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RETROFIT AND SUSTAINABILITY ANALYSIS FOR TODAY'S HOMES

A REPORT PREPARED
FOR BEACON PATHWAY LIMITED

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RETROFIT AND SUSTAINABILITY ANALYSIS FOR TODAY'S HOMES

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Team leader signature ……..

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ABSTRACT

The objective of this project was to develop a 'Pathway Navigator Concept' for Beacon Limited, a concept which motivates and guides homeowners to form an action plan for a home upgrade.

REFERENCE

Yannakis, N., Chung, O., Hart, S., Halverson, M., 2006. *Retrofit and Sustainability Analysis for TODAY's Homes*

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1. EXECUTIVE SUMMARY

It is widely known that New Zealand homes are not comfortable or sustainable, with widespread problems such as mildew, dampness and poor heating. 28% of New Zealand homes are estimated to be inadequately insulated. Because of the poor living conditions, New Zealand has one of the highest incidences of respiratory illness in the First World.

To overcome New Zealand's housing problem, renovating existing homes is pivotal. Action from local government, as well as homeowners, will be required to economically bring about this change. The current approach to solving the housing problem primarily consists of presenting homeowners with information on the various ways to upgrade their home. This is useful for decision making, however it fails to motivate and guide them through developing an action plan.

The objective of this project was to develop a 'Pathway Navigator Concept' for Beacon Pathway Limited, a concept which motivates and guides homeowners to form an action plan for a home upgrade. A website was selected as the final concept and developed. A slide by slide website prototype was created for validation. This consisted of presenting the prototype to homeowners, followed by obtaining their opinions of the concept and suggestions for its improvement through a survey. The validation results were positive, showing an increase in homeowners' motivation levels and overall satisfaction with its features.

Research was required to support the development of the Pathway Navigator. Homeowner demographic research was conducted to ensure the Pathway Navigator concept targeted the majority of New Zealand homeowners. Three homes were selected as case studies from the demographic research. The selected homes were monitored and energy-audited to aid the analysis of the renovations.

The Pathway Navigator concept is a step in aiding the goal of Beacon Pathway Ltd to bring 90% of New Zealand homes to a higher level of sustainability by 2012. Future work will be required to develop the concept to a full working prototype.

2. ACKNOWLEDGEMENTS

The team would like to thank the following people for support and cooperation during the project. Your assistance has been invaluable.

Dr. Susan Krumdieck — Academic Supervisor

Dr. Barbara Nebel — Project Mentor

Facilities Management:

- Beverley Austing
- Lindsay Hampton

Technicians from the Department of Mechanical Engineering:

- Julian Murphy
- Julian Phillips
- Eric Cox
- Ron Tinker

Tenants of monitored homes (5, 9 and 21 Montana Ave)

3. INTRODUCTION

3.1 Purpose of the report

This report delivers the results of the Final Year Project undertaken by the Retrofit Team for the sponsors, Beacon Pathway Limited (Beacon). The objective of the year-long project was to develop a Pathway Navigator. The Pathway Navigator concept motivates homeowners into renovating their homes to the first level of sustainability defined by Beacon's goal to bring 90% of New Zealand homes to a high level of sustainability by 2012.

3.2 Scope of the report

This report details the research and development work for the Pathway Navigator concept. The Pathway Navigator concept is also described in detail. Details of the demographic research, improvement database, monitoring programme, energy audit, thermodynamic model, theoretical renovations and concept validation are included in this report as separate documents.

3.3 Project team

The Beacon Retrofit Team members were Nicholas Yannakis, Sean Hart, Matthew Halverson and Olivia Chung. The role of each team member is as follows:

- Nicholas Yannakis – Team Leader, responsible for all analytical aspects (engineering modeling).
- Olivia Chung – Secretary, responsible for all experimental and practical designs.
- Sean Hart – Treasurer, responsible for the production of the prototype design.
- Matthew Halverson – Engineering Management/Risk Analyst, responsible for the Improvement Database.
- Dr. Susan Krumdieck – Academic Supervisor.
- Dr. Barbara Nebel – Project Mentor.

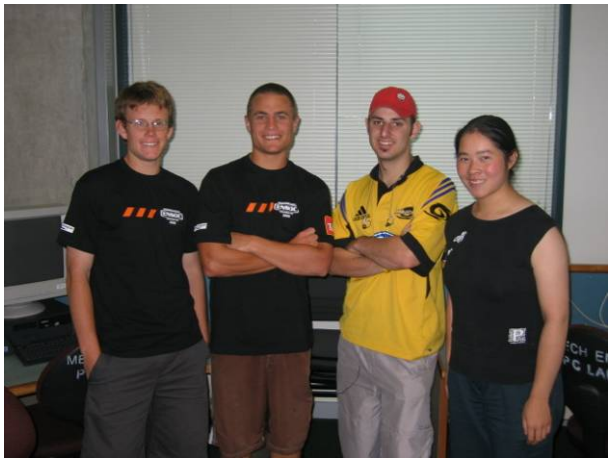

Figure 1: Beacon Retrofit Team photo

From left to right: Matthew, Sean, Nick and Olivia

4. BACKGROUND

4.1 Background to the project

A large number of New Zealand homes are not comfortable or sustainable, with widespread problems such as mildew, dampness and poor heating. One of Beacon's goals is to "help bring the vast majority of New Zealand homes to a high standard of sustainability by 2012." Sustainable living has been defined by Beacon as "using less and having more" [1]. Beacon has identified that retrofitting existing New Zealand homes is pivotal in achieving this goal.

The mission statement for the project was to develop an interactive Pathway Navigator to inform and motivate homeowners to undertake heating and dampness solutions that can improve their investment security and comfort requirements for a warm, healthy and sustainable home.

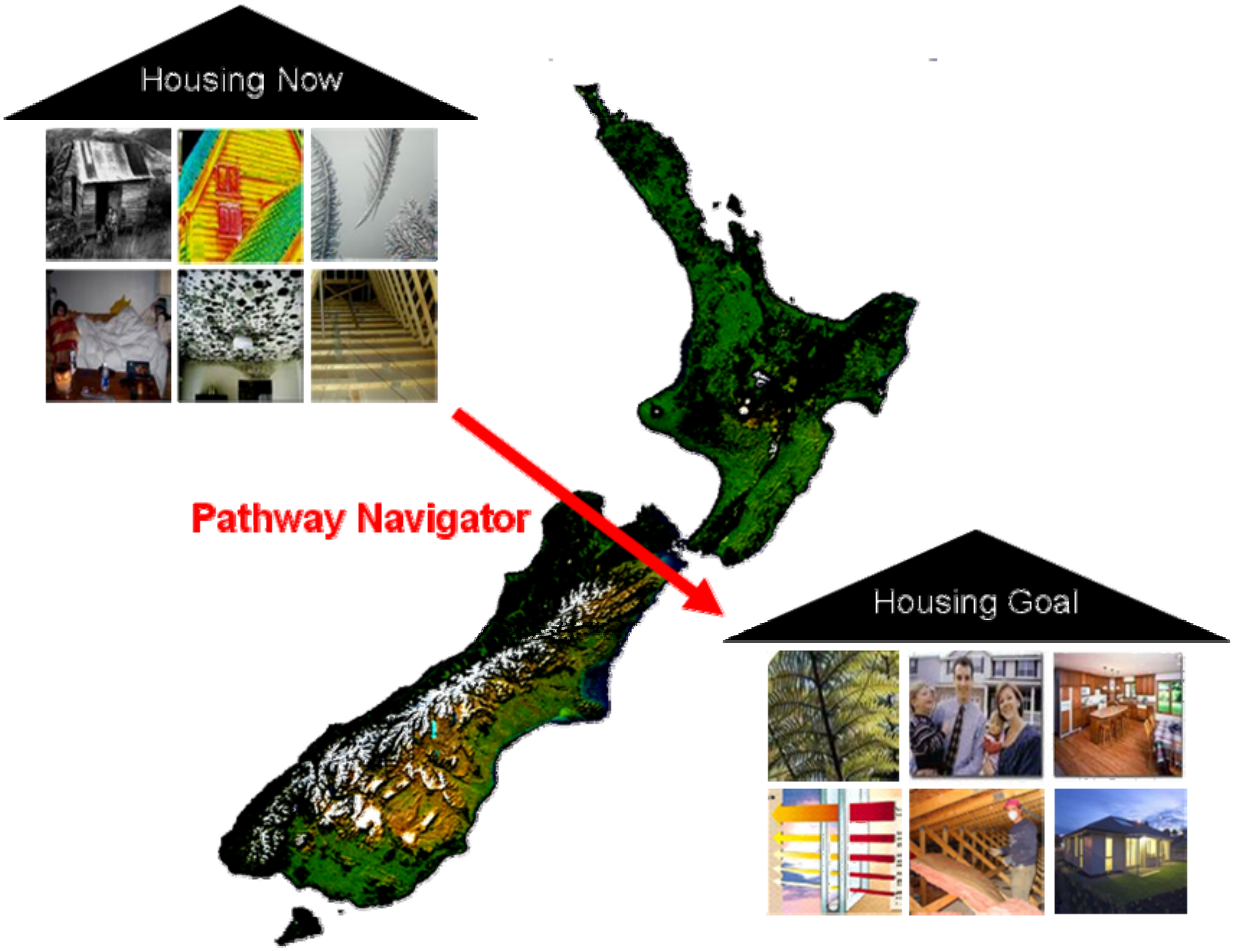

Figure 2: A visual representation of the Pathway Navigator concept

[1] Beacon Pathway Ltd, 2006. www.beaconpathway.co.nz, accessed 12 September 2006

4.2 Scope of the project

The project focuses on residential properties in the Christchurch region built prior to 1977. The target market is homeowners, in particular, motivations to retrofit their homes. Research on motivation was directed at technologies and retrofitting measures that specifically improve the indoor air temperature and health of the occupants. As part of the pathway to sustainable living, it is necessary to bring homes up to an acceptable standard defined by Beacon[2] , where the indoor temperature is at least 18 °C and is free from mildew or dampness.

The scope does not include investigating the retrofit of rental properties, lifestyle blocks, state housing and similar types of property, as regulation and policy rather than motivation changes are likely to be the main driver for the improvement of these properties. New homes built (or in the process of being built) after the change in the insulation code are also excluded from the scope of the project. Water heating, household appliances and lighting, while outside the scope of this project, do factor into the motivation for renovations and have been treated as decorative or lifestyle improvements rather than health and wellbeing improvements.

4.3 Background and fundamentals of the Pathway Navigator

Extensive research was conducted to gain knowledge in three streams: Christchurch homeowner demographics, existing technologies that improve heating and dampness performances in a residential home, and existing standards and energy initiatives implemented in Christchurch. The key findings are summarised in the following three sections.

4.3.1 Homeowner demographics

The key findings relevant to the development of the Pathway Navigator are summarised below:

- Retrofit candidate homes are 18% brick, 39% concrete and 29% timber.
- Heating is currently provided by 46% electricity, 18% gas and 27% wood.
- 55,000 retrofit candidate homes have insufficient insulation.

A detailed review of the home demographics is in a supplementary Christchurch Home Demographic Report.

4.3.2 Improvement database

The key findings to improving the thermal condition of residential properties are summarised below:

- Adequate Heating –
    - Electric Heat Pump – 1.3 – 7 kW – adequate for main area of a well insulated home. Additional heating required for bedrooms and bathrooms. Sustainable as long as renewable electricity generation is adequate.
    - Wood Pellet Fire – 2 – 16 kW – adequate for medium to small home. Will provide full heat load for well-insulated medium to large home. Sustainable as long as waste wood is available.

[2] Beacon Pathway Ltd, 2006. www.beaconpathway.co.nz, accessed 12 September 2006

- Wood Log Fire – 5 – 25 kW – adequate for main area of home - but drives infiltration, increasing the heating load. May over-heat well-insulated homes, and may cause serious air pollution if not operated correctly. Sustainable as long as waste plantation wood is available.
- Gas Fire – 5 – 18 kW – adequate for medium to small home – but, if unflued, will add moisture into the air. Will provide full heat load for a well-insulated home. Unsustainable as gas is non-renewable resource.
- Diesel Burner – 5 – 26 kW – adequate heating for medium home. Will provide full heat load for a well-insulated home. Unsustainable as diesel is non-renewable.

- Insulation – Adequate insulation must be applied in all areas – walls, ceiling and floor.
- Infiltration Management – draught stopping measures must be taken on all windows, doors and wall penetrations. In particular, recessed downlights in the ceiling should be a sealed and insulated type.
- Humidity Management – measures for reducing moisture in the air must be taken. In particular, using exhaust fans when cooking and in the bathroom.
- Ventilation – measures for replacing the interior air must be taken. Left unattended, the quality of the air will deteriorate, causing condensation, mildew and pollutants in the air.

A detailed review of heating and dampness solutions for a residential home is in a supplementary Improvement Database Report.

4.3.3 Existing building standards / energy initiatives

Existing building standards and regulations were investigated. Key New Zealand Building Codes:

- NZS 4214: Methods for Determining the Total Thermal Resistance of Parts of Buildings
- NZS 4218: Energy Efficiency - *Small Building Envelope* and existing information provided by Energywise and the Energy Efficiency and Conservation Authority (EECA).

Existing retrofitting programmes that target homeowners were investigated. The main energy programmes in Christchurch are:

- Environment Canterbury's (ECAN) "Clean Heat" programme
- Community Energy Board's assistance for low income families.

5. CONCEPT DEVELOPMENT

The Pathway Navigator was developed by identifying the barriers that prevent homeowners from retrofitting their home. The barriers were used to identify the required functions of Pathway Navigator. Various concepts for the Pathway Navigator were generated. A single concept was selected by evaluation and analysis of the various concepts. A website was selected as the final concept and a prototype was produced for validation.

5.1 Barriers to retrofitting

The first stage of concept development was to identify the common barriers which prevent home owners from undertaking a retrofitting project. The common barriers are listed below:

- *Number of Retrofitting Options*,

The vast majority of retrofitting options makes selecting the optimum solution for each particular home difficult.

- *Money Constraints*

Homeowners may have insufficient financial resources making it difficult to afford retrofitting their house.

- *Information Detail*

The majority of current retrofitting information is too vague and incomparable to make well-informed home retrofitting decisions.

- *Comfort Tolerance*

New Zealand home residents are well known for their tolerance of cold, damp indoor living conditions. A large number of residents prefer wearing warm clothing, as opposed to heating their home to feel more comfortable.

- *Property Rates*

Increasing the market value of a home through retrofitting will increase the property rates, which can deter homeowners from retrofitting.

- *Building permits*

Certain home retrofits may require a building permit from the council. The time and cost involved would prevent a number of homeowners from taking action.

- *Vacating House*

Residents may have to vacate the house for certain retrofits. Homeowners may feel the time and effort involved in vacating outweighs the benefits of retrofitting.

5.2 Concept function

The Pathway Navigator's primary function is to motivate owners of uninsulated, under-heated and poorly ventilated homes to undertake a full retrofit. Other important functions are to facilitate decision making which help the development of an action plan for a home retrofit. Figure 3 shows the sequential decision and action process home owners take to the desired outcome.

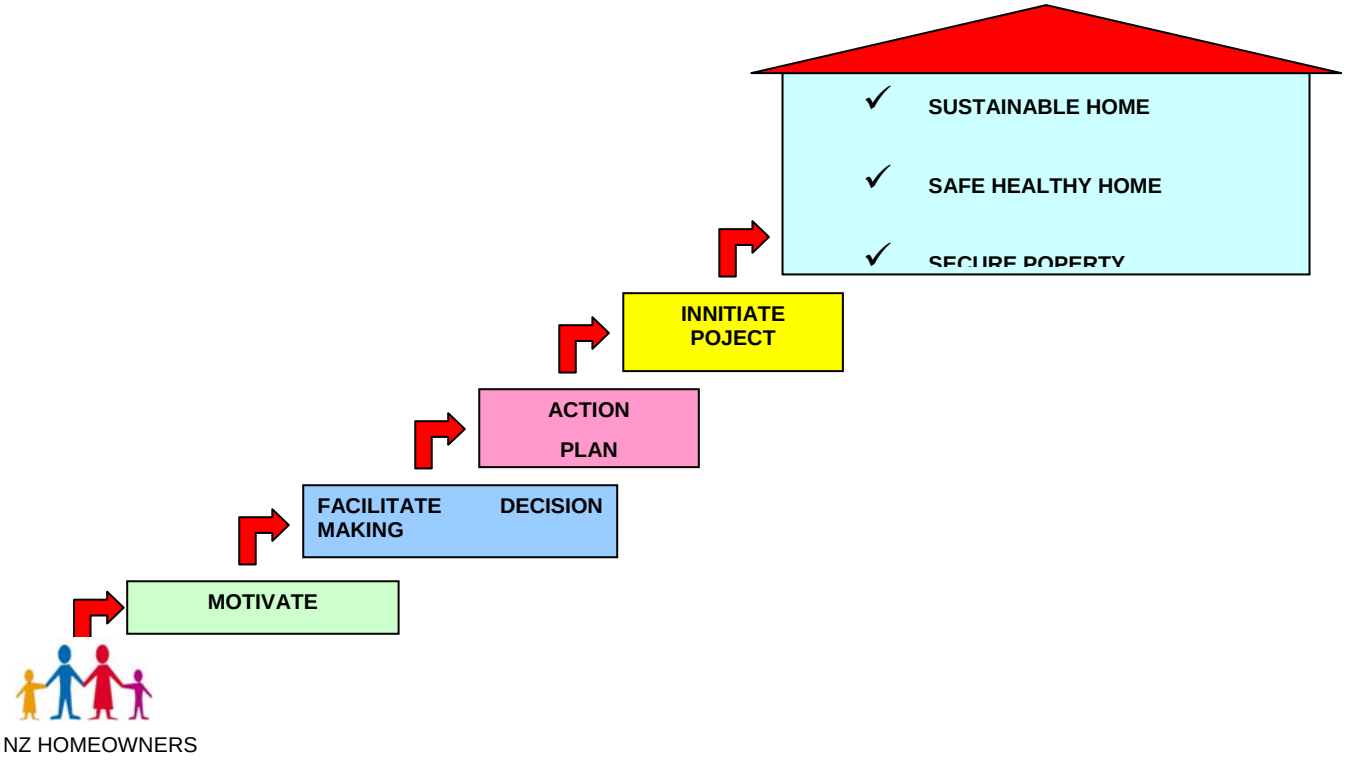

Figure 3: The Pathway Navigator's functions

5.3 Achieving the required functions

The Pathway Navigator concept was developed by first identifying its required functions, followed by finding ways to achieve these functions.

- *Motivation*

A technique for motivating people is giving them a vision of an outcome. The Pathway Navigator will need to give homeowners a vision of their home after undertaking a retrofitting project. The vision can be achieved by showing homeowners an ideal home, which is sustainable, comfortable and healthy. Making this more specific for each viewer, home-owners can access retrofitting case studies relevant to them. Case studies illustrate realistic outcomes from retrofitting as opposed to idealistic outcomes often provided by manufacturers of products in the building industry.

- Decision Making

The following are important decisions that homeowners are likely to make. These are:

- *Improvement Selection*
  Homeowners will need to select what improvements they will make to their home.
- *Programmes Selection and Qualification*
  A number of programmes exist which provide retrofitting assistance. This is provided through subsidies, discounts and free services. Homeowners will need to see if they qualify for any and which to use.
- *Service Selection*
  Homeowners commonly use the services of outside parties to perform home improvements. Homeowners will need to select what type of services they require and a provider of these services to use.

5.3.1 Concept ideas

Seven ideas were generated for the Pathway Navigator concept. Brief descriptions of each are given below:

- *Website*

A website is accessible to a large number of homeowners with its key advantage being its customisability, i.e. viewers can find information relative to them. The website could contain a variety of information, such as a retrofit case studies, improvement database, programmes and services.

- *Game*

A game could be an exciting way to educate homeowners, or used as a draw card to bring people to another tool, i.e. the website mentioned before. The game envisioned revolves around a house where players undertake different renovations. Points are given based on the comfort of the occupants, the energy bill and the sustainability of the house. The game can be made available through a website.

- *Television programme*

“Do It Yourself” (DIY) programmes are a popular method for educating and motivating homeowners to retrofit their home. A similar adaptation could be used for sustainable retrofits. Sustainability could be incorporated into current programmes which focus on aesthetic improvements as opposed to health, sustainability and comfort improvements. The major disadvantage of a TV show is the cost associated.

- *Magazine*

A periodic magazine could be published similar to current home magazines which give retrofit case studies. Manufacturers of sustainability products would be likely to use this to advertise their products, therefore producing additional income for the magazine owners.

- *Pamphlets*

Pamphlets can be used to directly target homeowners. Pamphlets will only provide very limited information, however they can inform homeowners of where they can obtain more relevant information, i.e. a website.

- Open home

A sustainable home open to the public would illustrate the features which make it sustainable, therefore educating the public. Beacon has already used this technique with the opening of the NOW Home™, a home with below average electricity and water consumption. The main disadvantage of the open home is its availability to the New Zealand public. However, information on the home and its features can be made available through other medias, such as a website.

- Model Home

A similar idea to an open home is a model show home. Model homes could be made available in public places such as hardware stores which may benefit from increased retrofitting activity from more educated and motivated shoppers. A model home however does not have residents to illustrate the realistic significance of these improvements.

5.3.2 Concept selection

To compare and analyse the ideas generated, five desirable features identified. These were:

- *High Availability*
  The concept being available to a large number of homeowners is important to effectively reach the majority of New Zealand homeowners.
- *Low Cost*
  The concept needs to achieve the desired result where resources are utilised in a cost effective manner.
- *Large Number of Homeowners Targeted*
  The target audience of homeowners needs to be reached without wasting resources on other demographic groups that are not relevant to aims of the Pathway Navigator.
- *Customisability*
  There is a large demographic range of homeowners[3] each with their own individual wants, needs and desires. The concept needs to be customisable for each of these different homeowners to provide relevant information.
- *Within Beacon's Capabilities*
  The design and/or manufacturing of the concept will need to be completed and maintained with the resources available to Beacon.

The five comparison categories were given a weighting out of 5, 5 being the most important. Each concept was given a score out of 10 for each category, 10 being the highest. The scores were given by the project group members. A total score was deduced using the category weightings. Table 1 presents the results for each of the ideas.

[3] Hart, S., 2006. Christchurch Home Demographic Report

	High Availability	Low Cost	Large number of Home Owners Targeted	Customisable	Within Beacon's Capabilities	Total Score
Category Weighting	**4**	**5**	**3**	**4**	**5**	
1. Website	8	7	4	8	9	**156**
2. Online game	8	6	3	7	7	**134**
3. Television Programme	7	1	8	4	1	**78**
4. Magazine	4	3	7	4	2	**78**
5. Pamphlets	6	8	8	4	6	**134**
6. Show Home	2	2	3	4	8	**83**
7. Miniature Model Home	3	4	4	4	6	**90**

Table 1: Concept comparison

The website scored the highest using the comparison table with a score of 156. A website is within the project group's capabilities to develop and produce a prototype for validation.

6. PATHWAY NAVIGATOR WEBSITE DESIGN

The first stage of the websites design was to develop a recommended path a viewer should take through the website. Figure 4 shows the basic layout of this path.

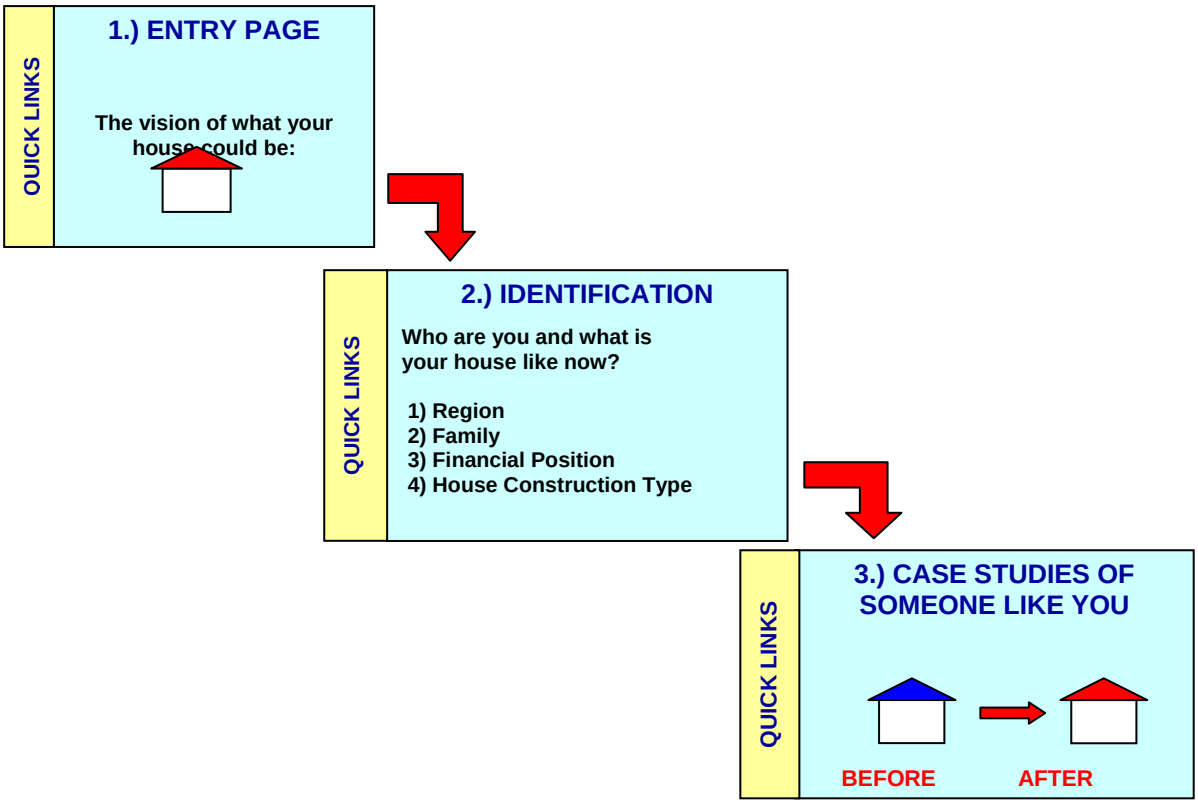

Table 2: Website design, systematic layout

The features of the website design are briefly described below.

1. *Entry Page*
   The first page displayed on the website gives an image of the idealistic, sustainable home. The user is invited to start the journey towards obtaining their own sustainable home.
2. *Identification*
   The second page identifies the viewer in terms of their household demographics and the housing problems they are currently experiencing.
3. *Case Studies*
   The information collected from the identification page is used to select and display case studies of homeowners similar to the viewer. Each case study will include the following information:
   - An introduction to the homeowners
   - The condition of the property before renovating in terms of:
     - Dampness
     - Temperature
     - Average power bills
     - Health and morale of the occupants

- Equity and property value

- The actions taken to improve the house in terms of:
  - Improvements carried out
  - Services used
  - Programmes used
- The condition of the property after renovating in terms of:
  - Dampness
  - Temperature
  - Power bills
  - Health and morale of the occupants
  - Equity and property value

4. Additional Decision Making Tools

After the viewer finishes looking at case studies, they will most likely require additional information. The following decision making tools will be included:

- An Improvement Database which contains information on different heating and dampness solutions such as their advantages and disadvantages.
- A list of the programmes/ energy initiatives available in the viewer's region of interest.
- A directory of architects, building contractors and similar contractors who specialise in sustainable and energy efficient building methods for the region of interest. Their contact details and links for their websites will be provided (subject to approval).

Quick links to all the tools and information sources are available so that the user can review or quickly gather specific information. The list of the links is provided below:

- Home page
- Reasons to renovate
- Improvement database
  - Heating
  - Moisture control
  - Ventilation
  - Insulation
  - Windows
  - Curtains
- Case studies
- Heath and security
- Property value
- Programmes
- Services
- Illustrative model

7. DEVELOPMENT OF PATHWAY NAVIGATOR CONTENT

7.1 Monitoring programme

A Monitoring Programme was set up to collect data of three thermally inefficient homes in Christchurch and to provide data for the case studies. The three homes were chosen on the basis of cladding type, size of the property and occupancy. The selected homes were 5 Montana Avenue (timber cladding), 9 Montana Avenue (concrete cladding) and 21 Montana Avenue (brick cladding). Images of these properties are shown in Figure 5. The University of Canterbury owns all three properties. Temperature and relative humidity was measured on each property for a one week period each using DS1923 iButtons. Separate temperature readings were collected at each property over a three-week period using the DS1921G iButtons. The Monitoring Programme was loosely based on the HEEP (Household End Energy-use Project) carried out by BRANZ Ltd.

(a) 5 Montana Avenue.

(b) 9 Montana Avenue.

(c) 21 Montana Avenue.

Figure 4: Images of the monitored homes

The key findings from the Monitoring Programme are listed below. A detailed review of the monitoring programme is in a supplementary Monitoring Programme Report.

1. The indoor temperature of 5, 9 and 21 Montana Avenue was below the recommended indoor temperature threshold of 18 °C. The average room temperature ranged from 6.55 °C to 12.70 °C (± 0.5 °C) in the coldest rooms of these properties. This data supports Beacon's evidence of poor indoor conditions.
2. The average relative humidity in the bathroom of 5, 9 and 21 Montana Avenue ranged from 69.46 % to 79.01 %. The relative humidity did exceed 100 % at times.

The lack of extractor fans may contribute the lack of adequate moisture control, although a dehumidifier was frequently used at 9 Montana Avenue to control the moisture levels.

3. Heating and cooling patterns differed between different socio-economic and demographic groups. New Zealand homeowners may have more conservative heating patterns than their overseas counterparts, although this claim could not be validly proven given the context of the Monitoring Programme.
4. Upgrading to better thermal, moisture and ventilation control solutions would significantly improve the thermal performance and indoor climate of the monitored properties. It is encouraging to know that the University of Canterbury recognises how the addition of technologies such as pellet fire burners can improve the indoor climate of their properties.

7.2 Energy audit

A Level 1 energy audit (as defined by AS/NZS 3598: 2000 *Energy Audits*) was completed to develop the work completed for the Monitoring Programme. The energy audit was completed for 9 Montana Avenue and 28 Ryeland Road (a privately owned property). The loading patterns, electricity consumption and energy conversion devices were examined for 9 Montana Avenue and 28 Ryeland Road. The performance of a thermally efficient property (28 Ryeland Road) was able to be observed and compared to 9 Montana Avenue. Recommendations for a 20 % reduction in electricity consumption were suggested for both audited properties.

The key findings from the energy audit are listed below. A detailed review of the homes audited is in a supplementary Energy Audit Report.

1. A large proportion of the electrical load is used for space conditioning (67 % for 9 Montana Avenue and 47 % for 28 Ryeland Road.) This trend is typically expected for the residential sector.
2. The energy consumed from using electricity was at least four times greater than the energy consumed from using natural wood pellets. (The energy consumed from using natural wood pellets was 4,830 kWh/year for 9 Montana Avenue and 3,780 kWh/year for 28 Ryeland Road.)
3. Seasonal trends for electricity consumption were generally evident. The reductions in electricity consumption over the summer are due to a change in activities (e.g. outdoor entertaining) and a reduction in the heating and lighting loads.
4. Suggestions for a 20 % reduction in electricity consumption are recommended for both audited properties. These are summarised below in Tables 2 and 3. These recommendations are practical if there was less dependence on the electrical load and there was an open attitude towards energy conservation.

Category	Recommendation/ Changes	% of Annual Electricity Consumption saved	Payback Period (Years)
Heating	Insulation	20.00	20.0
	Solar heating	10.00	12.5
	Heat pump	10.00	12.0
	3 Bedroom extractor fan/ ducting	15.00	7.0
	Hot water cylinder thermal wrapping	3.00	1.2
Lighting	ECO bulbs	4.00	N/A
Miscellaneous	Operation	7.79	N/A
	Selective films	3.00	7.0

Table 3: Summary of potential electricity savings for 9 Montana Ave

Category	Recommendation/ Changes	% of Annual Electricity Consumption saved	Payback Period (Years)
Heating	Insulation	20.00	20.0
	Solar heating	10.00	12.5
	Heat pump	10.00	12.0
	3 Bedroom extractor fan/ ducting	15.00	7.0
	Hot water cylinder thermal wrapping	3.00	1.2
Lighting	ECO bulbs	4.00	N/A
Miscellaneous	Operation	7.79	N/A
	Selective films	3.00	7.0

Table 4: Summary of potential electricity savings for 26 Ryeland Rd

5. The security of supply for both electricity and wood pellets is currently not in jeopardy. The security of supply (in electricity) will improve if the demand for electricity decreases. The security of supply for the natural wood pellets is dependent on Nature's Flame, the sole supplier of natural wood pellets in Christchurch.

7.3 Thermodynamic model of a home

A Matlab program was developed to model the theoretical heat flows of a home. The main assumption was that heat transfer was one-dimensional and was steady state. (The movement of moisture was not developed in the program). Several heat sources could be used as inputs to the model. The model was able to show how of changing the level of insulation and window properties (e.g. double-glazing) affected the performance of the building envelope.

The results from modeling a generic home that has been modeled using Matlab can be seen in a supplementary Matlab Model Report. The program is intended as a tool to help home-owners quantify the benefits and disadvantages (if any) of thermally retrofitting their home.

7.4 Modeling theoretical home renovation

The homes that were monitored in the Monitoring Programme (5, 9 and 21 Montana Avenue) were modeled using the developed Matlab program (described above). 3 – D Architect (a CAD program for architects) was used to visually model the homes. The performance of the three homes was modeled in its “as is” and “renovated” state. It should be noted that ventilation and the movement of moisture to and from the building envelope was not modeled.

The key findings from the Matlab and 3–D Architect modeling are listed below. A detailed review of modeled homes is in a supplementary Monitored Home - Renovations Report.

1. Adding insulation and double-glazing dramatically improves the thermal performance of the monitored homes. The use of insulation and double-glazing creates a sealed building envelope.
2. The costs to heat a home with a sealed building envelope decreases.
3. The type of exterior cladding does not affect the overall thermal performance of the home.
4. Window accessories (such as curtains) were not modeled extensively as they represent a small gain in thermal efficiency.
5. Using heat sources such as pellet fire burners are both more cost effective and thermally efficient than electrical element heaters.

8. PATHWAY NAVIGATOR PROTOTYPE

A prototype of the website was produced to be used for validation. The prototype consisted of a slide-by-slide power point presentation, illustrating the website's layout and available tools.

Figure 6 shows the prototype layout and descriptions.

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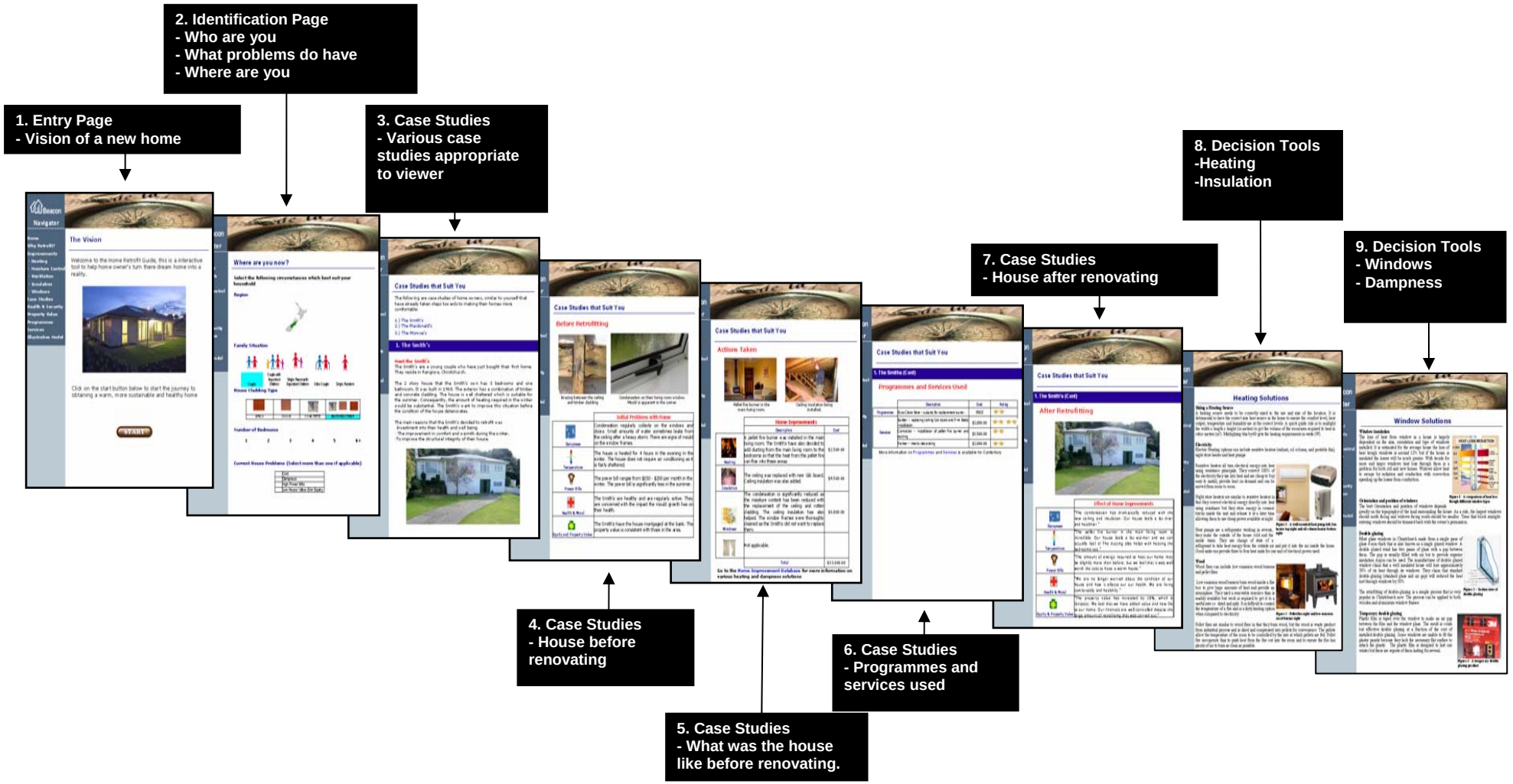

9. VALIDATION OF CONCEPT

The Pathway Navigator concept was validated using a survey. The survey was completed by interested homeowners at the end of a short presentation describing the Pathway Navigator concept. The testing took place on 1 September 2006 at Bunnings (Tower Junction branch).

Figure 5: Sean and Olivia taking a couple through the validation survey

9.1 Survey

The four purposes of the survey were:

1. To determine the initial homeowner attitudes with regards to the state of their living conditions.
2. To determine what areas homeowners had previously retrofitted (prior to the presentation of the Pathway Navigator).
3. To determine if, after the presentation of the Pathway Navigator, homeowners had been affected and showed an interest towards retrofitting their home (to becoming a warmer, healthier and more sustainable home).
4. To evaluate the prototype website design.

A self administered onsite survey was used for the concept validation. It contained a range of open ended and forced choice (closed) questions. The closed questions were presented in a multiple choice and rating format. The main text used when designing the survey was **How to Conduct Surveys – A Step by Step Guide** (3rd Ed) by Arlene Fink.

As resources were limited, a non–probability sampling method (using a convenience sample) was used to determine the sample size [3]. Thirty valid survey responses was the required sample size. The sampling method enabled the team obtain the required population without the need for random sampling. A screening question ('Are you a homeowner?') was asked to reach the target population.

Figure 6: Nick taking a survey participant through the prototype

9.2 Statistical analysis of the validation survey

A statistical analysis was performed on the results from the survey. The major findings are summarised below. A detailed review of the validation of the concept is in a supplementary Concept Validation Report.

1. Homeowners do not recognise the value of retrofitting and do not have a long term goal to retrofit their home. (The lack of financial resources and time were not seen to be a barrier to retrofitting activity).
2. A majority of homeowners had no intentions to retrofit their home (prior to the presentation of the concept).
3. 29 % of home owners surveyed have retrofitted their home within the last two years. Improving the heating system was the most common retrofit.
4. Better planning and more information on alternative heating options (such as central heating units) would improve the satisfaction level of the outcome and minimise stress in the retrofitting process.
5. The motivation level of home owners who had not retrofitted had improved after the presentation of the concept.
6. Personalising the Pathway Navigator would further increase the homeowner's motivation level as the homeowner would be interacting with the concept.

7. Home owners generally responded positively to the Pathway Navigator concept. Some homeowners described the Pathway Navigator as “really handy” and said that it would be “good to have as a resource”.
8. Several home owners surveyed preferred the use of the word “renovate” as they did not comprehend with the word “retrofit”.
9. Most people considered the internet to be an effective medium to portray the concept. Surveyed homeowners raised the fact that accessibility to the internet could be a potential problem. A pamphlet or brochure to complement this digital format was also preferred.
10. More information on building codes and regulations and BRANZ were requested. Product specific information was also widely recommended to be included in the Pathway Navigator.

10. CONCLUSION

10.1 Final prototype debrief

The project has delivered a valid concept that motivates home owners by giving them an initial vision of a desirable home. The Pathway Navigator concept is different to what is currently available. Homeowners currently acquire product based information provided by companies that have profit based objectives, as opposed to sustainable objectives.

The Pathway Navigator couples both motivational and decision-making features. Home owners will have access to unbiased information allowing educated decision making for the sustainable renovation of their home. The project has provided a platform for further improvements and enhancements to the Pathway Navigator.

10.2 Future work

The Pathway Navigator will need further development and refinement before a final working concept is completed. The validation of the initial PowerPoint prototype illustrates the positive potential for the Pathway Navigator concept. The following is a list of work recommended to Beacon required for the development of the website:

- Develop a standardised approach to case study research.
- Conduct case study research on homes that cover the wide New Zealand home owner demographic.
- Further develop the improvement database.
- Research regional energy incentives, subsidy programmes and services in all major New Zealand regions.

After suitable completion of the work above, a professional website designer should develop a full working prototype. The website prototype will then need extensive testing and validation to ensure it is up to a suitable standard before becoming available to the public.

11. REFERENCES

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Beacon
Navigator

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The Vision

Welcome to the Home Retrofit Guide, this is a interactive tool to help home owner's turn there dream home into a reality.

Click on the start button below to start the journey to obtaining a warm, more sustainable and healthy home

START

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Where are you now?

Select the following circumstances which best suit your household

Region

Family Situation

House Cladding Type

Number of Bedrooms

1 2 3 4 5 6+

Current House Problems (Select more than one if applicable)

	Cold
	Dampness
	High Power Bills
	Low House Value &/or Equity

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Case Studies that Suit You

The following are case studies of home owners, similar to yourself that have already taken steps towards to making their homes more comfortable:

1.) The Smith's
2.) The Macdonald's
3.) The Monroe's

1. The Smith's

Meet the Smith's

The Smith's are a young couple who have just bought their first home. They reside in Rangiora, Christchurch.

The 2 story house that the Smith's own has 3 bedrooms and one bathroom. It was built in 1968. The exterior has a combination of timber and concrete cladding. The house is well sheltered which is suitable for the summer. Consequently, the amount of heating required in the winter would be substantial. The Smith's want to improve this situation before the condition of the house deteriorates.

The main reasons that the Smith's decided to retrofit was
- Investment into their health and well being.
- The improvement in comfort and warmth during the winter.
- To improve the structural integrity of their house.

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Case Studies that Suit You

Before Retrofitting

Bracing between the ceiling and timber cladding

Condensation on their living room window. Mould is apparent in the corner.

	Initial Problems with Home
Dampness	Condensation regularly collects on the windows and doors. Small amounts of water sometimes leaks from the ceiling after a heavy storm. There are signs of mould on the window frames.
Temperature	The house is heated for 4 hours in the evening in the winter. The house does not require air conditioning as it is fairly sheltered.
Power Bills	The power bill ranges from $150 - $200 per month in the winter. The power bill is significantly less in the summer.
Health & Moral	The Smith's are healthy and are regularly active. They are concerned with the impact the mould growth has on their health.
Equity and Property Value	The Smith's have the house mortgaged at the bank. The property value is consistent with those in the area.

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Case Studies that Suit You

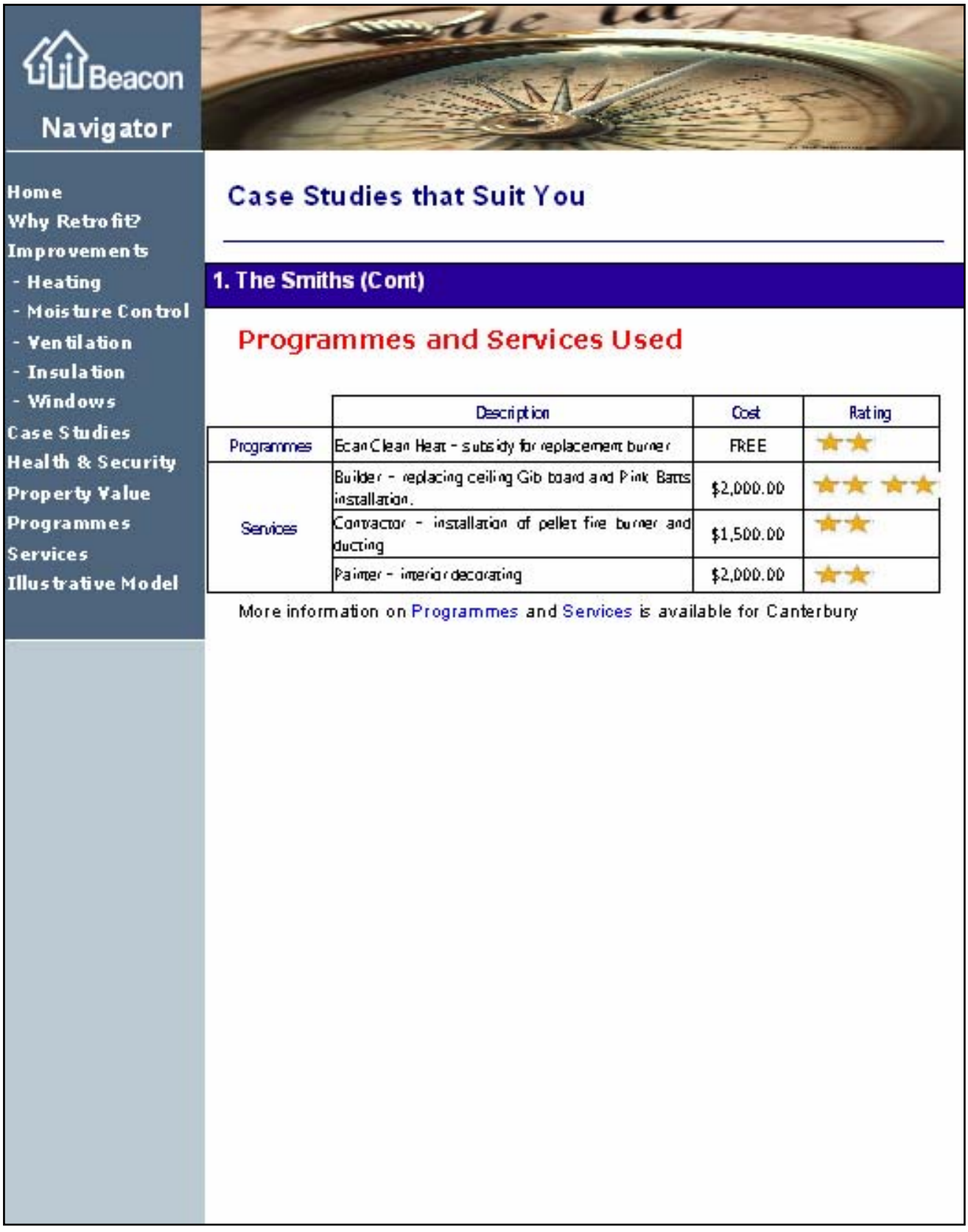
Actions Taken

Pellet fire burner in the main living room.

Ceiling insulation being installed.

	Home Improvements	
	Description	Cost
 Heating	A pellet fire burner was installed in the main living room. The Smith's have also decided to add ducting from the main living room to the bedrooms so that the heat from the pellet fire can flow into these areas.	$2,500.00
 Insulation	The ceiling was replaced with new Gib board. Ceiling insulation was also added.	$4,500.00
 Windows	The condensation is significantly reduced as the moisture content has been reduced with the replacement of the ceiling and rotten cladding. The ceiling insulation has also helped. The window frames were thoroughly cleaned as the Smith's did not want to replace them.	$6,000.00
	Not applicable.	
	Total	$13,000.00

Go to the Home Improvement Database for more information on various heating and dampness solutions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Case Studies that Suit You
1. The Smiths (Cont)
Programmes and Services Used
Description
Cost
Rating
Programmes
Ecan Clean Heat - subsidy for replacement burner
FREE
Services
Builder - replacing ceiling Gib board and Pink Batts installation.
$2,000.00
Contractor - installation of pellet fire burner and ducting
$1,500.00
Painter - interior decorating
$2,000.00
More information on Programmes and Services is available for Canterbury

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Case Studies that Suit You

1. The Smith's (Cont)

After Retrofitting

	Effect of Home Improvements
Dampness	"The condensation has dramatically reduced with the new ceiling and insulation. Our house feels a lot drier and healthier."
Temperature	"The pellet fire burner in the main living room is incredible. Our house feels a lot warmer and we can actually feel it! The ducting also helps with heating the bedrooms too."
Power Bills	"The amount of energy required to heat our home may be slightly more than before, but we feel that it was well worth the cost to have a warm house."
Health & Moral	"We are no longer worried about the condition of our house and how it affects our our health. We are living comfortably and healthily."
Equity & Property Value	"The property value has increased by 10%, which is fantastic. We feel that we have added value and new life to our home. Our finances are well controlled despite the large amount of retrofitting that was carried out."

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Heating Solutions

Sizing a Heating Source

A heating source needs to be correctly sized to the use and size of the location. It is detrimental to have the correct size heat source in the home to ensure the comfort level; heat output; temperature and humidity are at the correct levels. A quick guide rule is to multiply the width x length x height (in metres) to get the volume of the room/area required to heat in cubic metres (m^3). Multiplying this by60 gets the heating requirements in watts (W).

Electricity

Electric Heating options can include resistive heaters (radiant, oil column, and portable fan), night store heater and heat pumps.

Resistive heaters all turn electrical energy into heat using resistance principals. They convert 100% of the electricity they use into heat and are cheap to buy easy to install, provide heat on demand and can be moved from room to room.

Night store heaters are similar to resistive heaters in that they convert electrical energy directly into heat using resistance but they store energy in ceramic bricks inside the unit and release it at a later time allowing them to use cheap power available at night.

Figure 1 - A wall mounted heat pump left, fan heater top right and oil column heater bottom right

Heat pumps are a refrigerator working in reverse, they make the outside of the house cold and the inside warm. They use change of state of a refrigerant to take heat energy from the outside air and put it into the air inside the home. Good units can provide three to four heat units for one unit of electrical power used.

Wood

Wood fires can include low emission wood burners and pellet fires.

Low emission wood burners burn wood inside a fire box to give large amounts of heat and provide an atmosphere. They used a renewable resource than is readily available but work is required to get it to a useful sate i.e. dried and split. It is difficult to control the temperature of a fire and is a dirty heating option when compared to electricity.

Figure 2 - Pellet fire right and low emission wood burner right

Pellet fires are similar to wood fires in that they burn wood, but the wood is waste product from industrial process and is dried and compressed into pellets for convenience. The pellets allow the temperature of the room to be controlled by the rate at which pellets are fed. Pellet fire incorporate fans to push heat from the fire out into the room and to ensure the fire has plenty of air to burn as clean as possible.

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Insulation Solutions

Why insulate
Insulation helps reduce the loss of heat from the inside of a house. An insulated house needs less heating to remain at a comfortable temperature. As heat is put into a house it tries to escape, insulation slows its escape.

Where to insulate
It is important to insulate the areas of a house that are exposed to the outside which commonly includes walls, widows, ceilings and floors. If a preference be given to the insulation of the above the ceiling is most important then walls and finally under floor. This could differ between houses but most uninsulated homes lose 42% of heat through the ceiling and roof, 24% through walls, 12% from ventilation, 12% from windows and 10% through the floor. If you insulated one part of your house for example the ceiling the amount of total heat lost would reduce but heat loss out the walls, windows and floor would increase. Insulating one part at a time will reduce heat losses but complete insulation will give much better results.

Product Groups
Glass fibre Batts
Glass fibre batts are suitable for the insulation of ceilings, walls and under floors and are probably the most commonly used insulation product. They are made from recycled glass and do not readily burn, are flexible (allows instalment around pipes and cables). The level of insulation from glass fibre bats is proportional to their thickness, the thinker the batts the greater the insulation. Glass fibre batts are made to BRANZ standards, meet NZS 4218:1996 and provide good performance at a reasonable price.

Figure 1 - Glass fibre batts installed in a wall cavity

Wool fibre bats

Figure 2 - Installing wool fibre batts

Wool fibre batts are made from sheep's wool that has been treated to provide a natural alternative to glass fibre batts, glass fibre batts require seven times more energy to make than wool batts. Wool products for under floor insulation are usually a wool batt with laminated Aluminium foil on one side. The foil extends over the edges of the batt allowing them to be stapled to joists. Wool batts provide similar thermal and acoustic (sound) insulation to glass fibre. Wool batts are flexible, safe to install and are BRANZ approved and meet NZS 4218:1996.

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Moisture control and ventilation

Air condition (heat pumps)
The primary job of a heat pump is to heat a space and this function alone can reduce relative humidity if the level of moisture is constant in the air. The second function of a heat pump is to provide cooling, the third function is to dehumidify the air. Because dehumidifying is the third function of a heat pump it does not perform this function as efficiently as it's primary or secondary. Most vendors of heat pumps recommend over sizing the units capacity to provide greater efficiency and response to heating demand. This has a negative effect on the dehumidifying of the air as the heat pump will short cycle or not run long enough to dehumidify the air.

Dehumidifiers
The primary function of a dehumidifier is to reduce the level of relative humidity in the air. The cost, features and performance of these units vary greatly between brands. The top of the line Mitsubishi cost up to five times more than other cheaper brands but claim greater performance and additional features such as a clothes drying feature.

Figure 1 - A portable dehumidifier

Venation systems
Venation systems take advantage of the temperate climate with low relative humidly in New Zealand by replacing wetter inside air with dryer outside air. One disadvantage of this is the outside air is cooler and requires heating. Some systems use a heat recovery system such as a heat exchanger to take some warmth from the exiting warmer more humid air and put it into the cooler incoming air. Other systems have electric heaters installed into the ducting to warm incoming air. The basic systems are very cheap to run and are easy to install.

Extractor fans
Extractor fan systems placed in areas where large amounts of water vapour are put into the air can prevent the requirement of other moisture control systems. These fans are usually activated by a manual switch or by incorporating the fan into the electrical circuit of the activity causing moisture. An example of the fan being incorporated into circuit into a moisture generating activity would be on the light switch of a bathroom. When the user enters the room and turns on the light the fan is also turned on. Extractor fans are commonly found above cooking facilities, in bathrooms and in laundries.

Figure 2 - A shower extractor fan

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Window Solutions

Window insulation

The loss of heat from window in a house is largely dependent on the size, orientation and type of windows installed. It is estimated for the average house the loss of heat trough windows is around 12% but if the house is insulated the losses will be much greater. With trends for more and larger windows heat loss through them is a problem for both old and new homes. Widows allow heat to escape by radiation and conduction with convection speeding up the losses from conduction.

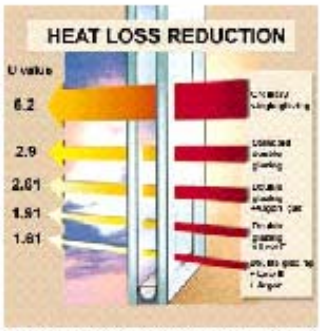

Figure 1 - A comparison of heat loss though different window types

Orientation and position of windows

The best Orientation and position of windows depends greatly on the topography of the land surrounding the house. As a rule, the largest windows should north facing and widows facing south should be smaller. Trees that block sunlight-entering windows should be trimmed back with the owner's permission.

Double-glazing

Most glass windows in Christchurch made from a single pane of glass 4 mm thick this is also known as a single glazed window. A double glazed wind has two panes of glass with a gap between them. The gap is usually filled with air but to provide superior insulation Argon can be used. The manufactures of double glazed window claim that a well insulated house will lose approximately 50% of its heat through its windows. They claim that standard double-glazing (standard glass and air gap) will reduced the heat lost through windows by 50%.

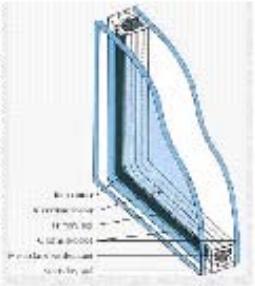

Figure 2 – Section view of double glazing

The retrofitting of double-glazing is a simple process that is very popular in Christchurch now. The process can be applied to both wooden and aluminium window frames.

Temporary double glazing

Plastic film is taped over the window to make an air gap between the film and the window glass. The result is crude but effective double glazing at a fraction of the cost of installed double glazing. Some windows are unable to fit the plastic panels because they lack the necessary flat surface to attach the plastic. The plastic film is designed to last one winter but there are reports of them lasting for several.

Figure 3 - A temporary double glazing product

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