS is reliability, particularly of control functionality. Demonstrated reliability can help engender wider trust in the platform or provider, while analysis or advice that conflicts with users' experience undermines trust.

Clear, effective and simple communication of information, recommended behaviour and potential savings is important to users, particularly in encouraging behaviour change for multiple occupants.

Apart from very committed early-adopters, consumers are cautious about the cost of SHEMS and seek justification from anticipated (and evidenced) savings (ROI) as well as from the value of convenience, automation itself, data visibility, or environmental benefit. The median suggested cost for a fully functional SHEMS with multiple device control was $200 a year.

Other than cost, users' primary concerns about Smart HEMS relate to security, data misuse and malfunction. Security concerns are widespread but may be allayed by using trusted technology and / or a trusted supplier.

Diverse user interpretations of the term "Smart" include automation, supplying information, personalisation and optimisation. For some, the term has lost meaning through overuse and may undermine trust.

Attitudes affecting demand response

Although a large proportion of participants are motivated, in part, by considerations of community benefit, attitudes to individual vs shared responsibility, self-interest vs community benefit, compensation, equity and independence are diverse and largely defy simple segmentation, within the constraints of this study.

Although there is some general awareness of network issues of high solar penetration, solar owners don't see them as a negative consequence of solar installation. Most see the major impact of their exported generation as a social or community good, while some see solar deployment as a focus for community building.

While some of this atypical cohort of solar owners feel shared responsibility for the grid as a community resource, others believe 'energy companies' and government should meet the cost of grid adaptation to high PV penetration**.** There is wide, but not universal, acceptance of the need for regulation of household interaction with the grid to ensure wider community benefit. A minority reject the idea of shared responsibility, believe that DNSPs and government should meet the cost of grid adaptation, and see any constraints on their export or control of their load for community benefit to be unacceptable overreach.

Fairness and equity are highly valued.

Community use of household assets is acceptable to many in principle but sharing of benefits must be reasonable and fair, and owners should not be disadvantaged. To engender the trust required for participation, PV installation constraints, export limits, or load curtailment need to be applied fairly across geographic and social boundaries. For a minority, fairness itself precludes the need for compensation, but the majority see a need to compensate asset owners for loss of control, lost revenue or reduced comfort, or simply in exchange for use of the asset.

Most consumers need to retain an absolute ability to opt out of any DR agreement, and see the need for exceptions for households with health or other constraints while, for a minority, equity and opt-out can be included in negotiations for suitably structured compensation.

Widespread distrust of energy companies (without distinction between retailers and DNSPs) reduces consumer willingness to accept reduced control, comfort or convenience for community benefit and undermines consumer confidence that any compensation would be administered fairly or equitably. In order to engender trust and engagement in demand response, there is a need for public education about the community benefits and for transparency around the distribution of benefits. This trust deficit may necessitate a role for government in regulating to ensure equity and transparency of resource use and compensation, or in incentivising consumers to take shared responsibility, although there is a lack of faith in government's ability to lead.

BACKGROUND

Project & Partners

This research was carried out as part of the **CRC-P Smart Home Energy Management Technologies** project led by Solar Analytics (SolA) in partnership with UNSW Sydney, Ergon Energy, SA Power networks, Wattwatchers and Apricus. The project is funded and funded by a Cooperative Research Centres Project Grant from the Australian Government.

The research was carried out by Dr Mike Roberts from the Collaboration on Energy and Environmental Markets (CEEM) at UNSW Sydney in association with Sophie Ellis and Amanda Palmas from Kickstand.

1 RESEARCH OBJECTIVES AND METHOD

1.1 Research objectives

1) To understand prosumer attitudes, motivations and needs in relation to energy management and HEMS.
2) To help identify where Solar Analytics (SolA) can provide unique value in Smart Home Energy Management systems (SHEMS) and priorities for further development.
3) To understand prosumer attitudes to the use of behind the meter DERs to provide demand response or other network benefits.

1.2 Research Questions

- How do energy-engaged electricity prosumers manage their energy use?
- What loads can be shifted and what are the practical constraints?
- What level of information, control and automation do energy-engaged electricity prosumers want from SHEMS?
- What concerns do people have about SHEMS and automation, and how can they be addressed?
- What will motivate prosumers to purchase SHEMS?
- What can incentivise prosumers to allow their DERs to be used to provide network benefits?

1.3 Method

This report draws together findings from two online surveys and a series of semi-structured in-depth interviews.

Two versions of an online survey were produced, aimed at two distinct cohorts:

a) Solar Analytics customers:

- ~10,000 SolA customers were invited through Monthly Report emails and SolA social media.
- Completed responses (completion rates): email 117 (53%), social media 5 (16%)
- 122 completed responses, 2 were eliminated – 1 SolA staff member, 1 not a SolA user

b) Existing SHEMS users:

- Invited through whirlpool “Green tech” forum, Facebook “My smart electric home” page, LinkedIn.
- Responses (completion rates): Whirlpool 31 (49%), LinkedIn 6 (43%), Facebook 4 (36%)
- 41 completed responses

The survey questions were reviewed and revised after feedback from Kickstand and road-testing by SolA staff. A $200 prize draw was offered to incentivise participation.

Initial findings from the survey were presented to a workshop facilitated by Kickstand (Sophie Ellis and Amanda Palmas) and attended by CRC-P research team, SolA staff and Dr Declan Kuch, UNSW. The workshop generated potential questions for further enquiry which were compiled by Kickstand to create a draft script for in-depth interviews. The script was further refined throughout the interview process.

Participants were selected for interview to achieve a balance across the five segments outlined below. 24 in-depth interviews were carried out. They were approximately 1-hour long, conducted by phone. The interviews were semi-structured; although based on the prepared script, they diverged to varying degrees following topics of interest to the participants. Interviews were recorded and transcribed.

2 PARTICIPANTS, MOTIVATIONS AND SEGMENTATION

2.1 Engagement and understanding

SolA customers are *not* early adopters of solar – almost all have installed solar between 2017 and 2019 in the world's most established residential solar market. However, in choosing to install monitoring, they are some of the most highly energy-engaged Australian prosumers. Moreover, survey participants are self-selecting and therefore the cohort is strongly skewed towards people with a strong interest in energy management and SHEMS

Participants in the "HEMS User survey" are similarly self-selecting through their engagement with specific web and social media pages and through their choice to respond to the survey. Most of these participants are, in fact, *not* SHEMS users, but have various levels of load monitoring and appliance control. A few have DIY HEMS systems.

Although participants are far more engaged in energy than typical electricity consumers or prosumers, being either the most engaged of SolA customers or electricity consumers with a particular interest in HEMS, their range of energy understanding is broad. At the two extremes, one interviewee has a sophisticated critique of his inverter's response to voltage disturbance, while another struggled to understand why she couldn't use her solar generation after sunset. When talking about their demand reduction or load shifting, *almost all* the interviewees confused energy (kWh) and power (kW) at some point in the conversation and only two showed a clear understanding of the distinction between retailers and network operators. The lack of understanding found even amongst this cohort has implications for communicating complex information around load shifting and demand management.

The interviews explored motivations for installing solar, for installing (or, more often for not installing) a battery, and for energy management.

Although interviewees were initially segmented according to their motivations for energy management indicated in their survey responses (i.e. whether they attached high importance to reducing carbon emissions or improving home comfort as well as or instead of reducing their energy costs), the interviews revealed more complex and sometimes contradictory motivations.

2.2 Solar Motivations

Reducing high electricity bills is the primary motivator for installing solar. Solar owners have a high level of awareness that solar will repay capital costs in a few years (reinforced by state subsidies). However, some (particularly for retirees) also value the use of capital to reduce ongoing living costs and minimise uncertainty in the face of unpredictable future energy costs.

For many, environmental concerns are an important driver for installing solar, but these are combined with financial benefits in different ways: for some, bill savings are the primary driver with emissions reduction as a "nice to have"; for others, environmental reasons are paramount but facilitated by low cost or fast payback; they want to "do the right thing" but the finances need to stack up.

> *Well, I think it it's about numerous factors. it's always about the money. I think that you've gotta be a little bit mercenary. It's all very well to have a kind of idealistic principles. At the end of the day, you've got to pay money out to live. …. I think that the planet's the planet and if it needs the benefit of doubt, it should get it. So, I think that the more things I can do to reduce my footprint and if everybody followed step and then I think that maybe the place would be a much safer place…. And I think that there's a responsibility to make sure that if you can do things better by a bit, and a lot of bits make a good thing. (i19)*

For others, the two motivations are equally significant.

> *Obviously, I am an eco-person, I want to be taking care of the environment but also it should make economical sense, financial sense. Both are equally important. (i18)*

As the environmental and financial benefits of solar are well aligned, this motivational distinction may be moot; for many, the opposition of environmental and financial drivers is a false one. In interviews, some discussed environmental and financial savings interchangeably conflating the two or treating one as a proxy for the other, an attitude expressed explicitly by one participant:

> *Of course, we all want to save money in terms of electricity cost but to me, that's more of a parameter to measure how effectively I'm using energy or being environmentally friendly (i22)*

Other drivers, often discussed as "nice to have" in combination with financial benefits, include independence (either generally or specifically from energy companies), increased comfort, and marketing benefits for rental properties.

2.3 Motivations for energy management

Unsurprisingly, when asked about managing their energy use, bills savings was the most important driver. On a scale of zero (not important at all) to 5 (very important), 85% of SA customers surveyed rated the importance of reducing electricity bills as 4 or 5 (from 5), with a mean rating of 4.4. compared to 4.1 for ensuring home comfort and 3.8 for reducing carbon footprint. (See Figure 1).

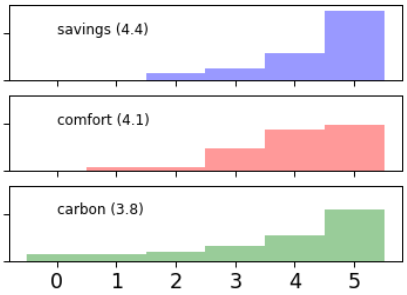


Figure 1 SolA Users' motivations for energy management

However, 45% of respondents rated 2 or more reasons as "very important". Analysis of these combined priorities reveals greater complexity: customers who rated bill savings as 5 (very important) also rated comfort as 4.3, on average, and carbon reductions as 3.8, while customers who rated carbon reduction as 5 also rated bill savings as 4.5 on average.

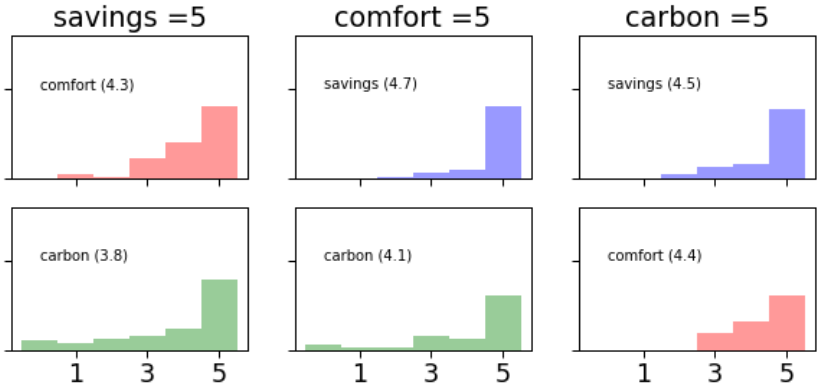


Figure 2 SolA users' combined motivations for energy management

An initial segmentation was applied to the participants based on these responses, and candidates were selected for interview to include a spread of motivations across all segments. With the addition of a group of battery owners, this generated 5 initial segments according to which priority or priorities they rated 5 (Very Important).

A: Battery owners.
B: Prioritise comfort or cost and comfort.
C: Prioritise reducing carbon footprint or cost and reducing carbon footprint.
D: Prioritise cost.
E: Prioritise cost, comfort and reducing carbon footprint,
or reducing carbon footprint and comfort.

However, the in-depth interviews further reinforced the finding that, as when installing solar, **customers' management of their energy use is driven by multiple and combined motivations.** Discussions revealed numerous examples of apparently contradictory or conflated motivations for managing energy use: For example,

- None of the 5 interviewees who rated 'Comfort' as a primary driver in the survey identified comfort as an important motivation during the interview, while they all identified cost reduction as their primary motivator and all but one discussed the importance of environmental benefits.
- One of the interviewees in the 'Cost' segment discussed environmental benefits as his primary motivator to the exclusion of all others.
- The interviewees identifying environmental benefits as the primary motivator for installing solar were distributed across all segments

2.4 Batteries

Solar Analytics users are attracted to the idea of batteries for reasons of energy independence and security or as a 'next logical step' after installing solar. However, only 10 of 120 SolA users who responded to the survey have a battery installed, along with 6 of the 40 of non-SolA users who responded to the 'HEMS User 'survey. Moreover, most of the surveyed SolA users are fairly unlikely to purchase a battery in the next 2 years.

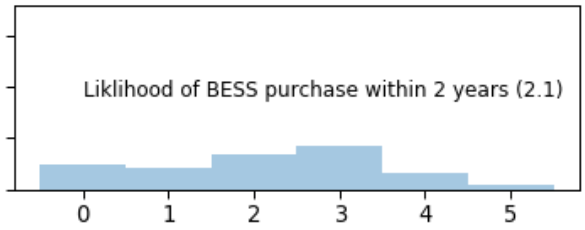


Figure 3 Likelihood of BESS purchase within 2 years (SolA user survey)

SolA users' understanding that home batteries are unlikely to create financial benefits for many householders is based on installer advice and / or media reports, and may be backed up by their own analysis (sometimes based on SolA data). Various estimated battery payback periods were quoted:

"More than 5 years", "10 years or longer", "16 years", "20 years", "67 years"
or *" very, very long"*

Some prosumers see environmental or independence benefits to batteries, but cannot see financial justification for the purchase. The complex relationship between financial and environmental justifications (described above) is exemplified by the users who installed solar for overwhelmingly environmental reasons but give cost as the main barrier to buying a battery. However, there is also quite widespread questioning of the environmental benefits of batteries, in terms of lifecycle energy and impacts of mining and disposal. So, although many SolA users' solar purchase was justified by aligned financial *and* environmental factors, they see no compelling case for batteries on *either* basis.

The complexity of users' decision making for solar, batteries and energy management renders the initial motivational segmentation described above less useful than initially supposed. Nevertheless, and **despite cost reduction being a primary motivator for most people, any strategy for engagement of**

prosumers should account for multiple motivations and address environmental concerns and comfort needs together with financial benefits.

2.5 Segmentation

This non-representative cohort contained a disproportionate number of households with someone at home during the daytime, particularly retirees but also including families with pre-school children, home workers and carers. The interviews revealed strong differences in user needs between households with daytime occupancy and those without.

Both the survey and interviews explored participants' preferences for their ideal degree of automation of energy devices. For the surveys, theses were characterised on a scale from complete "hands on control" (0) to full "set and forget" automation (5). Responses showed a wide range of consumer preferences (Figure 4) with a median value of 4.

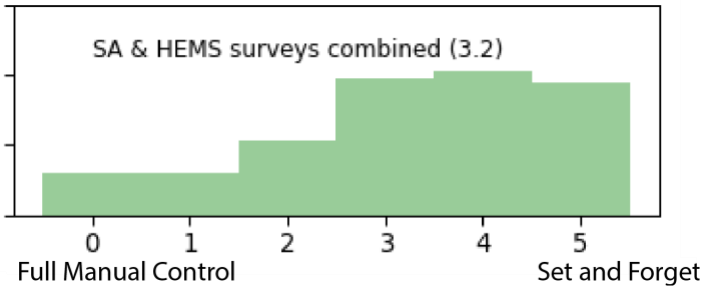


Figure 4 Automation preferences

In the interviews, however, although a few people showed a level of ambivalence, most participants showed a strong preference either for maximising automatic control, or for being given clear information and advice and the facility to control their own devices. These preferences have been characterised by 'hands-on' and 'set-and-forget' segments.

Users' automation preferences do not show any correlation with daytime occupancy levels. They appear to be a very specific preference, related to more general attitudes to technology, which strongly influences a user's needs from SHEMS.

Findings from the interviews suggest that segmentation by household occupancy and automation preferences could usefully aid understanding of users' needs. The interviewees were therefore allocated to 4 segments according to these parameters:

- 'at-home' households preferencing hands-on control (8 interviewees)
- 'at-home' households preferencing automation (8 interviewees)
- 'working-away' households preferencing hands-on control (4 interviewees)
- 'working-away' households preferencing automation (4 interviewees)

Figure 5 illustrates these 4 segments.

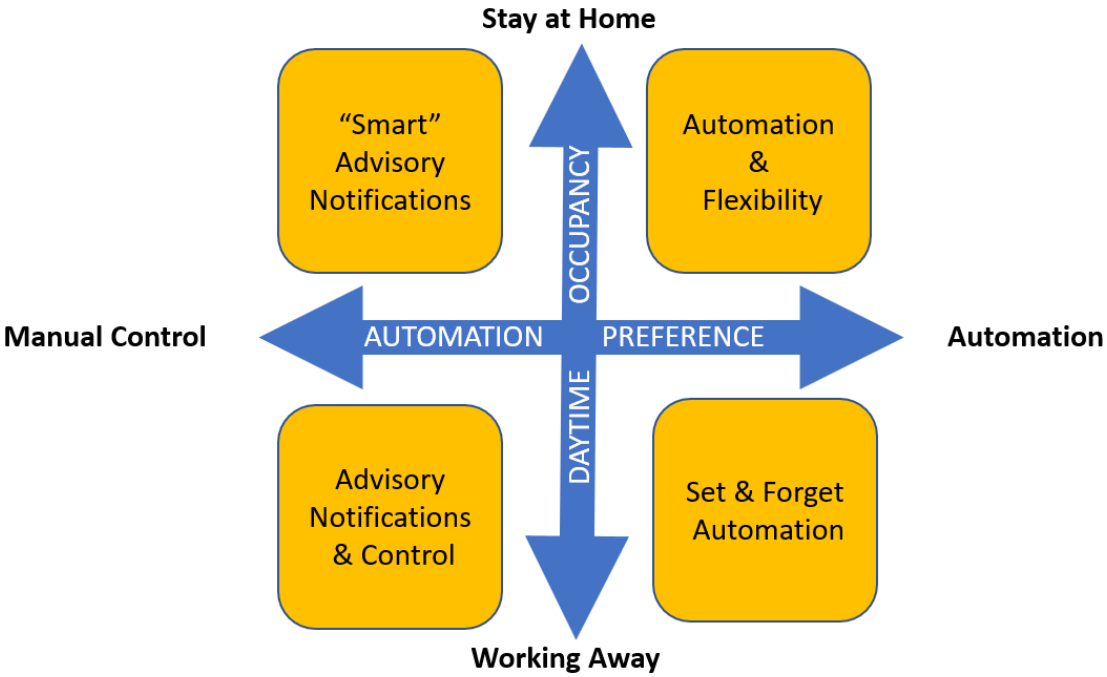


Figure 5 Segmentation of user needs by household occupancy and automation preferences

3 EXISTING LOAD-SHIFTING BEHAVIOUR

In order to understand users' needs from SHEMS, it is useful to first understand their existing energy management behaviours.

97% of Solar Analytics users surveyed said that the SolA dashboard does what they want it to do. When asked why, 61% described monitoring solar generation or system status, while 57% described load monitoring, suggesting that **SolA is used for load monitoring as much as for solar monitoring.**

When asked directly, 85% of the surveyed SolA users said that SolA helps them to manage their energy use, and, of these,

- 48% described using the dashboard to determine the best times to run appliances in order to maximise solar self-consumption or minimise grid import
- Only 4% described reducing their energy demand

Figure 6 shows the devices identified by respondents who mentioned shifting specific loads.

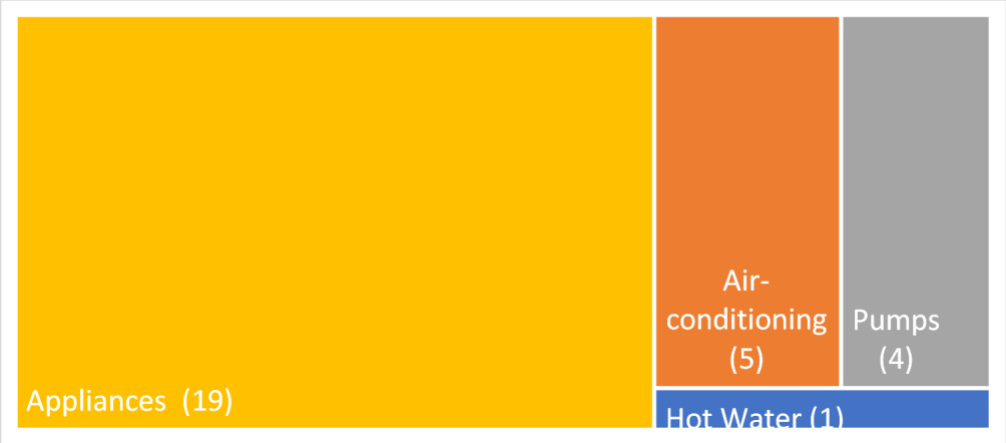


Figure 6 Load shifting by interviewees

3.1 Appliances[1]

The most common existing load-shifting behaviour is shifting appliance use to daytime, most often washing machines and dishwashers

For 'stay-at-homes', this is commonly achieved through manual operation of appliances, either responding to excess solar generation shown by the SolA app or dashboard or, more often, responding directly to the weather or the time of day.

'Working away' households either use built-in appliance timers or concentrate their appliance use at weekends when they use similar strategies to the 'stay-at-homes'.

There is awareness that clothes-drying is an energy-intensive activity and some interviewees restrict their dryer to daytime use. However, some energy-conscious consumers see dryer use as non-essential and may prioritise demand-reduction above load-shifting, therefore avoiding dryer use as far as possible. As times of excess solar production (except for from large systems) are likely to coincide with favourable conditions for air-drying, self-consumption of solar generation for clothes drying is less common.

[1] In common with the language used by many of the interviewees, the term "appliances" is used here to describe whitegoods and small pluggable appliances (washing machines, fridges, dishwashers, dryers, etc.). The term "devices" is used for a wider group of electrical loads that includes hot water, air-con, etc. In the survey, 9 people specifically mentioned washing machine, dryer or dishwasher, while 19 mentioned appliances.

If we have to use the dryer. It's probably raining, so it's probably not generating much anyway. (i01)

Conversely, for 'working-away' households, daytime clothes washing may be inappropriate as it would mean coming home to wet clothes, necessitating evening use of the dryer, while overnight washing means clothes can be air-dried during the day.

'Working-away' households may focus on demand reduction as easier to achieve than load-shifting, if they do not have access to automation or remote control.

We turn off pretty much everything, so our power consumption throughout the day is very, very minimal. Basically, everything that we generate gets fed back into the grid, and then we come home and then we use power in the evening. We try and be fairly frugal with that usage. (i22)

Other small loads that are shifted to daytime include slow cookers, ironing, battery-charging for power tools or motorbike.

Of course, the distinction between 'stay-at-home' and 'working-away' households, is an oversimplification, with different household members having disparate schedules. Several of the interviewees talked about educating other household members, including children and tenants, to shift loads, particularly clothes and dish-washing.

Some responses also highlighted the gender bias of the cohort (only 5/24 women). In some households, one technophile (male) occupant is engaged with energy and SHEMS technology while appliances are largely operated by the female household member(s).

We try to use the dishwasher after the sun comes up in the day, and the washing machine the same. We try and use that in the peak of the day, when the solar's working. My wife is aware of that. (i19)

We asked the au pair and I've asked my wife to please use the washing machine,… dishwasher and the dryer…during the day. (i05)

Appliance management involves multiple occupants, with different attitudes and motivations.

This has wider implications for ongoing research – highlighting the necessity of engaging *all* household members – and for SHEMS development – showing the importance of allowing for a range of communications and automations preferences.

3.2 Hot Water

Insights relating to hot water are limited because, of the 24 interviewees, 9 have gas HW, 6 have evacuated tube solar hot water (SHW) (2 gas boosted, 4 with electric), and 4 have HW on a controlled load. It is possible that there is a higher incidence of SHW amongst households installing PV compared to the general population.

Of the five households with general load electric HW, two have Catchpower diverters, one has HW timed to use solar generation, and two don't load-shift their hot-water load, seeing hot water as outside their control.

Hot water may be an 'invisible' load or not considered for energy management by some.

[I can] see when the hot water comes on and I can't do very much to alter [that]. (i07)

Even amongst this highly energy-engaged cohort, some people are unsure whether they have a controlled load for their hot water, or what type of tariff they have.

Supplying hot water from controlled load is often better value than self-consuming PV although it is important to account for the additional daily fee charged by some retailers for controlled load.

Hot water is on a controlled load circuit…Having run the numbers on that, the tariff for the controlled load is significantly less than our feed-in tariff [on all the flat and time of use tariffs]. (i12)

One of the users with *Catchpower* diversion found it underperformed on his three-phase system, only diverting a portion of excess generation, while the other was satisfied with the performance, but had needed to manually adjust the choice of location used for weather forecasting.

Some customers would accept occasional loss of hot water for the benefits of self-consumption

In my situation all the heating could be done during sunlight hours… So the risk of occasionally ending up with cold water would be a risk that I'd accept in order to save money overall. (i07)

…but the reality is that, if the hot water runs out, it's more likely because of the size of the tank than it will be because of an algorithm. So, I don't think that would faze me. Provided that there are benefits to having it, it really is saving a decent chunk of cash, then yeah, I'm happy to live with the occasional screw up. (i12)

Lack of info on existing H/W load-shifting does not preclude there being a strong opportunity here.

3.3 Air-conditioning

Many of the customers interviewed are familiar with the concept of pre-heating and pre-cooling to increase self-consumption of solar generation. Some 'stay-at-homes' profess to have successfully implemented pre-heating, but these households are benefiting directly from the increased daytime comfort as well as from any reduced evening demand, which diverges from the usual meaning of pre-heating. Similarly, because daytime temperatures are typically higher than evening, for 'stay-at-home' households, summer daytime air-conditioning use is more likely to be driven by daytime than by evening temperatures.

Either it's hot during the day and requires cooling or at night it might be a bit warm but it's not uncomfortably hot that you couldn't sleep just by having the window open. (i21)

Poor thermal efficiency precludes effective pre-heating and pre-cooling for many households.

I get maybe half an hour worth of benefit because it gets cold again once you turn it off pretty quick…I think to do that effectively and save a lot of money, you need quite a well-insulated house and a lot of houses aren't that brilliantly insulated. (i20)

For some, pre-heating is less effective than pre-cooling, either because of the thermal constraints of the building, or because of insufficient excess generation in winter, particularly on days with the highest heating needs. Personal preferences for ventilation or interior design can also preclude effective pre-heating or cooling strategies.

While for many consumers, the thermal constraints of their houses are non-negotiable barriers to pre-heating and cooling, others consider the opportunity for pre-heating or cooling to be an incentive for upgrading insulation.

Though much less significant than thermal building performance, solar system orientation may also impact the effectiveness of pre-heating or cooling; houses with west-facing PV systems have a shorter thermal decay period between PV generation and evening air conditioning requirement.

Given the slow pace of change of Australian building regulation and that new residential buildings rarely exceed mandated requirements for thermal performance[2], the thermal efficiency of buildings is

[2] Moore, T., S. Berry and M. Ambrose, *Aiming for mediocrity: The case of australian housing thermal performance.* Energy Policy, 2019. **132**: p. 602-610.

unlikely to improve at a sufficient rate to make widespread pre-heating and cooling viable in the near future.

> *This is a brand-new house. It's literally only a year old…And it doesn't have double glazing... In 2019, when there's so much climate change, everyone's talking about the environment, and yet still, the building code doesn't stipulate that you need to have double glazing. It's ridiculous. (i22)*

3.4 Pool pumps

There are an estimated 800,000 pool pumps in Australia (approximately 1 in 8 detached houses). Pool pumps are typically operated on 'dumb' timers for 6-8 hours a day. Some prosumers set timers to maximise solar self-consumption. **Pool pumps present an opportunity for load shifting without complex control, using existing timers.** However, there may be other constraints on operation times for pool pumps, including noise nuisance and interaction of sunlight with chlorine.

3.5 EVs

Only one interviewee has an EV, but there is awareness amongst more engaged early-adopter prosumers that widespread EV use will have significant impact on home energy total demand and daily profile, with implications for Smart HEMS requirements. In particular SHEMS will need to adapt to variable driving schedules and to EV's having non-negotiable minimum charge levels.

3.6 Financial benefits of load-shifting

Many of these energy-aware interviewees reduce demand "as much as possible", without quantifying energy or cost savings.

> *The more you use, the more you've got to pay. It's always at the back of our mind that if we can turn a switch off, we'll turn a switch off.*

Similarly, although a few of the interviewees were able to quantify the energy and/or cost savings from load-shifting individual devices, most were not. Decisions to load-shift appliances are often made on a "reasonably practicable" basis: if it's easy to shift a load to daytime then shift it. Despite the importance of cost savings, both in "big" financial decisions (buying solar or battery) and in motivations for managing energy demand, most prosumers either lack the knowledge or the time, or are disinclined, to quantify the savings they are making through load-shifting.

Despite cost-saving being a significant motivator, consumers rarely quantify the energy or financial benefits of their demand reduction and load-shifting behaviours.

4 ATTITUDES TO SMART HEMS

4.1 Desired information

Real-time monitoring of separate circuits is highly desired by SolA users, as is real-time information to tell them which appliances could be run from excess solar generation, and the potential savings from load-shifting or turning off specific appliances. (see Figure 7)

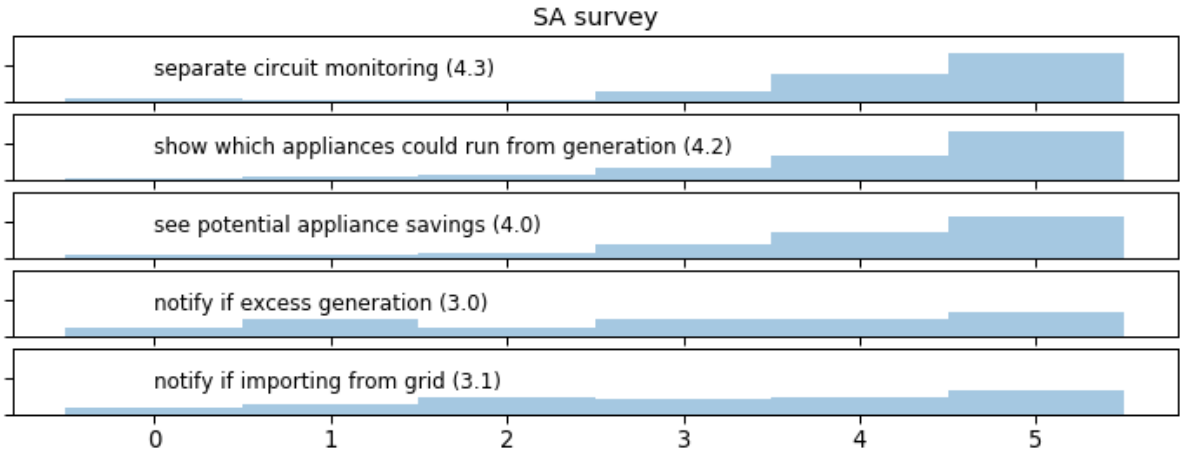


Figure 7 SolA users: how useful are real-time data and notifications?

4.2 Desired device control

Air-con and heating are the devices consumers most want HEMS to have control over (see Figure 8), likely because this is widely understood to be a major driver of demand and grid import. Around half of SA users would like to control appliances from their dashboard (either directly or through automation), perhaps a reflection of the loads they are already shifting manually. The desire for hot-water control is lower, in part due to the incidence of gas and solar hot-water, but this may also reflect the lower visibility of hot-water as a manageable load.

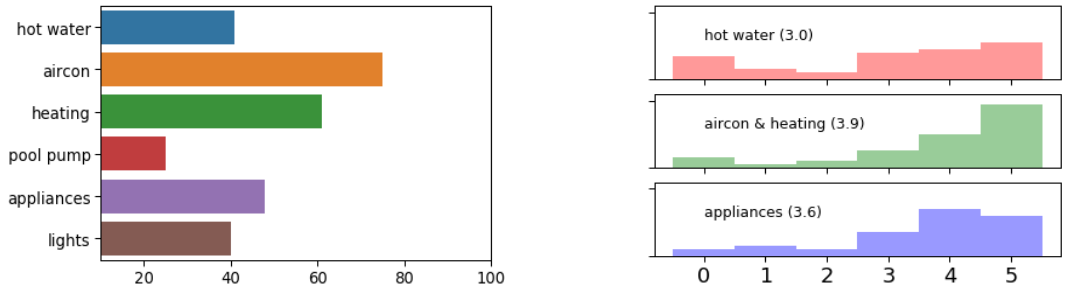


Figure 8 Desired device control: (l) Percentage of SolA users desiring device control, (r) HEMS survey – importance of device control

4.3 Automation preferences

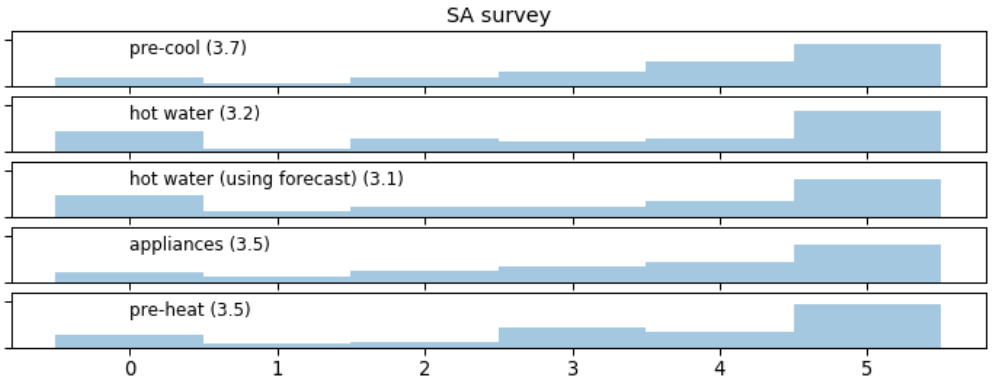


Figure 9 SolA Users: How useful is automation from 0 (full manual control) to 5 (set and forget)

4.3.1 Pro-automation

Figure 9 shows the range of SolA users' perceptions of the usefulness of automating various devices to maximise self-consumption. Although pre-heating and pre-cooling is valued, participants experiences suggest they are not viable for many households (see section 3.3).

Around half of the interviewees are *very* enthusiastic about technology in general, while some have developed some form of DIY HEMS. The majority of this group preference automation, seeing **the key benefits of automation as convenience and more optimal management of their energy use** than is achievable manually, as well as perceiving inherent value in automation itself. Indeed, they may justify their automation preferences in terms of beliefs or cultural values, as much as energy needs.

Automation is much more useful than interactivity. (i08)

'Cause I love the technology of the future. (i04)

I think anything that's controlled gives a better outcome…the less I've got to do, the better everything's got to be. (i07)

This segment typically values forecasting capabilities and machine learning to maximise the potential for optimisation of energy use.

To have a system that would automatically control the supply of energy to heat the water on the basis of actual solar production, considering weather patterns and forecast to make sure you don't run out and all that sort of thing. That's a fine ideal. Whether it can be done in a manner that is cost-effective, well, that's a different question. (i12)

The strongly technophile cohort who have experimented with DIY HEMS give insight into desirable features missing from some existing HEMS and monitoring systems, including:

- Individual circuit monitoring
- Calculation of potential financial savings from switching off or load-shifting devices.
- Real-time load and solar data accessible via an api
- Integration with Google Home, Alexa or similar
- Recommended behaviours based on forecast generation and consumption
- In-tank temperature monitoring as an input to hot-water control optimisation

4.3.2 Anti-automation

A minority of 'hands-on' users are simply resistant to automation, either because they are "too old" or because they lack trust in the technology or the organisations developing or controlling it.

Everything we do, we turn on and off ourselves. we've got Foxtel and we have a Foxtel app where you can go online and turn on a program to be recorded. And we've never done that, even though it's there. We are a bit old school, I guess. (i03)

I'm thinking, "No, that's Big Brother." I'm not into private enterprise or government controlling my life too much. (i23)

A minority of the highly technophile group also prefers to keep control themselves, less from distrust of algorithms than a desire to more fully understand their energy management.

I guess I like having the manual control myself so that I can have a really good understanding of where our energy is going and automating it might reduce that kind of level of awareness somewhat… (i02)

Others see a trade-off between simplicity and optimum performance, and question whether the potential additional savings from complex algorithms incorporating forecasting justify the complexity (and potential additional cost).

[Automation based on weather forecasting] is picking up peas in front of a steamroller type stuff. Some things aren't worth doing I don't reckon. No. I just cannot see the net benefit. I might eventually one day, but I just see it as a percentage, it's not worth it. (i11)

4.3.3 Daytime schedules

Appliance use and energy service needs can be affected by family needs or irregular lifestyle,

Let's face it, it might not work every day because every day is different. (i19)

I don't think we're that routine about anything. (i21)

We're at the stage of our life where no two days are the same. (i19)

As discussed above, preference for automation or control is not aligned with daytime occupancy. However, **the different lifestyles of 'working-away' and 'stay-home' households have different constraints which may require different approaches to home energy automation.**

Although 'stay-at-homes' might have more flexibility around when appliances are used, their energy service or appliance needs may be constrained by personal preferences, including non-negotiable daytime comfort and convenience needs. They may therefore require greater flexibility and user-interaction in HEMS control.

It's all good in theory to say when the sun's out do it. But again, it's not always practical… I'm not in the mood… I'll do it when I feel well enough to go and do it. (i20)

I tend to do it when it's more convenient for me … if there's no need to put it on, there's no need. I'd do it when I'm ready to do it. (i13)

Conversely, **the needs of working families are constrained by their more regular schedules, so are perhaps better suited to automated time control of devices.**

4.3.4 'Notify-and-control'

Amongst 'hands-on' consumers, **there is strong interest in receiving notifications and recommendations for potential actions to use excess solar generation**. For 'stay-at-home' households, notifications can save time spent looking at the SA dashboard or the weather to identify times of excess generation or identify load-shifting opportunities that might otherwise be missed.

If you could get some sort of alert or even a noise on your monitor or something that says, "Hey, you guys, you got heaps of solar going right this second, why don't you use it?"

That'd be brilliant… I'm at peak generation, I'm not using any and I'm not going to send it back to the grid so, "Hey, do you want to put the dishwasher on now?" That'd be awesome. Or just an alert that said you've got excess at the moment, this is the time to put the dryer on, that would be brilliant. That would be absolutely brilliant. (i20)

They'll be plenty of circumstances where I miss situations when I could do something. Because I'm busy or thinking about other things. So yeah, I would say suggestions in the form of a notification that you can very easily dismiss or act on would be a good way to do it. (i02)

Interest in notifications is not limited to 'stay-home' households, but **for 'working-away' households, they must be combined with the ability to control devices from outside the home to be useful.** For some, this satisfies comfort and security needs as well as controlling energy use.

But the remote-control aspect is critical, [so] I can control everything remotely. (i16)

Even for some "set-and-forget" users, a remote-control option is also desirable.

So if we're going out, we could set a timer on our air conditioner to kick off at any given time, but we don't know when we're going to be home. So if we have a remote control device that we can say, "Okay, I know that I'm hitting home in an hour, I'm hitting home now and I'll be home in an hour." (i22)

The most common reasons given for a preference for notification and control over automation relate to education (and behaviour modification) or the **complexity of lifestyle or household circumstances that require user input to facilitate intelligent decision-making**.

That direct feedback, I think is important because it can modify behaviour, very painless and very low impact. That's what I'm after. (i16)

Unless Solar Analytics knows how full my appliances are, I probably don't necessarily want it to, turn it on automatically (i02)

Advisory notifications should be evidence-based and linked to concrete benefits.

Like maybe "if you put your air-con up by two degrees, you could save this much power or this much money over the course of the month." (i09)

Notifications that conflict with consumers' experience or knowledge are unhelpful and undermine trust[3].

I'm not sure I believe this, but Solar Analytics in emails has said, "you could save energy by heating your house or cooling your house during the day, so you don't need to run your appliance at night." Now I don't have enough faith in the insulation to have actually done that. (i03)

But you [need] the ability to override this kind of stuff and not be annoying. [Don't] tell me that I should turn off my heating in the middle of winter. (i05)

I keep getting this cranky message from Solar Analytics. Like, John, you've been very naughty by using an air conditioner at night. I understand that, but it's really bloody hot. (i04)

[3] SolA customer notifications have been considerably updated and improved since these interviews

4.4 Limitations and barriers

4.4.1 Need for override

Most consumers, **even the most enthusiastic advocates of automation, need the facility to override automated settings**.

> *I would want to be able to override it, whenever I saw fit…The idea would be we just wouldn't then have to worry about it for the most part [but] there will always be exceptions to the rule and you would need an ability to cater for those exceptions. (i14)*

The most common need for an override is because of changes to occupancy – visitors increasing requirements for hot-water or temperature control, or holidays leaving the house empty.

Some see changes to the weather as a trigger to alter automation settings, even if weather data was included in the automation algorithm, presumably because they distrust temperature or weather forecasting. The override feature on Catchpower's hot water diverter is an example of user intervention needed in colder weather.

> *In summertime…I wouldn't worry about it, I'd just let it do its own thing, but in wintertime where we get perhaps more cloudy days than we might expect, then I would instruct it do a bit more heating than it might just do on its own. (i21)*

Other reasons given for needing to overriding automation include potential failure of the automation algorithm (resulting in, for example, having no hot water).

4.4.2 Need for personalisation

Automation needs personalisation or training to adjust to users' comfort and communication preferences.

> *The relationship with the app would be: "You like this, John" and you'd see a whole range of things occurring where I'm setting temperatures or doing certain things and the memory upload from that to the main base would then form a picture of John - this is what John likes, that's what he likes in his house. I think that would be the process. (i04)*

Although a small minority favour system simplicity above the option for customisation.

> *I think that my preference would be to go to the fully automated system. I can't imagine I have many preferences. I'm sure it would do all the right things anyway. (i07)*

Different lifestyles and preferences of multiple household members can significantly limit the opportunity for automation of energy use.

> *I don't think comfort level takes precedence. I shouldn't actually speak for myself. I'm looking at family and I've got three girls. It does become a little difficult for them. (i10)*

> *I think [the settings] depend on who's in the shower at the time. If it's me, I'll go, "****!" If it's Cath, or worse, her mom, when she's visiting. I'm not going to have the extended conversation to say, "Look, the heating algorithm didn't quite get it right today." (i12)*

> *I've got no problem with [learning to trust the technology to control thermal comfort and appliance use]. Personally, I think that my wife might have more of a problem… at least one of the people using the room [for a home business] would also have trouble with that, but me personally not a problem. I'm willing to have a go with it. (i06)*

4.4.3 Constraints on appliance control and automation

Although the ability to control and automate appliances such as washing machines, dishwashers and dryers is seen to be highly desirable, **there are significant technical challenges to improving on manual operation (for 'stay-at-home' households) or built-in timers (for working-away households)**.

For some appliances, operation using a third-party device (e.g. 'smartplug') to provide power is not possible, as program settings are not retained when external power is removed, and reconnecting power does not automatically commence a programme cycle.

> *When you introduce main power to our washing machine and our dishwasher, they basically just turn on, and they're in their default state. You can't pre-program them and then turn them off (i22)*

Even where third-party control is possible, **an additional barrier to automated operation is the need for user input** as appliances need to be pre-loaded (with clothes, dishes, soap, etc.) and a HEMS system notified of the status of the appliance. The interviews revealed widespread concern about operation of empty or un-prepared appliances.

> *I mean, you can turn the dishwasher on but what if no one stacked it? No one's got any dishes in it? (i20)*

> *I don't think you can do it entirely automated unless you can get a machine that's going to stack itself, you know? (i22)*

One DIY HEMS demonstrated another limitation of switching appliances to use excess generation: switching appliances on and off in response to fluctuations in generation (or to increased load) is impractical and may be damaging, so control systems must take account of appliance-specific programme durations.

Conversely, the 'notify and control' approach gives the user the final decision on operation.

However, for either approach, if automation or notification is based solely on real-time load and generation data, rather than incorporating forecast data, automating loads may result in additional grid import if excess generation becomes insufficient during the appliance cycle.

4.4.4 Limitations on air-conditioning control

Although similar concerns were raised for air-conditioning, the availability of direct infra-red control of air-conditioning via a third-party device make this a lesser issue than for appliances. But **for automation of air-conditioning to be effective, more comprehensive household control may be necessary**,

> *The concern is that it's turning all the air conditioning on, but you've left all the curtains open, and maybe even the windows are all open, so it's not taking that into account. You'd have to have a house that was designed especially for that system, with windows and shutters that you can control remotely, so you can build them into the system. (i19)*

There may also be issues with the energy used by older air-conditioning units on stand-by:

> *I've got a consumption meter on the invertor, I couldn't work out where 80 watts is going and that stinking thing sits there, sucks 80 watts day in, day out, just heating up the compressor. (i11)*

More significant are the thermal limitations on pre-cooling and pre-heating discussed above. However, there could be an opportunity for algorithmic load analysis to indirectly assess thermal building performance and inform advice or automation for pre-heating and pre-cooling

> *Measuring your electricity output and telling you when the heater's on, or the ducted air conditioning's on at their place, ..and actually be able to take into account how well your*

house holds that heat simply by your energy usage pattern analyse [which of] the two scenarios of running it to keep an empty house warm versus not running it works out the better value or the least electricity usage…that would be really quite useful and an attractive proposition to purchasing the solar analytics package.(i03).

4.4.5 Non-negotiable energy services

For some households, energy services are non-negotiable, for reasons of health, comfort, lifestyle or convenience, which precludes manual as well as automatic load shifting or demand reduction. In particular, thermal comfort may be dictated by specific activities or by the health of household members, as well as by financial and environmental concerns.

If we need the heater on, we'll put the heater on. It doesn't really matter what time of the day. If we can utilize it in the best solar times, yes, sure, we'll do that. But obviously that's not the case most times. (i20)

Unlike air-conditioning and appliances, optimal management of hot-water is not dependent on daytime occupancy, but on shower times, as shows are the major hot-water use in most households. Use of daytime solar generation for hot-water is more likely to be economically viable in households with evening shower use than morning.

4.5 User needs and concerns

4.5.1 Survey responses

Consumer perceptions of the main benefits of Smart HEMS are diverse, but bill savings and energy efficiency are rated highly by all groups. In particular, rating of the ability to control appliances remotely shows high variability, perhaps reflecting the division between 'working-away' and 'stay-at-home' households.

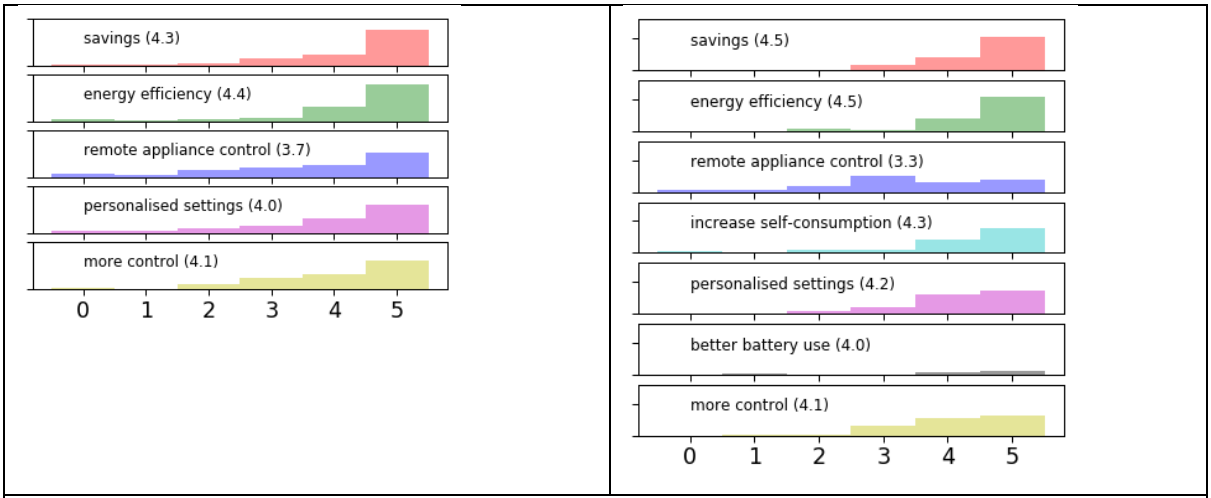


Figure 10 Users' perceived benefits of Smart HEMS from (l) SolA users' survey and (r) HEMS users' survey

4.5.2 Reliability

The most important criteria for a SHEMS system is reliability.

I don't think I'd be worried about anything. I'd just want it to be very competent… so long as it works, well, I'm happy. (i15)

Reliability would be the thing... I don't want to find myself having a system that's not operating properly, and then it's going to take three weeks for someone to get here to fix it. So, if I didn't have a sense of how well and reliable such a system was, I'd want to get it before taking the plunge. (i12)

Reliability, particularly of control aspects, needs to be demonstrated.

4.5.3 Intelligent advice, effectively communicated

The benefits of SHEMS (increased self-consumption, bill savings, emissions reduction) need to be quantified, evidenced and communicated to users.

> *I guess I would have to feel like it was effective in delivering the outcome that I was aiming to achieve. In my case, that would be reduce the level of import from the grid, keep the house comfortable and not compromise lifestyle too much. (i02)*

Effective communication of information, recommended behaviour and potential savings is important. Information and advice must be simple, particularly for encouraging behaviour change for multiple occupants.

> *As long as I have the chance to control, the appliances in my house the way I want it and I'm given clear information as to what the impact may be of my actions. (i05)*

> *What I would like is an information display out there that's usable without knowing anything. I'd like people to be able to know, for example, whoever's in the house, whether it's me, or my family, or people that are renting it, are they doing anything stupid in terms of energy use…I just think it's got to be simplified. People should not have to become geeks, to do really big things with solar. (i16)*

> *I think it would have to be quite dumbed-down technology because they are retirees. But I think there would generally be interest because they are very well-motivated to save where they possibly can. (i09)*

Participants had some simple UX suggestions:

> *What might be a good idea would be some sort of slide bar you could use on the screen between savings versus temperature. So you're kind of very aware of the trade-off that you're making. (i09)*

> *If you set the parameters for a particular time of year, or for a particular duration, I envisage a very simple UI where you can set what's your minimum free power generation is before it turns it on, on the basis that the house is 12 degrees, you know? And you'd only want to go until it was, say, 24 degrees. That's the way I would see it. (i14)*

4.5.4 Cost

Other than some very committed technophiles, people are cautious about the potential cost of a Smart HEMS system.

> *It would have to be a pretty attractive proposition in terms of the, you know, low cost implementation or something like that… to force me to go " yes, you know, I should do this because I'm going to win out of this and that everyone and the environment, me, everything is going to win out of doing this". (i03)*

Of the 17 interviewees who expressed a rationale for how they arrived at an acceptable price for a Smart HEMS system,

- 7 based it entirely on the anticipated bill savings or ROI,
- 3 based it on savings or ROI plus a component for value of control functionality, convenience, or novelty,
- 7 based it on non-financial metrics: functionality, control, convenience, novelty.

Some users see value in SHEMS based on convenience, on automation itself, on data visibility, or in a compelling case for environmental benefit.

It's a convenience thing too. And if it's making my life easier and making my footprint on, on the earth a little less, heavy, then yeah, I think it's worth something. I think it's worth my while to kick into buying that sort of thing. Yes. (i06)

So, you know, you should be doing it for… the world, not just your financial benefit. And… if it was a strong enough argument, I probably could be convinced of that too. But I'm currently thinking of it only as an economic thing. (i03)

Anticipated or demonstrated cost savings are crucial to the value of SHEMS for many prosumers.

Cost vs benefit. If I'm going to outlay something. What's the benefit to me? And I think once you get to show that the benefits far outweigh the cost, that's where you get people. (i04)

If it was purely economics, then it would have to probably pay itself back in preferably three and no more than five years. (i03)

I guess I got the analytics [more] because it was cool… than because of the payback. I mean, it may will pay itself off over some extended period of time, but that's not really why I got it. But I guess for [Smart HEMS], I'd probably be thinking a bit more about the payback. (i01)

Some consumers are resistant to subscription-based pricing, while others are resigned to it.

I tell you one thing that does put me off apps strongly is monthly recurring charges. I think I'd very much want it to be a one-off purchase. The subscription services I think are, well I'm not comfortable with them. (i02)

Acceptable price depends on comparison with the available, simpler alternatives:

Are you always playing it off against, "Well can I just stick it on a timer and be done with it?" (i11)

There is no obvious relationship between house occupancy and preparedness to pay for SHEMS.

Interviewees were asked to identify an acceptable maximum cost for a fully functional Smart HEMS controlling multiple devices with intelligent notifications and/or automation. Some specified a one-off cost, others an annual subscription. These figures were combined to give an 'acceptable 5-year cost' with the distribution shown in Figure 11.

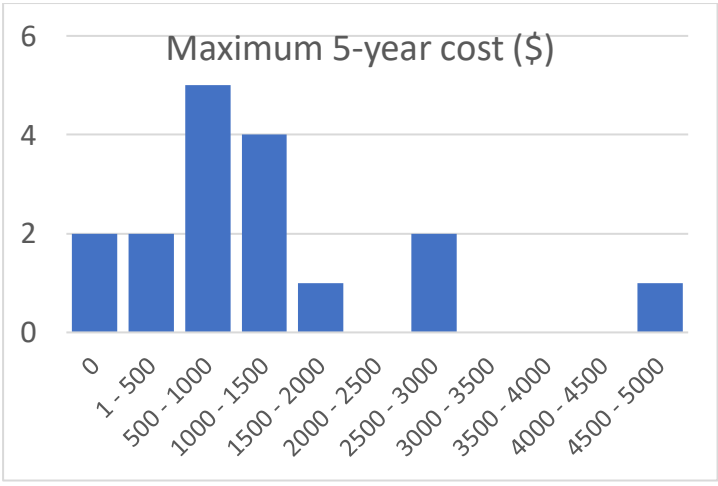


Figure 11 Maximum acceptable cost for Smart HEMS

The median acceptable cost for fully-functional SHEMS is $1000 over 5 years

4.5.5 Concerns

Other than cost, users' primary concerns about Smart HEMS relate to security, data misuse and malfunction (see Figure 12)

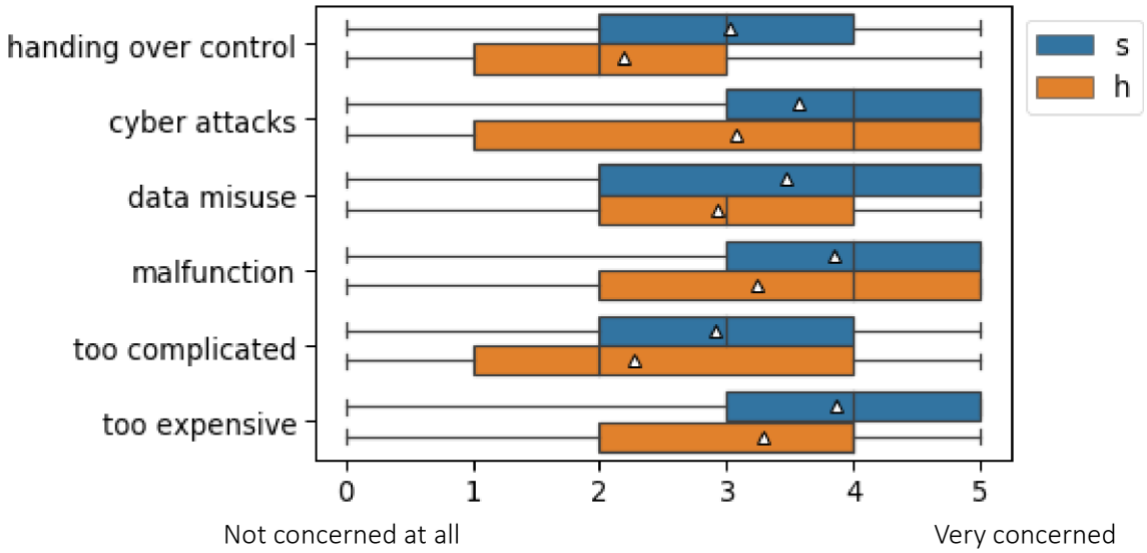


Figure 12 Level of concern about Smart HEMS from SolA users survey **(s)** and HEMS survey **(h)**

4.5.6 Security

System security and privacy were most frequently identified as the "biggest risk" of Smart HEMS by survey respondents (though this was less than 15% of total participants), with widespread concern about "hackers". The interviews revealed two main areas of concern:

- System vulnerability to cyber-attacks, leading to potential hostile control of household devices. Some concerns are based on technical knowledge and expertise, while others are more general.
- Security of user data, whether energy data or other personal data. This includes concerns of SHEMS companies misusing or selling data themselves, or poor SHEMS security allowing criminal access.

While some technically proficient users respond to this concern by keeping close technical oversight of their networks, for others, **concerns can be allayed by using trusted technology or a trusted supplier.** But opinions vary on who to trust, both from both a technical and ethical perspective.

> *I'd want to make sure that it could be segregated from my home network if I require it to be. I wouldn't want it to be just one of these things that you plug in and it just does its thing. (i22)*

> *One of the reasons why I went with Google devices and Google Assistant over the likes of Alexa. Simply on the basis of the robust security protocols that Google has. (i14)*

> *I don't trust Google too much actually. To the extent possible, I try and use Alexa for some reason. It's not to say that Alexa or Amazons better than Google… that's my gut feeling perhaps at the moment, but I don't certainly trust Google dealing with my information appropriately… I don't believe Google is so much about what their motto used to be, "Don't be evil," right? They're not any more the same company. (i18)*

> *But Solar Analytics, it's not just a tool, it's the people we're dealing with too, the help that you can get through … You do have faith in their service so when you have that kind of a relationship with a product, you do expect it to take care of your privacy issues. (i10)*

For some, this extends to a broader distrust of internet-connected apps, cloud services, of technology in general or of *"free"* technology in particular.

> *I would [have more faith in Solar Analytics than Google] in my house. I would expect them to be a little more careful with my stuff. It's because I've paid for a product. I didn't pay for Google. If you pay for a product, you own a product, you expect a lot more from it. That's where the value and the ownership of the relationship starts. (i10)*

4.5.7 Malfunction

Concerns about system malfunction range from the risk of automation making sub-optimal decisions, which may not deter (particularly technophile) users

> *I guess there's probably a downside of being an early adopter in that sense… maybe the predictions are no good for a little while. That's par for the course for things. (i01)*

to unattended device operation, causing property damage or systemic problems that undermine system confidence.

> *Wearing my wide-eyed future-loving nerd glasses right now, I'm loving it. [But] have you seen a movie called Brazil by Terry Gilliam? …At the back of my mind, I've got this Brazil where things don't quite work. A dystopian future where you know, it's all [automated and connected] and you know, should be working brilliantly, but not quite. (i06)*

This raises issues of liability if devices malfunction while under HEMS control.

4.6 Language

Levels of understanding of the phrase "Smart Home Energy management" vary widely. Some people interpret "Smart" to refer to the user: Give me useful information and I can be smart about how I manage my energy. For some, "Smart" suggests a system that is *automated* or *personalised*, or *optimised*, while for others, it simply means *control*.

Given this range, it's not surprising that opinions vary as to whether "Smart" is an appropriate term to describe an automated or optimised HEMS, or that, for some, "smart" has become meaningless through overuse, resulting in negative connotations.

> *I would call it smart, yes, but, honestly, I think I've got too many smart things around me already. You've got smart locks, water smart, energy smart, smart units… I think, probably, it's a word that's overused (i10)*

> *Anything that has got smart on it, machine learning, or AI, I just assume it's complete BS… It's just over-used and over hyped. I don't want something smart, I want something simple… the hype is just to be steered clear of, because I think it hurts trust. (i16)*

Some users preferencing manual or remote control prefer more passive language

> *Home Energy Hub (i16)*

"Optimisation" or "intelligence" could be used to describe the algorithm behind either automated control or recommendations.

> *Something along the lines of power optimization intelligence. (i09)*

A focus on comfort or convenience benefits:

> *something that talks about ease, comfort, and not much of input from your end. If there was a word that could put these two things together (i10)*

For a DR system, operated for network and broader community benefit (see Section5),

> *Neighbourhood Support, or something like that, you know, to engender that community sense of people in the geographic area. (i24)*

or where network / community benefits are balanced against household benefits:

> *It's some form of interactive partnership. You know, partnerships are based on people's ability to understand what's happening and if you talk about a whole range of things, if people don't understand it you can never have a partnership. (i04)*

5 ATTITUDES AFFECTING DEMAND RESPONSE

A section of the semi-structured interview aimed to explore participant attitudes to their loads (and also inverters and batteries) being controlled by DNSPs or others to provide network services. This included exploring ideas of community, the concept of the grid as a community resource, and the relationship between community and individual benefit, as well as potential compensation for reduced control or comfort, and the levels of fairness and transparency needed to instil trust.

While some participants have a sophisticated understanding of the energy transition, others rely on incomplete and/or erroneous media reports. Given the complexity of the subject, the analysis is necessarily constrained by the time and format of the interviews. Although a large proportion of participants are motivated, at least in part, by considerations of community benefit, attitudes to individual vs shared responsibility, self-interest vs community benefit, compensation, equity and independence are diverse and largely defy simple segmentation.

5.1 Grid as a community resource

5.1.1 Solar and community

Although there is awareness of network issues, most solar owners see the major impact of their exported generation as a social or community good, for example, because it offsets fossil fuel generation. And some consider their positive influence of their example on neighbours or community, with **solar deployment acting as a focus for community building.**

> *A lot of [chat] in this street primarily is about solar energy. And what's been really interesting is watching the panels appear on people's houses over the past, say 18 months, two years. Now there's about 4 don't have panels as opposed to only one or two having panels and you know, everyone talks about it, people have just gone and put solar panels on because of the conversation. There's no doubt monkey see monkey do.... (i04)*

For some, the inequitable distribution of solar ownership suggests community solutions….

> *We all stick these solar panels on the roof, but I think it would make a lot more sense if there was more a community minded thing about the whole thing and we put in our own solar farm somewhere... I often think that we're all doing the wrong way… you do it this way and you cut out your pensioners, all those people who can't afford it. I'm getting a benefit whereas somebody who can't afford it gets no benefit. (i11)*

while a minority, despite benefitting personally from low cost solar generation, strongly advocate for continued reliance on coal generation as the societal solution to energy supply.

5.1.2 Responsibility for the grid

As noted in the literature and in previous SolA customer research, a common motivation for installing solar is independence from energy companies, and grid disconnection is an early goal for some prosumers, but this motivation tends to reduce after purchase. Most people see the need for a network and many have a broad understanding of the need for storage. However, there is a wide range of views about where responsibility for the grid rests.

A (largely altruistic) **minority of solar owners see the grid as a community resource with a degree of shared responsibility**,

> *I think the grid's a useful thing and I don't think there's a need [in] our situation to think about disconnecting from it… and I think if the ability's there to be part of a network and contribute to it then why wouldn't you?... (i21)*

For some this is focused on a local level, with neighbourhood microgrids or solar sharing seen as a means of applying distributed generation to proximate loads.

Others see a direct role for government in funding and managing grid transition.

> *I think that the government has a responsibility given their mantra for the environment. They need to set aside moneys to future the networks to be able to store power. (i04)*

> *Oh, I think everyone should [pay for network updates] … Everyone wants to use electricity, so I guess that's another way of saying taxpayer funded through government led projects. (i21)*

5.1.3 Equity and system stability justify regulatory constraints

Solar owners are largely receptive to the idea of proportional export curtailment as an alternative to preventing other consumers from installing solar. If fairly applied, **export limits, inverter control or demand response are more acceptable than connection constraints.**

> *If the alternative was other people aren't allowed to have something I've got… well… they should be allowed to have it. I've got it, and so why can't they have it? Rather than I have it 100% and they not at all. If I'll only be able to have an 80%, but they'll be able to have it too. And that would be something I think is fair and reasonable. (i03)*

> *I think just stop other people installing it, you'd bring out such an outcry. I don't think you'd be able to stop other people installing panels… (i07)*

> *I think trying to restrict, what people do on their own houses, is going to get a bit of a backlash. you know, that's, that's one place where people will get very, very, very touchy about telling them what they can and can't do on their own home (i05)*

Many prosumers accept regulatory constraints are necessary for grid management, even if consumers and prosumers are disadvantaged as a result.

> *The reliability of the grid is more important than people having their luxuries… I don't know how they'd do it, but… I would put more priority on the stability of the grid than my own selfishness, I guess. (i22)*

> *My process is: there's systems and regulations in place that deal with [grid stability] and we should rely on that, which is why I'm not too fussed on questioning why our PV is limited to four and a half kilowatts. (i14)*

Conversely, for a minority, any attempt to regulate their interaction with the grid is unreasonable. Federal and state subsidies notwithstanding, most solar owners have paid for their system. Network stability is 'not my problem ' - an issue for network operators to deal with.

> *I had to save two years to put these panels on. And as far as I'm concerned, if the grid can't cope with the amount of power, then it's up to them to accommodate everybody in the whole of Australia. So, that's not something I should wear, it is something that they have to do. (i13)*

5.2 Community use of household assets

5.2.1 Sharing resources is reasonable

The principal of the use of household assets for community or network benefit is widely, though not universally, accepted, not only by those strongly motivated by altruism or community benefit. However, attitudes diverge as to what level of resource use, sharing of benefits, level of control and appropriate compensation is fair and reasonable.

> *[Network control of air-conditioning] is all right. It seems to be a sensible thing to do if it's going to overload the grid. I've got no problem with it. (i15)*

If it was something like hot water, it kind of is already, because it's a controlled load. That doesn't faze me. That's just changing when my water's heated. That doesn't bother me in the slightest. (i12)

I just like to think that most people are reasonable and do good for the greater amount of people than just a few. So I think that if someone was to say to me John both your batteries are full, how about you dump one to us and keep what you've got, I'll go, okay, no problem. (i04)

Sharing resources for community benefit must be reasonable. The resource owner should not be disadvantaged by the community use of the resource. For some, this means no additional cost or loss.

I'm actually okay with [benefits of batteries or load control being shared between the grid and the individual] if it's for the greater good and it's of no detriment to the person who's outlaid the cash and put the solar on their roof. (i22)

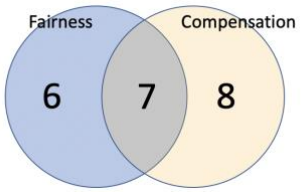
For more altruistically-motivated consumers, the overriding criteria is equity, 'as long as it's fair'.

Reasonable is about best intent. But reasonableness is about doing what's fair to the majority… if I said, look, we got to turn your power off because the hospital is struggling. That's reasonable. (i04)

The principal of 'no detriment' can be taken to an extreme. Though nominally supportive of community benefit, a few householders draw the line at any restrictions on individual behaviour, so only loads not being used anyway should be available for DR. Others reject any use of individual assets for community benefit and may prefer grid level solutions including community battery storage.

5.2.2 Fairness and compensation

The dominant themes emerging from discussions around demand response, PV curtailment, etc. are **fairness** and **compensation**, with a diversity of opinion as to whether one or both are required.



To engender the trust required for participation, PV installation constraints, export limits, or load curtailment or demand response need to be applied fairly across geographic and social boundaries.

For some, fairness may justify loss of comfort and preclude the need for payment, but a majority of interviewees identified the need for **financial compensation for loss of control, lost revenue or reduced comfort, or simply in exchange for use of the asset**. An alternative view suggests that any government subsidy (e.g. for solar or a battery) should come with an expectation that it can also be used for community benefit.

How are consumers fairly rewarded for the community or network benefit derived from use of their assets? An individual's assessment of fair compensation depends on their own acceptable levels of comfort and frequency of disruption as well as on their non-negotiable energy needs and their financial situation. For many, fair compensation also relies on equitable treatment of all households while, for others, sufficient financial compensation overrides the need for equity. Two participants suggested a fixed, per-household constraint on maximum power import at peak times would be a fairer way to reduce peak demand than demand response and would also address the difficulty of assessing a baseline for demand response.

Exceptions are needed where health or other constraints preclude any reduction of energy services, which presents a challenge of verifying exceptions and raises issues of trust (see para 5.3).

Most consumers need to retain an absolute ability to opt out of any DR agreement, while for others, the opt-out is negotiable. Reward structures can penalise opt-outs, e.g. with part of the payment due only if consumers participate in all offered DR opportunities.

5.3 Trust and regulation

Consumer confidence in the fairness of DR compensation, etc. requires trust in the technologies and organisations.

However, **distrust of energy companies is very widespread.** Solar owners are perhaps more prone to negative attitudes to energy companies than other consumers, either because they feel they have been penalised for installing solar or because their decision to install solar has been partly based on a desire for independence from the retailers. **For many (most?) people the distinction between retailers and network operators is not clear and, even for these well-informed, engaged prosumers, the distrust of energy companies includes both groups.**

This trust deficit has implications for willingness to cede direct control of behind-the-meter assets.

> *Those sorts of people in charge of what I do in the house… I'd turn in my grave thinking of that! (i05)*

The trust deficit reduces consumer willingness to sacrifice comfort or convenience for community benefit and undermines consumer confidence that any compensation is administered fairly or equitably. Distrust of energy companies can engender a desire for simplicity above all else, leading to resistance to smart meters, TOU tariffs or other innovations.

Although government energy policy, particularly regarding renewables, is held in low regard by many solar owners, government is more trusted by some who see it as somewhat representative of community and therefore subject to democratic control, while private companies are driven by profit above community benefit.

> *Boy, I, I don't know if I trust my energy retailer or my network wholesaler to that extent, I'm not sure I trust them actually… I would trust us, the voters more than I would trust private businesses I'm afraid, yeah. (i06)*

The **need for government leadership is a recurrent theme**, with potential roles including obliging energy companies to prioritise customer benefits; restoring trust by regulating for transparency in allocation of and compensation for load curtailment and shifting; or incentivising (or mandating) consumers to take shared responsibility.

> *People are reluctant to take social responsibility, because we don't see our leaders as taking social responsibility very seriously. (i24)*

But some people lack faith that government could or would show the leadership necessary to transform the energy system.

In order to engender trust in demand response, there is a need for public education about the community benefits.

> *Intellectually, I can see the need for [demand response], why it's going to be required to get an optimal outcome for everybody, and avoid building new power plants, and keeping the grid healthy, it makes sense. I just think there'll be a big... bit of a campaign of understanding before that would be accepted... If it's explained properly, I think people would understand why that makes sense. (i16)*

…and for transparency around the distribution of benefits.

> *If I handed over control of consuming devices in my household, I would want to… know that there had been a tangible productive outcome from having done that. If there was no immediate direct financial incentive for me to do it… then I'd want to be able to know that there was some kind of tangible improvements that have resulted elsewhere. So that avoided the cost of building this interconnect and avoiding that interconnector saved $100million and distributed across these electricity accounts that's 50 bucks each or something. If it just disappeared off into the aether and I just felt that, by signing up to this scheme I had contributed but had no understanding of the benefit, then I wouldn't feel as happy about that as I would if I properly understood what the outcomes were. (i02)*