The Papakowhai Renovation case studies

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The Papakowhai Renovation project

The Papakowhai Renovation project, in Porirua, was aimed at improving the performance of New Zealand's existing houses. It asked:

> *How can we make any house, whether built ten, twenty or fifty years ago, more energy efficient, more water efficient, healthier to live in and more affordable for its occupants?*

The Papakowhai houses were renovated with the goal of meeting the performance benchmarks of Beacon's High Standard of Sustainability in energy and water efficiency, and indoor environment quality (temperature and humidity). The project tested what steps need to be taken to reach these benchmarks and how to do so in the most cost-effective manner.

Whole of house renovation

The project was the first demonstration of our 'whole of house' approach to renovating New Zealand homes. Our focus goes beyond energy to improving the sustainability of the whole house. We believe a home's total performance reflects an inter-dependent web of features and design.

If one area only is addressed, it may compromise the performance of other aspects of the home. For example, high water use has energy implications - approximately 30% of typical New Zealand household energy consumption is spent heating water. We believe the health and environmental benefits of improved indoor environment, reducing waste to landfill, and the cost savings of water conservation (directly to homeowners if it is metered, or through their rates if it isn't), are equally important.

What did the project involve?

Nine houses in Papakowhai were selected as case studies, representative of New Zealand homes from the 1960s and early 1970s, a major home building era in New Zealand, with a legacy of about 400,000 homes. Housing in this era is known to be difficult to retrofit for energy efficiency.

The houses, all owned by the occupiers, were located in a middle income suburb of Porirua, and included a variety of house design and sizes. Houses with a Rateable Value of more than $410,000 were excluded.

Although the project commenced with early monitoring of the ten houses, one house was subsequently sold and the new homeowners were not keen to be part of the project.

Before any changes were made, the nine houses were all monitored for energy and water use, temperature and humidity, and the amount of waste produced. This data was compared to post-renovation data to evaluate the effects of the changes.

In the first part of 2007 the homes were renovated with energy, waste and indoor environment quality improvements. Each home had a different combination of features installed to allow comparison of their effectiveness. The aim was to identify the combinations of renovation options which are:

- the most cost effective
- easy to implement
- applicable to a range of house types and regions
- able to significantly improve how well the homes perform in energy efficiency, water conservation, waste minimisation and indoor environment quality.

The homes were then monitored for 15 months following the renovations to enable a clear comparison between the before and after performance of the homes.

The renovation packages

Each house was renovated with a different package of features addressing energy, water, indoor environment quality and waste. Some houses were brought up to a High Standard of Sustainability, while other houses had more modest interventions. This enabled researchers to compare alternative features and combinations of features to identify the best performance and cost-effectiveness.

The renovations ranged from relatively non-invasive, easy-to-install features, such as:

- ceiling insulation (R2.6) and underfloor insulation (R2.0)
- draught stopping
- compact fluorescent lightbulbs
- hot water cylinder wrap
- mechanical ventilation for kitchen and bathroom,
- venting of dryers to the outside
- low flow shower heads and flow restrictors on taps
- dual flush toilet

to measures aimed to make greater gains in the sustainability of the home. These may include:

- maximum insulation (especially to living spaces, bedrooms and south wall)
- double glazing
- solar hot water system or instant gas hot water
- efficient wood burner
- flued gas heater
- pellet burner with wetback
- heat pump
- heat transfer system.

Of the simpler measures, researchers assessed what each house already had. It is positive to note that few of the houses needed compact fluorescent lightbulbs, flow restrictors or dual flush toilets – they were already in use.

Beacon's High Standard of Sustainability

The High Standard of Sustainability sets benchmarks in five key performance areas:

- Energy
- Water
- Indoor environment quality
- Waste
- Materials

Demonstration projects such as the Waitakere NOW Home and now the Papakowhai Renovations project help to define these benchmarks. As more is understood about how to make houses perform better, the benchmarks can be further refined.

The original High Standard of Sustainability was published in 2006, and revised in 2008. The analysis in these Papakowhai Renovation case studies comments on the comparison to the 2008 benchmarks.

Beacon's High Standard of Sustainability 2008

Reticulated energy use

Climate zone 1	Climate zone 2	Climate zone 3
New homes: 5800 kWh/year	New homes: 6300 kWh/year	New homes: 7300 kWh/year
Existing homes: 6200 kWh/year	Existing homes: 7300 kWh/year	Existing homes: 8400 kWh/year

Reticulated water use

125 litres per person per day

Indoor environment quality

Average temperature

- Living room 5pm-11pm in winter >18ºC
- Bedroom 11pm-7am in winter >16ºC

Average relative humidity

- Living room 5pm-11pm in winter 40-70%
- Bedroom 11pm-7am in winter 40-70%
- Surface relative humidity <80% all year round

Checklist

- Mechanical extract ventilation of kitchen, bathroom and laundry
- Means to passively vent dwelling
- No unflued gas heaters
- Ground moisture barrier under house
- No indoor clothes drying.

Waste

- A maximum of 2.6 tonnes per house or 16kg/m^2 of construction waste
- Construction wastes separated for collection
- Waste management plan produced for site in accordance with REBRI guidelines
- Provide space in kitchen for organic collection - 5 litres minimum capacity
- Provide space for non-organic recycling bins in or near kitchen - 20 litres minimum capacity
- For detached dwellings on suburban lot sizes, provide space in garden of at least 1m^3 for organic composting. For sites of 250m^2 or less, provide worm farms, communal composting or kitchen waste collection.

Materials

Choose materials which

- Promote good air quality, e.g. through use of Environmental Choice certifed paints and finishes
- Have minimal health risks during construction or renovation
- Are durable and have low maintenance requirements
- Are re-used existing or demolished building materials or which can be easily re-used
- Are made from renewable or sustainably managed resources
- Have low embodied energy including impact from transport
- Make minimal impact of the environment (air, water, land, habitats, and wildlife)
- Have third party certification (e.g. Enviromental Choice, Forestry Stewardship Council).

House 1

Before renovation

House 1 belonged to a family with a preschooler and a primary school child. It was a typical 1970s split-level three bedroom house with a living area of approximately 120m^2. It had a skillion corrugated iron roof throughout with low value original insulation (approx R1) over upper two levels, and a mixture of sheet and weatherboard cladding around the outside. The lower storey had a concrete slab floor, while the upper floors had a timber suspended floor with a concrete perimeter wall. The windows in all rooms except the master bedroom were timber-framed and single glazed, and draughts were noticeable at times.

A woodburner was used to heat the open plan living areas in winter, while oil column heaters were used to heat bedrooms two and three.

The family found the house cold in winter, particularly in the children's bedrooms. They wanted to save money and create a healthier home for family members suffering from asthma.

The renovation package

House 1 received a medium sustainability package which included:

- lowering the skillion ceiling and installing R4.6 insulation
- insulating the suspended floor with R2 foil-backed bulk insulation (NOTE: this product is no longer recommended)
- installing a ground moisture barrier
- draught stopping the door to the garage
- adding R1.1 hot water cylinder wrap and 15mm pipe lagging
- replacing the older woodburner with a pellet burner
- ducting a heat transfer system into bedrooms 1, 2 and 3
- using compact fluorescent bulbs for main lights
- a plumbing maintenance check.

After renovation

The renovations made little change to electricity use, dropping from 301 kWh/week to 297 kWh/week. Overall energy use (which includes the wood or pellets) dropped from 332 to 305 kWh/week.

The extra insulation did improve indoor temperatures but not enough to meet healthy World Health Organisation temperatures.

The average temperature in the family room was only 15.7ºC and the bedroom average was 14.3ºC.

With still cold overnight temperatures, humidity during winter was also highest at night and morning reaching over 70% while the average winter humidity over 24 hours was measured as 67.88%.

What the family found

The family were pleased with the winter temperatures although they quite correctly still described the children's bedrooms as cold.

The pellet burner has been successful in warming the living areas – the family describe it as extraordinarily efficient, convenient, 'guilt free' and safe. In fact, they increased the level of warming in the family room, running the pellet burner from 4 pm to 10.30 pm in winter. They did, however, find that the pellet burner was noisy and felt that costs of pellets were high.

Our analysis

When this home's performance is measured against the benchmarks of Beacon's High Standard of Sustainability, it could still perform better for the family.

Using the pellet burner more often and for longer raised temperatures while energy costs stayed the same. However, despite the increases in temperatures, both the family room and the main bedroom remain too cold. Warmer indoor temperatures would be reached by draught stopping windows, using thick curtains and pelmets, adding wall insulation and double glazing windows, especially south-facing windows.

Humidity, the percentage of moisture in the air, is recommended to be between 40% and 70%. Humidity levels were tested in July and found to be above 70% three-quarters of the time. In cold temperatures, the moisture settles on cold surfaces such as un-insulated walls, ceilings and windows as condensation. Condensation and cold are the perfect conditions for growing mould. Increasing indoor temperatures and getting rid of indoor moisture (installing a kitchen rangehood and bathroom extractor fans would be a good start) will keep mould down and make the home healthier for asthma sufferers.

The household's electricity use remains high at around 11,000 kWh per year. The benchmark for electricity use is 7300 kWh per year. Installing a solar water heater would reduce water heating costs.

Apart from the plumbing check, no measures were undertaken in this house which would be expected to impact on water use. The household average per person water use was a fairly high 287 litres/pp/day compared to the benchmark of 125 litres/pp/day. Replacing the full flush toilets with dual flush toilets would address this.

House 2

Before renovation

House 2 was a two-storey colonial-style house belonging to a semi-retired couple. This four bedroom home had a coated metal tile roof and a mixture of weatherboard and sheet cladding. The windows were timber throughout, with the exception of three new aluminium windows in the master bedroom, which was recently extended by around a metre. The lower storey was smaller than the upper storey, and backs onto a bank. The upper storey had timber suspended floors, while the lower storey had a concrete slab floor. The living areas and three of the four bedrooms are upstairs. The living area was approximately 140m^2.

Fibreglass batts were installed throughout the ceiling cavity at least 24 years ago, and only the master bedroom had wall and underfloor insulation. The home still retained its original electric low pressure hot water cylinder, which was located within the ceiling cavity. The house was heated with a wood burner, and oil column heaters downstairs when adult children are home.

The householders reported high levels of humidity requiring a dehumidifier. They wanted to reduce energy costs, and also liked the idea of an 'eco-friendly' renovation.

The renovation package

House 2 received a basic renovation package. Insulation levels matched standards from Environment Canterbury and Ministry for the Environment energy retrofits, with the addition of improvements to indoor environment quality.

The renovation included:

- upgrading ceiling insulation to R2.6 and re-laying dislodged existing insulation
- insulating the suspended floor with R2 foil-backed bulk insulation (NOTE: This product is no longer recommended)
- laying ground moisture barrier
- adding R1.1 hot water cylinder wrap and 15mm pipe lagging
- adding an extra fan added to the heat transfer kit, and shortening ducting
- installing a new cat door to stop draughts from a broken cat door to the garage
- fixing a broken extraction fan in the bathroom
- using compact fluorescent bulbs in high-use light fittings.

After renovation

Temperatures in the family room and main bedroom improved significantly as a result of the measures. Average winter temperatures in the family room increased by 1.6^{o}C. Average winter temperatures in the main bedroom increased by 1.1^{o}C. However, temperatures were still low with an average temperatue in the family room of 16^{o}C, and a bedroom average of 15^{o}C.

Overall, the household used significantly less electricity to heat their water with a reduction of 11% in hot water energy use during winter. This contributed to an overall reduction in electricity use of ~6% over winter and ~35% over the whole year.

What the householders found

The householders have found the house to be much warmer – in fact, even warmer than the measurements suggest. Despite leaving the doors open, the family room is easily heated and they believe that they are receiving more benefit from their enclosed wood burner.

They have found the basement drier and can walk around the house in bare feet without becoming chilled. They put this down to the under-floor insulation which they would have installed earlier if they had known the benefits. They have given away their dehumidifier as they no longer need it. However, the householders removed the polythene ground cover in the basement after a previously unidentified site drainage problem caused water to build up on top of the polythene.

Our analysis

The household's electricity use is low at around 4900 kWh per year compared to the benchmark for electricity use of 7300 kWh per year. The lower power bills may also reflect changes in occupancy with adult children moving out of home. We would suggest replacing the old hot water cylinder with a heat pump hot water system.

While the temperature increases are good, both the family room and the main bedroom remain below the High Standard of Sustainability benchmarks. The average minimum winter overnight temperature was 13.4ºC in the main bedroom, and the average 24 hour winter bedroom temperature was only 14.2ºC. We suggest further improving the home's indoor temperatures by extending insulation to the walls, topping up the ceiling insulation to maximum levels and adding thick thermal curtains and pelmets. We also suggest replacing the old wood burner with a modern low emission wood burner, and installing a heat transfer system to take heat to the bedrooms.

Humidity, the percentage of moisture in the air, was found to be above 70% a third of the time. The polythene ground cover would have been effective in preventing moisture coming up from the ground into the house – a common cause of damp and mould. However, wider site drainage problems meant that stormwater going under the house ended up ponding on top of the polythene. The best option here would be for the stormwater to be diverted and the drainage problems to be sorted, as this moisture will continue to rise into the house.

Apart from the plumbing check, no water efficiency measures were undertaken. The average per person water use was 220 litres/pp/day compared to the benchmark of 125 litres/pp/day.

House 3

Before renovation

House 3 belonged to a young family of five. Built in the 1970s, the house contained a large open plan living and dining area, and kitchen on the upper floor. Upstairs were three bedrooms, a large foyer, bathroom and toilet while downstairs there was a laundry, toilet, and offices. The living area was approximately 120m^2 excluding the office space.

The exterior cladding was a mainly weatherboard and sheet cladding, with concrete block around the addition. The lower floor had a concrete slab floor, while the upper floor had timber suspended floors. The corrugated iron roof was in poor condition and was partly skillion, partly cavity. The windows were single-glazed in unventilated aluminium frames, which were badly degraded and in need of replacement.

Interestingly, the walls contained batts which appear to have been installed when the house was being constructed, yet the roof was uninsulated until the new owners installed R2.6 batts in the ceiling cavity over the bedroom wing. The skillion roof above the living areas and the underfloor area beneath the bedroom wing were uninsulated.

The house was heated with two heat pumps, a large unit upstairs and a smaller less efficient unit downstairs in the offices. A fan heater was also used in the offices. A wood burner was occasionally used in the lounge but had rusted under a leak, and the childrens' bedrooms were heated with oil column heaters. There was a heat transfer system from the lounge into the master bedroom. The hot water cylinder, while being under a decade old, was too small for a family of five at 135 litres capacity.

The family wanted to increase indoor warmth and improve energy efficiency. They felt the house had problems with noise, cold and excessive condensation.

The renovation package

House 3 was renovated with a high thermal retrofit including:

- lowering the skillion ceilings and insulating with R3.6 insulation
- replacing the roof and relaying existing insulation, R2.6 insulation put over top and over ceiling joists to remove thermal bridging
- insulating the suspended floor with R2 foil-backed bulk insulation (NOTE: no longer recommended) and laying a ground moisture barrier
- stripping, re-insulating and re-lining walls of thermal envelope to R2.4
- installing a new MEPS compliant woodburner
- replacing windows with standard clear double glazing and standard frames.
- installing an evacuated tube solar hot water system and 300L cylinder
- installing a kitchen rangehood
- a plumbing maintenance check, dual flush toilets, and flow restrictors in showers.

After renovation

Temperatures in the family room and main bedroom improved significantly as a result of the measures. Average winter temperatures in the family room increased by 1.7ºC and were above 16°C for most of the time. Average winter temperatures in the main bedroom increased by 3.8ºC - the temperature most often recorded in the main bedroom before renovation was 14ºC; after renovation, it was 19ºC. The heavy insulation and double glazing has helped retain the warmth in this home from the use of your wood burner and ducted heat pump system. The temperature increases occurred even though the efficient heating sources produced substantial reductions in heating energy use.

Humidity levels were found to be within acceptable range all of the time which is great.

The family's electricity use reduced considerably - largely as a result of the installation of the solar hot water system, the heat pump central heating and the improved thermal performance of the home. Overall, they used significantly less electricity to heat their water with a reduction of ~55% in hot water energy use during winter. They also used less ~62% less energy to heat their home. This contributed to an overall reduction in their electricity use of ~33% over winter and ~9% over the whole year.

The installation of the solar hot water system resulted in the family increasing their hot water use by 21%. Low flow shower heads have minimised the extra water use, and the free solar water heating has kept power bills low.

Our analysis

The household's electricity use is still moderate at around 9024 kWh per year. The benchmark for electricity use is 7300 kWh per year so further improvements could be made.

As a result of the improvements, the indoor winter temperatures meet our High Standard of Sustainability benchmarks of a minimum of 16ºC overnight in bedrooms and 18ºC in the evenings for family rooms.

As well as the plumbing check, dual flush cisterns were also installed in the home. The family's average per person water use was low at 125 litres/pp/day compared to the benchmark of 125 litres/pp/day.

Summer time temperatures increased quite a bit, resulting in the family using their heat pump system for cooling. However, this may negate their electricity savings - we suggest installing movable sun shades on western and northern windows, and passive vents or security stays to allow windows to remain open during summer for cooling

The ground moisture barrier stops dampness rising into the house from the ground, and the rangehood was installed to get rid of moisture-laden air from inside the house. Addressing indoor temperatures and moisture sources has reduced condensation and mould, making a healthier home for the family. We suggest a bathroom extraction fan would assist with the removal of indoor moisture.

House 4

Before renovation

This home was built in 1976, and was the only house with a fully concrete slab floor in the study. The roof was concrete tile, and the walls were mostly stucco on sheet material, with a partial brick veneer on the front of the home. The house contained three bedrooms, ensuite, separate laundry, toilet, bathroom, and a living room, dining and kitchen area. It had a detached double garage.

The ceiling cavity had been renovated with batts in the past decade or so, but the batts have been inappropriately placed at some stage. The walls remained uninsulated. The house had single-glazed timber windows throughout.

The fixed heating in the house was an enclosed flued gas heater in the lounge and an unflued gas heater in the hallway.

Change in plans

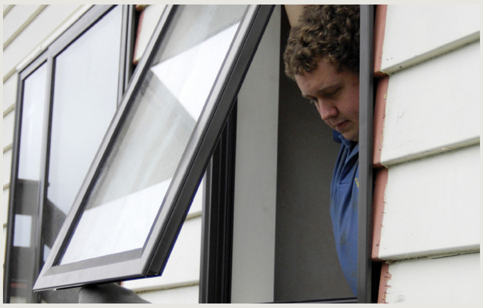
At the start of the project, the owners - a retired couple - were keen to participate as one of them had serious health conditions. However, there was a change of ownership of this house and the new owners declined to take further part in the project.

Elements of a high energy retrofit at Papakowhai

Ceiling, underfloor and wall insulation to higher than Code minimum levels

Ground moisture barrier made of polythene to stop rising damp.

NOTE: this photo shows foil backed insulation under the floor - this is no longer recommended



Double glazing

Efficient solar water heating with lagged pipes and wrapped cylinders

Efficient heating (low emission wood-burners, heat pumps) with heat transfer systems

House 5

Before renovation

House 5 belonged to a retired couple. It was single storey with three bedrooms, living room, and open plan dining and kitchen. There was an ensuite, a separate toilet, bathroom and laundry. The house was clad with brick in the east, and weatherboard on the rest of the house. The timber-framed windows were in good condition, apart from the stays which lead to draughts. The house had a metal tile roof. The majority of the floor of the living areas was suspended timber, apart from the concrete slab floor of the lounge and the attached garage.

This house had its roof insulated and hot water cylinder wrapped in an EnergySmart insulation renovation from the Hutt Mana Energy Trust a couple of years earlier. Some insulation was found in the garage walls but the underfloor is uninsulated. The home was heated with a flued open gas fireplace in the lounge and a convection heater in the dining room.

The householders were keen to make their home warmer.

The renovation package

House 5 received a standard thermal retrofit with instant gas hot water and a heat transfer system. With a low occupancy house, the use of a 'heat on demand' system will reduce heat loss from hot water cylinders and save energy.

The major features installed were:

- topping up ceiling insulation with a R1.8 blanket.
- insulating timber suspended floors with R2 foil-backed bulk insulation and laying ground moisture barriers
- replacing electric storage hot water cylinder with gas instant hot water units, one a high efficiency condensing model, at the two service areas
- draught-stopping sliding door
- installing ducted heat transfer system to move warm air into hallway by bedrooms
- installing a low flow shower head and a plumbing maintenance check
- ducting bathroom extraction fan to outside rather than into the roof cavity
- using compact fluorescent bulbs in high-use light fittings and replacing old inefficient recessed kitchen lights with CA-rated halogen downlights.

After renovation

Overall, the improvements in house performance were relatively minor. Average winter temperatures in the main bedroom increased by 0.6°C. but family room average temperatures didn't change. There was a ~1°C increase in the most common temperature experienced in winter in the family room and bedroom - the family room moved from 14°C to 15°C, and the bedroom moved from 13°C to 14°C.

Humidity levels were found to be above 70% over half of the time.

The household's electricity use reduced by 35%, largely as a result of the change in hot water system to instant gas hot water. A reduction in space heating energy was seen as a result of the thermal improvements making the home easier to heat. However, this efficiency was largely taken back in the second winter which often happens when householders can warm their houses more effectively.

What the householders noticed

The householders felt the house was warmer, even though the monitored temperatures did not increase by much. They felt that insulating underfloor and in the ceiling had made the most difference.

The new low flow shower head gave the impression of using less hot water, masking their increase in hot water use.

Our analysis

This home received a limited renovation, and its performance, as measured against the benchmarks of Beacon's High Standard of Sustainability, could improve.

The household's combined gas and electricity use remains high at around 12,500 kWh per year. The benchmark for electricity and gas use is 7300 kWh per year.

Despite the increases in temperatures, both the family room and the main bedroom remain below the High Standard of Sustainability benchmarks. The average minimum winter overnight temperature was 13.4ºC in the main bedroom, and the average 24 hour winter bedroom temperature was only 14.2ºC. It is quite common for occupants to feel that temperatures have risen more than they actually have after insulation retrofits. This is because we are sensitive to draughts, air movement, humidity and temperature which determine how cold or warm we feel. Further heat could be retained by draught stopping windows and installing heavy thermal curtains and pelmets.

No heating improvements were made in this home; however, it should have performed better for warmth with (old) wall insulation, moderate ceiling insulation and heavy under-floor insulation. This appears to confirm that an efficient heating system is needed alongside insulation, to get both long term energy efficiency and healthy temperatures. We suggest the next priority for this household would be an efficient heating system, possibly a heat pump in the bedroom.

Humidity, the percentage of moisture in the air, is high and we suggest installing a rangehood in the kitchen to remove moist kitchen air, in addition to heating the home more.

Apart from the plumbing check, no water efficiency measures were undertaken in this house. The household's average per person water use was 195 litres/pp/day compared to the benchmark of 125 litres/pp/day.

House 6

Before renovation

The sixth house, owned by a semi-retired couple with adult children often at home, was built in the 1970s, and had a living area of approximately 190m^2. The house was mainly of timber-framed weatherboard construction, with some sheet cladding around the lower part of the house and concrete block around the family room extension. The roof was concrete tiles, and the foundations were concrete slab beneath the garage and family room, and timber suspended floors under the rest of the house. The ceiling cavity was insulated throughout, but the insulation was patchy and poorly laid. The house also had downlights throughout, creating holes in the insulation throughout the house, and causing additional heat loss. Most of the underfloor and the walls were not insulated.

The home was heated with a woodburner in the family room, oil column heaters in the bedrooms, and a portable LPG heater which was moved where it was required.

The householders wanted to improve the warmth and dryness of their house and increase its liveability into their retirement. One bedroom was persistently damp and cold, and had affected the health of a daughter sleeping there.

The renovation package

House 6 was originally to be the control house for the project with no interventions at all. However, as House 4 changed hands and was no longer part of the research, House 6 received a basic ceiling top-up, the equivalent of earlier government subsidies. Data from this house enabled us to show that the basic subsidised level of insulation was not adequate to improve homes and has helped us to lobby government for higher subsidised levels. The top-up included:

- topping up the ceiling insulation with R2.6 to reach approximately R4.0
- wrapping the hot water cylinder and lagging the hot water pipes.

After renovation

The most common temperature experienced in winter in the family room and bedroom remained at 14ºC. The most common temperature in the master bedroom dropped a degree - moving from 14ºC to 13ºC. The drop in temperature was a result of less heating with the house being uninhabited for some of the time. While the house had some insulation improvements, these alone won't make a house warm, but they will help keep heating from escaping outside the house.

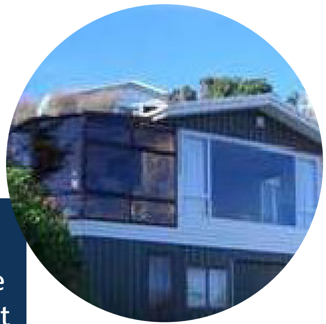
Relative humidity remained below healthy levels, and this dwelling performed worst of all of those in the study in relation to both humidity and temperature.

The household's electricity use did reduce (11%) - largely as a result of reduced hot water use and changing occupancy. Total annual reticulated energy reduced from 7100 kWh/year to 6300 kWh/year.

What the householders found

Unsurprisingly the household found little improvement from the basic top-up of insulation, but some small improvements in water heating costs from simply wrapping cylinder and pipes. They were relying on electric blankets and spot heating as they felt they couldn't heat the house adequately. They were disappointed not to have had a more extensive renovation.

The householders tell us what they really need is information on how to improve the comfort and energy efficiency of their home. They were prepared to spend money to put the house right but wanted to know what interventions were likely to give them the greatest 'bang for the buck'.



Our analysis

Although limited, this basic renovation has been useful in showing that even a simple and cheap intervention, such as lagging pipes and wrapping cylinders, can have an effect on power bills. Equally, to get healthy indoor temperatures, much more than ceiling insulation is required.

Both the family room and main bedroom remain below the High Standard of Sustainability benchmarks. The average minimum winter overnight temperature was 13.7°C in the main bedroom, and the average 24 hour winter bedroom temperature was only 12°C. We suggest the next step for insulation is the walls, starting with the main bedroom and the lounge, then any south-facing bedroom which will be occupied. Where the exterior walls are concrete block, installing polystyrene insulation will help prevent heat escaping through the wall into the bank from the family room. This can then be rendered with plaster. Draught stopping windows and using thick thermal curtains are relatively cheap ways of preventing heat loss through windows.

This household significantly under-heats the family room, even in the evening, with only minor increases in temperature. We suggest the household upgrades their heating, by either using their wood burner more, or looking into buying a heat pump. A heat transfer system can take the heat from the room with the wood burner to the bedroom, provided that the wood burner is used more often so there is excess heat to be transferred. Alternatively, install a new efficient wood burner in a more central room in the house, so that the heat is better spread around the house.

Relative humidity levels were tested in July and found to be above 70% almost all of the time. There are a range of things which we think are contributing to the dampness of this home. As well as needing more insulation and better heating, 25-30kg of moisture rises up from the ground underneath a house every day - a polythene ground moisture barrier can stop this at relatively low cost. It is also important to get rid of moisture from bathroom and kitchen use - a rangehood in the kitchen will vent that moisture outside. The family's unflued LPG heater will also be adding a lot of moisture as well as a range of toxic gases such as carbon monoxide and nitrogen oxides to the home. We strongly recommend the household get rid of this heater.

House 7

Before renovation

House 7, owned by a couple, was built in the 1970s. The occupants had replaced most of the older aluminium windows in the upper part of the house with 10mm laminated glass and new frames to reduce noise and provide better insulation. Downstairs, the windows were a mixture of timber and aluminium frames, all in poor condition. The house had a ventilated concrete perimeter wall, suspended timber floor upstairs, and an uninsulated concrete slab floor downstairs.

The ceiling cavity was insulated with Code insulation in the living areas, and there was blown insulation in varying condition throughout the rest of the house with many holes for halogen downlights. Only the walls of the living areas and one bedroom were insulated, and the underfloor area was uninsulated. The living areas were heated with a large, new, enclosed woodburner in the lounge. A heat transfer system had been installed to pull warm air from the lounge up to the top of the hallway by the bedrooms.

The householders wanted to achieve a warmer house which they describe as being like a 'fridge'.

The renovation package

House 7 received a moderate to high thermal retrofit with some small scale heating, hot water and ventilation improvements:

- topping up the ceiling insulation with R2.6, and tidying up existing insulation
- adding R2.4 wall insulation in bedroom wing.
- insulating timber suspended floors with R2.0 foil-backed bulk insulation (NOTE: no longer recommended) and laying a ground moisture barrier
- adding R1.1 hot water cylinder wrap and 15mm pipe lagging
- relocating the thermostat for the existing heat transfer system to the lounge rather than the hallway and extending the heat transfer system into bedrooms
- ducting the bathroom extraction fan to outside and installing a Showerdome
- a plumbing maintenance check.

After renovation

Temperatures in the family room and main bedroom improved significantly, with average winter temperatures in the family room increasing by 1.1°C, and in the main bedroom by 1.0°C. The most common temperature in the family room both before and after renovation was 13°C, although the coldest temperatures occur less often. The most common temperature in the bedroom dropped from 13°C to 12°C, although the frequency of higher temperatures increased.

The ceiling and under-floor insulation has helped retain the warmth in this home from the use of the wood burner. The temperature increases occurred without any increase in the amount of wood used.

Relative humidity levels were above 70% more than three quarters of the time. While there was some improvement in relative humidity levels as a result of improvements made (removal of bathroom moisture, ground moisture barrier), levels are still high, probably because of the cold temperatures normally found in the house.

The household's electricity use reduced noticeably - partly from the improved efficiency of the hot water system from wrapping the hot water cylinder and lagging the pipes and the changes in occupancy. Overall, they used significantly less electricity to heat their water with a reduction of 30% in hot water energy use during winter. This contributed to an overall reduction in their electricity use of ~20% over winter and ~17% over the whole year.

What the householders found

The householders noticed that they spent less on electricity, and believe it's because they didn't need to use their dehumidifier in winter. The heat transfer ducting has spread more warmth to the master bedroom than they expected, although they report that the family room temperature is much the same.

Our analysis

This family's electricity use is fairly low at around 7000 kWh per year, compared to the benchmark for electricity use of 7300 kWh per year.

Despite the increases in temperatures, both the family room and the main bedroom remain below the High Standard of Sustainability benchmarks. The average minimum winter overnight temperature was 12.4°C in the main bedroom, and the average 24 hour winter bedroom temperature was only 14.7°C. We suggest the household replaces single paned glass in modern aluminium frames with double glazing, and installs heavy thermal curtains and pelmets.

A well designed heat transfer system makes a big difference to cold bedrooms. To get the best effect, however, it is important that the main living room is adequately heated, so there is excess heat to transfer. Like so many New Zealand homes, this one appears to be underheated. We suggest considering a secondary heating source for the bedroom if the woodburner is not running enough - a wall mounted electric panel heater or heat pump are potential options.

We suggest the household upgrades their hot water system by adding a heat pump hot water heater - models are available which can use their existing A grade cylinder.

House 8

Before renovation

House 8, belonging to an adult couple and their university student daughter, was constructed around 1965. The house was split level, with the higher part, used for a gym, added in 2004. The gym included two double glazed windows and a part-concrete slab, part-timber suspended floor on an enclosed concrete block footing.

The lower part of the split-level downstairs area had timber-framed windows and a timber suspended floor. The majority of the windows had recently been replaced with tinted single glazing with aluminium frames. There was ceiling insulation throughout, with holes for recessed halogen lights in the bathroom and the living areas. The walls were uninsulated, aside from the exterior walls of the downstairs gym. The underfloor was entirely uninsulated.

Underneath the house, subsidence around the new addition had caused a clay downpipe sump to break, leading to a small stream of water trickling under the house and pooling. A waste pipe under the house was also leaking a little.

The home was heated with two nightstore heaters, one in the hallway of the bedroom wing upstairs, and one in the rumpus room downstairs. There was underfloor heating in the family room.

The family wanted to achieve capital gain on their property as well as reduce their energy costs through solar water heating. The home was also quite damp, with three dehumidifiers operating.

The renovation package

House 8 received a moderate to high thermal retrofit with a solar hot water system and some other small scale improvements, including:

- re-laying ceiling insulation and adding a second layer of R2.6 over existing insulation and across ceiling joists to r raise insulation to approx R4.0
- adding R2.4 insulation to the rear wall of bedroom 4 and gym
- insulating timber suspended floors with R2.0 foil-backed bulk insulation (NOTE: no longer recommended) and laying a ground moisture barrier
- installing solar water heater with 300L cylinder
- fitting double glazing panes into existing aluminium frames
- installing a showerdome to address condensation and mould in bathroom
- a plumbing maintenance check.

After renovation

Temperatures in the family room and main bedroom stayed the same; however, the home required substantially less energy to heat. The temperature most often recorded in the family room both before and after renovation was 18°C. The most common temperature in the bedroom increased from 16°C to 18°C.

Relative humidity levels were found to be above 70% about a fifth of the time. Given that the significant moisture sources in the home (bathroom, kitchen and under-floor) were being managed, these relative humidity levels can be explained by the low temperatures and drying clothes indoors. With the extra insulation in this house, the main bedroom got substantially warmer in summer - we suggest shading of northern or western windows, as well as window opening for cooling.

The solar hot water system meant the household used significantly less electricity to heat their water with a reduction of 70% in hot water energy use during winter. Despite no changes in how the home was heated (two electric night store heaters and an under-floor heater), they used 15% less energy. The ceiling and under-floor insulation and double glazing has helped retain the warmth from the family's heaters inside the home. These factors contributed to an overall reduction in their electricity use of ~33% over both the winter period and the whole year.

What the householders found

The family reported a marked improvement in the comfort of their home. They needed to heat the home less and noticed significantly reduced electricity usage despite increasing hot water use. The house is drier too, with reduced use of their dehumidifiers. An additional benefit for the family has been peace and quiet.

Our analysis

The family's electricity use has reduced to 13,400 kWh per year but this is still high with their electric heating a big contributor. The benchmark for electricity use is 7,300 kWh per year. The night store and underfloor heaters are big users of electricity so we suggest they install a heat pump, pellet burner or wood burner.

The temperatures in this home in winter are still lower than the High Standard of Sustainability benchmark. The average minimum winter overnight temperature was 14.4ºC in the main bedroom and the average minimum winter evening temperature in the living room was 16.2ºC. The decreased heating in the second year may be a type of "reverse takeback", where the household decided to revert to the pre-retrofit temperatures and comfort, and gather further energy and cost savings from reduced heating. Further gains could be made in heat retention by installing heavy thermal curtains and pelmets, draught stopping remaining wooden windows, and installing wall insulation - starting first with the bedroom and south facing walls.

Our strongest suggestion is that the family stop drying clothes indoors. This is a major source of moisture in a home, and may be a reason why they need to use their dehumidifiers so much. We also suggest the family upgrade their bathroom extraction fan so that it is ducted to the outside.

The household's average water use was 265 litres per person per day compared to the High Standard of Sustainability benchmark of 180 litres per person per day.

House 9

Before renovation

House 9, with a single occupant, was a typical two-storey townhouse, built in 1976. The downstairs was clad in sheet material and had a concrete slab floor, while the upstairs was clad in fibre cement weatherboards and has a timber suspended floor. The windows were all single-glazed with older aluminium frames. There was a concrete block firewall between the two townhouses on the western wall. The roof was concrete tiles. Upstairs contained an open plan kitchen, dining and family room area as well as two bedrooms, a bathroom and a laundry. Downstairs had a single internal garage below the master bedroom, a large rumpus room and an unused sauna.

The walls and ceiling of the house were insulated with low levels of older batts, while the underfloor area remained uninsulated.

Heating included a fan heater in the master bedroom, a portable halogen radiant heater, and a fan heater downstairs in the rumpus room.

The householder wanted to increase the warmth of the home, reduce cold-related health problems and reduce energy costs.

The renovation package

House 9 received a moderate thermal retrofit with some other small scale improvements, including:

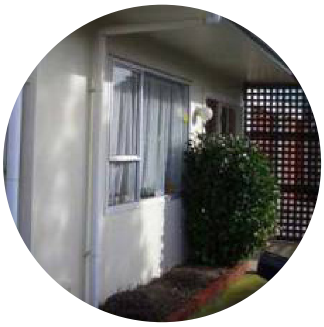
- putting a layer of R2.4 batts over existing insulation and ceiling joists to remove thermal bridging, raising insulation to approximately R4.0.
- insulating timber suspended floors with R2.0 foil-backed bulk insulation (NOTE: no longer recommended) and laying ground moisture barriers
- installing mid-floor insulation between the garage and master bedroom
- installing wall insulation on rear of wall to underfloor and garage
- installing a Showerdome to address mould in bathroom
- installing a heat pump
- draught-stopping the sliding door to the garage
- adding R1.1 hot water cylinder wrap and 15mm pipe lagging
- using compact fluorescent bulbs in high use fittings.

After renovation

There was little change in average temperatures in the family room and main bedroom although the home required less energy to heat. The most common temperature in winter in the family room, both before and after renovation, was 16°C, and the most common temperature in the bedroom remained at 15°C. In both rooms, however, there has been an increase in the frequency of warmer temperatures, and a decrease in the frequency of colder temperatures.

Relative humidity levels in the home, while at times elevated, were normally within an acceptable range in the main bedroom.

The hot water cylinder wrap was the main contributor to energy efficiency from the renovation. However, other changes in the occupant's use of the house, such as the extent of heating, resulted in more energy being saved than the hot water cylinder wrap achieved. Overall, the householder used significantly less electricity to heat their water with a reduction of 21% in hot water energy use during winter. This contributed to an overall reduction in their electricity use of ~20% over the winter and ~12.5% over the whole year.



What the householder found

The householder noticed lower electricity bills, which was attributed to lower hot water energy, and was pleased with the warmth indoors during winter. He reported having fewer colds. The householder was satisfied that winter temperature problems have been resolved but found that the house overheats in summer. Cooling actions undertaken were mainly opening windows; the heat pump was not used for cooling. The householder reported that he would look for good insulation and double glazing in any future homes, and that the experience had taught him the value of trapping the sun.

The Showerdome reduced mould in the bathroom and the householder reported that he didn't need to use as much hot water.

Our analysis

Electricity use has reduced to 4,900 kWh per year which is quite low and compares well to the benchmark for electricity use of 7300 kWh per year. Further reductions in electricity use could be made by upgrading the fridge/freezer and chest freezer with a modern, energy efficient appliances, and by installing a solar hot water system.

The average minimum winter overnight temperature was 15.5ºC in the main bedroom and the average minimum winter evening temperature in the living room was 16.9ºC. Temperatures didn't fluctuate much inside the home as a result of the ceiling, wall and floor insulation keeping the temperature relatively even throughout the day and night. The temperatures in this home in winter are still lower than the High Standard of Sustainability benchmark, mainly because there is not adequate heating. We suggest installing double glazing, or secondary double glazing, on southern windows to further retain heat. To reduce overheating, we suggest installing shading (such as an awning) on western windows.

Relative humidity levels were only above 70% occasionally - about a tenth of the time - and are linked to cold indoor temperatures.

Average water use was 193 litres per person per day, compared to the High Standard of Sustainability benchmark of 125 litres per person per day.

House 10

Before renovation

House 10 belonged to a family of five and was built in the early 1970s. The family had progressively been relining parts of the house, and had installed double glazed window units in the children's bedrooms.

The upper level of the house was clad in sheet materials with timber-framed windows. The floor of the living areas was concrete, while the rest of the upper level had timber suspended floors. The lower level had a concrete slab floor, and concrete walls.

The ceiling cavity had some older insulation which had been lifted and piled up in places leaving large areas without insulation. The walls were uninsulated apart from downstairs, where battening and new plasterboard lining had provided an air gap which provided a small amount of insulation to the concrete walls of the downstairs bedroom or rumpus. The floor was uninsulated throughout. The house was heated with an older recessed enclosed woodburner in the lounge, and oil column heaters in the bedrooms.

The family were most concerned with cold, damp and mould in the home.

The renovation package

House 10 was renovated with a high thermal retrofit with efficient heating and a solar hot water system, including:

- insulating and lining the flat roof above foyer with R3.6 mid-floor batts
- putting two layers of R2.6 over old insulation and ceiling joists.
- stripping walls, insulating with R2.4, and re-lining
- insulating timber suspended floors with R2.0 foil-backed bulk insulation (NOTE: no longer recommended) and laying a ground moisture barrier on sub-floor
- replacing inefficient woodburner with new high efficiency woodburner and wetback pumped to hot water cylinder
- installing solar water heating system on foyer roof.
- replacing rotten window frames with double glazing units and window frames
- using compact fluorescent bulbs for main lights
- installing extraction fans in bathroom and laundry and a plumbing maintenance check which led to fixing a leaky tap.

After renovation

Average winter temperatures in the family room increased by 1.4ºC. Average winter temperatures in the main bedroom increased by 2ºC. In the main bedroom, the most common temperature increased from 13ºC to 17ºC with a big reduction in the frequency of cold temperatures.

The improved efficiency of the solar hot water/wetback system, and the improved thermal performance of the home, reduced electricity use by ~23% over winter and ~30% annually. 70% less electricity was used to heat water Hot water energy use during winter reduced by 70%.. Although the solar hot water system is providing nearly 100% of hot water needs in summer, the family has also been able to increase their hot water use by 25% since they got the new system.

However, a ~45% reduction in total reticulated energy use in the 2007 winter was reversed in the 2008 winter with a ~39% increase in total reticulated energy use. Most of this extra energy use came from portable heaters and appliances. As a result, a significant component of electricity savings from the change in hot water heating methods was taken back in other electrical services within the home.

What the family found

The bedrooms no longer feel cold; although when it gets really cold, they do run supplementary heating in the bedrooms. Overall, the family noticed that temperatures have risen in the house during winter, with the morning temperature "much higher". The family found it too hot in the house over several weeks in summer, but opening the windows and doors solved the problem.

The living areas are no longer damp and the bathroom/laundry extractor fans are "excellent". Dehumidifiers were no longer needed. The family acknowledge that they are using more water, now that they no longer worry about hot water running out.

The family report having a lot less colds, runny noses, and flu. They commented that they all felt more relaxed, and that being warmer makes them happier.

Our analysis

The family's electricity use is quite low at around 5600 kWh per year, compared to the benchmark for electricity use of 7300 kWh per year. The solar water heater is performing very effectively for the family, especially given their hot water use has increased and given the monitoring period was over the winter months. The panels were well oriented for winter sun with panels twice the size of an installation undertaken under the EECA subsidy scheme.

As a result of the improvements, winter temperatures come very close to meeting our High Standard of Sustainability benchmarks. The mean minimum family room temperature in the evenings is 17.8ºC and the mean minimum in the main bedroom overnight is 15.8ºC. We suggest installing a heat transfer system to ensure that heat generated in the family room is more effectively spread around the house. The family found it difficult to keep an even temperature from the wood burner, suggesting that learning to operate the wood burner optimally may be helpful. Summer temperatures increased, particularly in the bedrooms, with the highest temperatures around 27ºC. We suggest installing sunshades on western windows to provide late afternoon shading.

Humidity levels at times exceeded the benchmarks. This may be largely due to under-heating of the home leading to elevated relative humidity levels.

The family's average per person water use was 151 litres/pp/day compared to the benchmark of 125 litres/pp/day.

What did we find out from the case studies?

Insulate everywhere

The houses which had the full thermal envelope insulated and efficient heating installed saved the most reticulated energy and had the most temperature improvement.

Two homes, for example, received the full treatment: the ceiling, walls and floors were fully insulated, double glazing was fitted, a layer of polythene spread on the ground beneath the house to inhibit rising damp, and an energy efficient heating source was installed. Pre- versus post- monitoring revealed that homeowners enjoyed substantial savings on their energy bills as a result of the retrofits - between 23% (2480kWh) and 33% (930kWh). As well as cost savings, there was a dramatic shift in the mean winter temperatures in both the family areas and bedrooms, in one case rising 3.3^{o}C and 5.5^{o}C respectively, in the other rising 2.5^{o}C and 2.9^{o}C.

Other homes received a more modest thermal makeover, with efforts centred largely on ceiling and underfloor insulation. While these upgrades did result in energy savings and temperature improvements, not one of these homes had a healthy mean minimum temperature in the depths of winter.

The lesson from these houses is not only to install high levels of insulation as a basic first step to a warm home, but when a house already has some insulation, add insulation in un-insulated areas before topping up existing insulation. The study highlighted the need for wall insulation to achieve good reticulated energy savings and healthy indoor temperatures. It needs to be promoted as a ‘must have’ retrofit solution, rather than the current perception of it being a ‘nice to do’. Double glazing should also be considered, particularly with glass-only retrofits or if windows need replacing.

Combine insulation with efficient heating

Results from the Papakowhai homes confirm other research findings that insulation improvements must be complemented by an efficient heating source. Four homes received either efficient heat pumps, low emission pellet burners or low emission wood burners. When coupled with good levels of insulation, the potential exists to experience good temperature and energy efficiency gains. But to enjoy the full benefits, the technology must be used properly - success often comes down to education.

Homeowners in the Papakowhai Renovation project were given no special training in how to maximise the benefits of their sustainable renovations. This lack of knowledge was reflected by several homeowners’ decisions not to increase their heating. As a result, although they noticed some energy savings, it was at the expense of temperature which, in these homes, fell below the recommended minimums to maintain good health.

Bedrooms need to be warmer

Several homes had heat transfer systems installed with pellet burners and efficient wood burners. Often a central heat source does not warm beyond the main living area. Heat transfer systems or ducted heat pump systems push the warm air through to bedrooms and bathrooms, ensuring an even heat through the house. These homeowners report finding that the wood burner combined with the heat transfer system heats the whole house. However, the effectiveness of such systems depends on installing correctly sized heat transfer ducts and using suitably powerful fans.

Hot water cylinder wraps are a great energy efficiency measure

In terms of value for money, hot water cylinder wraps and pipe lagging remain a fantastic investment. While cylinders ranged in age (1970s -2005), wrapping proved worthwhile in all cases, boosting efficiency between 11% and 30%. In fact, the cylinder wraps appear to be worthwhile even on modern A-grade cylinders, particularly if only low volumes of hot water are used.

Solar hot water systems can perform well, even in winter

The study also established that solar hot water systems can provide the majority of water heating needs and optimum installations will clearly deliver the best results. The three homes with solar water installations had 55% to 70% of their hot water needs provided by solar - in winter! Summer performance would be closer to 100%. And, for a moderate increase in cost, a wetback is very effective in combination with solar hot water.

Combine solar/instant gas hot water systems with low flow tapware

Interestingly, the study confirms that low-flow shower heads and flow restrictors should be included alongside solar/instant gas hot water systems. With the seemingly endless supply of hot water that these systems promise, householders began taking longer showers. Low flow devices combat this effect.

Extra value for the homeowners

Homeowners in the project valued the renovations for more than energy efficiency and warmth. Those with double glazing and/or increased insulation were surprised at the effect of reducing noise indoors. In particular, homeowners were delighted that they could no longer hear train noise filtering up from the main trunk line.

Householders also report better family health associated with warmer winter indoor environments and, for those with solar water heating, increased access to hot water. This goes beyond health status to mental health benefits, expressed as an enormous sense of well-being derived from the warmth in particular, the reduction of noise and being able to improve their living conditions.

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

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About this Report

Reference
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