# The HomeSmart Home case study

Beacon

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# The HomeSmart Home: A third demonstration home

Another live research project, the HomeSmart Home was a collaboration between Beacon and the New Zealand Housing Foundation, a charitable trust dedicated to assisting low-income households into their own homes.

Beacon's HomeSmart Home guidelines were tested in the design and construction of the home. These provide advice and instruction on creating a new home which will meet the benchmarks of Beacon's High Standard of Sustainability.

In addition, the aim was to show that relatively simple and cost effective features can improve both the performance and the affordability of a home.

Affordability is a key issue for the Housing Foundation. They aimed to a comfortable and healthy home, where the household could also see the benefits of energy and water efficiencies. The HomeSmart Home tested the use of such features for future Foundation housing projects.

## *Monitored in real-life conditions*

Not only was the house designed and built to meet strict performance goals, it was extensively monitored in real-life conditions. As the family of six living in the house went about their day-to-day lives, the performance of the HomeSmart Home was remotely monitored.

Data was collected on energy use, water use, rainwater collection, temperature, indoor air quality, humidity and moisture levels. It has provided sound scientific proof of the benefits of living in a sustainable home.

Interviews with the family gave good feedback on their experience of the house.

# The path to the HomeSmart Home

## *Inspired by the two NOW Homes*

The HomeSmart Home followed on from Beacon's two demonstration sustainable homes, in Rotorua and Waitakere. Each home was lived in by families and monitored, as 'live' research projects, aiming to show that sustainable homes can be achieved now with existing designs, materials and products.

Beacon used the performance data of these homes to develop and test the High Standard of Sustainability, a set of benchmarks for a high performing, sustainable home.

## *The New Zealand Housing Foundation*

The HomeSmart Home was developed in partnership with the New Zealand Housing Foundation.

The New Zealand Housing Foundation is a not-for-profit charitable trust that assists low- and mid-income householders to buy their first home through shared ownership and home equity programmes.

Shared ownership involves first home seekers purchasing around 75% of the value of the property with the Housing Foundation purchasing the remainder. The new home owner can choose when and if they wish to purchase more, or the house can be sold and the profit used to purchase their own home outright.

In home equity programmes a household occupies a Housing Foundation home and pays a market rent, and the Housing Foundation helps the household through advice and support to clear its debts. Over time, the household gets 75% of the property's increase in value to use to buy their own home.

With philanthropic funding from the Tindall Foundation, the Housing Foundation was able to pilot this project and fund the additional features to review their cost effectiveness and benefits for their housing on a wider scale.

## *Designing the HomeSmart Home*

The HomeSmart Home amended a standard Housing Foundation design using Beacon's HomeSmart Home guidelines and with advice and guidance from Beacon's research team.

The house was built by Goldsmith Developments Ltd as part of the Housing Foundation's West Coast Road subdivision in Glen Eden, Waitakere, Auckland.

It was completed in 2009 and a family of six moved in to the house in September 2009.

**"The HomeSmart Home uses simple, proven designs and technologies in combination to address the whole house. We believe that sustainable homes are not just about energy efficiency: they are about using water wisely, creating a healthy indoor environment, selecting renewable and recyclable materials, and reducing construction and household waste."**

## The HomeSmart Home at a glance

Its simple features include:

- A design which faces the north with lots of windows on the northern side
- High levels of ceiling, wall and floor insulation, much higher than in the Building Code
- U-PVC framed and double glazed windows to keep the heat in and the noise out
- Grid-linked solar power system capable of producing in excess of 2100kWh per year.
- 4-star rated heat pump hot water system
- Water efficient taps, toilet and appliances
- A rainwater tank to collect and reuse rain
- Greywater system to supply toilet
- Ventilation of moisture in the kitchen and bathrooms
- Passive ventilation to keep down moisture and avoid overheating
- Good natural light in all rooms combined with LED lighting

### The statistics

- The HomeSmart Home is a two storey home with a double garage
- It has 4 bedrooms, 1 bathroom and 2 toilets
- It has a floor area of 160 m2 (including garage)
- Valued at around $410,000 at the time of construction in 2009.

## Layout and design

The HomeSmart Home is based on one of the New Zealand Housing Foundation's standard designs, adapted to take into account Beacon's HomeSmart Home guidelines. Adaptations included improving the thermal envelope and adding energy and water efficiency features, rather than major changes to the design.

### *Designed for the sun*

Housing Foundation homes are generally designed for the sun and this house is no exception. The house is sited on a 'zipper lot' that orients the house to the north for solar gain. The section features a southern boundary 'zero lot line' that maximises northern outdoor space.

Additionally the HomeSmart Home's layout places living areas and bedrooms on the northern face of the house with the garage to the south. Most of the home's windows are along this northern side with no windows facing south.

### *Layout*

The HomeSmart Home is a two storey building with kitchen, living and dining areas on the ground floor together with a toilet. The second floor has four bedrooms and a bathroom. The overall floor area is 160m$^2$. The house has a weatherboard and brick exterior with Colorsteel roofing.

Internal doors are used to isolate the entry area from living areas to minimise heat loss and to shut the living areas off from the rest of the house. There is internal access to the double garage.

The external heat pump hot water system, water tanks and greywater system are located at the back of the garage away from direct contact with living areas and bedrooms. The laundry is in the garage with direct access to the backyard utility area.

## What the family noticed

With two teenage sons, teenage lodger, and baby, the family appreciated the four bedrooms and built-in closets. Although they described the bedrooms as "not too cramped", they noted that the main bedroom was only slightly bigger than the others. The large back section was also considered a plus.

The double garage was highly valued but not for its use by cars! In their previous house, the family only had a carport so it was a major plus to have a big garage. It was a place to put the boys' bikes and weights set, and to keep things dry. The family's comment: "You can never have enough storage space." At Christmas the family put a table tennis table in the garage, which doubles as a rumpus room and was reportedly great for the boys.

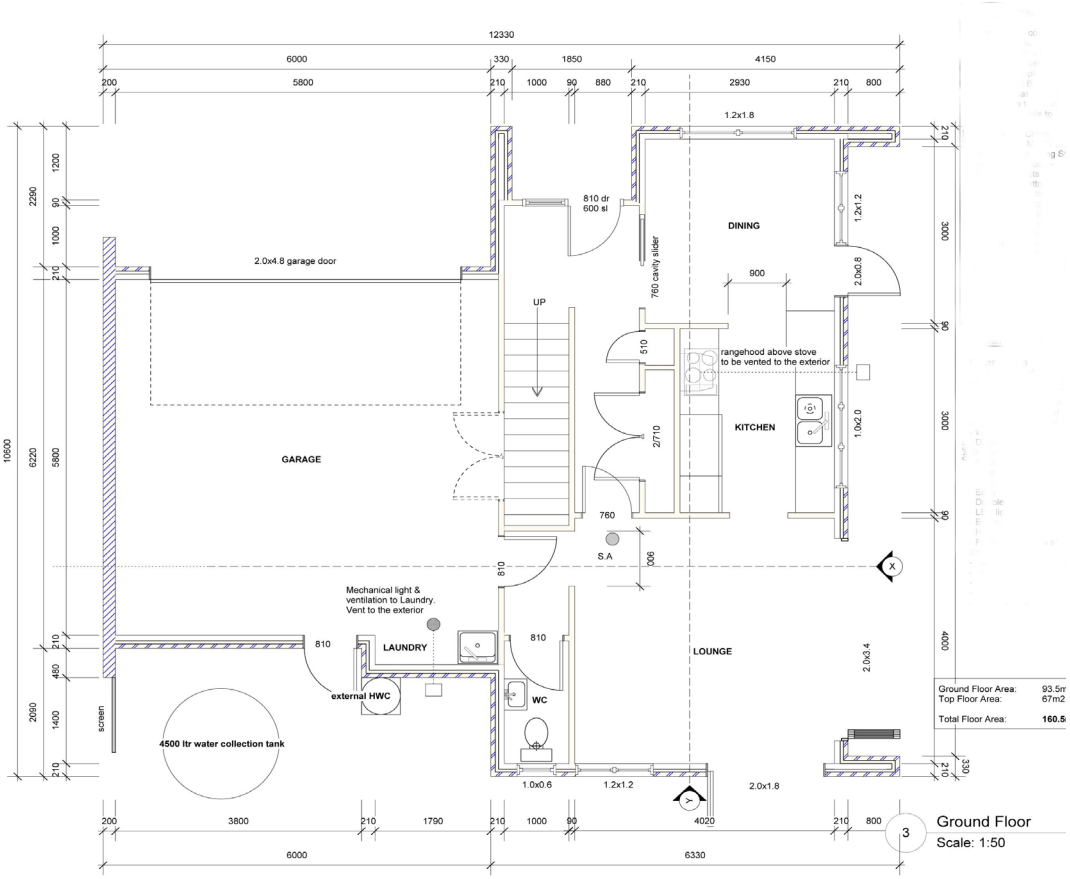
While the house was considered to be a good size, the homeowners felt that the downstairs area needed to be more open plan. Rather than separate living, dining and kitchen rooms, they thought these areas could have been combined into a more open plan and functional space.

The location of the downstairs toilet next to the lounge was questioned - it reduced the size of the lounge further, as well as creating privacy issues. Privacy was also in issue with the family keeping curtains closed in the downstairs windows facing the street.

## *Our comment*

The design and layout of a home is not only important for solar gain; it impacts on how people feel about a home, and its effective function. A more open plan layout would increase the amount of usable space on the ground floor, losing less room to circulation.

As can be seen from the ground floor plan, the double garage takes up a lot of space. In this case, its relatively large floor area could be reduced to a single car size, reallocating the floor area to living space/ storage. This would provide a better-insulated, more appropriate space for family activities.



## Healthy living indoors

### *Passive solar design*

The HomeSmart Home is designed with living areas and bedrooms on the northern face of the house and the garage to the south. Most of the home's windows are along this northern side with no windows facing south. This maximises use of the sun's warmth while minimising heat loss through the relatively cool southern windows.

### *Insulation*

The HomeSmart Home's walls and ceilings were well-insulated with R4.6 insulation (inserts and a blanket) in the ceiling and R2.6 insulation in the external walls. The concrete floor however, was a rib raft floor with edge insulation only. Rib raft floor have been shown to be poor thermal performers in BRANZ testing.

### *Preventing heat loss through windows*

Most of the home's windows are along the northern side with no windows facing south. Northern windows were U-PVC-framed and double glazed. Thermal curtains were used to further prevent heat loss.

### *Getting rid of damp*

Ventilation is very important, especially in Auckland, to get rid of indoor moisture. A ventilation fan in the HomeSmart Home's bathroom was linked to the light switch, and the stovetop was ventilated by a rangehood.

### *Passive ventilation and summer cooling*

The HomeSmart Home featured a low profile, roof mounted solar powered ventilation vent with on-off switch. This was placed at the top of the stairwell to catch rising heat. Large windows could be opened in all living spaces and bedrooms, with the upstairs windows able to be left open on security stays. The north face of the house was designed with an overhang to shade the lower storey windows. Thermal curtains are equally useful for keeping hot summer sun out.

## How the house performed

### *Temperatures*

The improved thermal envelope (heavy insulation, double glazing) reduced heating requirements and energy draw to virtually nil, meaning that the house was warm, dry and healthy throughout winter. Double glazing with low emissivity glass is a better option again, at the very least in bedrooms and, if possible, the main living area.

A portable electric heater and the lounge inset heater were used initially to keep the newborn baby warm, but subsequently the heaters were not used at all.

The HomeSmart Home was warm and healthy in winter with an average 19°C in the living room, and 18°C in the bedroom. This met Beacon's High Standard of Sustainability benchmarks of 18°C in living rooms in evenings and 16°C in bedrooms overnight.

The average daily temperature in winter was higher in the bedroom than the living room. This is unusual in New Zealand homes, where living areas are more likely to be heated, and is likely to be because the upstairs bedrooms both receive more winter sun, and because the stack effect means that heat rises.

In summer, the home tended to be too hot, with temperatures above 25°C common.

### *Humidity*

The humidity levels in the home averaged 62% in the living room and bedroom, meeting Beacon's High Standard of Sustainability benchmarks of between 40-70%.

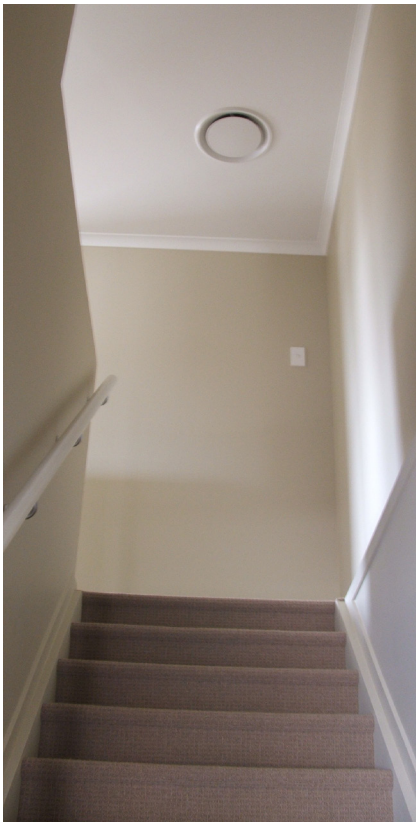
The living room had consistently higher humidity than the bedroom in both winter and summer. This can be partly explained by the higher temperatures found in the bedroom during winter (warmer air can hold more moisture and thus has lower relative humidity). However, the other contributing factor was that the rangehood was not externally vented, increasing moisture levels in the adjacent living area.

## What the family noticed

The family found the house to be very warm. Due to the very young age of the baby, they had at first used both a portable electric heater and the lounge inset heater to keep the baby warm but, after this initial period, the heaters were not used at all. The family's last house was described as a 'fridge box' so the warmer winter performance was a highly valued feature of the home.

The high levels of insulation and double glazing meant they didn't need to heat the rooms and the kids didn't get sick any more ("they were always getting sick in the last place which was damp and cold").

The family did find that the house overheated in summer, particularly upstairs, where it was difficult to sleep at night at the hottest times. The family ran the solar powered stack vent continuously, and left the upstairs windows open permanently during summer; however, these were limited in their ventilation ability as security stays prevented the windows from opening very effectively. Ventilation through the living room doors (which don't open fully) and a lack of shading into the living area were also considered problems, and the family intended to install additional shading ahead of the next summer.



## *Our comment*

It is pleasing to see the effect of a well-insulated thermal envelope on the need for heating, and therefore the running costs for the homeowners. It shows it is possible to meet both temperature/humidity benchmarks and energy use benchmarks.

Summer overheating could be addressed by providing deeper eaves for shading on both upstairs and downstairs windows. Future designs could consider high windows which can be left wide open without security stays or alternate window designs with a smaller, separate upper opening which was secure to leave open for natural ventilation.

While the humidity results are very pleasing as humidity levels are difficult to control in the very humid Auckland conditions, the living room at times has relative humidity levels which are on the high side of what is ideal. It is likely that the unvented kitchen range is a significant source of moisture into the living room and that if that it been externally vented, relative humidity levels in the living room would have been lower. Other improvements should include an opening window and an externally-vented fan in the laundry.


# Energy efficiency

## *Using free energy - Energy generation*

The HomeSmart Home featured a grid-linked solar power system capable of producing in excess of 2100kWh per year. The system is made up of three main components: solar modules, inverter and array frame. The solar modules comprise eight Sharp 175W 24V panels with a total surface area of 10.4m2. The panels, mounted at an angle of 28° facing north-west-west, are fastened onto the roof using a Conergy solar array frame. The DC power produced by the solar panels is fed into a SMA Sunny Boy 1700 inverter which converts the energy to 240V AC. The resulting energy is connected to the switchboard in the house and then either used to meet the power needs of the home, or fed to the grid.

## *Using less energy*

### Space heating

A small wall-inset electric heater in the lounge is the only space heating provided in this house. The HomeSmart Home relies on solar passive heating combined with good thermal envelope insulation for retaining warmth.

### Water heating

A 310 litre Rheem heat pump hot water system with a 4 star energy rating provided water heating. This is an all-in-one system with the cylinder and heat pump together in the utility area at the back of the house, below the bathroom and not far from kitchen and laundry. This system was eligible for Energywise heat pump water heating grants and in the North Island, can save up to 62% of the energy used by a conventional electric hot water cylinder.

### Appliances

The HomeSmart Home is equipped with energy efficient appliances - a 4 star washing machine, 3.5 star dishwasher, and a 4 star fridge/freezer.

### Lighting

Energy efficiency was also a consideration when planning the lighting. With large north facing windows in living areas and bedrooms, the house has good natural light where it is needed. LED light bulbs are used throughout except for the kitchen where halogens are used for task lighting. Most importantly, there are no downlights inset into the thermal envelope - downlights are only used in the bottom storey where heat cannot be lost through the ceiling.

### Standby system

The HomeSmart Home featured easy reach switches and a remote control to turn off appliances on standby.

## How the house performed

### *Overall energy savings*

The HomeSmart Home was an exceptionally low energy home, exceeding Beacon's High Standard of Sustainability reticulated energy use benchmarks by 1910kWh, with a very low 3980kWh per year.

It compares particularly well to Beacon's other monitored homes, the Waitakere NOW Home (7400kWh/year) and a typical group builder home in Rangiora (14400kWh/year).

### *Free energy*

The photovoltaic system generated nearly a third of the electricity used in the home, about 2000kWh per year. This amount was about what was expected based on Auckland's predicted solar radiation, indicating that the system was optimally installed. The occupants directly used 1000kWh, while the rest was returned to the grid.

Generation was greatest in summer, where the photovoltaic system was providing more than half the electricity used in the house. Over winter, generation dropped back, and with the increased lighting, heating and hot water requirements, the contribution from the photovoltaic system to total electricity sourced was considerably less.

### *Keeping the house warm*

The improved thermal envelope (heavy insulation, double glazing) reduced heating requirements, and energy draw, to virtually nil. A portable electric heater and the lounge inset heater were used initially to keep the newborn baby warm, but subsequently the heaters were not used at all.

Monitoring showed that the house was warm throughout winter, and met the High Standard of Sustainability benchmarks for living room and bedroom temperatures.

### What the family noticed

The homeowners appreciated the significant cost savings and noted the house was very cheap to run. Compared to an average house in Auckland, the savings could have been as much as $1625 per year from the energy efficiency and generation measures.

The family were particularly happy with the performance of the heat pump hot water system - even with two teenage boys in the house, they had no problems with hot water running out. In addition, they believed the hot water system was a big contributor to the lower power. However, they felt that a split system (with the hot water cylinder located in the garage) would be a better option - less heat loss from having the hot water cylinder outside, and better aesthetics.

While the family valued having the LED lighting, they felt it could have been better located for greater effectiveness to light up the bench area as task lighting, rather than its more general use. More natural lighting was needed in the hall and stairwell, with a Solatube a suggested solution

## Our comment

### *Low energy and healthy*

The HomeSmart Home has shown that it is possible to have a warm, dry, healthy home which is also low energy-using and affordable to run. The combination of improved insulation and double glazing, good solar design, energy efficient lighting, appliances and water heating, and energy generation have made this home an affordable long term proposition for the homeowners.

The improved thermal envelope (heavy insulation, double glazing) had a substantial benefit - both in reducing the heating requirements to near nil, and meaning that the house was warm, dry and healthy throughout winter. Double glazing with low emissivity glass is a better option again, at the very least, in bedrooms and if possible the main living area.

LED or compact fluorescent lighting is a particularly simple energy efficiency improvement. LEDs have become more available since the HomeSmart Home was built and use 85% less electricity than an incandescent or halogen built. They can save $100-$300 in running costs over the life of the bulb.

### *PV system*

In terms of simple cost benefit, the photovoltaic system cost $19,000 installed, and generated $530 of electricity per annum - giving a simple payback period of just under 36 years. This will come down as the price of photovoltaic systems is decreasing and residential power prices have risen almost 50% since the year 2000 with no indications that the increasing price trend will not continue.

Unfortunately, in New Zealand, excess electricity produced by a photovoltaic system cannot reverse flow through the meter and instead bypasses it, which means the homeowners are not getting the financial benefit of electricity exported back to the grid.

### *Heat pump hot water*

The heat pump hot water system saved significant amounts of electricity. The HomeSmart Home system cost $6000 installed. Based on the current 'per unit' electricity rate of 26.6c/kW, then the payback period would be similar at 12.5 years. However, since the HomeSmart Home was built, heat pump hot water systems have come down in price - and cheaper, better performing systems are available.

When installing heat pump hot water systems, watch out for:

1. Noise - the unit is noisy and shouldn't be located outside bedrooms - or neighbours' bedrooms
2. Hot water pipe lagging and heat loss from outdoor cylinders. It's important to lag hot water pipes and ideally wrap cylinders.
3. Size of your household. Hot water heat pumps perform better with frequent draw-downs of water. They're not an ideal technology for small, low-hot-water-using households.

## Water conservation

### *Using less water*

Appliances in the HomeSmart Home were chosen for water efficiency, using the WELS rating system. These included a 4.5 star dishwasher and a 4.5 star washing machine.

Likewise, shower, toilets and taps were water efficient. The 4 star toilet has a 4.5/3 litre dual flush option. Taps were 3 stars while the shower head was also 3 stars.

### *Using free water*

The HomeSmart Home reused both rainwater and greywater. The 4500 litre rainwater tank was plumbed for garden use, while the EcoPlus greywater system supplied the toilet. The greywater system was used by the family for 243 of the 257 monitored days with the family switching the system off when they left the house for several days.

## How the house performed

### *Reducing the effects of stormwater*

As well as reduced impermeable area in the landscaping and the rainwater tank, the HomeSmart Home featured a rain-garden to filter stormwater.

### *Overall water use*

Water use in the home was modest at an average of 117 litres per person per day. This met the High Standard of Sustainability benchmark for reticulated water use of 125 litres / person / day.

### *Water re-use*

On average, the greywater system saved 23 litres of water per person per day, removed 115 litres of wastewater per day from the waste stream and used 68 kW of electricity over a one year period. It is estimated that the greywater system reused about 30% of the total greywater produced by the household on an annual basis. Use of the greywater system saved the HomeSmart Home 42m$^3$ of water, which corresponds to an annual saving of approximately $182 for the household.

## Our comment

Despite having both rainwater and greywater systems, no alternative water supply was provided for the laundry or shower - yet these account for about 50% of total water use in the home on average. In Auckland, rainwater systems are a good option, and should be plumbed to at least the washing machine and toilet as well as for garden watering, with a larger tank size in order to optimise the financial benefit to home occupiers. As a consequence of less than optimal tank size and location, the HomeSmart Home did not benefit as much as it could have from the rainwater tank and had a higher per person water use than either the Waitakere or Rotorua NOW Homes.

The greywater system resulted in significant water savings, although it was also a user of electricity. Running the greywater system requires 68 kWh of energy. Based on the unit rate of $0.266 per kWh, the cost to be offset is about $18. Additional expenditure associated with the greywater system includes chemical treatment of the water. Recommended in the owner's manual of the system is the use of two standard calcium hypo-chlorite tablets per week with an estimated cost of around $45 per year. On balance, the greywater system produces an overall annual financial benefit to the household of $120. The greywater system cost approximately $3,745 excluding installation. Based on these calculated savings, the simple payback period on this system is at least 32 years.

Because of the substantial water shortages in Australia, there is no additional cost for water efficient fittings and fixtures with a 3 star showerhead, 4 star toilet and 4 star taps all able to be purchased for the same price than inefficient models. Because there is no extra cost, and a direct financial benefit in relation to water and wastewater costs, as well as electricity costs in the case of shower heads, water efficient fittings and fixtures should be a standard selection for an affordable homes.

### What the family noticed

The greywater system was a success. Despite an early malfunction which was repaired under warranty, its use and maintenance was straightforward. The homeowners quickly got into a regular routine of putting the chlorine tablet in once a week when they put the rubbish out.

The rainwater tank was less successful. In the early days, watering the new lawn, combined with the drought over the 2009/2010 summer in Auckland, meant the rainwater tank was quickly exhausted, and not replenished. The family also found the low location of the tap for the rainwater tank difficult, and suggested it needed to be put up on a base to get better flow from the gravity feed, as well as more easily access the tap to use the water.


# Living in the HomeSmart Home

## *Cost of living*

Being energy and water efficient has really benefited this family which loved having a house that is cheap to run. They noticed big differences on their power bills compared to previous homes and credited the PV system and heat pump hot water system.

The cost savings were significant - compared to an average house in Auckland, the savings could be as much as $1625 per year from the energy efficiency and generation measures.

## *Health benefits*

While the homeowners' last house was described as "a fridge box", the HomeSmart Home was warm and cosy. So cosy in fact, that they needed very little extra heating.

As a result, the family has enjoyed better health. Previously, the boys had often been sick and snuffly, and asthma inhalers were used regularly. Now, the inhaler wasn't needed at all and no-one had been sick since arriving in the house. The father commented that "now we know the baby is teething when he is out of sorts" (instead of being cold or sick).

## *Changing their lives*

Living in the HomeSmart Home has been good for this family. Its location, close to extended family and in a strong local community, has given them a sense of security and day-to-day support.

The experience of living in the HomeSmart Home has had a lasting impact on the family's behaviour and awareness. Living in an energy efficient home made conserving energy normal, and having water and energy meters in the home helped both adults and teenagers to watch - and manage - their consumption.

After receiving an early high water bill (from watering the just-sown lawn), the family made an effort to keep their water use down. Consequently, there had been a gradual reduction in water use over time.

The family's general awareness of the environment has increased, including power usage and greenhouse gases. One of the adults noted that, until a few years ago, they had not cared about "what we eat or consume, but lately I have been more focused on what we consume. Now I am keen to grow our food and control what we eat, and to see the impact on mine and my family's health".

The family plans to grow some of their own food in the garden, using the rainwater tank water to water the garden when it has enough water in it, and they compost their kitchen waste.

Being in the house has influenced the family; one of the adults reported that before arriving he was aware that they needed to reduce their carbon footprint and look at what they ate and so on, but "coming here has helped us to do it - by having a 'green house' I can make a difference". He noted that "before it was just an idea to compost etc, but this made it a reality, it was all done for me and made it easier to do".

## Their next home

The HomeSmart Home has changed what the family would look for in future houses. They would look for a home which is warm and well insulated, with double glazing, good ventilation, open plan layout and space, plus with a split system, efficient model, hot water heat pump. In terms of any future neighbourhood, the family would look to live close to extended family and in strong local community.

If the family purchased the HomeSmart Home under the New Zealand Housing Foundation's scheme, they would look at the following improvements:

- moving the stove to the outside kitchen wall
- making the living areas open plan
- connecting the pathways outside of the house (currently there are unconnected concrete slabs in the back yard)
- sitting the rainwater tank on a higher base (the outlet is currently too close to the ground and more pressure is gained if it sits higher)
- removing carpet from the dining room (there is carpet throughout the house except for vinyl in wet areas)
- putting a splashback around the oven's stove top (these little features actually have quite a big impact over time on the house)
- moving the toilet from being adjacent to the lounge (this took up valuable lounge space and raised privacy issues).

## The neighbourhood

The HomeSmart Home was part of a nine-home New Zealand Housing Foundation development off West Coast Road in Glen Eden.

The home is close to the Glen Eden shopping centre which includes supermarket, banks, post office, medical centre and chemists. The area is well-served by several bus routes to both the City and local hub, Henderson, and the Glen Eden train station.

The family enjoyed having extended family nearby - "the kids love having family close, they can play close by." They believed their family's wellbeing was also enhanced by living close to family and strong relationships with neighbours.

## Find out more about Beacon

Our website includes all the research undertaken in Beacon's original government research contract, and information on current research and projects.
www.beaconpathway.co.nz

Check out our Facebook page:
www.facebook.com/beaconpathway

Check out the Beacon Blog
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### *About this Report*

Reference
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