



Subtask 2 – New Zealand: *PowerCo Smart House Pilot*

Task 24 – Phase I

Closing the Loop – Behaviour Change in DSM:
From Theory to Practice

July, 2014

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(with many thanks to Jamie Silk and PowerCo)

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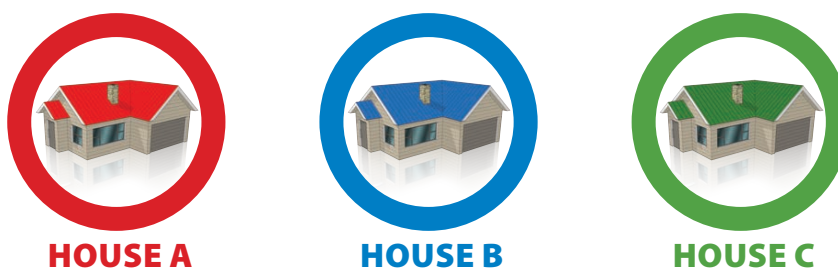
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Introduction to the case story

This document presents the general observations and lessons learnt based on the empirical analysis of the New Zealand case study **PowerCo Smart House Pilot**. This case study is part of Subtask 2 (Case Studies) of Task 24: *Closing the Loop - Behaviour Change in DSM: From Theory to Practice*. Stakeholder analyses from New Zealand (undertaken at two Task 24 workshops in February 2013 and March 2014) identified behaviour change related to building retrofits and smart meters/smart grids among the top priorities in DSM. This case study encompasses both domains. A short description of the pilot and a story of the project is provided. Next, in random order, key lessons are presented from the household and project manager interviews on how to achieve and keep end user engagement.

[PowerCo](#) is New Zealand's second largest gas and electricity distribution company, with 30,000km of electricity network length and over 420,000 customers. The Smart House programme aims to accelerate PowerCo's understanding of and positioning for significant changes that may affect the business and consumers over the coming 5-10 years.

Three houses have been designed to capture future potential household scenarios based on the dynamic market and technological landscape. These houses are fully interactive with PowerCo's information networks, and test three market hypotheses about how consumers will behave going forward. The homes are (Figure 1):



HOUSE A: POWERCO MANAGED

Occasional critical peak pricing drives the best response and long run costs. Value consumers want reduced consumption on these infrequent occasions.

HOUSE B: SMART TARIFF OPTIMISED

Daily higher pricing at peaks (TOU) from retailers drives consumer response. Value consumers want to shift consumption every day.

HOUSE C: THE OPEN HOME

Personal motivation (sustainability, early adopter, social pressures) lead some consumers to adopt new solutions. This house aims to assess how demand profiles may change with these products under current, TOU and CPP, and TOU layered with CPP scenarios.

Figure 1. Three Pilot Homes in the Smart House Pilot (Fig from PowerCo)

An introduction to Smart House

The Smart House Pilot was started in 2014 by PowerCo, a large New Zealand distribution company. It currently involves 3 houses in 3 geographical centers on the North Island of New Zealand - Tauranga, New Plymouth and Wellington. The houses were chosen as the most appropriate out of 23 applicants, all PowerCo employees, from around the country. The pilot will run for at least 2 years. It is meant to model, for example, how consumers could respond to “critical peak pricing” prior to PowerCo changing pricing structures and to changes in heating technology, small-scale generation via solar PV, feedback and remote controlling of appliances. The work will determine if a valuable response can be achieved and be a basis to demonstrate to consumers how they can respond to and benefit from any potential price and technology change. Potentially, the lessons will contribute to developing new service offerings or products for consumers (whether by PowerCo or 3rd parties).

As individual homes cannot provide an ‘after’ diversity view of consumer behaviour, this programme is supported by 5-6 further installations of the FastTrack demand controller and participation in the government-funded [Green Grid](#) project. The small number of houses mean that we can not undertake statistically significant comparisons between them, however, detailed quantitative and qualitative analyses will be undertaken in each home to enable in-depth learning and analysis. The Smart Houses primarily focus on demonstrating how an impact (the consumer comfort/value and network deferral price) can be achieved from specific interventions in a real world context (consumer behaviour and environmental factors). It seeks to illustrate the inherent challenges and opportunities. There will be an extensive testing regime over the two years of the trial which includes physical and behavioural tests, involving monitoring, review and recording of perceptions and feelings.

The Intervention: PowerCo’s future planning indicates there will be three main types of Consumer on the PowerCo network, which we can characterise as Life-Style Consumers, Green Consumers and Value Consumers (Figure 2).

| | Consumer Drivers | Implication | Example |
|----------------------|--|---|--|
| Life-style Consumers | Value high quality products/services, reliability and certainty. Early adopter of new technology. | Dependent on the latest technologies for comfort, heat, security and entertainment - and a low tolerance for inconvenience - they will pay for uninterrupted service. | Lease, sell or fund integrated home energy management systems with smart appliances, EV, PV, fail-over supply, automated management system and maintenance contract. |
| Green Consumers | Doing their bit to live sustainably. | Energy spend will shift to grid tie PV, energy efficient homes, smart appliances or storage to displace gas peakers. | Fund, lease or sell solar panels. Packages for fed in micro-generation, energy storage or energy management of appliances that optimise the ‘green’ experience. Aggregators for ‘negawatts’ for demand response. |
| Value Consumers | A ‘fair’ price for a fair service. Timely communication of planned or unplanned power cuts. | Part of a highly connected society they need to be valued. More spent on energy efficient buildings, ‘cheap’ PV, etc. Interest in other services that cut bills without loss of comfort or convenience. | Integrated outage management and communication systems pushing out fault data to interested consumers in real time. Adoption of services pioneered for greens as economics dictate. |

Figure 2. Different consumer segments (from the PowerCo Smart House brochure)

The three chosen homes also fall into three of the four categories from the [Energy Cultures](#) research project (the lead researcher of Energy Cultures, Prof Janet Stephenson, is also the New Zealand National Expert for Task 24). These are: *Energy Economical*, *Energy Extravagant*, *Energy Efficient* and *Energy Easy* (Table 1). All categories, except the Energy Economical were represented in this trial.

Table 2. Distinct Energy Culture clusters in New Zealand (from Energy Cultures research)

| | Energy Economic | Energy Extravagant | Energy Efficient | Energy Easy |
|-----------------|--|--|---|---|
| % of population | 24% | 19% | 20% | 31% |
| Demographics | Younger, poorer and smaller households. Students and Unemployed. | Families – dependent children aged under 50. Highest income. | Older – often empty nesters, part time work. Owner-occupied. Mostly in small centers/rural. | Middle-aged or older Europeans. Few children. Second-highest income, but many retired. Auckland and Wellington. |

The Smart House homes

House A in Tauranga belongs to the Energy Cultures' *Energy Efficient* cluster and PowerCo's *Value Consumers*. A young couple and a baby live in the house, as well as 3 cats. The homeowners are using only a little over 6000kWh pa and operate only 23 appliances. The House was built in 1998, has 100m² and had good insulation and weather tightness (though no double glazing, which is typical for New Zealand. None of the houses in this trial have double glazing). The house operated on tariff-reduced ripple control for the hot water (from 11pm-7am and 1pm-3pm). There was no heated towel rack or clothes dryer. Heating was originally undertaken via portable heaters and a water radiator with plug-in timers. They also use electric blankets in winter and a HRV heat replacement system which is on 24h a day.

The house received 1kW of Canadian Solar PV installation, and a network-controllable (for occasional critical peaks) heat pump, as well as an energy efficient ceramic topped stove, a smart hot water controller using timers/delay functions and smart plugs and web/phone reporting and control for a number of the home's appliances. Monitoring is undertaken via room sensors to assess temperature distribution and circulation; water flow meters to measure hot water supply to heating, tank and use; circuit monitors; heat pump setting to measure temperature and use; PV monitoring software to measure generation; as well as via energy diaries (both written and as iPad apps) and interviews to assess attitudes, norms, engagement and behaviour changes.

House A is scheduled to be tested in 5 categories, 3 of which will require householder engagement, one is monitoring and the 5th is not in play until Year 2. The behavioural considerations around home heating are perceptions between old and new heating; demand shifting (including impacts from externally controlled demand shifting); appliance use demand shifting (controlled by householders); low energy alternatives for cooking during critical peak periods (CPP) and ventilation thermal comfort.

House B in New Plymouth belongs to the Energy Cultures' *Energy Easy* Cluster and PowerCo's *Consumer-Tariff-Driven Home*. A young professional and her flatmate live in the house, as well as a dog and two cats. The homeowners are using about 9000kWh pa and operate 34 appliances. The house was built in 1990, has 175m² and needed underfloor insulation and ceiling insulation top-up and had some weatherisation issues that needed to be dealt with. The house had a dryer, which was used about once a week in winter, two bathrooms with fans and heated towel racks, a pool, a very old gas heater and a heat pump.

The house received a new gas heater, an infrared panel heater and a 1200W radiator heater as well as 3kW solar panels an inverter, a smart hot water controller using timers/delay functions or smart plugs for laundry, dishwasher, de-humidifier and towel rails; ceiling and underfloor insulation and IC rated downlights; new bathroom heaters and fans and web/phone reporting and control for a number of appliances. Monitoring is undertaken via room sensors to assess temperature distribution and circulation; water flow meters to measure hot water supply to heating, tank and use; circuit monitors; smart gas meters to measure use; PV monitoring software to measure generation; as well as via energy diaries (both written and as iPad apps) and interviews to assess attitudes, norms, engagement and behaviour changes.

House B is scheduled to be tested in 4 categories, 3 of which will require householder engagement and the 4th is PV which will require some engagement in Year 2. The behavioural considerations around home heating are perceptions between old and new heating; demand shifting (including impacts from externally controlled demand shifting); appliance use demand shifting (controlled by householders and towel rail timers); low energy alternatives for cooking during critical peak periods (CPP) and PV thermal comfort (for potential air cooling).

House C in Wellington belongs to Energy Cultures' *Energy Extravagant* cluster and PowerCo's *Open Home*. A family with two teenagers (one is now at University) live in the home, plus a dog. The householders are using almost 14000kWh pa and operate 36 appliances. The house was built in 1987, is 270m² and had good insulation and weather tightness but a very old gas water heater which needed to be replaced. The home has a dryer which is rarely used, a DVS heat replacement system, a large gas cooker/oven, bathroom heat lamps and towel rack heaters, two heat pumps and oil filled radiators, a vertical radiant heater and 3 econ heat panel heaters.

The house received a new gas boiler which compliments PV (fast boost, not peak priced) and central gas heating, as well as a gas fire; 3kW solar panels and inverter; a smart hot water controller using timers/delay functions or smart plugs for laundry, dishwasher, de-humidifier, slow cooker and towel rails; an 8kW MyGrid energy storage unit; different downlights installed in the ceilings to reduce the peak heating load and new towel rail heaters and timers. Monitoring is undertaken via room sensors to assess temperature distribution and circulation; water flow meters to measure hot water supply to heating, tank and use; circuit monitors; smart gas meters to measure use; PV monitoring software to measure generation; and energy storage monitoring to measure battery use and supply of power; as well as via energy diaries (both written and as iPad apps) and interviews to assess attitudes, norms, engagement and behaviour changes.

House C is scheduled to be tested in 6 categories, 4 of which will require householder engagement, the 5th is PV which will require some engagement in Year 2 and the last is ventilation analysis only. The behavioural considerations around home heating are perceptions between old and new heating; appliance use demand shifting (controlled by householders and controlled towel rail timers); low energy alternatives for cooking during critical peak periods (CPP) and PV energy transfer to water heating; thermal comfort around ventilation and storage (can it sufficiently cope during CPP).

What is the stated aim and target of the intervention?

Understanding the challenges and opportunities arising allows PowerCo to:

- Better design tomorrow's network, including determining if current investment profiles for 50 year+ assets is appropriate, and where new investments are appropriate to support. For instance, two way power flows
- Determining pricing strategies to enable consumers to make appropriate choices for them whilst encouraging optimal ongoing use of the network
- Understand the threat to existing features such ripple control from changing technologies and commercial strategies
- Guiding the development of appropriate policy, connection or technical standards for an efficient NZ system (I.e. 'smart' inverters for voltage control
- Understand the distributor's role in facilitating or investing in these changes (whether through an extension of regulated services, funding of assets or new energy services)

The problem addressed by this intervention is Demand Side Management Challenges from the perspective of a distribution company.

The goals in terms of behavioural changes are to: increase comfort, increase thermal performance, decrease peak load, incidental energy conservation.

The **target group** of the intervention is *Households*, the **Domain/s**: *building retrofits and smart meter/feedback*.

The intervention focuses on:

- *Individual behaviours*: on a household level
- *Social norms*: the establishment of different social norms, particularly around peak use and becoming prosumers
- *Social practices*: addressing daily practices like washing, caring, cooking - especially during peak hours and related to PV generation
- *Institutional environment*: future DSM and network design; implementing 54Q of the Commerce Amendment Act 2008¹
- *Physical infrastructure & technology*: building architecture, smart meters, feedback devices, smarter technology

What is the methodology and theoretical underpinning of the intervention?

Models of Understanding (MoU) and Theories of Change (ToC)

The experimental case study methodology is broadly informed by R K Yin (2009)² and we cover a multi-disciplinary approach here. Underpinning theories combine [neo-classical economics](#) (ie what can we financially incent), [Energy Cultures](#) (ie what non-economic factors are in play) and [Technological Innovation Systems](#) (ie what is emerging that may break through and change the options). [Transition theory](#) informs the view that understanding these may allow an incumbent player adapt with new offerings for consumers that maintain and build its relevance. '[Moments of Change](#)' is the theory of change that we believe may lead to long-term changes in energy habits and behaviours in the households.

Principal Experts of these models/theory

The New Zealand regulatory system is strongly influenced by **neo-classical economics** so this is the basis of current business analysis. **Energy Cultures** and behavioural work is influenced by engaging through the IEA DSM Task 24 team especially Dr Sea Rotmann and Task 24 NZ Expert Dr Janet Stephenson, who leads the Energy Cultures research project. **Innovation theory** is drawn on by referencing literature initially – specific research work in this field is being sought. All these theories and models have previously been applied in the (NZ) energy system but their combination, and an in-depth field experimental case study research specific to NZ conditions is believed to be unique. Due to the multi-disciplinary nature, qualitative and quantitative analysis is appropriate, bolstered by in-depth *pre-, ex durante- and post-interviews* as we progress through the field experiments.

Over a 2 year programme there will be significant habitual behaviour monitoring. Specific tests may involve actions that are infrequent (but may be habitual to specific infrequent circumstances). Anecdotally, habit changes due to the '**Moments of Change**' (Kurt Lewin) enforced by this trial (eg installing technology; testing regimes; feedback...), will be captured by the behavioural interviews.

For a detailed interview with the programme manager on the background of programme design, the organisational culture and wider context etc, please refer to Appendix 1.

¹ A Commerce Commission obligation incentivising energy efficiency and demand side management in energy distribution businesses (EDB).

² Yin, R.K. (2009). Case study research. Design and methods. 4th ed. Thousand Oaks, California

³ Yin, R.K. (2009). Case study research. Design and methods. 4th ed. Thousand Oaks, California

³https://www.dropbox.com/s/5unijwsesefb8j2/PDF_4_EECA%20Report%20Thorndon%20and%20Wadestown%20%28St

Implementation

Context and History - an Overview

New consumer-oriented technology and social preferences will present opportunities and challenges for networks. Realising the integration of the 'internet of things' (billions of inter-connected devices), widespread penetration of solar panels and battery storage technology (both mobile and stationary) and significant changes in retailer offerings with smart meters and smart tariffs may seem like a long-term vision of the 'smart grid'. However, today's asset management plans are deploying assets that will have decades of life - much of which may be in a very different world.

Whilst there are significant global research and pilots, New Zealand's social, climatic, regulatory and commercial environment indicates that direct experience is needed to interpret these for local conditions. High smart meter penetration in 2-3 years and retailers' trials of smart tariffs, home energy management solutions and PV/storage offerings all suggest evolving commercial plans in New Zealand. A change in Government to a Labour/Green Government could lead to significant changes in the energy system, including subsidisation of solar PV reaching a significant uptake, progressive pricing and *NZ Power*, a single Government buyer of cheaper residential electricity.

These trends can aggravate a trend to reduced kWh relative to peaks, increasing network drivers to assess demand side solutions. These are documented in PowerCo research papers. Unexpected impacts and costs may also arise for consumers if the market and regulatory infrastructure does not respond.

The regulated industry must operate in the NZ system which is based on strong micro-economic modelling which suggests rational economic outcomes (and a *Homo economicus*) and future scenarios under a certain set of assumptions. Good commercial business means starting with an economic perspective, and technology is a main focus so more thought usually goes into technology as a main driver. In order to report to regulators any project has to be coached in economic terms. But with climate change drivers and impacts, it needs to be more discussed around behaviour change, norms etc but the wider system is not there yet, it is still **neoclassical economic**. Societal tipping points for technology futures are much more interesting. *Transpower* (NZ transmission monopoly) scenarios still show BAU linear growth for the next 40 years out. This study is, however, aware of the research that looks at wider social contexts and beyond a completely rational, extrinsically-motivated energy consumer. Instead, it also uses behavioural models and theories such as **Technological Innovation Systems** (including *Agent based diffusion modelling* and *Roger's innovation curve*), and the **Energy Cultures** framework.

A big affect was the *Electricity Act* (2010) change, and *Section 54Q* which is in the Commerce Act and removes disincentives to stop energy companies to disinvest in DSM and energy efficiency. In the moment, there are no strong incentives to change business models. The industry is still working out how to best employ these legislative changes. It is important to remove disincentives - delivering aggregate energy efficiency means losing a lot of revenue now in NZ. There are currently no positive incentives that say they can do anything with the lines that go into peoples' homes. These case outputs are meant to show how money can be made for PowerCo (their main mandate) and also helping consumers, by thinking more holistically. Making an impact improves a whole lot of other factors and is influenced by a lot more eg norms, lifestyles, behaviours.

A lot of international work is showing that DSM can work, but also that it is generally done quite badly so far. In NZ, the state of housing and cultural norms are very different to other global examples. For example, in the UK there is controlled central heating but a real antipathy towards ripple control. Most people here don't even know about having it (on NZs hot water systems) and the disruption is so occasional that they don't worry about it.

Barriers (From the interview with Jamie Silk)

The go-to response of current infrastructure managers is often that it's just too hard to take people into account. There are \$2 billion worth of assets out there for the next 40-50 years, and it is important to understand that is the primary mandate for them. There is also a wide geographic footprint, a long country with distinct population nodes, climates, urban vs rural areas. Network planners have to think a lot about managing the network, it is basically an engineering business. That means there is a big barrier to go into consumer DSM and what consumers think and how they behave. Where these managers are really good at is design standards of concrete poles exposed to certain winds. With the rollout of the smart grid it becomes more difficult to know what will happen and consumers come more into the forefront. The old way of working worked well for 40-50 years and it is hard to break old habits, also as lines distribution managers.

There need to be economic incentives to manage the assets effectively and more efficiently. If you want step change, as lines company you need a good relationship with retailers who have the relationship with consumers, but they are not in the same space regarding their incentives of what infrastructure to put out. PowerCo only has the physical connection, retailers have the consumer connection. This affords a great collaboration opportunity in a whole system view. In NZ, there are not the same drivers as in the rest of the world, our energy system is envied for its large component of renewables, but it also means there are no big drivers for a carbon transition here. We do not have the same energy security concerns as other countries (except in transport). In other countries you could also appeal to a public sense of duty which doesn't really exist here and which may cause less change. But different business models and technologies becoming the norm elsewhere may be transferred here (see Figure 3).

STRATEGY FOR SMART HOMES: IMPLEMENT AND MEASURE

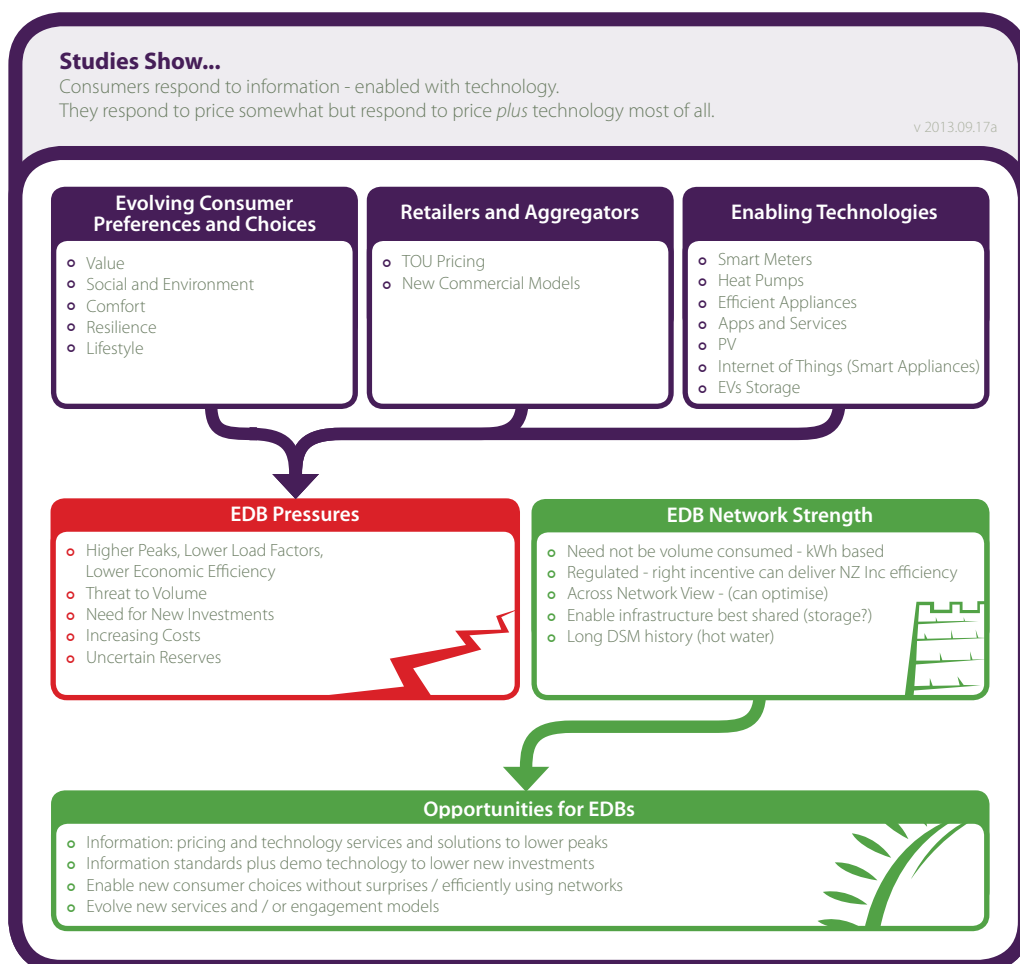


Figure 3. Overview of the Smart House strategy (from PowerCo brochure)

Methodology

This case study analysis is based on an analysis of project documentation provided by PowerCo and 4 semi-structured interviews (3 with (all of) the householders and one with the project manager). The interviews were adapted from the 'Beyond kWh' paper by Karlin and Ford (in prep) and the laddering technique used by the Energy Cultures research team in 2010³. The interview questions are given in an Appendix but they were ordered as follows: *Context* (demographics and house characteristics), *user experience* (not yet applicable), *knowledge, attitudes, behaviours* and *feedback requirements*.

The householders 'energy stories' were also filmed⁴. The interview with the Project Manager was based on the interview questions created for Subtask 2, which are meant to compliment the template which was used in Subtask 1 to collect case studies from around the world (also shown in the Task 24 '[Monster](#)').

A pre- and post-testing interview was conducted with all the householders in June and July 2014, respectively. The technology had already been installed in the pre-testing interview, but the householders were not yet given much information or feedback as to its intended use. The interviewer (SEA - Sustainable Energy Advice Ltd) asked the homeowners to walk around the house and point out all the (new) technology and describe what they thought it was meant to do. This provided some insights into the energy literacy of the householders and their engagement with the technology. The findings on end-user engagement, and from the perspective of these end-users will be contrasted to findings from other case studies (see especially the Dutch [PowerMatching City](#) case study) and used in more detail as the New Zealand case study on how to support the 'Behaviour Changers' for the Task 24 extension.

Limitations

The biggest limitation is the small number of houses and consumers in this trial and the variability between the houses, home owners' energy cultures and technology that was installed. However, the pilot was set up to be able to deal with this issue and not meant to compare and contrast directly between the houses. Instead, in-depth analysis, both technological and behavioural will tell the realistic 'stories' of each of the householders and their new energy system.

In addition, the findings need to be understood in the specific context of a pilot being conducted with the aim to learn about a technical system not yet mature and potential end-user issues of a system not yet easily available in the market. As such, the findings would most likely differ in some aspects when dealing with a technologically mature system or in a mass-rollout phase. Where this is the case this is discussed in the report.

By drawing on **Energy Cultures** and **Transition** thinking the programme aims to look across behaviours and interactions. Using real world homes and families as well as multiple project stakeholders, it will not be possible to isolate most tests to discrete changes, events and behaviours.

The project has also only just started, and this is the first phase of the pilot. There is thus limited monitoring and evaluation data so far.

³https://www.dropbox.com/s/5unijwsesefb8j2/PDF_4_EECA%20Report%20Thorndon%20and%20Wadestown%20%28St%20ephenson%20et%20al%202010%29.pdf

⁴ See <https://www.youtube.com/watch?v=wbe83S8FfO0> for examples from Task 24 experts.

The Story of PowerCo's Smart House Trial⁵

Once upon a time...there was a beautiful country called New Zealand. Even though its inhabitants thought they lived in the South Pacific, it was not a tropical country and the houses were cold and damp and the electricity network struggled, especially in winter during peak load.

Every day... the brave and staunch Kiwis would put on yet another jumper and crank up their old heaters.

But, one day... a clever research team from the second largest energy distribution company decided to be proactive and see how it could help its customers get warmer and more comfortable but at the same time reduce the load on its network.

Because of that... they chose 3 different houses from 3 of their employees and retrofitted them with all sorts of clever technology - different heaters, clever water heating, smart meters and feedback devices and solar PV. One house even got some fancy new battery storage!

But then... they realised that putting in technology alone wasn't enough and they needed to also make sure that their research subjects were accepting of the new technology, and were using it wisely.

Because of that... they collaborated with a bunch of behavioural researchers to find out more about consumer motivations, attitudes, social norms, values and how to best change their behaviours.

So, ultimately... there was a very in-depth study undertaken on the 3 houses and its inhabitants, which gave them much more insight into the many opportunities and challenges that present themselves when doing proper, integrated DSM.

But finally, the research proved to be successful in showing that the world was indeed changing and we shouldn't just keep doing the same old thing just because we know it. So New Zealand became a much more clever country, thanks to the example set by PowerCo and was using its energy better to get warmer, drier and smarter. **The end.**

⁵ For a description of the use of storytelling as a methodology see Mourik, R.M. and Rotmann, S. (2013). *Most of the time what we do is what we do most of the time. And sometimes we do something new.* Analysis of case studies IEA DSM Task 24 Closing the Loop - Behaviour Change in DSM: From Theory to Practice. Deliverable 2 for IEA Implementing Agreement DSM Task 24.

Also: Rotmann, Goodchild and Mourik (in press). *How to tell a good energy efficiency story that sticks.* eceee summer study 2015.

Main results so far

It is a little early to get to key lessons although some aspects are already becoming clear. In the sections below we will present the key findings on end-user engagement extracted from the household interviews. The same interviews will be conducted in 6 months and towards the end of the trial to trace any changes in knowledge, attitudes, behaviours and to try and follow the progression of which of these changes may have related to a change in kWh use of the house (other than technology changes). The key findings are told in the house 'stories' and ordered around the main interview sections (context, knowledge, user experience, attitudes, behaviours and feedback). Under each heading the subthemes are first outlined in summaries and then discussed by means of citations and an analysis.

The different PowerCo Smart Homes

The Story of House A

Context

House A had one inhabitant who was highly motivated by environmental reasons, and one more motivated for financial reasons. Both were highly energy conscious and using already very little energy - almost half of the average NZ household⁶. They owned a relatively new, small, 2 bedroom house with good insulation and a third fewer appliances (26) compared to the other two houses.

Knowledge

Both had good energy knowledge - for example, the wife knew about fuel poverty, particularly in the elderly from her job; she knew that energy waste was 'bad' and renewable energy was 'good'; both had fair knowledge on how to save energy in their home and which appliances were big energy users - eg worried about front loader washer/dryer in winter or about heat pump as it was previously seen as a luxury item (though not the TV, it was never turned off at the wall and always on standby); also knew which technology would work well for their situation (PV due to high sunshine hours and roof angle) and which one wouldn't (wood pellet burner as no space for pellets); and knew eg that hanging washing up inside the house could cause sore throats. The husband was aware that CFLs were better for lighting and downlights were bad due to the large amount of space needed to insulate safely around them. They had used the EECA insulation subsidy to insulate their home and talked to their neighbour about energy use - their neighbours were also low energy users, it was thus something of a social norm. Especially since they had their PV installed, their neighbours were very interested in the trial and thought they they were definitely influencing them.

Both said they learnt the most from traveling, and told a very impactful story on seeing polar bears in Churchill, Minnetoba (CA) being put in 'polar bear jails' because they were starving and foraging into town, attacking dogs and going through the rubbish. They both think that polar bears will be extinct in 20 years and thus were very concerned about climate change, as they had a personal experience tying their story to it. Incidentally, when SEA told the wife, whose biggest energy luxury were long showers about a shower water flow meter that would feed back energy use by showing a polar bear on an ice floe slowly drowning as the ice floe melted⁷, she exclaimed: "*Oh no, that would totally stop me from having long showers! So, please don't tell my husband about it! (laughs)*". They also knew first hand about bad pollution from eg coal-fired power, in China their friend had to wash their vegetables for hours to get rid of the dirt from pollution. On the flipside, they also changed their social norms when coming back to New Zealand - in Canada, they weren't paying for the electricity bills and had the house at 25C all year round, with the underfloor heating so hot that it sometimes burnt their feet! Now they are very aware of energy waste and costs and rather frugal, but they both commented on the shocking state of NZ building stock and how cold and damp everything here was.

⁶ <http://www.physics.otago.ac.nz/eman/hew/ehome/energyuse.html> Though depends if electricity only was measured - the NZ average is 7700kWhpa

⁷ Why polar bears are good to have in the shower: <http://www.slideshare.net/drsea/verena-tiefenbeck>

User experience (preliminary)

The PV feedback in particular was a favourite. Being part of this trial changed their behaviour even more significantly - particularly around the adage 'washing when the sun is shining' - see also another Dutch case study⁸ looking at a similar pilot. The stay-at-home mom was really excited about using the power her own house generated: *"The sun is free! It's a natural resource so it doesn't cost anyone, it's a total win-win!"* Her husband was a bit more practical saying *"It would be stupid not to use it ourselves - if we use it we save 28c/kWh whereas if we feed it back into the grid, we only get 7c/kWh"*. The wife really liked the way the PV visualisation clearly showed with different coloured blocks how much energy was generated and was checking it every morning to see if she should use the washing machine, and when to turn it on. On a cloudy day, she would now not do the washing and would only turn the dishwasher on if it was completely full.

When asked what of the technology they would have considered without the trial, the wife said a heatpump (but see her concerns re the higher cost above) and the husband said: *"Definitely the heatpump, but the PV not at all, it is far too expensive for its Return of Investment. Our system is only 1kW. The payback will be over the trial period, as we only pay depreciated cost at the end. 3 years is the return of investment but full price it'd be 7-8 years. Still I think it'd probably be a good thing for most homes our size."*

They would have very much preferred to keep their old retailer but couldn't because of the PV. The old price was better, billing was clear and not estimated. They would definitely consider more solar PV panels, but would prefer to get storage as well as the peak loads are not at the same time as peak generation. They like the idea of big time of use tariff discounts. For a certain level of financial savings, they would be happy to give up control over certain appliances but not heating (although limiting it during peak times is OK) and the shower (especially the wife). They had a bad experience with a landlord in London who turned off their heating but are happy to do a lot of own DR interventions by remote control or turning of/down appliances when they're at home. They found one phone call from PowerCo a little 'Big Brother' as someone asked if they had their heatpump on because a spike in electricity use was seen. But they weren't too concerned about it.

Feedback from the second interview post-testing

They both didn't like the testing at all, especially putting the old heaters on. Because of the testing, they realised just how good their new heating system was: *"It was barely warm in the lounge with the old heater, even with the door shut and the minute you turned it off you were just freezing again."* It got so bad, that on the second day of testing the wife asked her husband to turn it on just for an hour and tell PowerCo they didn't want to do the test anymore! It also didn't help that they were getting sick at the same time but they didn't cheat: *"They'd know anyway, cause we knew they were watching our consumption"*.

They are very unhappy with their electricity bill feedback and the new supplier, as they keep estimating the bills. They rung them and read out their actual readings and got a new bill but the next month it was estimates again. They are very annoyed as they still don't know what they are actually using and what it is costing them.

The PV is also regarded as not good in winter. The husband, who was skeptical anyway, had a much higher figure in his head for generation in winter (though he was underestimating their generation in summer). They were lucky to average 1kW per day but the weather had also been really bad. Even on not-rainy days the shadowing of the lower angle of the sun made a real difference. The husband was amazed how much shadowing affected the PV, even a clear day with high wispy clouds made a big difference. They would like to know what the different sides do (morning vs afternoon) and if two North-facing panels added to the array would pick up the slack in between. They still tried to use their laundry and dishwasher only when the sun was shining (and PV was generating). They are not looking as much at the PV feedback display as they are starting to know how much less it generates eg during cloudy weather. They are really looking forward to getting access to the live data which will give them a much better idea how to best match up the washing machine and dishwasher with the PV.

⁸ In the Task 24 'Monster' report: Dutch 'Jouw Energie Moment' p96-98; p119-20; p121 www.jouwenenergimoment.nl

The Story of House B

Context

House B has one inhabitant who is not motivated by environmental reasons and who was not very energy literate or interested at first. The other occupant is slightly more energy interested and described themselves as a 'light green' but environmental issues were not on the forefront of their energy-using habits. Both used quite a lot of energy - more than the average NZ household⁹. One is the owner of the relatively new, medium-sized, 4 bedroom house which had inadequate insulation, a lot of appliances (34) and a pool. The flatmate has a central European background¹⁰.

Knowledge

Both had not that much energy knowledge although one was more aware of that than the other. One knew quite a bit about technology but somewhat less about how to use it most appropriately. The owner was largely motivated by getting more information and increasing her energy knowledge through the trial. Her natural inquisitiveness and willingness to learn how to become a better energy user was a major driver. She also made sure to include her flatmate as much as possible in conversations and in the set up of the trial as well. He said he knew how he could be more energy efficient and can find out anything he needed to know himself. He didn't think he was going to get much increased knowledge from the trial.

When asked where she thought she could save more energy, the house owner mentioned turning lights off, not using the dehumidifier and heating but she was not sure how she could reduce it (but compare this with the post testing interview). Also, she mentioned getting more energy efficient appliances & heating, and more insulation. Rather than changing behaviour, she said she'd invest in different things. She was very keen on tariffs for peak load to save money. PowerCo hadn't established the baseline use and they didn't use the software for measuring their PV generation yet. She also didn't know how she could use PV for peak load, as she doesn't have battery. She sees off-peak as 'solar time' and wants to time the washing machine and dishwasher with solar output but needs an incentive. Selling power back to grid is not big issue for her and she doesn't worry about being self sufficient. She is also not particularly loyal to her electricity supplier: *"I'm happy to change, I did the 'what's your number', but stayed with Genesis. The hassle factor stopped me but not if there was a significant cost difference."* They needed to switch to a different company for selling back the electricity, which didn't worry her (contrast that with House A). She also doesn't worry about not having feedback yet eg via the app.

User experience

Both thought the technology was very user friendly, especially the heaters and the remote control for the heat pump. They had not yet received their *Wemo* remote control and weren't sure if they would be able to use it with the flatmate's heaters. The flatmate avoids electric blankets *"They are just not very healthy, they dry out your skin. I never had one growing up, I'm not used to them."* The flatmate's windows were very draughty and should potentially be weatherised to avoid further heat loss and reduce condensation.

When asked what other technology they would have considered before the Smart House trial, they answered quite differently, but understandably so, seeing they come from very different cultures. The house owner would have considered a HRV mainly. *"I wouldn't have put in the gas fire but I am stoked with it. I grew up with wood burner, so it's nice to see the flames."* The existing insulation was inadequate, and although underfloor insulation would have been considered, they thought the ceiling was adequately insulated before being told otherwise. They would not have done PV without the trial but now would consider putting more on. Getting an energy storage unit would be a big factor then. The flatmate would have wanted double glazing and solar water heating - both things that are exceedingly common on Austrian homes. *"We heated the hot water for the whole house*

⁹ <http://www.physics.otago.ac.nz/eman/hew/ehome/energyuse.html> Though depends if electricity only was measured - the NZ average for electricity is 7700kWh pa

¹⁰ incidentally, they grew up in the same country as SEA, so there is some common understanding of cultural norms, building infrastructure and traditions - this will feed into the explanations

with just 4 panels. There's no point putting the electricity back into the grid, you make hardly any money without a feed-in tariff. We need batteries to store it but environmentally, they're not great." He also thought there wasn't much improvement from the insulation yet but did think the gas heater was much better than the old heat pump.

It was obvious that there are indeed attitudinal differences to the environment between the owner and the flatmate, the flatmate being more open to energy efficiency on a personal level. They are both not overly optimistic about its importance to wider society and both don't feel there is a strong social push on having to be more energy efficient (in their closer community).

The owner was particularly open to time of use tariffs, whereas the flatmate wasn't as he really wouldn't consider washing at night, for example (for reasoning see above). In terms of giving up manual control over appliances, the owner said it would depend on the appliance. The washing machine really wouldn't bother her but the heater and electric blanket she wants total control over. Getting up early to hang the laundry out after a nightwash wouldn't worry her (but see flatmate's refusal). Comfort levels are most important to her, convenience not so much and she would definitely change her behaviour. The Flatmate wants to be in control, he doesn't like others controlling his energy. He would like to automate, set the controls himself. In terms of what level of service they would be willing to sacrifice, the owner said everything but heating and she'd want money and information in return. The flatmate said he didn't really know what he'd sacrifice as he didn't believe he used much energy anyway.

Feedback from the second interview post-testing

The owner said she felt the testing period was quite interesting as she hadn't used her heatpump in a long time. *"I wasn't to use the gas heater, only the heatpump. I found it really blowey, like a hair dryer, it was really noisy, and took a while to heat up room. But the good thing was that it managed to heat the dining and kitchen area and my bedroom, which the gas doesn't manage. But if I'd have to pick one I would certainly chose the gas."*

Following the testing period, the owner in particular was also much more conscious about keeping heat in, eg closes doors now and has a bell on it which the dog rings when she wants to go out (see Figure 4), she put draught stoppers on internal doors and created a makeshift door handle to pull the office door completely closed. She also put a curtain on the door to the kitchen to keep heat in. *"I am a lot more conscious now, previously I wouldn't have even thought about it. Especially the curtain door, that was my own idea. This is not a chore for me, I am thoroughly enjoying being more knowledgeable and learning these things and making my house better and warmer. I can feel the difference and I want to do more."*



Figure 4. Some of the alterations the owner of House B made after the testing trial

The flatmate was happy with the new heating system but did not like the new bathroom heatlamp. He has thought a little bit about PV but in the moment thinks that it doesn't suit his lifestyle, as he doesn't have any appliance he can use during day although he thinks of putting the heatpump on earlier to heat house up. He thinks that batteries would be really useful to store the energy that gets otherwise lost. He still doesn't think about doing laundry in morning before going to work, as he does it mainly on weekends anyway. He had discussion with PowerCo about installing solar water heating but it was deemed too complicated, as it needed pipes etc *"I was disappointed about it. I'm also disappointed that PV was installed but it'd only need a bit of a rail to get better angle. It seems half-hearted and inefficient, I don't like that. I'm not sure if it's too expensive but PowerCo said they could run models to see what the difference would be between 25 degrees and 35 degrees. In Austria, PV just follows the sun all day! But surely we are not THIS far behind in NZ."*

The Story of House C

Context

All inhabitants of House C claimed to be quite motivated by environmental reasons (they all said they were about a 5 or 6/10 green). One occupant was somewhat more energy technology interested. They were emigrants from the UK and had lived in NZ for 8 years. The household was using quite a lot of energy - almost twice of the average NZ household¹¹. There were two parent owners of the relatively new, large, 4 bedroom, two-storey house and two teenage children, one of whom had left home for University. There were a lot of appliances in the house (36) but it was well insulated and quite weather tight already.

Knowledge

Both of the home owners had good energy knowledge - for example, the wife could point out all the technology and the husband could provide very in-depth explanations of how the engineering of eg the hot water system worked. The teenage son was the least energy literate and admitted to not being very interested in the technology or what it did. The wife had relatively good energy knowledge though wasn't entirely sure about different energy units and needed to be prompted to think of gas and petrol as types of energy. The son had some idea of how to save energy but overestimated the power of turning of plugs when nothing was plugged in and the phone charger. He also said *"I put things in the laundry even when they are not dirty because it's just too convenient for me. But mom rejects them if they're clean (laughs)."* Car fuel was the only energy-related talking point with his friends as he pays half of the fuel. He said the topic also *"doesn't come up in school although petrol prices come up in economics."*

User experience

The husband was concerned about privacy issues and the fact that the open trial meant that people could find out what they were doing inside their home. Information disclosure was an important issue to him. The wife also was inconvenienced by the disruption of putting in the technology but said their impetus to be part of the trial was to do good things for the house. They did not know they were on a low water pressure system, for example and that they had to replace their old cold water Dux pipes to change it. That also meant that every room had to be re-painted.

The wife wasn't sure why the hot water cylinder had no insulation and initially thought that the material of the boiler meant it was insulated (it later turned out that it was). When told that it was probably because the main consideration of the trial was peak load shaving, she exclaimed: *"That is such a pointy head researcher response, isn't it? It shouldn't just be about peak demand, if they make us do all this, they should tell us everything that we can do to save more energy and money, not just what suits them. They need to think about this from the consumer perspective or they'll lose our trust."*

The husband likes the Wemo remote control as *"it is a new gadget"*. They have a central thermostat for all the new radiators which are set for two times in the morning and evening to bring

¹¹ <http://www.physics.otago.ac.nz/eman/hew/ehome/energyuse.html> Though depends if electricity only was measured - the NZ average is 7700kWhpa

them to 22C and at a set point of 16C for when they are out of the house. They all love the radiators, as it reminds them of what it was like in the UK, where they are from. They wanted the radiators and not infrared panels. They actually now wanted to get rid of their old heat pump. They were a little bit confused as to the towel rack thermostats in the bath and if they fed back into the central unit and felt they needed more information on how the technology worked together, particularly the controllers. They didn't have heated towel racks before but did ask for the heated mirror, which they love as it removed condensation.

The husband of House C said he would set the Wemo to set dishwasher, washing machine to wash when the sun is shining. He was very skeptical about the website showing PV generation, which House A loved and said *"I may use it twice, because it's new gadget. But will you use it when you are busy at work? There aren't many ToU tariffs in NZ and it's more expensive at peaks, so we're subsidising PV. I just don't think it's a worth-while investment, but my wife does. I will take control for the first month and then give it to my wife. If the Wemo doesn't work it may stop our good habits. We want simple traffic light feedback, I don't want to know the peak, I want it simple."* He thought his wife would hate the clothes getting wrinkly and smelly if the washing machine was set to wash when the sun was shining but she disagreed *"I usually put them in last thing at night, getting up early to hang them out doesn't worry me."*

The householders were both interested to know how things will be evaluated and any iterations that occur. The husband said he will only do behavioural changes if he knows why and what it will affect. The husband also liked the Powershop app and liked to buy forward packages and specials and seeing the comparison to last year. The new provider's Brownie Points were seen as a gimmick. The husband liked graphs, time series and data whereas the wife liked the idea of Opower-style bills where it was simply shown if they were above or below the average compared with their neighbours. Both didn't mind giving control up as long as they could over-ride it, if needed. But especially for the wife it was important that she could trust the trial providers that it was not just about the peak load but general energy savings. The wife would be willing to give up certain services for environmental or financial reasons, but not to 'help out Transpower'. The husband wants comfort and convenience over money and would only give it up if he didn't notice it, like ripple control.

Feedback from the second interview post-testing

They said the testing 'was all good'. They turned their new heaters off in a chilly week. The immediate difference in the warmth of house was noticeable. The heatpump upstairs and in the lounge were pretty efficient but overall the house was cold, especially the kitchen, hallway, bedrooms. The husband also had the flu during the testing. They had to put the oil-fired plug-in heater on for 3 days because he was so cold from being sick. They couldn't keep warm towel rails on during the testing, and said they got used to it in both bathrooms, but didn't like damp towels to try over the railing on stairs. They were given a plug-in Power Meter, and realised that *"the oil heaters burn up a lot of power! It's like having a kettle on all the time. But the oil heaters do give off quite nice heat. The heatpump is a different warmth than gas fire, they had to crank it to 25C, whereas gas fire is set only at 20C."*

They were also not sure if they were using the PV generated energy or not, it was never made clear. The wife couldn't tell now if it's better or not than before. So she has no feelings yet at all about the PV. The husband didn't like that they turned everything off remotely, he said he didn't know they had the capability to that and they hadn't been explained how to change the settings themselves. He said he already had the password for the app on the iPad but hadn't been taught how to use the iPad and the apps. Now he can turn things on/off.

They also said the information needs to be better managed and physical installation hasn't been coordinated (the technician needing to come back 10 times). There was not a single technical Project Manager who had oversight over the whole thing. They don't want the information to be too dumbed down (*"We don't need the polar bear"*) but they need to start to have the information eg how to use their gas etc most efficiently. They didn't feel that they changed their behaviour because they were told not to at this part of the trial as it was first about the overall physical and technological fit-out. Once they get all the feedback it will influence if they will change their behaviour or not.

A quick summary and key lessons

The main findings

Household politics are very important

This was the main reason why all house occupants were interviewed - and separately at first - in order to avoid any influence of one over another. In **House A**, for the already energy efficient owners, it was very obvious that there was a lot of similarity around expectations, engagement, energy behaviours and attitudes (despite self-reporting as more and less environmentally motivated), with some very notable exceptions around the use of TVs, the shower, and their perception of the cold (heating). Fortunately, they were aware of these differences and have put ways of dealing with them in place (two TVs, reduce hot water waste elsewhere to be able to use it in longer showers, electric blanket for the wife and good communication around heating comfort, including the wife always wearing more layers than the husband). The only issue that came up was that with the remote control setting, the electric blanket was now sometimes turned on too late or not high enough. However, as there was a safety and health risk due to the wife sometimes falling asleep with the blanket turned on the highest setting, she was happy to live with the compromise. The husband also proudly told how his energy 'sin', the plasma TV was now set on a timer. However, the wife said: *"Yes, it now goes off sometimes in the middle of the day when I watch it! At least now I know I can just turn it back on, at first he didn't tell me that I could"*. They were laughing about this, but it needs to be taken into consideration that giving control via a remote to the more technically-savvy person in the household means that they can start controlling and impacting the comfort or entertainment of the other occupants which can cause friction.

The owner in **House B** feels responsible for her flatmate's wellbeing (see **We all make trade-offs** below) and tried to include him as much as possible in the discussions. Even though she was initially much less energy literate and interested than her flatmate, she is now embracing the trial to the fullest and has notably changed her behaviour much more than her flatmate, who is still rather skeptical about many of the technological improvements. Energy was used abundantly to create everyone's level of comfort and entertainment.

House C also had similar levels of comfort and energy using behaviours. The Daughter was the most environmentally motivated but didn't live in the house anymore. The Mother was very keen to do what was best for the house and their investment but was also quite strongly environmentally motivated. She had some of the strongest views and reactions to the trial, particularly around the importance of trust and consumer involvement (see **Trust is Everything** below). The Son was quite uninterested and the Father was very skeptical. Energy was used abundantly to create everyone's level of comfort and entertainment.

Different attitudes may get the same outcome

One of the occupants in **House A** said she was highly motivated by the environment and not wasting, the other by money and technology but both are very similar in their behaviours and their willingness to invest in certain energy efficient technologies. When their answers to the attitude questions were compared, they were almost identical, differing only around perceptions of comfort and a general skepsis (by one) of the 'goodness' of people and their willingness to do the right thing: *"People are hard to change. So I'm not sure if this will work on the bigger level, people just don't care. They may complain but they won't change. It's a good thing that we're pre-motivated and reasonably efficient already. I'm not sure if the effort is worth the technology cost. Return on investment is really important to me."*

One thing that became quite apparent was how much the closeness of the relationship (eg married couples) and length of time of living together (House A and C vs House B) informed attitudinal similarities.

Waste can be a gateway to other green energy measures - or not...

The mother and wife in **House A** had very strong feelings about cloth nappies and how to cut down landfill waste since having her baby. It definitely made her more aware about wider issues eg

with energy and water waste too and was a big motivator to be part in this trial. *"It scared me to think how much waste a little baby would create in the first few years of its life. It is so easy to make your own wipes and use cloth nappies, I don't know why more people aren't doing it. They probably don't know how easy it is."*

House C also said recycling was very important to the whole family. But **House B** was a big contrast to both House A and C in terms of their waste disposal habits. Even though the owner recycled in the old house, and the flatmate remarked how bad recycling was in New Zealand compared with Europe, neither did it now as *"there is no bin and it's not convenient here."* They both would like the Council to make it easier and provide some leadership. Both recycle at work and the owner said even though it was never done when she grew up her dad now recycles and reuses a lot in his business. They composted as children but never burnt rubbish, as the neighbours did and it 'ruined the washing'. She has a compost bin now but doesn't use it even though she did in the old house. But *"I have a waste disposal unit in my sink, so I use that it's much more convenient."* (see also **Convenience isn't everything although it is a lot**).

Infrastructure locks you in

The (non) existence of the right infrastructure is obviously a huge driver for behaviours. For example, as much as the owners of **House A** loved using the tube in London, the slowness of the public transport system in Tauranga meant they wouldn't use it. **House B** was used to recycling in previous locations but because it wasn't easy and the New Plymouth City Council didn't provide the right bins, it was simply disregarded. Most houses preferred their gas fire, but if there is no gas infrastructure, it is obviously not an option. If the roof angle or solar orientation of the house does not lend itself to PV, it is also not an option. Space for eg energy storage or outside heatpump units are also considerations.

Stories are hugely powerful

Some of the most powerful stories were told by the homeowners, like the experience of seeing 'polar bear jails' in Canada really bringing home the reality of climate change, or hearing about Chinese friends spending hours scrubbing their vegetables clean from pollution. These stories formed a core of their values and reinforced their attitudes towards the environment. Similarly, their stories of their upbringing and their parents and grandparents, like how important baking was or putting on another layer or growing your own food and understanding the cycle of life, was a powerful reinforcement of their deeper value system. Every household had some good stories that illustrated their energy 'life' and described their wider values and attitudes well. Collecting, telling and fostering these stories is an important tool for Behaviour Changers as everyone can understand them and finds emotive 'hooks' that personalise them more than facts and figures.

'Moments of Change' (like this trial) can be the most powerful habit breakers

The trial definitely changed energy-using behaviours and habits in all houses and especially the PV was a very powerful motivator, as soon as it was put in. The wife in **House A** vigilantly monitored the solar output and changed her washing habits (both laundry and dishwasher) accordingly. Both inhabitants of House A were very disappointed in the much lower winter output of the PV (so was the flatmate in House B). In **House B**, a heated towel rail was installed and put on full time for 24h. The home owner said *"It comes on at two set times, but I found that I didn't need to use it, I don't need a warm towel, only a dry towel. So I'd rather have it on during day to dry towel (after shower in the morning), and use the PV to heat it and not have it on at night. This really made me think for the first time in a practical way about how to use my electricity."*

She was also much more conscious about keeping heat in, eg closes doors now and has a bell on it which the dog rings when she wants to go out (see Figure 4), she put draught stoppers on internal doors and created a makeshift door handle to pull the office door completely closed. She also put a curtain on the door to the kitchen to keep heat in. She looks forward to trialling 'poor man's double glazing' on her windows, her sister sent her information on it and she really pushed PowerCo to do it. She will test moisture, as she thinks she has a moisture monitor. She may put it on all the windows if it works. *"I am a lot more conscious now, previously I wouldn't have even thought about it. Especially the curtain door, that was my own idea. This is not a chore for me, I am thoroughly enjoying being more knowledgeable and learning these things and making my house*

better and warmer. I can feel the difference and I want to do more." (see also **Knowledge is Power**).

However, her flatmate said he hasn't really changed as much his behaviour as his landlady. *"The most difficult thing is to be aware of not using things during peak times. The testing didn't communicate that well yet, I need to have more feedback to think about the right times. I had to do my laundry at 6pm yesterday because I had to get my washing done before my flight to Europe. I would have preferred not to do it in peak time though. If I had to cook my dinner in the oven, I'd start earlier as well."* He would like to know exact definitions of peak time and maybe little reminders on appliances on how much energy they use on and off peak.

House C also clearly said the trial changed their habits and what they would consider to invest in, considerably: *"The retrofit definitely pushed us to look at things like this which we wouldn't have otherwise. We did much more investment on the house because of the trial but we hope we can get it back not just in reduced heating costs but in comfort and by increasing the total house value. It would be good to get more than the investment back in the sales price."*

Despite varying views of skepticism towards the value of PV and the fact that none of the households would have chosen it as a technology option without the trial, they all wanted to have more arrays now and energy storage (where not yet available). The PV self-generation also led to significantly greater interest in feedback, energy bills and energy behaviours and how they could be optimised. In this case, a technology is definitely a 'gateway' for wider energy literacy and behavioural change.

Tradition is everything - the way you grow up will effect you for life

Growing up with conservative parents that were always looking out to reduce waste, reuse and recycle, save money and grow and cook their own food, had a very big impact on the environmental and economic values of the occupants in **House A**, especially the wife. Seeing the real relationship between heating water with wood fire, made her very conscious of hot water/energy waste relationship. The wife said her parents were conservative because they were used to living like that - mottos were *don't waste, be careful with money*. The husband's grandparents were in the war and *"they were always conservation minded as well - use all the resources, grow your own food, don't waste what you are given, save money by being smarter. To me, it always made sense what they did."*

The wife of **House C** said *"We like opening the windows on a nice day when we're home. We are more conscious of dampness here than in the UK because of the crying windows. Closing doors is a big throwback to my childhood as is ventilating. My parents were very energy conscious, only some rooms were warm. We don't close doors as much now as we always live in well insulated houses. I like the open plan living. Turning lights off is definitely a hangover from our parents, they were very energy conscious."*

Sometimes, we turn against traditions and rebel against our upbringing, as the home owner in **House B** demonstrated: *"I learnt using the washing machine on the shortest cycle in cold water from my parents, my dad is plumber. He was really into saving electricity - always turned the lights off so us kids sat in dark. So now I rebel against my dad and leave the lights on all the time (laughs)"*.

Seeing (energy) is believing

The wife in **House A** talked about her upbringing and how they had a woodburner with a wetback to heat the water: *"I have always associated hot water with using energy."* This informs her attitudes about saving hot water elsewhere so she could 'waste it' in the shower to this day. The preference for the gas fire and open flames was also apparent in all households. It was associated with comfort, coziness, tradition and a perception of heating up much quicker (real or imagined) - see also **Buttonpushers vs Pyros**.

Is doing the laundry the most variable energy-using behaviour in any given house?

Every household had some interesting attitudes and behaviours regarding the washing and drying of laundry. **House A** was worried about drying outside in the winter but she doesn't like a dryer

due to the high energy costs. She also likes the idea of drying in fresh air and sunlight, as it's free and doesn't chew power unnecessarily. She thinks that the clothes get more worn using a dryer and she hangs them in the shade if they are black so they don't fade in the UV light (there is a clothing line in the carport for dark items). She doesn't do any more handwashing (except for woollen blankets) as she has a washing machine without an agitator for convenience and to save time. She had very strong feelings about her baby's nappies, hygiene, waste and the environment (see **Waste can be a Gateway**).

House B also got a top loader without an agitator, though the flatmate thinks he needs to do the washing on the longest, hottest setting *"cause it's a rubbish machine, that top loader, I want my clothes clean."* He waits until he is out of clothes, about once a week. He only does the washing when he has to do it *"The dog often sleeps on my bed so the sheets get messy but I just don't like washing."* But he refuses to do it at low peak times as he doesn't want it to wrinkle in the machine (he doesn't iron). This is the main reason why he would refuse a ToU tariff and is skeptical about the usefulness of solar PV. He never uses the dryer *"The dryer isn't good for clothes. I hate the drying rack, it's too inconvenient. I only use the outside line for sheets. I dry inside the spare room."* When asked, he said he was aware that it increases moisture, but was not too worried about the spare room because it was sunny and had windows. The owner of House B also dried on racks inside the house but mainly because she was 'too lazy to walk to the garage to the dryer.' (see **Convenience isn't everything**).

For the wife in **House C** cleanliness was all about 'the washer, the dryer, the iron'. She uses a big steam iron as it is quicker and they use the dryer all the time 'as we are a sporty family'. But she also likes line drying *"In summer. I like it cause it is a nicer smell and I am conscious how much the dryer uses energy. Some items are also not made for the dryer. I use a rack inside in winter but am conscious that it causes dampness."*

Convenience isn't everything, although it is a lot

Convenience is an important driver for our energy behaviours and habits, though it is not always that straight forward. All participants mentioned convenience (or inconvenience) at some stage to explain why they behaved differently to what their knowledge, values or attitudes would dictate sometimes. For example, the flatmate in **House B** now never uses the dryer because it is 'bad for the clothes' although he used it in Holland cause it was 'conveniently stacked on the washing machine'. His landlady brings the washing into the living room in winter to dry with the heater and uses the dryer only once a week in winter for small stuff, because: *"The dryer is in garage. I reckon I would use it more if I didn't have to walk (laughs)."* She also keeps the lids off when she cooks because *"I like to see what goes on when I cook. Also, often it boils over when a lid is on and this way I don't need to wash the lids!"* There was also an interesting difference in cleaning behaviours by the flatmate in House B to his flat vs his 'man cave' in the garage *"I don't vacuum enough in my flat. I do more vacuuming in my workshop, as it's easier. The access is harder in the flat, and I need to tidy up the floors first. But I clean up my mess in workshop instantly."*

The mother in **House C** said energy was *"everything to do with convenience. We are busy, we both work, we need energy quick and on the first go."*

Mobility and transport is often the biggest 'energy sin' because of (in)convenience. The wife in **House A** said about public transport: *"Having a bus outside the door isn't enough if it takes 3 times longer to get somewhere."* Both occupants in **House B** love going for walks with the dog, but both often drive to take the dog out. The flatmate mainly does so for long walks, when he drives her to good locations. The house owner has a little Mazda, petrol, 2002 which is fairly efficient. She drives it every day for commuting and to take dog for her walk. She also drives home for lunch, to *"get away from work and I eat healthier at home"*. She says: *"Walking? No way, cycling doesn't really interest me either and there is no good public transport so I drive everywhere. The dog park is just down road, even when on same street but the car is warm, especially in winter. I like the convenience and speed of driving, and anything else would mean less time in bed."*

The flatmate also says public transport is not an option: *"The bus stops close by but is expensive. I don't see why to use bus, my first word was turbo! (laughs) In Holland, I mostly biked because it was fun and convenient. I had to pass a school in morning if driving, and they were Kamikaze kids."*

It was a luxury, driving in Holland and when I was younger. Growing up, I used to bike into town, and used the train to go to Linz. My high school was 20km away, I rode my Vespa, the bus or hitchhiked every day back home. I had to wait 1h for bus and then the bus took 1h. Sometimes I had to walk home from the disco for 7km.” He says here “You have to drive somewhere to walk. Even when I go running, I drive somewhere first. But I walk a lot in the town center, where it’s convenient.”

For the wife of **House C**, size and efficiency of a car were important, looks or brand was not. She takes the dog for a walk but *“I drive as it’s 2km away, same with the shops. It is too inconvenient to walk, takes too much time.”* She could see the irony of taking the car to go to the gym. The son had an old car to learn how to drive, the school is at the other side of town and he is very independent. *“I’m not too fussed about it right now but would like to drive dad’s car, because it is newer, more flash. Looks are important but it’s safer too.”*

There isn’t always an attitude-behaviour or value-action gap

Attitudes, knowledge and values can sometimes definitely lead to very strong behaviours - the strong environmental ethos of the wife in **House A** is being displayed very strongly in many energy-saving behaviours and there is a lot of enthusiasm for learning more and doing better. And the same strong motivator/value to be financially savvy by the husband in House A also lead to very similar behaviours. The stay-at-home mom was really excited about using the power her own house generated: *“The sun is free! It’s a natural resource so it doesn’t cost anyone, it’s a total win-win!”* Her husband was a bit more practical saying *“It would be stupid not to use it ourselves - if we use it we save 28c/kWh whereas if we feed it back into the grid, we only get 7c/kWh”.*

We all make trade-offs and rationalise our biggest energy ‘sins’

People are often quite aware of the things they could do better or where they are rather wasteful in terms of energy usage, but they usually have (for them) very rational explanations or trade-offs. For example, the wife in **House A** trades off her long showers with being very vigilant in her hot water use elsewhere. She knows her strong ‘story’ around seeing the polar bears close to extinction would make her very amenable to reducing her showers if she would see a polar bear drown on an ice floe (see above) but she wouldn’t like having that feedback/guilt trip as the showers are hugely important for her comfort levels, especially in winter. The husband in House A is highly motivated by financial savings, new technology and being capable/smart, however, he is willing to trade this off when it comes to the Plasma TV, where the most important function is picture quality and size, not at all money or energy considerations: *“Return of investment is SO important to me.”* (When asked, if that applied to the TV as well): *“Not on the plasma though, there bigger is better (laughs). Picture quality is what’s most important there, not energy efficiency.”*

In **House B** the home owner didn’t make the connection of drying her wet clothes inside the house and too much moisture in the air. She also thought about getting an HRV system, as she really liked it in her last house. She says that *“My flatmate uses an awful lot of dehumidifiers but if he didn’t have it I would use it even though I cut down on the dehumidifier because of energy consumption. But I feel I have responsibility for his wellbeing, so I don’t mind him using it.”* Her flatmate ventilates, and opens his windows even if the dehumidifier goes as he really likes fresh air. *“I know its bad combo, having the windows open and the dehumidifier on at the same time. I have thought of having them closed til lunch and then open them when home for lunch. But the dog on the bed farts a lot, and so I need air even at night. But I have thought about the dehumidifier cleaning the outside world if the windows are open.”*

The homeowners of **House C** called their central heating/hot water closet *“The Brewing Room.”* *The gas heats the water to 70C in the tank and the tampering valve mixes it to 55C. We wanted it at 70C otherwise we run out of hot water after 3 showers. We are going to use more hot water, cause it’s on high pressure now. That’s one of the reason not to get low flow shower heads, we want the high pressure! It won’t be cheaper but we’ll get better service now.”*

Every one of the 3 houses rationalised their driving behaviour, even when they acknowledged that it was ‘ironic’ to drive to the gym, or to go for a run or to walk the dog. A lot of them would consider cycling for health/entertainment (eg mountain biking) but not for commuting. A lot of them like walking and hiking and are very outdoorsy and sporty, but drive in order to get somewhere nice to

walk¹². Even where there are very strong values, attitudes, knowledge and solid energy-saving behaviours elsewhere, we all have some boundaries for certain practices or technologies that we are not willing to cross. That is perfectly normal and good to bring to peoples' attention either way. Knowing and being able to explain and rationalise the things they do very well, and how, and the things they don't do so well and why not, is a big step towards greater energy literacy and engagement and will open the door for bigger trade-offs (both technology investment and behaviourally) in the future.

Peer to peer discussions are powerful, but not all powerful...

House A talked a fair bit about energy to their neighbours and their family, and they definitely thought there was quite an impact this was having (both ways). However, hearing about something being great is often not enough to believe it is worth spending the investment on, as the heatpump clearly illustrated in House A. The mother of the wife had talked about how wonderful her heatpump was but they decided against getting one as it was a 'luxury item'. Only after they had one and once they were made to go back to their old heaters during the testing, did they realise how absolutely wonderful it was: *"We didn't realise how good a heatpump is until we lost it. You don't realise how good it is when you just go into someone else's house and experience it but when you have one and you are not allowed to use it, it's terrible. We don't even know how we survived for so long with the old heater! You can have it on all day and sit right up against it and it never warmed the air and the rest of the house. The heatpump makes the air warm and you can walk around the house and it's the same temperature even in the bedrooms! That's when we realised it actually warmed the whole house"*. They were so unhappy about not being able to use it they thought about throwing the trial! Having a technology demonstrate its value in your own home is very, very powerful. The flipside could be seen with the PV, where House A was very concerned about its loss of generating power in winter and from shadowing. But it made them more determined to find ways of making it work better, even though initial cynicism about it seems to have been justified for one of them.

House B became really motivated by the power of information even though saving money is her biggest driver, as she sees it as a long term investment in her home. Learning is second. *"I talk about the trial a lot and my friends/family are really interested. There is much more interest than in previous times. I really like being a maven, cause I'm generally noseey and curious (laughs)."*

The mother in **House C** said she talked a fair bit about energy to other people especially power bills, cost of energy, how they heated their house. She was very aware and tried to get information where possible, reading brochures and articles, watching the 'Energy Spot'¹³ etc. After they had to remove the black Dux piping for water because it snaps extensively, the wife realised it was *"a big issue in NZ. Good we weren't on full pressure cause it could have snapped sooner. Insurers don't insure you if your house has it in it. It's a big talking point now that I realised it."*

We can all have some very different rationalisations for why we do things the way we do

Cooking behaviour was a good example of that. The wives in **House A** and **C** always covered their pans when cooking. The wife of **House C** said *"The water boils quicker and it doesn't smell so bad. The steam spreads fat and smells. I also always have the extractor fan on when cooking."* The flatmate in **House B** said he usually covered the pans but 'liked to interact with what I am cooking'. His landlady had a totally different rationalisation for why she never put lids on her cooking (however, she associated lids neither with saving energy nor with reducing moisture content) *"I like to see what goes on when I cook. Also, often it boils over when a lid is on and this way I don't need to wash the lids!"*

Big brother is watching you - and giving you energy

It was quite interesting to see how different the attitudes to energy suppliers and the trial researchers were between the houses. **House A** was very attached to their old energy supplier and really unhappy with the new one that was necessary to switch to because of the PV,

¹² See also Dr Ruth Mourik's energy story here: <https://www.youtube.com/watch?v=GTZ205rf8UE>

¹³ <http://www.energywise.govt.nz/how-to-be-energy-efficient/energyspot>

particularly around how feedback was given by the new supplier. They also were very aware of the PowerCo team monitoring them, but didn't mind it so much: *"We couldn't cheat even though we wanted to. They'd know anyway, cause we knew they were watching our consumption"*. They found one phone call from PowerCo a little 'Big Brother' as someone asked if they had their heatpump on because a spike in electricity use was seen. The home owners of **House C** said, a little tongue-in-cheek: *"We watched the World Cup really early, so a spy could see we didn't go to work so we could watch the match."*

House B was much more relaxed about being monitored and about switching suppliers: *"I'm happy to change, I did the 'what's your number', but stayed with Genesis. The hassle factor stopped me but not if there was a significant cost difference."* The home owner was also quite keen on time of use tariffs and managing peak load shaving better via her (new) appliances, but the flatmate didn't really like ToU pricing, as he would *"never do my washing at night. I don't iron and so it'd wrinkle and go smelly. Sometimes I forget my washing for a few hours and then I just do it again. I do it on the hottest, longest setting because these top loaders are rubbish. I want to get my clothes clean."* (see also **You can leave your home but you can't leave your culture**).

The husband of **House C** was concerned about privacy issues and the fact that the open trial meant that people could find out what they were doing inside their home. Information disclosure was an important issue to him. He also preferred their previous energy supplier as he 'liked the Powershop app and liked to buy forward packages and specials and seeing the comparison to last year'.

You can leave your home but you can't leave your culture

This was particularly apparent with the flatmate in **House B**, who grew up and lived in Central and Northern Europe before coming here a little over a year ago. He often compared energy habits, technology and the building stock between the countries and generally thought New Zealand was 'far behind'. He often made reference to cultural differences and attitudes, particularly around heating. In New Zealand, most kids grow up with electric blankets but in centrally-heated Europe, they are a rarity. His views on their health effects are interesting: *"I never use electric blankets. They are just not very healthy, they dry out your skin. I never had one growing up, I'm not used to them."* He said he would like a central heating system. *"As kid we had a column heater in bedroom, and a Kachelofen¹⁴ for the whole apartment building, and it heated the whole house which was 100s of years old. My parents built it themselves, it was also a wetback and you could make Schweinsbraten in it (pork roast, an Austrian national dish). Every autumn we'd winch up 6m³ of wood for the Kachelofen for winter."* Another source of complain was about New Zealand water taps *"You burn your left hand and freeze your right hand, I just don't get it."*

The wife of **House C** (from the UK) also said: *"There is a thing about aesthetics. Wearing more layers inside is not nice, but so very Kiwi. They have this misconception of living in the tropics."* House C all love the new radiators, as it reminds them of what it was like in the UK, where they are from. They wanted the radiators and not infrared panels. The husband said *"I started Bikram yoga and I didn't like it and the infrared heat feels kind of like that. I also don't like big panels on the ceiling but we're used to seeing radiators in each room from the UK."* They actually now wanted to get rid of their old heat pump.

Where the Kiwis said they would have considered HRVs as the technology they would have invested in without the trial (if they didn't have it yet), the Austrian flatmate in **House B** was different, saying double glazing, underfloor and central heating and solar water heating would have been his preferred options: *"I don't believe in HRVs. I'd rather have underfloor heating. We heated the hot water for the whole house with just 4 panels. I don't know why we are not doing solar water heating here as well. There's no point putting the electricity back into the grid, you make hardly any money without a feed-in tariff. We need batteries to store it but environmentally, they're not great. They use a lot of resources, a Prius is a perfect example. It actually is worse for the environment than a normal, efficient car."*

¹⁴ Kachelofen: <http://en.wikipedia.org/wiki/Kachelofen>

All three households have previously lived in Europe and there were definite changes in behaviours based on different cultural norms and other contexts like infrastructure (see **House A**'s hot underfloor heating in Canada vs putting on more layers before turning up the heating in New Zealand). Another example was the flatmate in **House B** who bought a bicycle to commute but: *"I was so used to cycling in Holland but now I don't want to cycle. Here are no good cycling facilities, bad drivers, the husband of a colleague just got run over."*

Women are from Venus and Men are from Mars after all, at least when it comes to feeling the cold

It became very apparent, that the women occupants felt the cold more than the men, sometimes there were significant comfort differences (especially in **House A**). It is thus not surprising that the women felt a lot stronger about heating options and potentially losing control over them. For example, in terms of giving up manual control over appliances, the owner of **House B** said it would depend on the appliance. The washing machine really wouldn't bother her but the heater and electric blanket she wants total control over. Getting up early to hang the laundry out after a nightwash wouldn't worry her (but see her flatmate's refusal to do so). Comfort levels are most important to her, convenience not so much and she would definitely change her behaviour. In terms of what level of service they would be willing to sacrifice, the owner said everything but heating and she'd want money and information in return. The flatmate said he didn't really know what he'd sacrifice as he didn't believe he used much energy anyway.

The owners of **House A** said *"For a certain level of financial savings, we would be happy to give up control over certain appliances but not heating (although limiting it during peak times is OK) and the shower (especially for the wife). We had a bad experience with a landlord in London who turned off our heating but we are happy to do a lot of our own demand response interventions by remote control or turning of/down appliances when we're at home."*

The wife in **House C** also said she would be willing to give up control *"For the environment or to save money. But not to help Transpower!"* (NZ transmission system operator). All men in all three houses were more interested in being/staying in control and particularly using and setting up the technology, like the remote control Wemo and the iPad App. The Flatmate in **House B** said *"I want to be in control, I don't like others controlling my energy. I would like to automate, but I need to set the controls myself."* All men were also significantly more skeptical about the technology that was put in, particularly the PV. When contrasting how much savings each person estimated (a - from peak load shaving, b - in total, c - how much of the PV would be self-consumed), the men often had lower estimates (the Husband in **House C** was the only one who said he expected zero total energy savings, just more efficiency gains).

If it's not about me I don't care. Unless polar bears are drowning!

When asked about environmental impacts from energy production and use, the home owner in **House B** made the link between energy and climate change and climate change and increased natural disasters. Despite this knowledge she said *"This doesn't really worry me though, I don't have kids and it don't think it'll happen to me. I'd have a different outlook if I had kids because it would be more personal. I'd also want to educate them about it."* But when asked about how she felt about the impact on biodiversity and eg polar bears she said *"Oh, the polar bears really get to me, when you see them drowning on the ice floes. I love animals. I'm very concerned about the impact on the animals, I hate shark finning for example."*

All the other people claimed a stronger personal responsibility over not wasting energy for wider environmental reasons (as shown by their attitudinal answers).

Health can be a bigger driver than environment or money

The home owner in **House B** was not very driven by environmental concerns and said about her energy bill *"Before the trial I didn't care about wasting energy until I got the bill, but then I forgot again. Now I'm much more conscious, I really want to reduce my consumption."* However, health was a big consideration for her when buying her house: *"Our forefathers weren't really into warm houses, were they? They would have had a lot of problems with asthma and allergies. I actually bought this house for health reasons because I knew it would be good."*

Knowledge IS Power - but sometimes it's not enough

House A did not want to be contacted too often “Every 3 months sounds good, every month is too often” but they were very vigilant about getting information from their gentailer (see **Big Brother is watching you**). Both participants of **House B** wanted to be contacted very frequently, the owner ‘loves information’ and both are happy with email contacts. In terms of what other interventions they would be open to the owner said *“Anything, really. I am quite open to anything as there is a large knowledge/interest component for me now. This is a total shift that trial has done, it has really engaged me! I’m not a big gadget person but I really love the wemo on my cellphone. I really surprised myself.”*

The flatmate of **House B** claimed to be quite energy literate and thought a lot of energy appliances and installations and the building stock were sub-standard in New Zealand, compared with Central Europe where he grew up (probably true, to be fair). However, despite this attitude and self-professed knowledge of better options, he was very attached to his dangerous (both for health and fire safety) old gas heater: *“They removed the old gas death trap. It’s a shame cause it was nice, dry heat and I liked it, although I know it probably was a bit dangerous. I liked the open flame.”* (see also **‘Buttonpushers vs Pyros’**)

House C was very clear about how much and how often and what way they wanted their knowledge delivered. They would like to get a monthly 1-page dashboard, no newsletter or long emails just the key metrics that were explained to them beforehand. And they would like a 6-monthly winter/summer report to show the seasonal variability. They would also like to know how things will be evaluated and any iterations that occur. They said they need someone with continuity in the project to do the feedback, like SEA. The husband will only do behavioural changes if he knows why and what it will affect. There were some difference in the level of feedback that would be preferred by the husband and wife, also in House A and the flatmate in House B would want considerably less feedback than his highly engaged landlady (see **Feedback needs to be tailored**).

‘Buttonpushers vs Pyros’

As EECA research (2010) previously discovered, people seem to fall into two categories according to their heating preferences - the ‘buttonpushers’ who loved the convenience and ease of a heatpump where you could just push and on or off button and ‘the pyros’ who really loved to see open flames (woodburners and gas heaters). Our houses were no different, with people falling into the two categories. We already heard about **House B’s** flatmate’s attachment to the old dangerous gas fire and his landlady also said: *“I wouldn’t have put in the gas fire but I am stoked with it. I grew up with wood burner, so it’s nice to see the flames.”* (see also **Tradition is Everything** and **Seeing (Energy) is Believing**)

House C were also very happy with their new gas heater, so much that they wanted to get rid of their heat pump. The teenage son said *“It just feels warmer, it is faster to warm up. It adds ambience and comfort. I’m used to layering but I prefer walking around in my shorts and a T-shirt.”*

Who you are determines how much power you use

The **Energy Cultures** segments that each of the 3 households fell into were borne out not just by the average kWh use and number of appliances but also by the different attitudes and values that were looked at in this study. For example, the *Energy Efficient House A* had the strongest views on the environmental attitude questions (mostly 1s or 5s), the *Energy Easy House B* which claimed the least environmental values had more neutral views. When asked to rank the areas of most importance in terms of their energy use, House A said: money, the environment, smarts/capability and tradition/upbringing with habits being least important. House B said convenience, comfort, money and habits were most important, and the environment least. **House C**, the *Energy Extravagant* house (which also had the largest house and most inhabitants) said convenience, comfort and upbringing the most and cost the least.

Feedback needs to be tailored, sometimes to individual occupants, not just the household

A hugely emotive and impactful drowning polar bear image for one is a *“silly way of showing me how much energy I use”*, but for another it would stop her using the shower so much - this type of

feedback also definitely showed a gender difference as all the women would have been affected by it and changed their shower habits accordingly (see **Women are from Venus**). The husband of **House C** said he would set the Wemo to set dishwasher, washing machine to wash when the sun is shining. He was very skeptical about the website showing PV generation, which **House A** loved.

The wife said she would feel empowered when she received more information. The husband was rather cynical about the usefulness of feedback but wanted *“analysed data instead of raw data. Banks, telecoms etc should tell you what's best for you. Powerco should be ambivalent how much energy people use. They're even incentivised to make them use more. But they need to give people choice on health, comfort etc - that's all very important not just an on/off peak trial. I am not that bothered if it doesn't save money, because the house has already been improved. But we need ongoing monitoring and feedback to optimise it.”* The husband also liked graphs, time series and data whereas the wife liked the idea of Opower-style bills where it was simply shown if they were above or below the average compared with their neighbours.

Trust is really important - if you break it, you're in real trouble as it's hard to re-gain

Even though all participants were very engaged with the trial, worked for PowerCo and had close contact with the research team, there were some issues around trust and skepticism (the latter usually more pronounced by the men). The husband in **House A** was very skeptical about the return of investment of the solar PV system, which seemed to have been justified with the low winter generation. The flatmate in **House B** was also skeptical about the usefulness of the trial, PV and ToU pricing. He thought he was already doing pretty well. The husband in **House C** was skeptical of almost all the interventions, although he did enjoy 'new gadgets' and knew a lot about the new hot water heater which tied in with the central heating, solar PV and energy storage unit.

House B and C were also not happy with other intermediaries who sold them products that were not the most appropriate for their needs. **House B** was given LED lighting that was much too bright for the comfort level of the home owner, yet she had not been given a choice or much information about different types of lighting. **House C** was previously strongly marketed by heat pump manufacturers who persuaded them to put in the heatpump. After this trial, they realised that it wasn't that efficient or that good for their heating needs and they now want to get rid of it. They were also told they needed to upgrade their DVS mechanical ventilation system but *“We don't use it, it's rubbish. We were told we should upgrade but didn't listen. When it was disconnected during the retrofits it didn't really make much of a difference. It's just good for the hallway where we have no windows. When it didn't work it actually blew cold air in! We'd be interested to turn it off and see how much energy it uses.”* The large new hot water heating system also raised some comments: *“It's like we are brewing something in the cupboard upstairs, it's this huge technology. It's definitely bigger than just what we need, and it's also important to consider wider factors like what happens to the family.”* The wife said: *“We need to be able to trust the people the most who come into our home otherwise we will start questioning other things eg is 16C minimum the right temperature?”*

The wife of **House C** wasn't sure why the hot water cylinder had no insulation and initially thought that the material of the boiler meant it was insulated. When told that it was probably because the main consideration of the trial was peak load shaving, she exclaimed: *“That is such a pointy head researcher response, isn't it? It shouldn't just be about peak demand, if they make us do all this, they should tell us everything that we can do to save more energy and money, not just what suits them. They need to think about this from the consumer perspective or they'll lose our trust. Going forward they need to look at the whole combination of factors including conservation. It's all about knowledge and people will see you as being a more responsible provider if you give other tips. It's an important image to maintain.”* In addition she said *“I Need to be able to trust the trial to give me all the right advice, then I will happily do things for them. For me, the whole point is to be more energy efficient, not just off peak. You can't isolate it. You need to learn how to deal with the consumer which means not telling them just what you want but what they want!”*.

The three main lessons of the *PowerCo Smart House Trial*

1. We are not there yet but: Can or can't we make a significant technical shift in peak demand self consumption?
2. Every consumer, every intervention, every household has a different response, it is very complex. It's about the conversation the consumer wants to have, not what the market or government want to have. It is about finding the best solution for consumer and good compromises. This is a good learning.
3. We need to go beyond classical economics and BAU models, the world and the system is changing.

A story to conclude

Once upon a time...there were 3 households in New Zealand. One was very energy efficient, one was energy easy (not that interested or efficient) and one was energy extravagant.

Every day... they went about their business, one by saving energy, one by being comfortable and one by being comfortable and convenient.

But, one day... a clever research team from their employer, PowerCo, invited them to partake in a trial to change their energy technology and their energy-using habits.

Because of that... they were retrofitted with all sorts of clever technology - different heaters, clever water heating, smart meters and feedback devices and solar PV. One house even got some fancy new battery storage!

But then... they realised that putting in technology alone wasn't enough and they needed to also make sure that their research subjects were accepting of the new technology, and were using it wisely and didn't feel like they were left out.

Because of that... they collaborated with a bunch of behavioural researchers to work out more about their householders' motivations, attitudes, social norms, values and how to best change their behaviours.

So, ultimately... there was a very in-depth study undertaken on the 3 houses and its inhabitants, which gave them much more insight into the many opportunities and challenges that present themselves when doing proper, integrated DSM. It also showed many similarities and differences between the houses, their upbringing, their cultures and their attitudes and values.

But finally, it was also just as obvious that new technology and good feedback could actually lead to a 'moment of change' where suddenly, all the habitual energy use was being looked at more closely and rationally. Each and every one of the households changed their behaviours and used energy more wisely, more efficiently and more comfortably. **The end.**

Appendix 1 – Interview with the Programme Manager

What drove the Programme Manager to this intervention?

Peak demand, long term capital costs that can be reduced, to be able to quantify better, find the best technology, enact broader societal changes. PowerCo has a large CAPEX management programme, and needs to justify that the capital is used efficiently. But it is also about better consumer choices and cost structures, if it proves it's very difficult to switch to PV and ToU tariffs (which a lot of people assume), at least then they know. Secondary considerations are around technology adoption, especially PV. We need to know how does this work in the NZ context? These are investments for the next 40-50 years, we need to make sure they don't become useless. Right now, new smart meters need to be taken out if PV is put in. That is not very smart and could become a problem with wider rollout. What PowerCo does is publicly known to gentailers and other lines companies and research is shared. Commercial sensitivity is not the same as in a private company. PowerCo also want to affect the institutional/policy environment. A particular technical solution may look attractive for a centralised model, eg ripple control with PV - using hot water tanks as storage. This could change the way PowerCo operates in the electricity value chain.

How has the organisational culture affected design and implementation?

PowerCo has a monopoly status and the programme design was influenced by that. They have public disclosure needs for example around climate change and showing that they do sufficient work that shows alternatives or that they do the best thing they can. They also can work more closely with Universities and policymakers as they have no product IP that needs to be protected. Their shareholders are also consumers, so they need to give value back to local communities. Their main shareholders - the Queensland state pension scheme, infrastructure funds from PNP - are mainly in Australia and view them as a long-term asset, thus they want secure, low risk return. Some of the main stakeholders and direct customers are the gentailers (Generator/Retailer). Their mandate is a safe, secure, reliable electricity and gas network that's cost-effective. However, climate change policy also forces them to do things in the long term interest to consumers. DSM in New Zealand has happened for decades through ripple control, the way we have access to it in NZ is exceptional in scale. If there is a better way to offer DSM services, aggregators and retailers may change their services as well so existing ripple control may, for example, become less attractive. It is important for PowerCo to be cogniscent of all these potential changes.

How have earlier experiences influenced the choice for a particular intervention, the design and implementation of it?

An important question was how to interact with consumer inside their homes. How do changes in technology influence consumer behaviour? PowerCo manages extremes of the network grid, it is a huge cost to replace old lines - there is the question what about putting some of them on distributed generation instead? This is just a modular solution, it was rolled out to 10 consumers to date, to look at how that could work. It is enabled by the Electricity Act in 2010, which is not looking at physical lines supply but how to best deliver energy needs to the consumer and look at whole value chain (this was Green Party policy). It meant a big change, and hard work both for PowerCo and consumers. There is a grid-connected house in New Plymouth - the Fast Track house which included PV, storage, a controller to drop excess peak load, and it is automated completely. The home owner engineer at WELLS, he developed it himself. He had huge personal interest and knowledge already. The controller achieves a lot more than PV and energy storage - in the best case 30% peak shift, and total energy savings without storage are about 20%. So this shows what can be done in a best practice scenario.

More detail on the Model of Understanding (MoU)/Theory of Change (ToC) used here

The Models of Understanding Behaviour/Theories of Change (MoU/ToC) mentioned above describe behaviours and habits in different ways but in this research, we look at proxies of comfort (individual), thermal performance (physical), decrease in peak load/PV self use via changed behaviours (physical but a function of a set of actions that collectively represent behaviour) and investment behaviour (eg retrofitting and PV installation). Our end goal focuses on aggregate peak and PV energy use but monitors energy services on the hypothesis that, ultimately for a transitional

impact, we need to target specific energy services with new solution sets. The role of different contexts in their effective implementation of behaviour change is as follows:

- *Technology* – we are constrained by our material environment. Technology shifts may change the material environment.
- *Infrastructure* – the programme is run by an incumbent infrastructure owner aiming to see how best to deliver that infrastructure in the future and to ensure it adds value to the consumer. The programme aims to build on a locked in pathway in meeting future needs by co-opting emerging solutions.
- *Institutions* – the MoU notes incumbency of existing institutions re-inforced by norms, policies, standards, and the regulatory regime. The programme aims to provide information to see if the norms and regulations are constraining an alternate pathway and a change in institutional arrangements can open up better options.

The different drivers of *stakeholders/actors* is emphasised by these MoU/ToC with the programme focused on understanding consumer response potential, the impact on energy distribution businesses (EDBs) and then the appropriate messaging to regulators. The MoU/ToC are implicit across programme, but test planning includes an explicit literature review that explicitly draws on and references these models and theories.

Two factors drove considering **Energy Cultures** and **TIS** as the main MoUs. A very strong industry focus on **neoclassical economics** for decisionmaking means that the full energy need of consumers is not considered – PowerCo ‘research’ work on off-grid solutions flagged the need to address wider factors. Culturally, the ‘regime/industry’ is very well established and reinforced by a regulatory regime with a relatively common outlook. The MoU/ToC were used in the design, implementation and evaluation of the programme and they clearly added value by introducing reference points not common to the current EDB environment.

The MoU/ToC will be made practicable to DSM practitioners when discussing/reviewing the results from this programme. The **Energy Cultures** framework is easy to relate to and can operate at many levels (but has to have quantitative support). **TIS** is more complex when looking at longer term change that is harder to get a clear focus on.

Have these MoU/ToC and (other) social scientific insights of use?

The immediate usefulness is for the high level analysis that is going on. The **Energy Cultures** framework is really good, as it helps people like the PowerCo project manager to think much more widely than just the energy supply network, which is PowerCo’s immediate mandate. However, it can also of course be ammunition for people who say PowerCo shouldn’t move outside their comfort zone and immediate mandate. But PowerCo can’t change the energy system on their own, it is important to understand how PowerCo fits into the wider ecosystem. **Transition pathways** are interesting for economic planning for a 5-10y period. How can programme make sure we look across different levels - it needs to have a multi-level perspective, who are the incumbents in the existing regime, who are the niche companies or technologies and how can they evolve within the current industry and in PowerCo’s investment timeframes. Can we make quite substantial change? It is important to look at broader theoretical techniques and how they work within their planning horizons and to have tools to go beyond BAU.

What monitoring and evaluation metrics or key performance indicators have been used to evaluate the outcomes of the intervention?

Detailed time series and activity data on energy use and temperature (to proxy comfort), are supported by behavioural interviews. Studies will then correlate data through tests to comparable periods and other homes, where relevant, to assess impact and response. These are measured with: Temperature and moisture monitors, circuit monitors, electricity bills (kWh and price), behavioural interviews (attitudes, values, behaviours, knowledge, user experience, wider context). The **Energy Cultures** framework helps focus on what we do (very extensive test conditions and measurement data supports this), what we have (extensive technical data covers this) and what we

think (interview data covers this). **Neoclassical modelling** will further draw on extensive supporting pricing and costing data. **TIS** supports a focus on multiple actors including those outside the existing regime. A stakeholder inventory and analysis needs to ensure an appropriate level of work addresses the key actors. Liaison with regulators and the industry assists regime-level thinking. Interaction with other actors (suppliers) and some innovators is part of the programme and will be expanded on as part of the 'Helping the Behaviour Changers' research of the IEA DSM Task 24 extension.

What trade-offs have been made in terms of the scope of the project, elements addressed, and in terms of monitoring and evaluation?

Obviously, a statistically meaningful sample would have been optimal. But a lot of in-depth work was done instead on those 3 homes, to find the best options for the consumers in those 3 homes. Their opinions and wishes were taken into account. There were compromises in terms of what consumers could do if they were not overly financially constrained. The households are also PowerCo employees with a particular technical perspective which may not be the same when it comes to the 'average' Kiwi. But the people in the trial needed to have initial reasonable belief sets and commitment and provide a financial contribution. To roll this out on scale, we need to know what is the capital spent on infrastructure vs what can be offset by demand response? To do this, we need to look at the consumer service perspective rather than just network upgrades. As we don't yet know the answers PowerCo should look at these questions in more depth before doing BAU network investment. Then it can get a lot of co-benefits.

However, it also needs to be stated that there are competing activities including for R&D investment, the focus of this business means this is not an immediate priority. Reliability, better assets for the future, better information for the network are. These frameworks and models allow us to look longer term, at the value for the consumer and across the whole network. Particularly if assets are locked in for the long term, it's important to understand what happens with change. The smart grid change is big driver, there are lots of questions still. Community energy sharing enabled with smart meters and PV could be possible under the current pricing system. It won't be the same as the historic system, there is bigger risk to technology and a business model change including dealing with prosumers. This is not a negative risk, it could be really good both for prosumers and the network. But PowerCo need to think of the commercial model though and how to use their assets. For example, the network is built for cold winter peaks and would have to be set to cater for different peaks during the day. It is all about avoiding to waste infrastructure investment.

How successful is the intervention? In what terms? How has this been assessed?

The previous Fast Track pilot showed that significant technical interventions can make a big difference. But it also showed that different lifestyles need different solutions. The fundamental measure is reducing peak (% in kWh or ratio) - to make the load curve smoother; to support energy substitution eg underutilised gas networks; and to show what self-consumption level people can achieve with PV - how much do they export? It's hard to get it right economically without feed-in tariffs. But if people can achieve a higher level of self consumption, they will get confident to save more and more. It may shift the balance of making PV economical on a larger scale. Self sufficiency is a big issue for New Zealanders, for example a lot of them still grow their own veg gardens. Sharing PV with their immediate community may also be a big cultural driver for Kiwis. But it is important to put numbers around that, including the perceptions of homeowners, what motivates them, what do they like?

To what extent is the intervention useful for replication?

The pilot's idea is to check what can be replicated. There is going to be a learning curve, but NZ's ripple control, central heating in Nordic countries and other service offerings have shown you can get wide acceptance. There is no reason why, if we understand right motivations, it shouldn't be widely replicable. The demand control used in Fast Track could be really good on a wider scale. If we focus on certain consumer segments eg very large energy users who may not care about bill (the **Energy Cultures** 'Energy Extravagant' segment), they may well be the richest target in terms of peak load shifting potential.