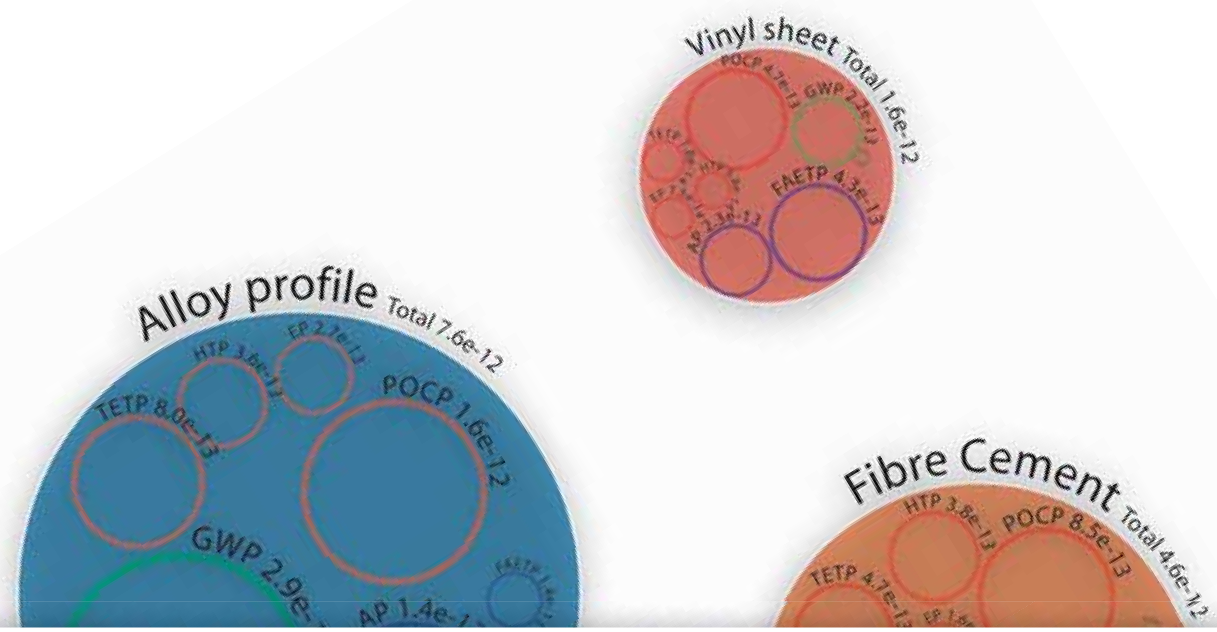
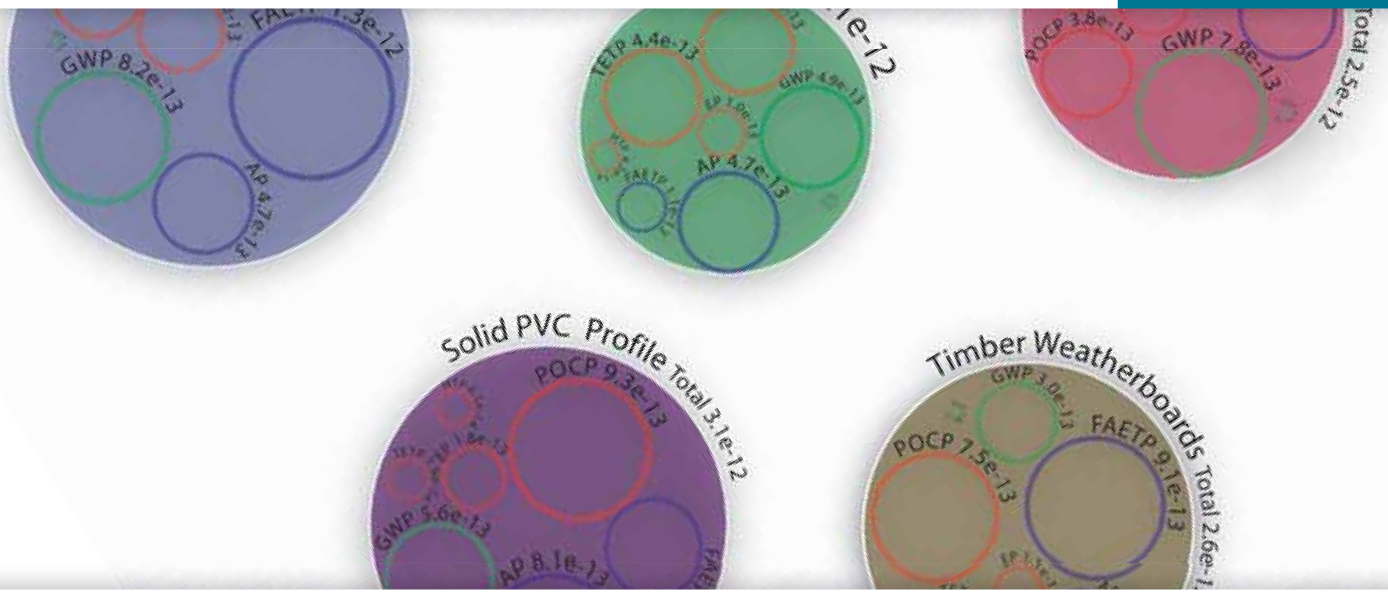


PROJECT :
Guardian

TITLE :
Exterior Cladding

CLIENT : Sicon Research
PROJECT CODE : 1402-02
DATE : 04/08/05
AUTHOR : Timothy Allan
KEYWORDS : timber, cladding, New Zealand



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locusresearch
Sustainable Design & Development

Client Name/Code: SCION
Project: Guardian Exterior Cladding Project

Job code: 1402
Project Manager: Timothy Allan
Research Team: Timothy Allan, Barbara Nebel, Jonathan Harrington, Bernard Dawson

Client Manager (Key Contact for project)
Mr. John Gifford

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Document Title:

Guardian; developing a new exterior cladding solution

Keywords: Guardian, Exterior Cladding, Timber Weatherboards, holistic framework™, life cycle assessment, life cycle costing, quality function deployment, visiometric, visualisation.

Aim:

"To create a branded, high quality, value added external cladding system to be marketed throughout Australasia, and Internationally."

Executive Summary

Timber has played an important historical role in the exterior cladding market within Australasia and elsewhere. It has defined the appearance of traditional and classical looking residential homes through its physical application in the form of weatherboards.

The appearance of weatherboard housing has been picked up by a wide range of alternative material producers including fibre cement, PVC, Aluminium, Steel, and other synthetic products. These high volume processes are capable of producing a more consistent and stable product at a lower cost. This has led to an erosion of market share for timber.

In addition, the leaky building problem coupled with changes in what consumers are looking for has led to a large increase in the use of brick construction in residential dwellings. This has been attributed to clay bricks historically reliable performance, solid appearance and low maintenance level.

Maintenance is a key factor. With the increasing time deficit in peoples daily lives maintenance has become a negative factor. Low maintenance has become a basic functional requirement of the exterior cladding category.

Increased urbanisation has also led to a change in building construction with intensified apartments a key tool in the urban planners kit to combat sprawl and reduce environmental impact whilst still providing high quality public infrastructure. Timber cladding products are not well suited for this type of construction with its large wall spans and different cost imperatives.

It is clear that solid timber weatherboards have a place, but not in the mainstream market. They are a high-end product that is mainly used in architecturally designed homes. However, there would appear to be opportunities to develop new products for the mainstream residential, commercial and industrial cladding markets.

Residential Cladding		Cross Over	Commercial Market	
Solid Form	Profile Form	Sheet Form	Sheet Form Med	Sheet Form Hi
Solid Timber product High quality Top end of market Internationally competes against top timber cladding systems.	Composite product. Mass market large volume product. Competing against mainstream residential cladding systems with existing and new shape concepts.	Bio plastic sheet product for mid to lower price point residential housing. Target new and existing style concepts.	Medium rise sheet cladding system. Medium performance requirements.	Hi Rise sheet cladding system. High Performance requirements.

Figure 1 Product range structure

A structured response could meet these challenges and provide exiting new products (See Figure 1), and design avenues for architects, specifiers and end users. Using a systematic design approach, these new products could set a benchmark in cladding systems by targeting key customer requirements, and fulfilling them with a high level of functional performance.

With a clear range of potential products, it is proposed that a ‘concurrent’ approach is adopted (See Figure 2). This would allow the development of three solutions that were, short, medium, and long term, reducing potential development time from 10-15 years to 5 years. Products would be sequentially released to enable critical mass to be generated, and an ongoing feedback loop to be established with the market for the new product. It would also make responding to the new developments difficult for competitors.

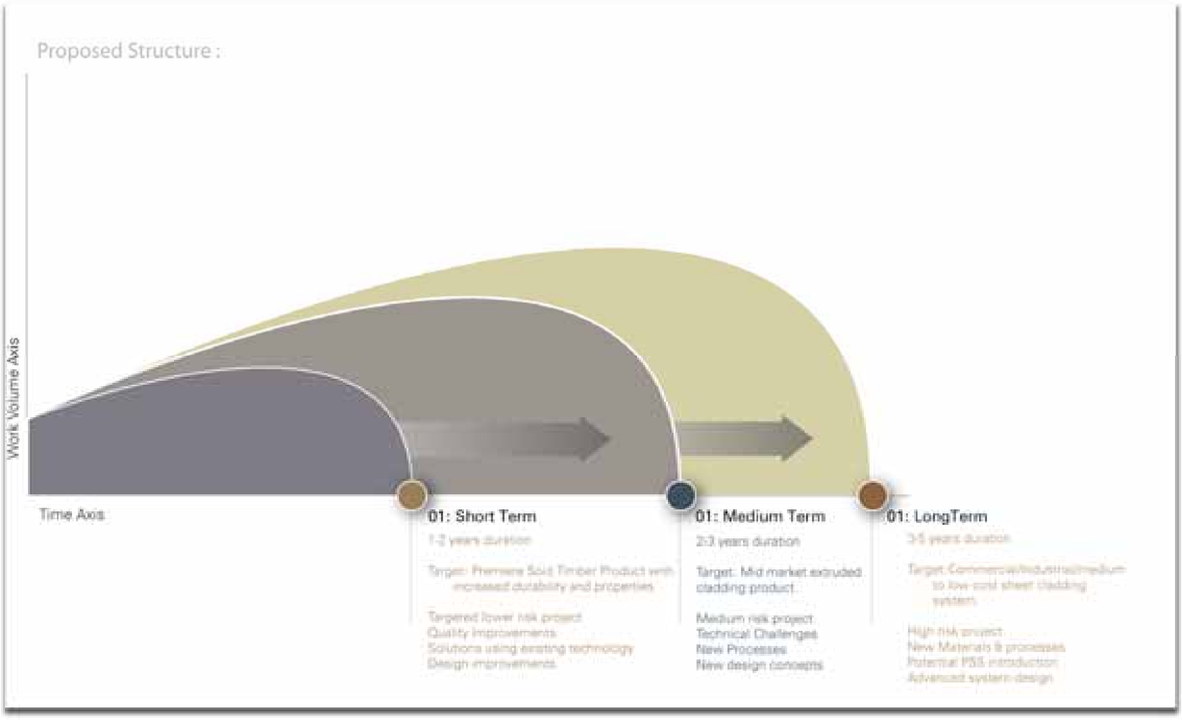


Figure 2 Proposed project structure

Contents

Project Outline

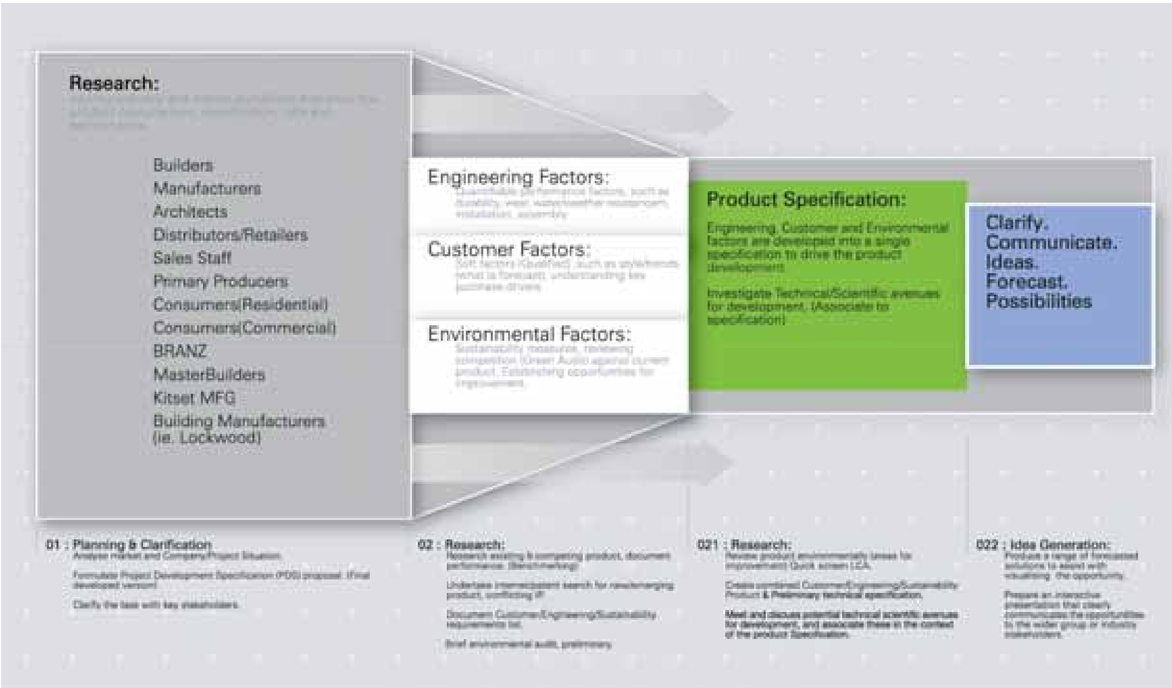
In 2004, Scion Research (Scion) broadly investigated the topic of "Wooden Exterior Cladding Systems"; following on from this Scion identified the need to carry out further research into the development of '*a high value, high quality branded, exterior cladding system to be marketed throughout Australasia*'[1]. The initial discussion paper outlined that in addition to improvements to the product itself, a more advanced 'system' oriented approach was required. This could include dedicated installers to more effectively control installation.

Locus Research (Locus) is a design consultancy that operates in the fields of product design, applied research, sustainability and manufacturing. Locus specialises in sustainable product design with a holistic, life cycle approach to research and development.

Locus was approached to investigate this project and propose a structure that would satisfy the required outcomes. The project was entitled 'Guardian', a term which means '*One that guards, watches over, or protects*'. This provides a conceptual theme for the project and a focal point.

The primary objective of this project was to establish the feasibility of developing a new timber exterior cladding system and to provide a direction for this potential development. The secondary objective was the use of a different development process and model of thinking. The proposed structure is outlined in Figure 1.

Figure 3 Project Structure (For a full view please see Appendix 1- Project Structure)



The project combined design and scientific methods to analyse environmental, customer, and engineering factors. This was done using an established systematic design method that couples consumer research with technical engineering factors called 'Quality Function Deployment' (QFD), and Life Cycle Assessment (LCA) to comparatively assess the environmental performance of a range of cladding products.

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[1] "Wooden and exterior cladding system project overview" Forest Research (Scion)

A 'life cycle thinking' approach has been taken to capture information about the lifespan of cladding systems from manufacture, installation, use, through to renovation and disposal. This approach has been applied to all facets including functional, consumer, and environmental to build a strong profile of the cladding context.

The project looked at the whole exterior cladding context, not specifically at the wood or wood based systems, to capture some of the key drivers that affect the selection and use of cladding systems.

The project structure outline in Figure 1 is outlined below:

01: Planning and clarification

- Analyse the market and the product context.
- Finalise the Project specification.
- Clarify the task and research plan.

02: Research (Phase 1)

- Research competing product performance and pricing.
- Internet and literature search.
- Intellectual Property search
- Investigate and document Customer requirements.
- Investigate and document engineering requirements.
- Gather environmental information for assessment.

021: Research (Phase 2)

- Screening Life Cycle Assessment
- Quality Function Deployment (QFD) Matrix development
- Document Product Design Specification.
- Brainstorm ideas with the project team and selected others.

022: Idea Generation

- Produce a range of forecasted solutions to assist with visualising product opportunities.
- Prepare interactive presentation of work for discussions with stakeholders.

As the guardian project progressed some additional aspects were added into the work programme, for example the Visual Diary[2] was included to illustrate the market position of timber cladding more effectively. In addition, a visiometric[3] method of illustrating the results was developed to more accurately look at environmental, economic, and social (customer) factors.

A by-product of the research has been the development of the '*Holistic Framework*' (outlined in Appendix 2), which is a methodology and visualisation technique that allows the comparative presentation of economic, social and environmental aspects of the product, service or system. This method will be detailed in a separate discussion paper later. The Holistic Framework combines Life Cycle Assessment (LCA), Quality Function Deployment (QFD), and Life Cycle Costing (LCC) to present a balanced assessment of these three key areas presenting them in a clear comparative scale.

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[2] The visual diary is a photo-journalistic diary taken from a range of site visits to give an impression of material usage.

[3] Visiometric is a term Locus has developed to represent visual diagrams that are data driven and measurable interpretations of research.

Assumptions

The Guardian project has been deliberately undertaken in a broad manner. It has been designed to cover a wide range of information and assemble a macro view of the cladding product context. Key issues can be investigated further to provide conclusions that are more detailed.

The Quality Function Deployment (QFD) section uses some unorthodox methods to try to inject some life cycle parameters into the matrix. The questionnaires for this section have been undertaken across multiple user groups and market segments to assemble a broad first pass and attempt to isolate some of the most important issues that a team should focus on.

Life Cycle Assessments have been undertaken in a screening capacity, so have limited application, other than providing an initial indication of the environmental efficacy of competing systems.

The research is produced with the development of a new product in mind so always attempts to relate the information back to the application and how it might benefit the potential development.

Glossary

Scion	Scion Research
Locus	Locus Research
QFD	Quality Function Deployment
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
BRANZ	Building Research Association of New Zealand
FS	Functional Structure
PLC	Product Life Cycle
PDS	Product Design Specification
NZBC	New Zealand Building Code
EIFS	Exterior insulation finishing system, a polystyrene block system that is coated in plaster reinforced with glass mesh
IP	Intellectual Property
Visiometric	Data driven visual representation
Visual Diary	Photo journalistic diary of products and their setting

Team

The team was formed from Scion an Ensis staff with Locus Research coordinating the work. The team was drawn from a range of areas that represented the skill set that was required for this project.

Timothy Allan, Locus Research	External project manager, Project development and sustainable product design.
John Gifford, Scion	Project Oversight, Direction, and Internal Project Management.
Barbara Nebel, Scion	Environmental
Bernard Dawson, Ensis	Chemistry
Jonathan Harrington, Ensis	Engineering

01 Planning and Clarification

The initial investigation was undertaken through the Internet, informal and formal interviews and a literature review. A comprehensive list of research contacts of people and organisations was established as a reference for the project. This was augmented by a list of the relevant standards, and industry information such as the ‘Wall Claddings Manual’ by BRANZ.

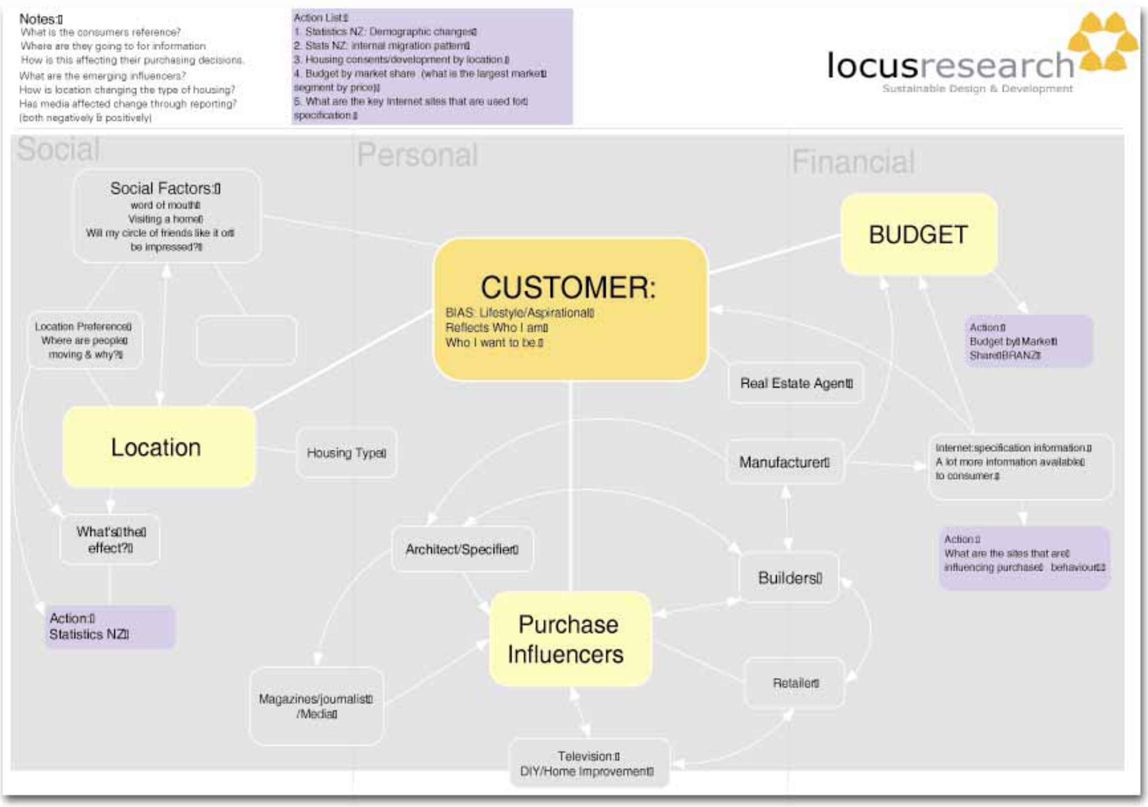
The key tasks of this phase were as follows:

- Analyse the market and the product context.
- Finalise the project specification.
- Clarify the task and research plan.

The consumer

The consumer is central to the development of any new product or service, as such, it is important to understand their motivations. The design team mapped these out diagrammatically (Figure 4) to get a better idea of the things that would influence purchasing behaviour both now and in the future. This is critical as any new product could be several years in development and needs to be relevant and responsive to changes in the market that are likely to occur.

Figure 4 The Customer and their motivations (refer to Appendix 3 for full view)



Trends and change

These diagrams created an action list of issues to explore further. These included the demographic shifts (location) and definition of market share related to the value of the building. Statistics New Zealand had information on both internal migration (to give an idea of the location people are living in) and the division of value in residential and commercial, and the building type (such as apartment, standalone).

Several trends were identified; firstly the growth of apartments and the intensification of housing, and secondly the 'lifestyle' shift to lower density areas such as Bay of Plenty, Nelson, and the Hawkes bay.

The huge growth in apartment construction is illustrated in Figure 5, (300% since 2001). Apartment units now account for 15 percent of all new dwelling units. This is coupled with the fact that three out of ten New Zealanders now live in the Auckland region (this is projected to increase to 36 percent by 2021) creates a strong indication of the demographic changes that are occurring.

Figure 5 New Building Consents[4]

Building Consents Issued – February

	Residential Buildings							
	New Dwellings					Dwelling Alterations & Additions	Domestic Outbuildings	Total Residential Buildings
	New Apartments		Total Dwelling Units - Number	Area m^2 (000)	Total Value $(million)			
	Number	Value $(million)				Value $(million)		
2001	2,189	$201.2	19,670	3,446	$2,878.6	561.7	165.5	3,605.8
2002	3,022	$262.8	21,038	3,791	$3,278.0	596.4	159.1	4,033.5
2003	5,563	$469.8	27,769	4,900	$4,446.8	680.8	178.8	5,306.4
2004	5,417	$579.2	31,323	5,727	$5,530.4	802.9	217.4	6,550.7
2005	5,868	$602.8	30,265	5,495	$5,826.9	933.3	238.9	6,999.1

The 'lifestyle' demographic shift is harder to discern, an indicator is that out of the two regions likely to grow by percentage and total population in the next 15 years, Bay of Plenty is one of them.

Some other key findings from Statistics New Zealand were as follows:

- In February 2005: Building consents were issued for 2,145 new dwelling units.
- The total value of consents issued for non-residential buildings was $316 million.
- The total value of building consents issued for all buildings was $861 million.
- Residential consents were 63 percent of the total value of all buildings, (compared with 72 percent in February 2004).
- The trend for the value of non-residential buildings has increased 25 percent since February 2004.

Market Segment and house type

To investigate trends in market segment, housing value and type further the team decided to produce a visual summary of housing in a typical mainstream development for intensified housing, and general medium to low-density sub division.

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[4] Statistics New Zealand

Figure 6 Visual Summary (refer to **Appendix 4** for full view)

Figure 6 indicated that most houses being constructed in mainstream residential developments were not timber clad. There was a predominance of clay brick, which was substantiated by Figure 7; Clay brick dominates new residential homes with 42% of the market.

One notable exception is the shadowclad series[5] undertaken with Signature Homes and Carter Holt Harvey. This series of architecturally designed production homes uses plywood exterior cladding as a key feature. Carter Holt took the initiative to get a range of homes architecturally designed using shadowclad (exterior plywood cladding), giving them increased sales and an increased brand awareness of the product.

Medium rise apartments were visually dominated by concrete, metal and glass. This is mainly due to the different type of construction involved and the fact there are not suitable timber cladding systems for these applications. The differing requirements of the intensified urban environment for low to medium rise constructions enable certain materials to function more effectively. It would require a product tailored to suit these factors to succeed in displacing other cladding products.

Figure 7 Market share of cladding type[6]

Figure Note: the color and size are governed by the Market Share percentage.

[5] (http://www.signature.co.nz/default,shadowclad.sm)
[6] BRANZ quarterly building survey Feb 2005, Data courtesy Ian Page, BRANZ

The area where solid timber cladding was primarily used was in higher value, architecturally designed homes. These homes are more likely to have a higher cost level due to the customised nature of the design and construction.

When analysing the market share of new building values in Figure 8 it is possible to see a very strong band from the $150-250,000 where almost 50% of the market by volume and value is.

Figure 8 Market share of new building value[7]

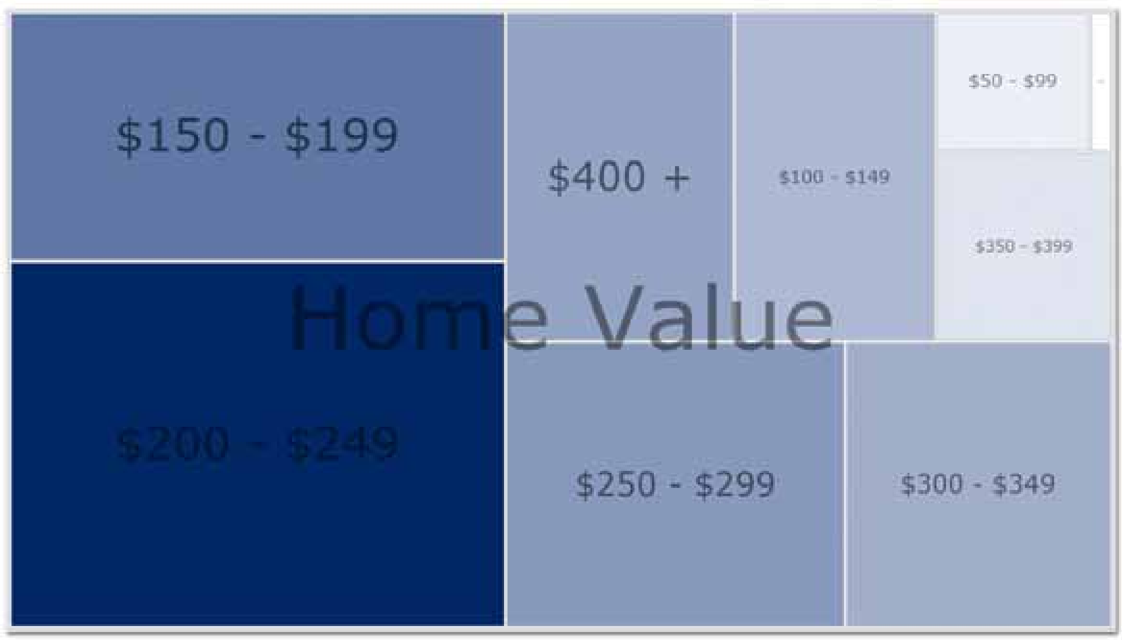


Figure Note: the color is governed by volume of consents, and the sizes are governed by the total value. The names refer to the new home value category.

Viewed in isolation these facts seem interesting but when considered together with:

1. An increase in population percentage in Auckland will create more intensive housing development, where timber is not a natural fit.
2. Internal migration to medium density 'lifestyle' areas.
3. Mainstream development in medium density (bulk part) of the market has moved away from the use of timber, and will use alternatives where it does try to achieve a similar aesthetic.
4. Lack of a timber cladding product for intensified urban areas.
5. Lack of a sheet cladding product in the portfolio.

These factors could lead to a further contraction of market share for solid timber cladding without the introduction of products that address the changes that are occurring.

Functional Structure

Products interface with people, services, systems and other products over their lifespan. This is termed the products 'Functional Structure'. By analysing and defining the functional structure, it is possible to understand how and why a product performs various functions over its lifespan and what aspects are the most important.

Quality Function Deployment (QFD) is the methodology used to capture the

[7] Data courtesy of Ian Page at BRANZ

functional structure. It combines customer requirements with technical and measurable properties of a product. This Project also injects an additional layer, the product life cycle.

Although mechanically simple, the cladding product has a number of phases that influence the effectiveness, performance and cost. The product also interfaces with a number of different user groups that have different agendas. A typical cladding PLC was documented to visualise and evaluate the opportunities for development within the various stages such as installation or maintenance.

A clear delineation that was made early on within the functional structure of all cladding was the difference between non-structural and structural exterior cladding. This division is an important fundamental consideration in the development of a new cladding system.

This difference in the functional structure is characterised by the requirements of the New Zealand Building Code (NZBC). Non-structural cladding has to (satisfy the lesser of) either 15 years or the life of the building, whereas structural cladding must have a life of 50 years, a significantly higher performance requirement.

Product Life Cycle (PLC)

Part of determining the functional structure is defining the PLC. The cladding PLC was derived by reviewing the steps that current exterior cladding systems commonly use. The steps in Table 1 are required by most exterior cladding systems regardless of material or method of installation. Some systems may not require all of these stages, such as PVC profiles, which have an integral finish.

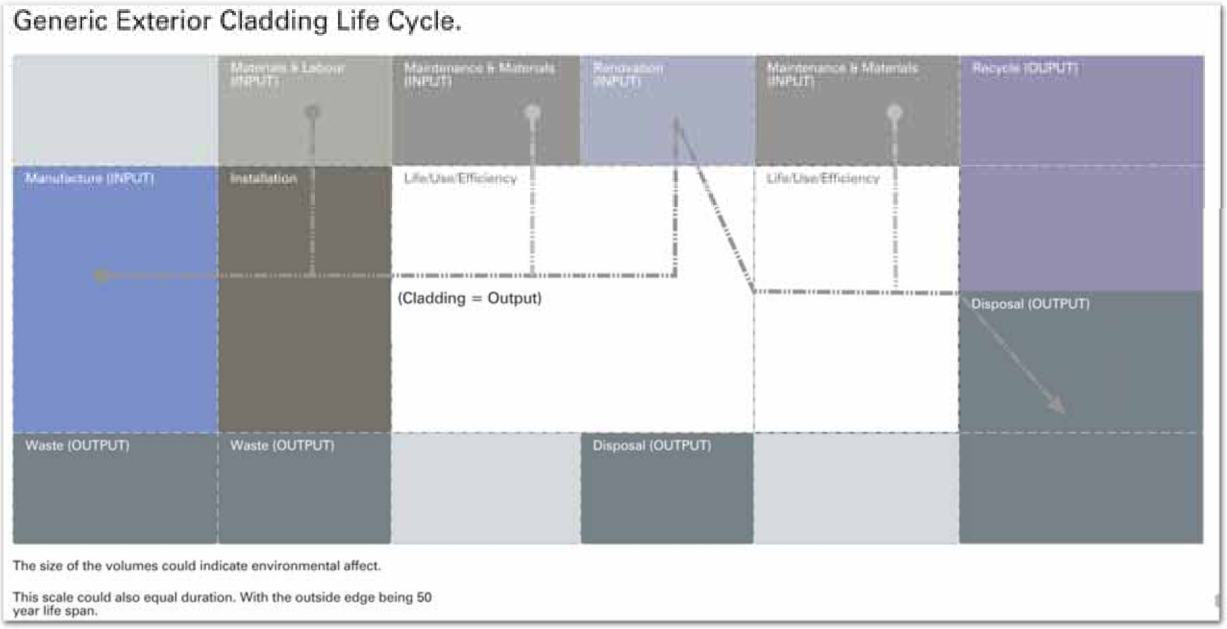
A well-defined PLC enables 'life cycle thinking' to be adopted across all facets of the development project.

The cladding life cycle was interpreted into a diagram (Figure 9) that could serve as a guide to sketch out the lifecycles across different products. This diagram could also be used as a method to design a 'new life cycle' for a cladding system after completion of the initial research phase.

Table 1 Exterior Cladding Product Life Cycle

Step	Phase	Probable User Group
1	Manufacture	Manufacturing Enterprise
2	Specification	Architect/Design/Specifier
3	Sale (Retail or Distributor)	Retailer or Distributor
4	Transport to installation location	To site
5	Storage (onsite)	Prior to use onsite.
6	Preparation (pre installation)	Such as Sheeting or special amendments to conventional construction.
7	Installation	Installation of cladding onto house structure.
8	Finishing/Painting	Onsite (excludes prefinished products)
9	Intended use	1st Lifespan of the home.
10	Maintenance	During 1st Lifespan
11	Renovation	Renovation of House
12	Intended Use	2nd Lifespan of the home
13	Removal	Of cladding/excluding structure but including any dependant components
14	Reuse/ Recycle/Disposal	Of cladding and dependant components.

Figure 9 Typical Cladding Life Cycle Diagram (Refer to **Appendix 5** for full view)



Definition of User Groups

Defining the PLC helped establish the range of users that are affected and who would need to be consulted during the customer requirements and subsequent research phases.

Each of the groups listed in Table 2 have the ability to affect the purchase of cladding products. The users are divided into primary (those that directly affect purchase) and secondary (those that are involved indirectly).

Table 2 Primary and Secondary User Groups

Primary Groups

1. Architect/Designer/Specifier (has to design with it)
2. Builder or Building Manufacturer[8] (has to build with it)
3. Installer (where builder does not install)
4. Finisher/Painter (where product is not pre-finished).
5. **Home Owner/Consumer (Most significant User)**

Secondary Groups

1. Manufacturer (of product to be installed)
2. Sales (sale and display of product in retail context)
3. Transport (From Manufacturer– Sales – Site)

The homeowner is classed as the most important group in the functional structure. If they are not happy with the performance or aesthetic attributes, this will directly affect the potential viability of the cladding product. The table is in chronology of use not order of importance. This enables it to be related to the PLC.

A secondary group is involved in the process of the production and distribution, but

[8] The building manufacturer has a lot more purchase and influence in today's market, but is still heavily influenced by consumer demand.

have less of an impact on the selection, specification and use of the product.

There are also a defined group of key stakeholders. The product affects these groups and it is considered that a successful product will balance the agenda of the groups listed below:

Figure 10 Key Stakeholders

Manufacturer Architect/specifier Builder Home owner

This information creates a clear understanding of the product life cycle and the interacting user groups, which even at this early stage create a greater level of insight into the possible developmental avenues of the product.

020: Research Phase 1

With the product context and the functional structure broadly defined, a range of more detailed steps were undertaken which included a competing product review, focus groups with architects, field visits to sites, user groups surveys, and the life cycle inventory information for use in the screening LCA assessment.

These steps produced a clear view of the customers requirements and a definition of where timber weatherboards sit in the exterior cladding context. The information provides the basis for both the QFD matrices, and the LCA impact analysis.

The key tasks of this phase were as follows:

- Research competing product performance and pricing.
- Internet/literature search
- Investigate and document customer requirements.
- Investigate and document engineering requirements.
- Gather environmental information for assessment.

Competing product review

A key tool in product design is the analysis of competing products, not as a mechanism to mimic, but to clearly understand the features and benefits of the product context. This investigation looked at all types of cladding used in the New Zealand market not just weatherboards. This provides a good indicator of where timber weatherboards sit in key performance categories and price.

Each major products features and benefits were analysed from a range of sources including; the BRANZ wall-cladding manual, the teams own assessment from available information and anecdotal feedback from architects, specifiers and builders. These products were documented in the manner of Figure 11 (for all cladding systems refer to Appendix 6 - Competing Product Assessment Sheets).

Figure 11 Typical products analysis page

The major products were compared against each other in the in the key performance categories in a performance matrix (Table 4) using a simple 5 point rating scale. The matrix in is not weighted so does not look at which factors are considered more or less important by the key user groups. Table 3 outlines the scale used for the matrices.

It provides a broad performance overview of the products against each other. Clay brick and solid concrete are ranked in the top three due to their durability, low maintenance and all round properties. Tilt slab is an emerging construction technique and does not yet have the infrastructure supporting it that others do, but with its combination of properties, it is likely to be a strong competitor in the future.

Timber weatherboard was placed in the middle of the pack with a good balance of properties. Key areas for improvement as described in Table 4 are acoustics, thermal insulation, and maintenance.

Table 3 Performance Matrices Rating Scale

5	Excellent
4	Very good
3	Good
2	Average
1	Poor
0	Very poor

Table 4 Performance Matrices

	Durability	Low Maintenance	Impact Resistance	Acoustics	Thermal Insulation	Resilience*	Light Weight	Surface Options	Ease of Installation	Easy finish(coating)	Flamability/Combustability	Total	Normalised total	% Total	Rank
Concrete/Tiltslab	5	5	5	5	5	3	0	5	2	4	4	43	0.10	10%	1
Clay Brick	5	5	5	5	4	1	1	3	3	5	4	41	0.10	10%	2
Solid Masonry	5	4	4	5	5	3	1	2	3	3	4	39	0.09	9%	3
Aluminium	4	4	5	2	1	2	3	5	4	5	3	38	0.09	9%	4
Lockwood	3	4	4	3	2	4	4	3	3	4	4	38	0.09	9%	5
Timber Weatherboard	3	2	4	3	3	5	4	3	4	3	3	37	0.09	9%	6
Sheet Metal	3	3	3	1	0	2	4	5	5	5	3	34	0.08	8%	7
PVC	3	3	3	3	2	3	3	4	3	5	2	34	0.08	8%	8
Timber Plywood	3	2	4	1	1	3	5	3	5	3	3	33	0.08	8%	9
Vinyl Sheet	2	3	1	1	1	2	5	2	5	5	1	28	0.07	7%	10
Fibre Cement	2	3	1	1	1	1	2	4	3	3	4	25	0.06	6%	11
EIFS	1	1	1	3	5	2	4	2	1	3	1	24	0.06	6%	12
Total	39	39	40	33	30	31	36	41	41	48	36	414	1.00	100%	

* Resilience: refers to the ability to withstand movement that might occur through both general house movement and geological movement.

The perception of timber

A review of marketing material led to an interesting point; timber figures highly in competitive literature. This may be in part due to the historical use of timber cladding, and its appearance. Most synthetic weatherboard products (fibre cement, vinyl etc) refer to achieving the classical 'look of timber' but having lower maintenance level and a longer lifespan. This implies the timber has a perceived value in the marketplace but reveals the contradictions in the perception of timber cladding products.

Some of these comments have been catalogued and read as:

- *"Classic Groove SupaClad® Twin Wall weatherboards impart an appearance* of well-maintained, dressed, select grade timber with two subtle classical Grooves on the forward flat faces”[9].

- *“Palliside seeks to recapture the appeal of timber weatherboards without the maintenance and deterioration”*[10]
- “Shiplap's appearance recalls that of rusticated timber weatherboard and looks smart applied either horizontally or vertically”.

Physical styles and ready meals

Currently, there is a wide range of physical styles of cladding on the market. These systems can be broadly classified into three categories, Solid, Profile and Sheet cladding systems. Within each of these categories, there is a range of variations, both in materials and in design. The physical styles also represent different price points (refer to costing summary Page 22).

Sheet cladding systems have the advantage of being cost effective, lightweight and easy to install. Sheet products are defined by a thin wall section, and a large format sizing. They generally lack the durability and strength of solid cladding materials. Sheet materials dominate the low cost niche and industrial-commercial construction. Conventional New Zealand market sheet materials are augmented by vinyl siding, which is common in the US market for residential housing. It is plausible that our construction may move to more sheet materials over time.

Figure 12 Certainteed vinyl siding

Solid cladding systems are more expensive and labour intensive than the sheet systems. By definition solid exterior cladding systems are either block or solid profile. Solid timber and fibre cement weatherboards are classed as solid products as they do not have a thin wall construction and are not extruded. This enables them to occupy the dominant position in the residential building market in mid-upper price points.

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9 http://www.svpindustries.com/products/twinwall.htm

10 http://www.palliside.co.nz/facts.shtml

Figure 13 Solid Cladding (Firth masonry)

Profile cladding systems are recent additions to the market, and include plastic and aluminium. Profile systems are defined as those with thin wall sections that are produced via extrusion techniques and are predominantly plastic and metal. These systems are mainly used in middle market areas, although some aluminium profiles such as Nuwall are being used in the upper market segment. It is also notable that the Lockwood system utilises an aluminium shell on its laminated timber boards to increase the longevity of the finishing in its housing system. They possess durable integral finishes and materials but present some difficulty flashing with their thin wall sections.

Figure 14 Profile Cladding (Nuwall alloy sections)

Products that can be delivered with different 'style' choices in a coordinated range have the advantage of providing specifiers with a comprehensive choice of options without having to use another product.

With a renewed focus on cladding through the leaky building problem, there are increasingly stringent legislative requirements. This has driven manufacturers to offer cladding products in a systemised 'ready meal' style, with all the detailing and flashing pre-designed and sold with the product. This is done to reduce installation error, comply with the building code, and cut design and construction cost.

Architects and specifiers also have more work to do ensuring building compliance, which means detailed, accurate specification information on products needs to be readily available

James Hardies have a systemised range with their fibre cement products. They span residential and commercial construction with a variety of performance levels in the same product platform. The product information is delivered cohesively through manuals, online (website) and in advertising. Their website it credible and contains a raft of very detailed information and good summaries on each product. It also clearly shows the 'range' of their offering, which endorses the products perception.

Cost Comparison

The cost structure of a typical exterior cladding system is affected by a range of factors; including the cost of raw material, processing, installation, finishing, and maintenance over its lifespan.

Initial cost comparisons were undertaken by contacting a variety of merchants, retailers, product distributors and manufacturers. Prices were requested on a trade basis. The prices in Table 5 represent a typical 'kerbside' view of the product for the consumer and have been categorised by the material to develop an understanding of the effect of material on pricing structure.

Table 5 Basic cladding cost analyses per M2 of wall cladding.

	Clay	Composite [11]	Concrete	Metal [12]	Plastic	Stone	Timber
Minimum Cost	94.00	46.00	55.00	52.28	92.31	136.00	49.79
Average Cost	110.00	124.50	132.82	85.38	117.44	136.00	109.40
Maximum Cost	126.09	210.75	141.30 [13]	145.00	160.00	136.00	169.49

This informal process was augmented by other industry sources such as Rawlinsons[14] and BRANZ[15]. The data provided in Table 7 and Table 8 is based on 2003 Rawlinsons data. (This data is detailed and fully supported). Full-unedited versions of the cost analysis are included in the Appendix 7 for reference.

The BRANZ data summarised in Table 6 has been produced using a life cycle costing (LCC) approach. This takes into account the time-based value of money and other variable factors of an investment. If maintenance was deferred for 10 years it is worth less than if it were undertaken now because the money can be invested and

[11] Includes composite plaster systems and fibre cement board systems
[12] Includes aluminium profiles and sheet steel cladding
[13] These are structural systems, so contain the cost of structure as well.
[14] www.rawlinsons.co.nz
[15] 'Selecting Wall Claddings Manual' BRANZ

achieve a return in the interim period. It also takes into account the annualised costs of the system and the maintenance over its lifespan. For example, two systems may have the same maintenance cost but System A has an estimated lifespan of 50 years and System B has a life span 100 years. In this case, System B would have a lower annualised maintenance cost.

The Rawlinsons data evaluated includes total structure, cladding material, installation and finishing and maintenance costs. These figures do not take into account LCC factors and as such are 'raw' costs at today's rates. Table 7 outlines the total initial Cladding cost per square metre. Table 8 has the costs broken down into cost per square metre including initial cost and ongoing maintenance.

Table 6 BRANZ cladding Life Cycle Costs

Cladding Material	Initial Cost $/m²	Life years	Initial Cost $/m²	Maintenance Cost $/m²/year	Total Cost $/m²/year
Cedar Weatherboard	$111	45-55	$9.0-9.2	$0.0-2.50	$9.20-11.50
150 Timber Weatherboard	$106	50-70	$8.50-8.7	$1.80-1.90	$10.3-10.60
Clay Brick	$94	80-100	$7.50	$0.10-1.50	$7.60-9.0
40mm EIFS	$77	30-40	$6.50-6.80	$0.50-0.70	$7.20-7.30
PVC weatherboard	$70	30-55	$5.70-6.20	$0.0-1.80	$6.20-7.50
Stucco	$66	35-66	$5.30-5.70	$0.0-1.80	$5.70-7.10
Concrete Masonry (block only)	$55	50-90	$4.40-4.50	$0.20-1.90	$4.70-5.90
Fibre Cement Weatherboard	$37	45-50	$3.0-3.10	$1.40-1.60	$4.50-4.60
15mm Plywood	$48	30-50	$3.90-4.30	$0.0-1.80	$4.30-5.70

(Orange highlights denote the best in each category)

Table 7 Average Initial house-cladding costs (Rawlinsons 2003)

Cladding description	**Materials** ($)	**Labour** Fixing ($)	**Trims/ fixings** ($)	**Finishing** Prime/ u/coat ($)	Paint (2 coats acrylic)	Stain	**Total ($)**
Timber Weatherboard (Cedar)	12,622	6,351	1,398			1,620	21,990
Fibre cement Weatherboard	8,135	5,846	3,126		1,640		18,747
EIFS system	18,013	incl	incl	incl	incl		18,013
Timber Weatherboard(Pine)	8,437	6,351	654	-	1,726		17,169
Clay Brick	16,725	incl	incl				16,725
Concrete	15,207	incl	incl				15,207
Alloy Profile	9,790	5,214	incl				15,004
Reconstituted Hardwood	5,229	5,214	687		1,112	1,726	13,967
PVC weatherboard	6,686	4,370	1,781				12,837
Plywood Sheet(Painted)	4,370	3,304	476	926	1,438		10,514
Plywood Sheet(Stained)	4,370	3,304	476			1,350	9,500
Sheet Steel	2,542	2,831	1,904				7,276
Composite Sheet	2,848	2,697	1,043				6,588

Table 8 Cladding cost per m^2 including maintenance (Rawlinsons 2003)

Cladding description	Price fixed (per m2	Refinishing costs (per m2) 5 yrs time	10 yrs time	15 yrs time	20 yrs time	Total Maintenance	Total PerM2	RANK
Timber Weatherboard (Cedar)	$168	14	14	14	14	56	$ 224	1
Timber Weatherboard(Pine)	$131		20		20	40	$ 171	2
EIFS system	$138		15		15	30	$ 168	3
Fibre cement Weatherboard	$143			15		15	$ 158	4
Reconstituted Hardwood	$107		15		15	30	$ 137	5
Plywood Sheet(Stained)	$ 73	14	14	14	14	56	$ 129	6
Clay Brick	$128					0	$ 128	7
Concrete	$116					0	$ 116	8
Alloy Profile	$115					0	$ 115	9
Plywood Sheet(Painted)	$ 80		15		15	30	$ 110	10
PVC weatherboard	$ 98					0	$ 98	11
Sheet Steel	$ 56					0	$ 56	12
Composite Sheet	$ 50					0	$ 50	13

Structural versus Non-Structural

The effect of structural or non-structural cladding systems on the comparative costing is discernable. In the case of a fibre cement weatherboard the Cost of the structure are $52.

Fibre cement (Linea) 180mm weatherboard[16]:

- Cladding only: $71
- Complete structure: $123.

This cost is equitable with the cost of solid masonry, filled block walls and reinforced, which is $123. What is unclear is how these systems affect the total construction cost of a house. Further analysis into the cost structure of structural and non-structural systems would need to be carried our in order to ascertain the general differences between the systems.

Sheet, Profile and Solid Cladding forms

The cost variation between Sheet, Profile and Solid cladding was investigated further.

- Sheet: Systems supplied in a sheet form,
- Profile: Systems supplied in an extruded profile;
- Solid: Systems supplied in solid block, machined profile or assembled form.

The summaries in to Table 11 **'Profile' Cladding cost summary** show the pricing difference between the categories. Sheet cladding is on average the cheapest at $74.41, followed by profile at $135 and then solid systems at $147.79.

[16] Rawlinsons Construction Handbook 2004, 19th edition

Table 9 ‘Sheet’ cladding cost summary

TypeA		Company	Tradename	Material	Cost per M2
Sheet	Composite	James Hardie	Harditex	High Density Cellulose Fibre, Cement, Silica	$ 116.22
Sheet	Plastic	Masada	SupaClad series2000	Vinly Sheet	$ 92.31
Sheet	Timber	CHH Woodproducts	ShadowClad 'Texture'	Plywood, knot free	$ 86.22
Sheet	Timber	CHH Woodproducts	ShadowClad 'Groove'	Plywood, knot free	$ 86.22
Sheet	Composite	James Hardie	Titan® Facade Panel	Medium Density wood Fibre, Cement, Silica	$ 84.55
Sheet	Metal	Pacific Coil Coaters	Colorcote	Steel	$ 58.84
Sheet	Metal	Dimond	Dimondclad	Steel	$ 52.28
Sheet	Timber	Tenon	Origin Plywood	Plywood	$ 49.79
Sheet	Metal	Nulite	Aqualine	Corrugated fibre-bitumen sheet	$ 46.00
				Average	$ 74.71

Table 10 ‘Solid’ cladding cost summary

TypeA	Category	Company	Tradename	Material	Cost per M2
Solid	Timber	CHH Woodproducts	Pinex	Pine	$ 169.49
Solid	Composite	James Hardie	Linea	Medium Density wood Fibre, cement, Silica	$ 135.11
Solid	Clay	Monier/CSR	Varied/Bricks	Clay Comp	$ 126.09
Solid	Stone	Firth	Hinuera	Natural Stone	$ 136.00
Solid	Concrete	Firth	Summit Stone	Concrete	$ 141.30
Solid	Timber	Jenkin Timber	Trupine	Pine	$ 155.30
Solid	Composite	Nu-Age plaster	Nusolid	Plaster	$ 210.75
Solid	Composite	Nu-Age plaster	Nulite	Polystyrene,glass fibre mesh,Light weight Plaster	$ 137.04
Solid	Composite	Nu-Age plaster	Nutherm	Fibre cement sheet, glass fibre mesh adhisive coarse Plaster	$ 141.81
Solid	Concrete	Supacrete	TiltSlab	Concrete	$ 125.00
					$ 147.79

Table 11 'Profile' Cladding cost summary

TypeA	Category	Company	Tradename	Material	Finish	Cost per M2
Profile	Plastic	Masada	Masada Twin wall weatherboard system	Extruded PVC	Integral	$ 160.00
Profile	Plastic	Dynex	Pallisade	Solid UPVC foam	UV and Impact Resistant top coat	$ 100.00
Profile	Metal	Ullrich	Ultraclad	Extruded Aluminium	Powdercoated or anodised	$ 145.00
					Average	$ 135.00

Focus Groups

Three focus groups were held with architects: Page Henderson (Te Puke), Pete Bossley Architects (Auckland), and Arc Angels (Auckland). Some of the key aspects from these sessions are listed below.

Pete Bossley Architects:

The introduction of the cavity area in the new building code was seen as an area of concern with increased complexity and cost in both the design and building phase. A lot less risk is allowed in buildings now, which has meant a reduction in experimentation with new construction techniques.

Pete Bossley commented on the Lockwood system, as he was involved in developing some of their new designed homes. He felt that the system was quite highly resolved, although it could face issues with the new code and the level of thermal insulation required.

Bossley has very effectively used vertically oriented solid timber cladding without heavy fixing details to great effect. Their studio uses timber on a range of residential dwellings, as it is a quality natural material.

Also notable was the highly effective use of plywood in high value homes[17]. Finishes on timber homes tended to be were clear or colour stained not painted.

Page Henderson

Appearance was seen as highly important to this group of architects, but projects tended to be specified according to the clients budget. Low maintenance solutions were popular, but were often construed to mean 'no maintenance'.

David Page said that people that were spending a lot of money were less likely to be interested in knowing what the cost of ownership was. They would usually provide 'cost in place', and felt that cost of ownership was not a real factor with their clients.

Weatherproofing ranked as the most important issue to the architects in this studio generally.

Their use of timber was limited, although they would readily use it. Plywood was felt to be generally a lower cost solution. Most of the timber used was Cedar weatherboard, reflecting the higher value usage of solid timber weatherboards. Where timber was used, it was stained to show the timber through the finish.

When guarantees were discussed, it was felt that they were a bit dubious due to the onerous maintenance conditions it placed on the homeowner. A colour steel example was cited.

Arc Angels

The team explained that a lot had changed with the leaky building problem and there was a renewed focus on cladding now. Weather resistant detailing was considered important in both plywood and timber.

These architects used timber a lot in their projects, which tended to be predominantly renovation and rebuilding projects. They felt that timber was a durable solution in exposed locations, although stability could be an issue. They did note that clients decisions often veto material decisions made by the specifier.
An interesting idea was presented that "timber is the only cladding made to shed water", this could be worth further exploration as a concept.

Tolerance for movement was an issue, something that had a lot to do with the leaky buildings. The buildings affected were not made to withstand movement and remain water resistant. 25mm movement could be expected in an average house in New Zealand.

We discussed the predominance of monolithic building; people seemed to like the 'solidity' of those systems, whereas thin materials were perceived as cheap.

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[17] www.bossleyarchitects.co.nz

Customer requirements (the customers voice)

The customer requirements or 'customers voice' is a key component of the QFD methodology. This is defined from a range of sources including; competing product, interviews, field research, literature and experts in the field and are broadly defined under the categories of pre-purchase, post purchase, and the life of the product.

To explore and document these requirements a series of affinity diagrams (Figure 15) and tree diagrams were created and then exported and refined into hierarchical tables.

Figure 15 Customer requirements affinity diagram (Refer to Appendix 8 for full view)

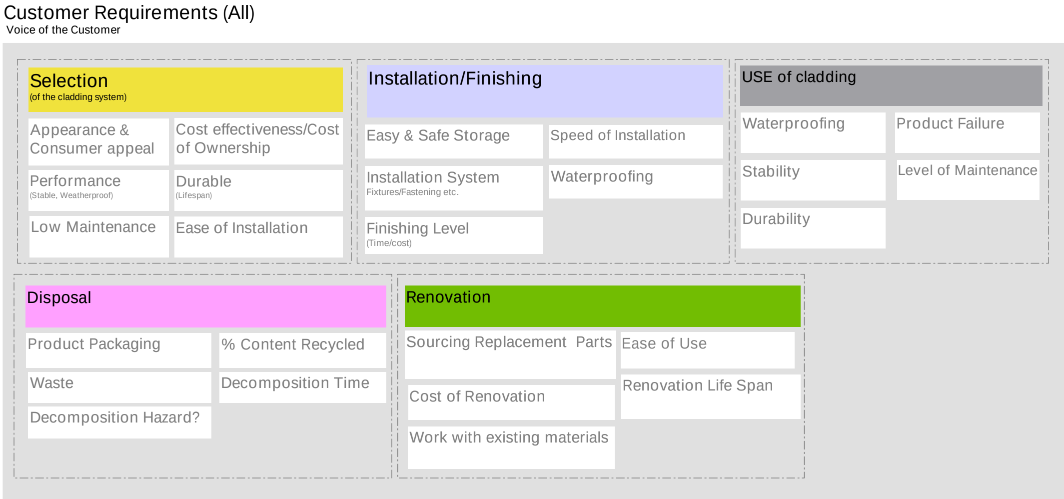
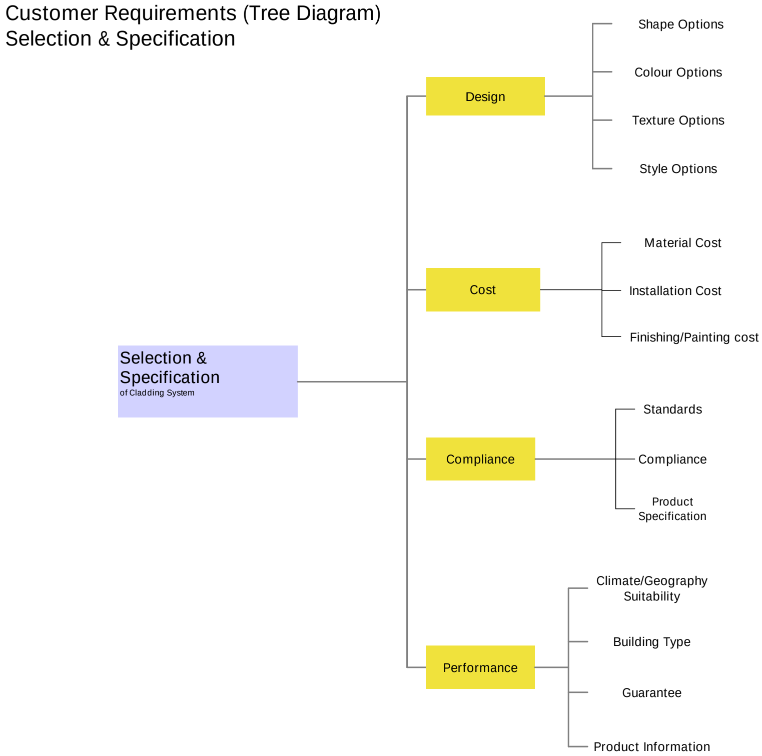


Figure 16 Customer Requirements Tree Diagram



Defining the Customer Requirements List

The customer requirements list was refined and documented into Table 12. This was structured against the PLC. The customer requirements form the basis of the questionnaire; this enables an attribute weighting to be applied to requirements. The questionnaires were filled out by a wide range of the specified user groups (see Appendix 9) to obtain an aggregate result. To get more specific and robust information each user group should be targeted separately with a targeted questionnaire.

Table 12 Customer Requirements

Pre-Purchase	Selection	Appearance & Appeal
		Cost effectiveness/Cost of Ownership
		Performance
		Durable
		Low Maintenance
		Ease of Installation
		Environmentally Benign
Post Purchase	Installation Finishing	Easy & Safe Storage
		Quick to Install
		Safe to work with
		Good Installation system
		Weatherproof System & Detailing
		Good Finishing Surface
Life of Product[18]	USE	Weatherproof
		Low Level of Maintenance
		Stable
		No Product Failure
		Durable
		Quiet
		Warm
		Cost Efficient (running cost)
	Renovation	Sourcing Replacement Parts
		Ease of Use
		Safe to work on
		Renovation Lifespan
		Works well with other materials
	Disposal	Easily Disposed
		Low Cost
		Low Environmental Impact
		Good Return on Investment

Attribute weighting

A critical element of QFD is weighting the requirements, which discerns how important the various requirements are. The questionnaire data was summarised into tables to create a '*customer importance*' rating. This in effect is used to weight the value of the different customer requirements. The questionnaire asked people to compare each sub category and choose the three most important factors ranking, one being the most important. This data has been collated from approximately 50 questionnaires.

This data is normalised against the total score of the category across all respondents to provide a percentage of preference. The data is converted across to the accepted weighting scale of 1-5 (5 being important). Attribute scores are the weighted average of the attribute rankings. The weights used are 5, 3, 1 and -1 for high, medium and no importance respectively. A unit offset is applied to the weighted averages to ensure that attribute scores lie between zero and six.

Figure 17 is an example, which summarises the pre-purchase 'selection' category outlined in the customer requirements in Table 12. Here the questionnaires responses are normalized against the total of all feedback, with the last column showing the attribute weightings. All attribute summaries are included in Appendix 10.

Figure 17 Customer importance (Selection)

Customer requirement	Total	Normalised	%	Attribute Weighting (Importance)
Appearance & Consumer Appeal	125	0.34	34.34%	5
Cost Effectiveness/Cost of Ownership	52	0.14	14.29%	3
Performance	128	0.35	35.16%	5
Durability	51	0.14	14.01%	3
Maintenance Level	12	0.03	3.30%	1
Ease of Installation	-4	-0.01	-1.10%	1
	364	1	100.00%	

This summary indicates that Appearance and Performance were the key considerations during the selection phase of the product life.

Technical Measures

The customer requirements are interesting and worth further analysis but they need to be paired with the technical aspects of a product to be valuable to a prospective product development team.

Most technical requirements exist separately to the customer requirements and represent the domain experts or companies view; it is also commonly referred to as the 'Companies Voice'. The technical requirements have to be measurable so that they can be benchmarked.

Defining the Technical/Functional Measures

The technical requirements list was defined by the team through a series of discussions and meetings after reviewing some of the initial research. The measures for this project were broadly defined under the same categories as the customer requirements (Pre-Purchase, Post Purchase, and the life of the product). The orange rectangle in Table 13 highlights the data that would be used in the QFD matrix.

Table 13 Technical/Functional Measures (categorised)

[19] Technical Benchmarking			Unit of Measure
Pre Purchase	Manufacture	Material Cost	%
		Processing Cost	%
		Preservation Cost	%
		Packaging Cost	$
		% Waste	%
		Environmental Impact of MFG	TBA
	Material Properties	Decay - ASTM log type scale (1 to 10)	No.
		Cladding Weight	KG/p/ m^2
		Bearing Load (Vertical)	KG/p/Lm of wall
		Moisture Conductivity	Kg/p m^2/psec
		Thermal Mass	SHxAM
		Heat Conductivity (Insulation Value)	R Value
		Quietness (Sound Transmission Class, SCT)	SCT
		Impact Resistance (Drop test)	TBA
		Shear Load	K/p/Lm
		Out of Plane Load	K/p/m^2
	Selection / Specification	Design Cost	%
		Initial Cost	$
		Estimated Cost of Ownership	$
Post Purchase	Installation/Finishing	Flashing (skill/ease factor 1-5)	No.
		Installation Time (Hrs/p/ m^2)	Hrs/p/ m^2
		Installation Cost (Total)	$
		No. Coats Paint	No.
		Installation Tolerance (Movt in mm)	Mm
Life of Product	USE	Total Cladding Lifespan (Yrs)	Yrs
		Tolerance over Life (Movt in mm)	Mm
		Maintenance time (Hrs)	Hrs
		Recoating Cost ($)	$
		Coat Durability (Yrs)	Yrs
		Weather Resistance	TBA
		Property Loss	TBA
		Stability	TBA
	Renovation/Disposal	% Content recycled	%
		% Content Disposed	%
		% Content Reused	%
		Decomposition Time	Yrs
		Decomposition Hazard	TBA
		Total Life Cycle Cost ($ over 50 years)	$
		Life Cycle Impact (Eco Point)	Eco-Point

[19] Orange area demarks the aspects that were included in our QFD matrix.

021: Research Phase 2

This phase consolidated a range of research undertaken in the previous phases to enable it to be assessed and summarised. The information was summarised through QFD matrices, screening LCA conducted in Gabi, and a Product Design Specification.

A fundamental component of design research is 'applying' it to a context. In this instance, QFD has been used to condense this information, and create observable relationships between the various aspects of the product. The relationships between the different information allow us to ascertain the key drivers for the product development in an objective and structured manner.

The key tasks of this phase were as follows:

- QFD matrix development
- Screening LCA assessment
- Document Product Design Specification

Quality Function Deployment (QFD) Matrix

Once the customer requirements and the technical measures defined, the QFD matrix can be created, Figure 19 & 18 briefly illustrate the process of using the QFD matrix. (For an explanation of the methodology, please refer to Appendix 11). It is at this point a relationship is created between the customer requirements and the technical measures. The relationship is coupled with the attribute weighting to create a 'weighted' set of scores that reflect the importance of certain aspects to the customer.

Defining the Relationships

The strength of the relationship is important to the outcome, so a scale needs to be used. The scale chosen (Figure 18) to establish the linkages is widely used by experienced researchers including the co-founder of QFD method Dr. Yoji Akao and well-known practitioner Glen Mazur.

The stronger the relationship a measure has with the customer requirements the higher the score, and the level of technical priority. Logically this would signal an area where a development team should concentrate.

Figure 18 Relationship Scale

Relationship	None	Weak	Medium	Strong
Scale	0	1	3	9

The matrices were generated category by category for assessment purposes. This enables each phase to be assessed independently. The phases in the QFD matrices were:

1. Pre Purchase,
2. Post Purchase;
3. Use – Life of product.

The full QFD cladding matrices are included in Appendix 11 for reference; compacted versions of these with the technical priorities are illustrated in this document.

Figure 19 QFD matrix illustration

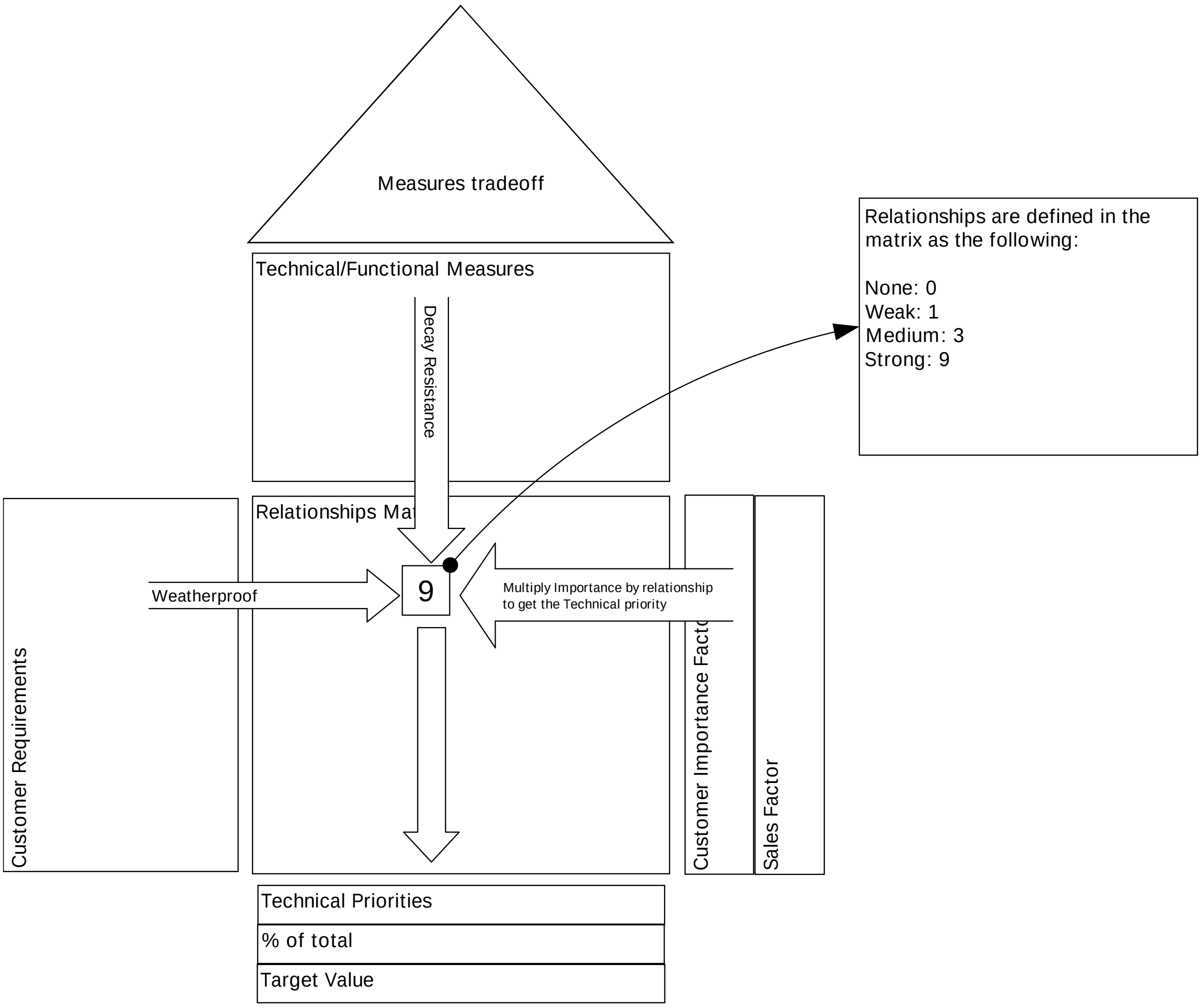
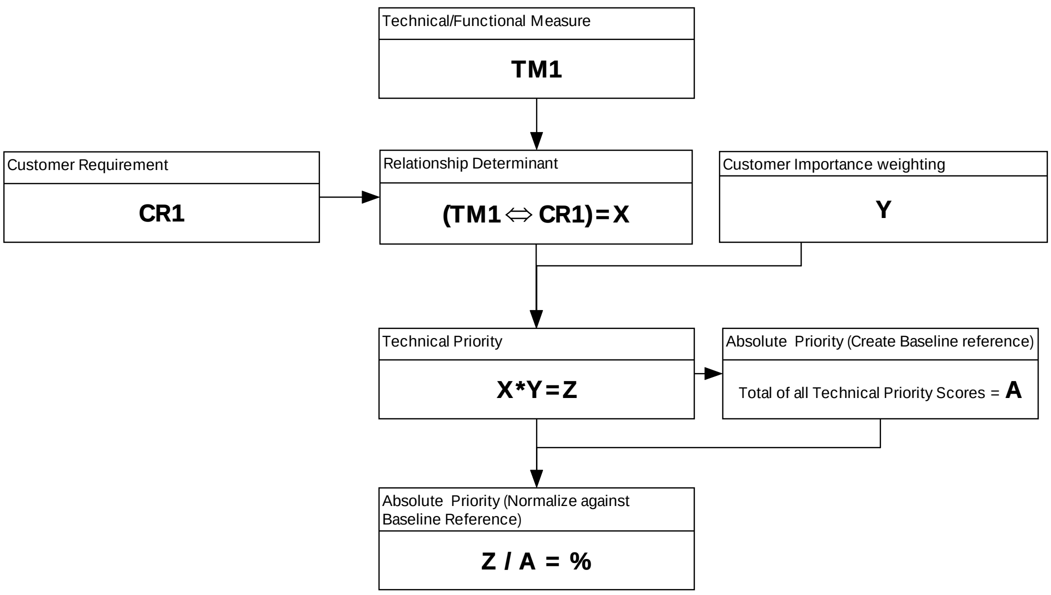


Figure 20 Calculating the technical priorities.



Cladding QFD Matrices

Figure 21 Pre-purchase QFD chart

Pre-Purchase	Customer importance	Decay - ASTM log type scale (1 to 10)	Cladding Weight	Heat Conductivity (Insulation Value)	Quietness (Sound Transmission Class, SCT)	Impact Resistance (Drop test)	Estimated Cost of Ownership	Flashing (skill/ease factor 1-5)	Total Cladding Lifespan(Yrs)	Tolerance over Life (Movt in mm)	Maintenance time (Hrs)	Coat Durability (Yrs)	Weather Resistance	Stability	Total Life Cycle Cost ($ over 50 years)	
Appearance & Appeal	5	1	1	0	0	0	0	0	1	1	1	1	3	1	0	
iveness/Cost of Ownership	3	3	0	3	0	1	9	3	3	0	3	3	3	0	9	
Performance	5	9	3	9	9	9	0	9	0	9	0	0	9	3	0	
Durable	3	9	3	0	0	3	0	0	9	3	9	3	9	3	0	
Low Maintenance	1	3	0	0	0	1	3	0	9	9	9	9	9	3	9	
Selection: Ease of Installation	1	0	9	0	0	3	1	9	0	0	0	0	0	9	0	
Environmentally Benign	1	1	1	9	0	0	0	0	0	0	0	3	3	0	0	
Technical Priorities		87	38	62	45	60	30	62	50	71	50	37	108	41	38	1129
Percentage of Total		7.75%	3.36%	5.50%	3.99%	5.33%	2.63%	5.50%	4.46%	6.31%	4.46%	3.31%	9.58%	3.66%	3.33%	100.00%
Technical Bench: Unit of Measure		ASTM (1-1(	Kg/p/m2	R Value	SHxAM	IZOD	$/M2/Yr	Rating 1-5	Yrs	mm	Hrs	Hrs/p/m2	TBA	mm	$	
Solid Timber Weatherboard		TBA	9.2	TBA	TBA	TBA	10.3-10.6	4	50-70	TBA	TBA	TBA	TBA	TBA	171	
Exterior Plywood Sheet		TBA	7.1	TBA	TBA	TBA	4.3-5.7	4	30-50	TBA	TBA	TBA	TBA	TBA	129	
Linea Weatherboard		TBA	27.6	TBA	TBA	TBA	4.5-4.6	3	45-50	TBA	TBA	TBA	TBA	TBA	158	
Clay Brick		TBA	5.1	TBA	TBA	TBA	7.6 - 7.9	3	80-100	TBA	TBA	TBA	TBA	TBA	129	
Design Targets		TBA	9-10	TBA	TBA	TBA	7	5	70-90	TBA	TBA	TBA	TBA	TBA	125	

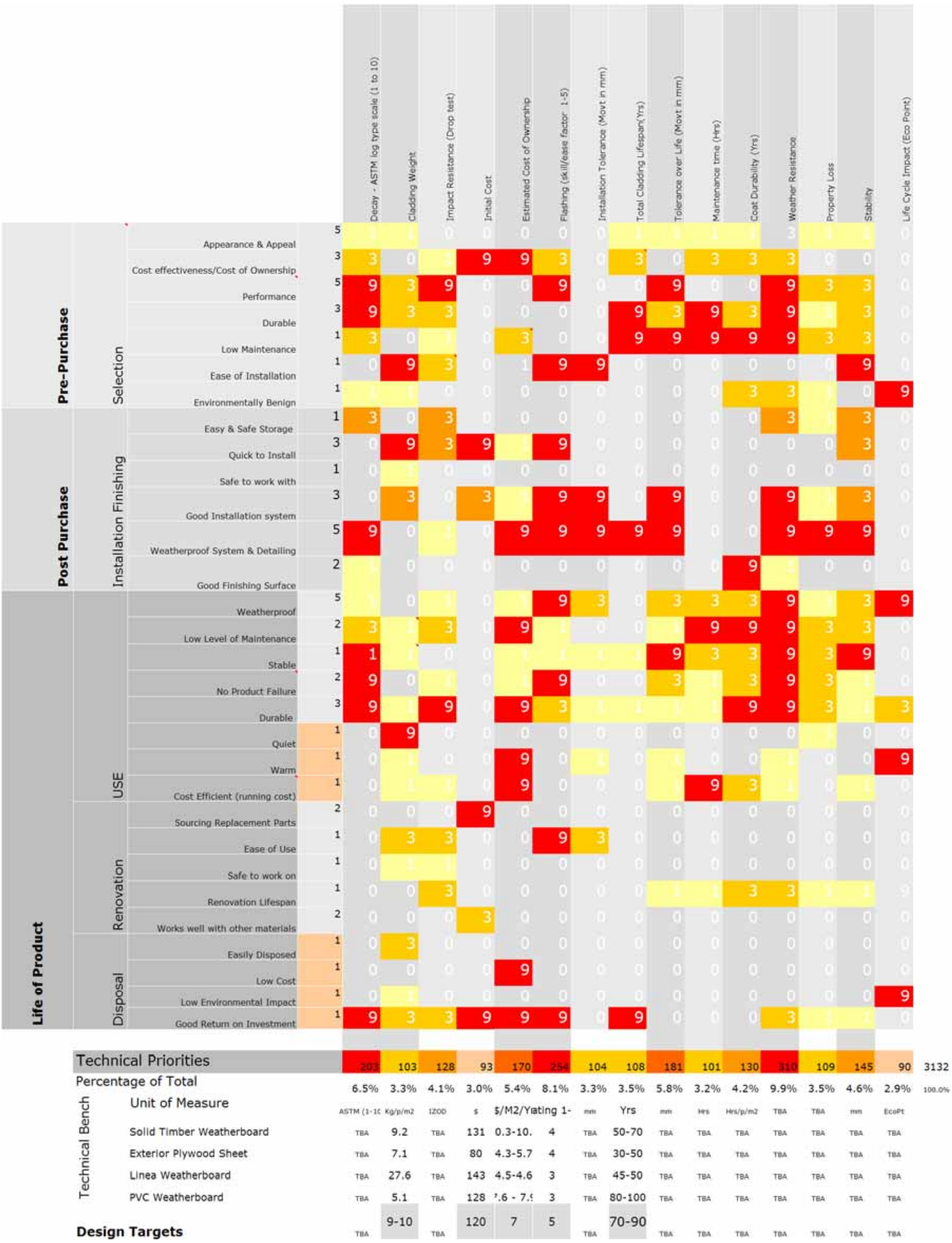
Figure 22 Post Purchase Results

Post Purchase – Installation Finishing		Decay - ASTM log type scale (1 to 10)	Cladding Weight	Initial Cost	Estimated Cost of Ownership	Flashing (skill/ease factor 1-5)	Installation Time (Hrs/p/M2)	Installation Cost (Total)	No. Coats Paint	Installation Tolerance (Movt in mm)	Total Cladding Lifespan(Yrs)	Tolerance over Life (Movt in mm)	Weather Resistance	Property Loss	Stability	
Easy & Safe Storage	1	3	0	0	0	0	0	0	0	0	0	0	3	1	3	
Quick to Install	3	0	9	9	1	9	9	3	3	0	0	0	0	0	3	
Safe to work with	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	
Good Installation system	3	0	3	3	1	9	9	9	3	9	0	9	9	1	3	
Weatherproof System & Detailing	5	9	0	0	9	9	0	0	0	9	9	9	9	9	9	
Good Finishing Surface	2	1	0	0	0	0	0	0	9	0	0	0	1	0	0	
Technical Priorities		50	37	36	51	99	54	36	36	72	45	72	77	49	66	866
Percentage of Total		6%	4%	4%	6%	11%	6%	4%	4%	8%	5%	8%	9%	6%	8%	100%
Technical Bench: Unit of Measure		ATSM (1-10)	Kg/p/m2	$	$/M2/Yr	Rating 1-5	Hrs/p/M2	$	No.	mm	Yrs	mm	TBA	TBA	mm	
Solid Timber Weatherboard		TBA	9.2	131	10.3-10.6	4	TBA	50.1	3	TBA	50-70	TBA	TBA	TBA	TBA	
Exterior Plywood Sheet		TBA	7.1	80	4.3-5.7	4	TBA	29.48	3	TBA	30-50	TBA	TBA	TBA	TBA	
Linea Weatherboard		TBA	27.6	143	4.5-4.6	3	TBA	60.9	2	TBA	45-50	TBA	TBA	TBA	TBA	
ClayBrick		TBA	5.1	128	7.6 - 7.9	3	TBA	50	0	TBA	80-100	TBA	TBA	TBA	TBA	
Design Targets			9-10	120	7	5	TBA	50	TBA	TBA	70-80	TBA	TBA	TBA	TBA	

Figure 23 'Life of Product' Results

Life of Product		Weight	Decay - ASTM log type scale (1 to 10)	Moisture Conductivity	Impact Resistance (Drop test)	Estimated Cost of Ownership	Flashing (skill/ease factor 1-5)	Maintenance time (Hrs)	Coat Durability (Yrs)	Weather Resistance	Total Life Cycle Cost ($ over 50 years)	Life Cycle Impact (Eco Point)	
USE	Weatherproof	5	1	9	1	1	9	3	3	9	0	9	
USE	Low Level of Maintenance	2	3	0	3	9	1	9	9	9	9	0	
USE	Stable	1	1	0	0	1	1	3	3	9	0	0	
USE	No Product Failure	2	9	1	1	1	9	1	3	9	0	0	
USE	Durable	3	9	0	9	9	3	1	9	9	0	3	
USE	Quiet	1	0	0	0	0	0	0	0	0	0	0	
USE	Warm	1	0	0	0	9	0	0	0	1	0	9	
USE	Cost Efficient (running cost)	1	0	0	1	9	0	9	3	1	9	0	
Renovation	Sourcing Replacement Parts	2	0	0	0	0	0	0	0	0	0	0	
Renovation	Ease of Use	1	0	0	3	0	9	0	0	0	0	0	
Renovation	Safe to work on	1	0	0	1	0	0	0	0	0	0	0	
Renovation	Renovation Lifespan	1	0	0	3	0	0	1	3	3	0	9	
Renovation	Works well with other materials	2	0	0	0	0	0	0	0	0	0	0	
Disposal	Easily Disposed	1	0	0	0	0	0	0	0	0	0	0	
Disposal	Low Cost	1	0	0	0	9	0	0	0	0	9	0	
Disposal	Low Environmental Impact	1	0	0	0	0	0	0	0	0	0	9	
Disposal	Good Return on Investment	1	9	0	3	9	9	0	0	3	9	0	
Technical Priorities			66	47	51	89	93	51	75	125	45	81	1137
Percentage of Total			5.80%	4.13%	4.49%	7.83%	8.18%	4.49%	6.60%	10.99%	3.96%	7.12%	100.00%
Technical Bench	Unit of Measure		ATSM (1-1	TBA	IZOD	$/M2/Yr	Rating 1-	Hrs	Hrs/p/m2	TBA	$	Ept	
Technical Bench	Solid Timber Weatherboard		TBA	TBA	TBA	0.3-10.	4	TBA	TBA	TBA	171	TBA	
Technical Bench	Exterior Plywood Sheet		TBA	TBA	TBA	4.3-5.7	4	TBA	TBA	TBA	129	TBA	
Technical Bench	Linea Weatherboard		TBA	TBA	TBA	4.5-4.6	3	TBA	TBA	TBA	158	TBA	
Technical Bench	PVC Weatherboard		TBA	TBA	TBA	7.6 - 7.9	3	TBA	TBA	TBA	129	TBA	
Design Targets						7	5	TBA			125		

Figure 24 Full QFD results



QFD Results

The results summarise the scores of the individual life cycle phases across all technical measures, whereas the combined summary summarises customer requirement scores across all technical measures to give an overall total of the most important technical priorities.

Pre purchase

The top 5 technical measures:

Rank	Technical Measure	Score	%
1	Weather Resistance	108	9.58%
2	Decay Resistance	87	7.75%
3	Tolerance over Life	71	6.31%
4	Heat Conductivity	62	5.50%
5	Flashing	62	5.50%

The matrix ranks weather resistance the most important technical factor (which would be consistent with public awareness around the leaky buildings issue), decay resistance, heat conductivity (thermal insulation), flashing ease, and tolerance to movement are ranked in a group close behind this.

Post purchase

The top 5 technical measures:

Rank	Technical Measure	Score	%
1	Flashing	99	11%
2	Weather Resistance	77	9%
3	Tolerance over Life	72	8%
4	Installation Tolerance	72	8%
5	Stability	66	8%

Flashing skill and ease become very important in this phase, along with installation time, tolerance for movement, and stability, whilst weather resistance remains amongst the highest scores. This reflects the builder as a user group identifying these key issues.

Life of Product

The top 5 technical measures:

Rank	Technical Measure	Score	%
1	Weather Resistance	125	11%
2	Flashing	93	8%
3	Estimated Cost of Ownership	89	8%
4	Life Cycle Impact	81	7%
5	Coat Durability	75	7%

In the Life of product matrices weather resistance is again at the top, with flashing, estimated cost of ownership, life cycle impact and coat durability closely ranked.

Combined Results

The top 5 technical measures:

Rank	Technical Measure	Score	%
1	Weather Resistance	310	10%
2	Flashing (skill/ease factor 1-5)	254	8%
3	Decay - ASTM log type scale (1 to 10)	203	6%
4	Tolerance over Life (Movt in mm)	181	6%
5	Estimated Cost of Ownership	170	5%
6	Stability	145	5%
7	Coat Durability (Yrs)	130	4%
8	Impact Resistance (Drop test)	128	4%
9	Property Loss	109	3%
10	Total Cladding Lifespan (Yrs)	108	3%

The combined results give us 10 clear technical priorities that could be used as the target for further development. Some sensitivity analysis and further work would need to be done on the QFD matrices that have been developed, but it gives a good framework for the project to start on.

The next step would be for the project team to benchmark key competing products against the weatherboard and define the design targets. The targets would consider a range of factors including degree of difficulty, price, and manufacturing issues.

Figure 25 Technical Priorities

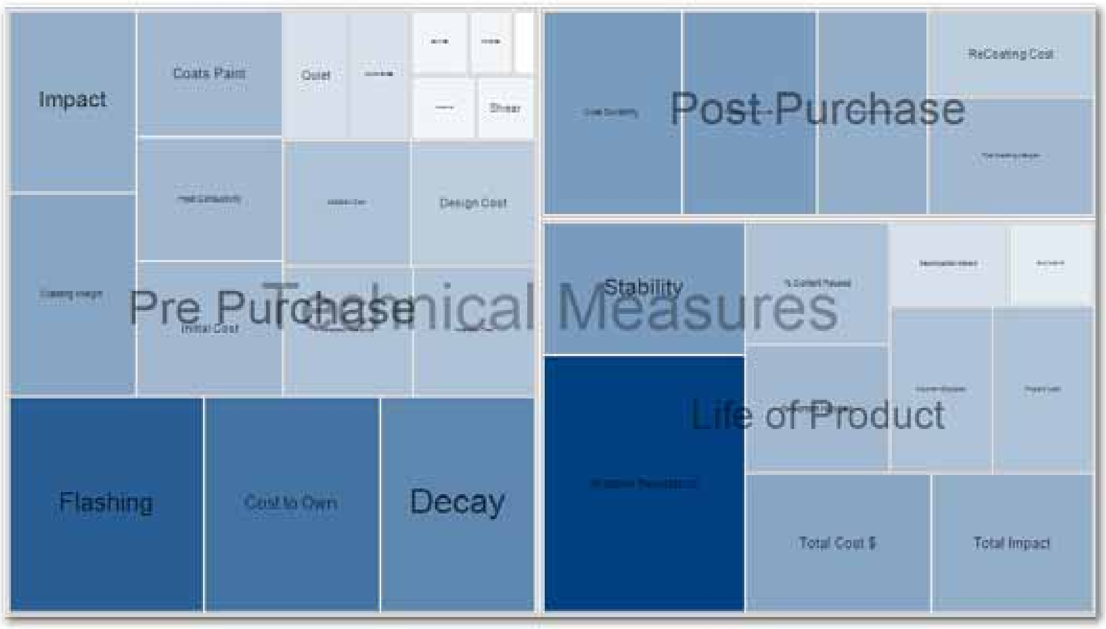
		Decay - ASTM log type scale (1 to 10)	Cladding Weight	Estimated Cost of Ownership	Flashing (skill/ease factor 1-5)	Tolerance over Life (Movt in mm)	Maintenance time (Hrs)	Weather Resistance	Property Loss	Stability	Life Cycle Impact (Eco Point)
Technical Priorities		203	103	170	254	181	101	310	109	145	90
Percentage of Total		6%	3%	5%	8%	6%	3%	10%	3%	5%	3%
Technical B.	Unit of Measure	ASTM (1-10)	Kg/p/m2	$/M2/Yr	Rating 1-5	mm	Hrs	TBA	TBA	mm	EcoPt
	Solid Timber Weatherboard		9.2	10.3-10.6	4						
	Exterior Plywood Sheet		7.1	4.3-5.7	4						
	Linea Weatherboard		27.6	4.5-4.6	3						
	PVC Weatherboard		5.1	7.6 - 7.9	3						
Design Targets			9-10	7	5						

These results are visualised in

Figure 26 across all technical measures and are related to the PLC phase they are most relevant. The size and darkness colour of the box are driven by the technical priority score. Large and dark are the most important.

To make reviewing the technical priorities easier the information has been converted into tree map diagrams which shoe hierarchy via grouping, colour, and scale.

Figure 26 Total QFD matrices Tree map



Customer Perception

Part of the survey addressed peoples comparative views on the 10 predominant cladding systems in the market. It did this with three questions covering consumer preference, perceived quality, and actual performance.

Clay brick was ranked the highest overall, and Timber was a close second. Consumer Preference was highest for Clay brick over all categories.

Figure 27 Cladding perception (Please refer to Appendix 16 - Customer Perception Tables

Life Cycle Assessment (LCA)

With environmental considerations becoming increasingly important in the built environment, the team undertook a screening LCA of 12 prevalent systems representing a range of claddings. A detailed view of the methodology used is included in the Appendix 12.

A visualisation technique was developed during this project to enable accurate communication to stakeholders. This novel method allows a layperson to clearly see the comparative environmental performance and easily understand it. The results are also transparent, clearly showing the contribution of the key impact categories.

Goal and scope

To assess a range of the prevalent cladding systems to establish a comparative index of their environmental performance. This data would be exported and mapped across Global, Regional and Local Criteria as detailed in 1402-02-009 Environmental Assessment[20].

The 'functional unit', which is the core comparative scale in this assessment, has been in part derived from the ZALEH (Zero and Low Energy Housing) study undertaken by BRANZ (Roman Jacques) and Andrew Alcorn. This study used 50, 100, 150-year lifespan. This study would restrict analysis to a 50-year period to establish environmental load.

Jacques and Alcorn have also established that "the service life (durability of components) of a product is annualised, avoiding the difficulty of comparing differing lifetimes for differing materials[21]", they also note that this is the default method for this type of analysis (SETAC, 2003).

Maintenance schedules would be based on BRANZ 'Selecting Wall Claddings' manual. Conservative maintenance options would be selected from within the available schedules.

Analysis Categories

From wide range of systems, the major categories were isolated through discussion. These systems are functionally described as 'non-structural' and 'structural'. This division was put in place as the two types of systems have a different function and cost structures.

Figure 28 System Divisions

Structural Cladding **(SC)**	The cladding system integrally provides the wall structure, these elements do not have to be load bearing (for roofing), but are characterised by the fact they eliminate the requirement for any form of secondary structure or system to be attached.
Non Structural Cladding **(NSC)**	A non-structural wall cladding is mainly characterised by the fact that they require a secondary structural frame or system to be attached.

The systems that have been selected are divided into SC and NSC groupings for

[20] 1402-02-009 Environmental Assessments
[21] ZALEH Project 'Draft LCI of Twelve Domestic Technology/Materials' Alcorn, Jacques

analysis. Systems in the NSC category will use a generic Timber Framing as their primary structure. This allows both structural and non-structural system assessments to be made comparatively.

Figure 29 Component breakdown for assessment

Non Structural (NSC)	Structural (SC)
Aluminium Profile (AP)	Timber Framing[22] (TF)
Plywood Sheet (PS)	Solid Masonry System (SMS)
Timber Weatherboard (TWB)	Tilt Slab Concrete (TSC)
Solid UPVC Profile (SPVC)	Lockwood System (LS)
Fibre Cement Sheet/Profile (FC)	
Vinyl Sheet (VS)	
Brick Veneer (CBV)	
Exterior Insulation Finishing system (EIFS)	

The following categories have been selected for impact assessment:

Figure 30 Impact Assessment Categories

Category	Reference
Global Warming Potential	GWP
Ozone Depletion Potential	ODP
Acidification Potential	AP
Human Toxicity Potential	HTP
Photochemical Oxidant Creation Potential	POCP
Eutrification Potential	EP
Aquatic Eco Toxicity Potential	AETP
Terrestrial Eco Toxicity Potential	TETP

Visiometric Results

Making the LCA results accessible and informative for a range of stakeholders was perceived as important. In order to do this the team developed a visiometric method to display the normalised results in the key impact categories (Figure 31). The Product Environmental Map (PEM) visualisation clearly demonstrates comparative results, whilst retaining an important level of transparency, which enables the viewer to see the biggest contributing impact category.

The map in Figure 31 shows the Alloy Profile to have the largest total impact and the Lockwood system the lowest total impact. The alloy profile reflects the energy and resources required to make aluminium, whilst Lockwood reflects the fact that the cladding system is integrated as a structural component, eliminating the treated timber framing, battens and wrap.

Figure 32 illustrates a single assessment of the Timber Weatherboard so we can analyse the contributions of each impact assessment category. This is an important step to identifying what aspects can be targeted for improvement. We can see that POCP and FAETP are the largest contributors. Evaluating the POCP and FAETP impact categories in the GABI LCA tool (example Figure 33), we see that the biggest contributor to the POCP is Acrylic paint

[22] Not applied on its own, only applied paired with an actual cladding system

Figure 31 Product Environment Map (PEM)

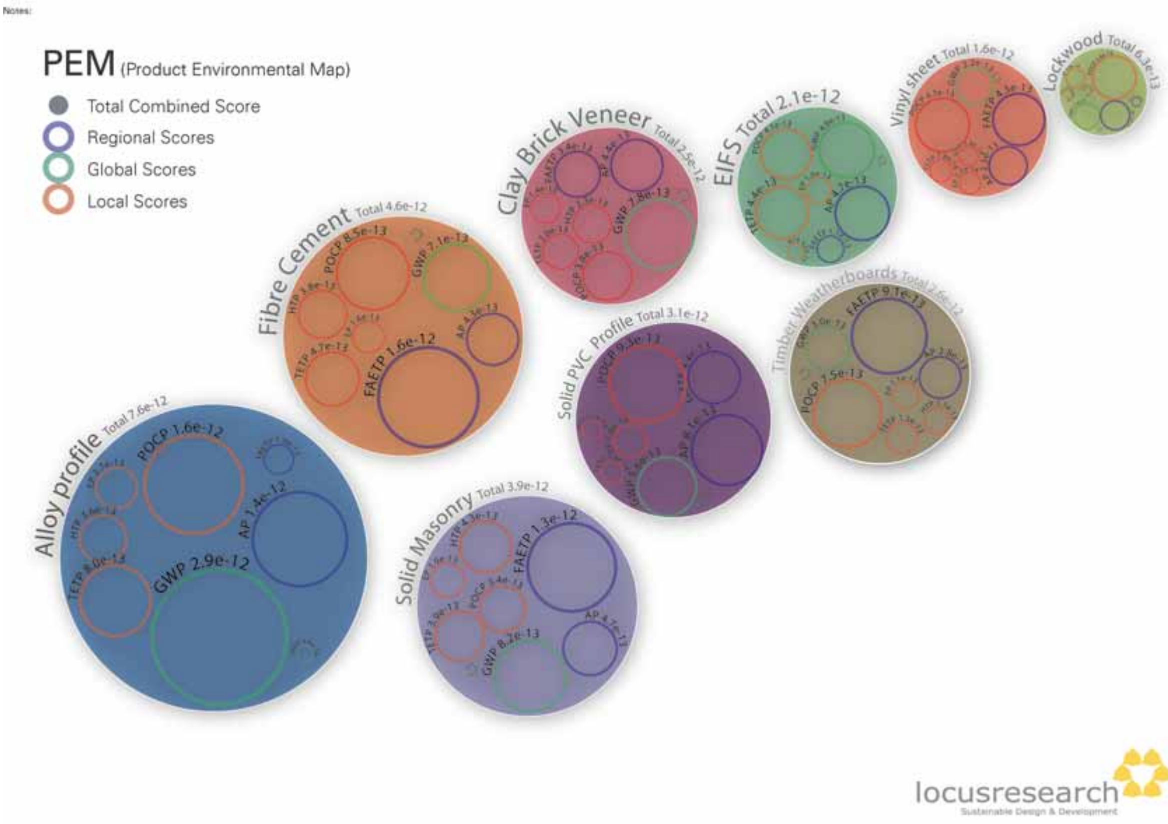


Figure 32 Timber Weatherboard Impact Result

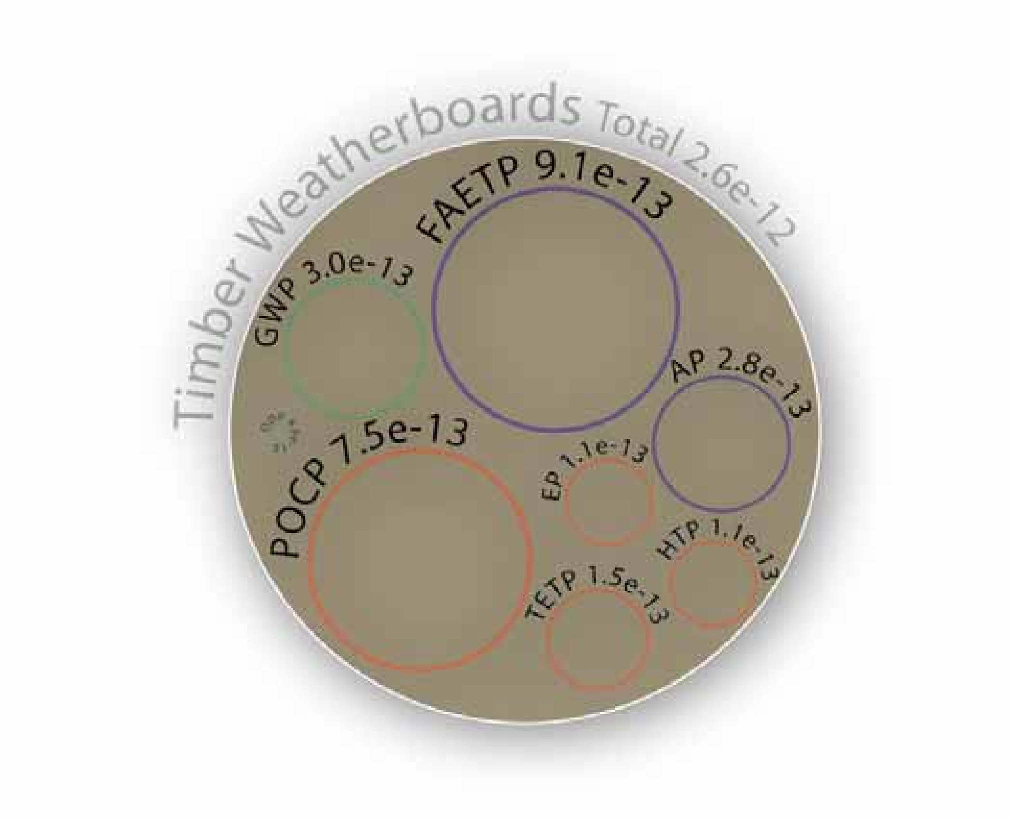
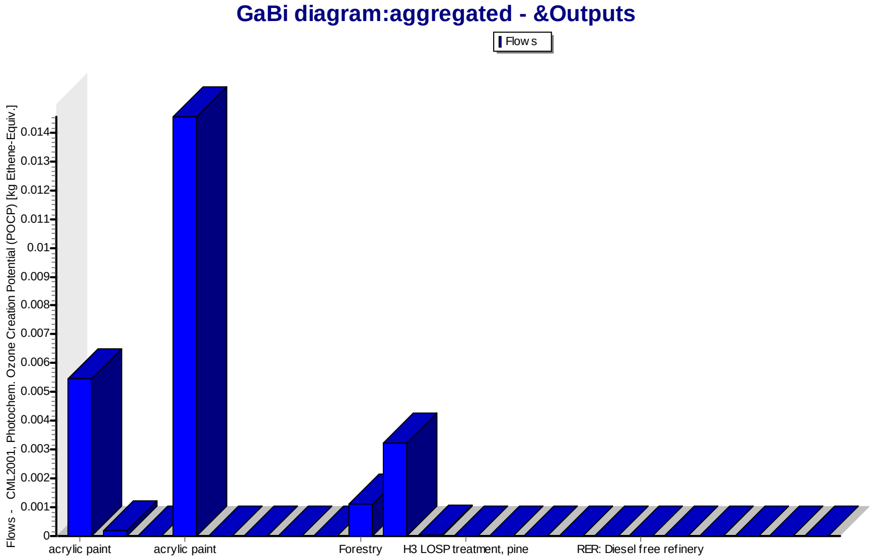


Figure 33 Timber Weatherboard Aggregated Outputs



022: Idea Generation

With a wide range of technical, market and product data, an idea generation component provided a forecast on how these results could be utilised.

The brainstorm and idea generation components investigated possible project constructs, the application of product service systems, and product range structure as well as actual product ideas.

The key tasks of this phase were as follows:

- Brainstorm ideas with the project team and selected others
- Document potential directions and structures for the project.

Brainstorming Session

A structured brainstorming session was held to generate a few concepts around some of the early research conclusions. This group included the core team as well as a selected group of other people from within Scion and Ensis with related expertise that the team felt would be useful (John Turner, Dave Page, Karen Bayne, Doug Gaunt).

There was a range of useful points bought up at the meeting. There was a tendency for the discussion to focus on the negative performance factors of timber cladding and the fact that people liked the 'look of timber'. These aspects are excluded due to the fact they are covered in other areas of this report.

Some of the key suggestions were as follows:

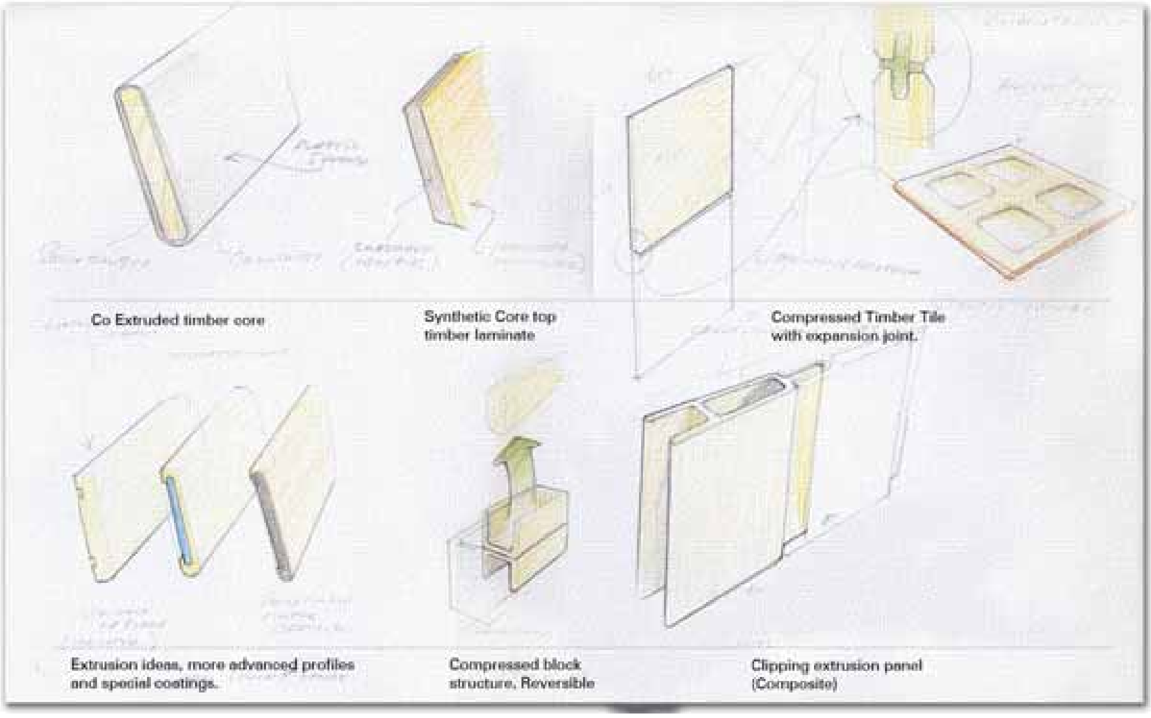
1. Give consumers a new system that they can 'believe' in.
2. 10yr Guarantee included in the actual price of the product ('hassle free').
3. Wooden bricks or blocks (like concrete block installation).
4. Plastic end caps for boards.
5. Compressed timber tile (like stone panel installation – bracketed to the wall).
6. Foamed block (lightweight)
7. Advanced profile designed to drop moisture easier (German example)
8. Stability + Durability achieved by acetylation (technical concept)
9. People like the look of wood so how can we retain this with a clear but very durable finish.
10. Quarter sawn board – edge glued (to enhance appearance).
11. "Breathe" – healthy home, right designs for the material is important.
12. Designed to be replaced in a set period of time– Product Service System. Homeowner does not own cladding but leases the cladding, reducing initial home purchase (lease would include correct maintenance).
13. Lamination: using good timber as the face and then using a stable downstream substrate as the body to increase stability and durability.
14. A clear table of attributes and comparative characteristics.

Idea generation

Physical style

Interesting ideas were discussed during the brainstorming session these represent some physically different styles of cladding. Figure 34 illustrates the importance of ‘format’ in the cladding area. Different formats provide different options for architects and specifiers. The formats explored included cover tiles, extrusions, Blocks, sheets and solid and laminated profiles.

Figure 34 Brainstorm ideas visualised (Refer to for a full view)



Product Service System

Several of the concepts surrounded the use of a Product Service System (PSS) approach. The PSS concept has primarily emerged from the European context. They are designed to counteract the ‘*rebound effect*’, which broadly relates to the economic phenomenon of:

The longer a product exists:

a. The cheaper it becomes to manufacture
b. More companies manufacture it
c. Greater competition
d. More customers buy it

This creates a problem that can negate the environmental efficacy that has been thoughtfully designed and developed into a product.

PSS is a hybrid concept that incorporates both a product and a service. A product is a tangible commodity that can be manufactured and sold, whereas a service is an activity (work) done for others[23].

Generically a PSS can be defined as:

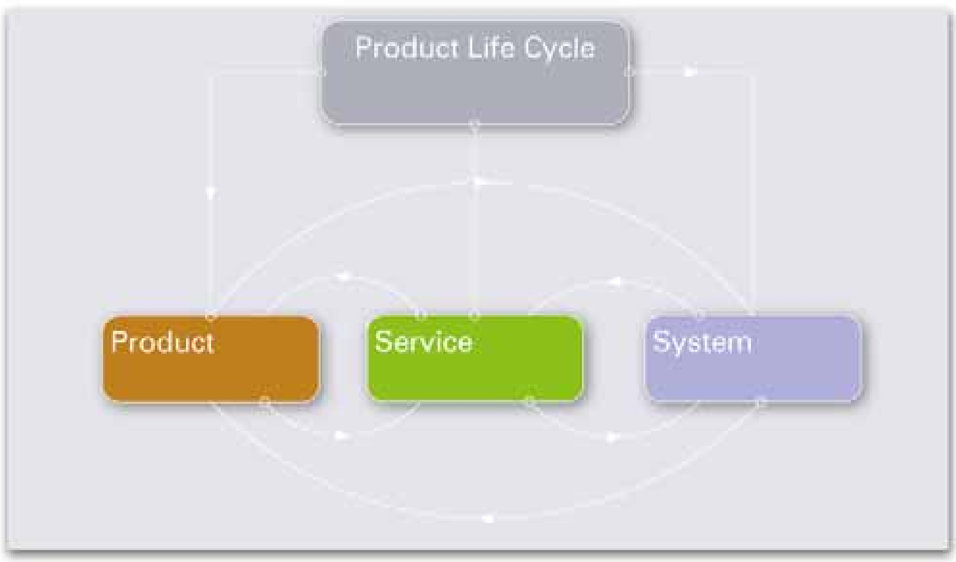
‘*A Product Service system (PS system) is a marketable set of products and services Capable of jointly fulfilling a user’s need The PS system is provided by either a*

[23] ‘Product Service Systems; Ecological and economic basics’ Mark J. Goedkoop MSc. Cees J.G. van Halen MSc. Harry R.M. te Riele MSc. , Peter J.M. Rommens MSc. (1999)

Single company or by an alliance of companies. It can enclose products (or just one) plus additional services. It can enclose a service plus an additional product. And product and service can be equally important for the function fulfilment. The researcher's need and aim determine the level of hierarchy, system boundaries and the system element's relations'[24].

By evaluating a product life cycle, it is possible to visualise the potential applications of a PSS approach within the exterior cladding context. Figure 35 illustrates the relationship between the elements and the life cycle. Most products by default have services around their use, in the case of cladding; these might be defined as installation, finishing, maintenance and renovation.

Figure 35 Product Life Cycle and PSS diagram[25]



The scope of potential solutions for a new cladding system are greatly increased if a PSS approach is considered, as some aspects can be converted from hard product and service, thereby making the design process more elastic.

In the cladding context a PSS could include:

- A product with maintenance built into the price.
- A product that is leased for an annualised cost to the consumer, so they don't 'own' the cladding. This could be show in LCC to be a good idea.
- Companies collaborate (manufacturer, builder, sales) to implement a coordinated new product system.

Product Range and Structure

Another key aspect to come out of the idea generation phase was the concept of a product range. Timber cladding products are not presented in one succinct product range that can meet the demands of residential and commercial situations. By considering all timber derived products under one umbrella we can start to visualise the potential of a cohesive range that covers LVL, Solid, Fibre Plastic, and Bio Materials.

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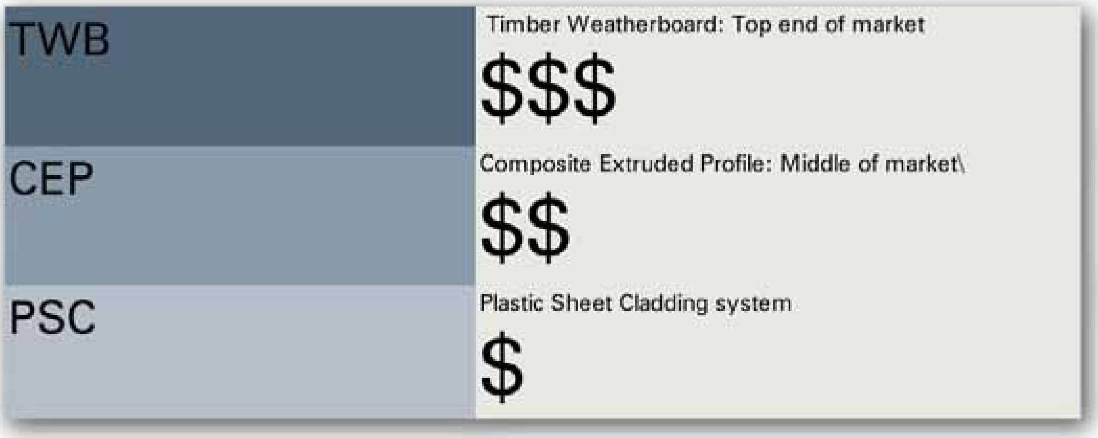
[24] 'Product Service Systems; Ecological and economic basics', Mark J. Goedkoop MSc. Cees J.G. van Halen MSc. Harry R.M. te Riele MSc. , Peter J.M. Rommens MSc. (1999)
[25] Diagram © Locusresearch Ltd

Figure 36 illustrates the simple concept in of breaking the potential product range down into three price categories, and thinking what format product would best suit each category.

Figure 36 Range definition



1. **TWB:** solid or laminated timber profiles, a premier high-end product for sale internationally. For use in architecturally designed homes, this product would be a highly durable product that would seek to exceed current solid timber weatherboard product performance. This product would be finished to retain the timber appearance (short-medium term project).

2. **CEP:** an extruded fibre composite thin wall profile product that is stable, and integrally finished (and paintable). This product would target builders and building manufacturers. Easy to assemble with an excellent profile design, this product would be easy to paint, but potentially available in a range of standard colours (medium term project).

3. **PSC:** sheet plastic product that would be a fast installing lower cost option for mainstream and lower cost housing, but also have applications for the commercial/industrial sector. This would have integral colouring, and would not require painting to keep the cost down (long term project).

This would also provide short, medium and long-term projects that would provide increasing sales and an increasing market share for these products.

Summary

The idea generation phase demonstrates that through a range of approaches such as new physical styles, PSS, and product range structures an interesting new range of products could be delivered to the market.

The concepts presented here are not mutually exclusive and many could work together if developed further.

023: Results conclusions

Guardian has affirmed the feasibility of the developing a new exterior cladding solution, providing insight into how this development could be structured and what the targets should be.

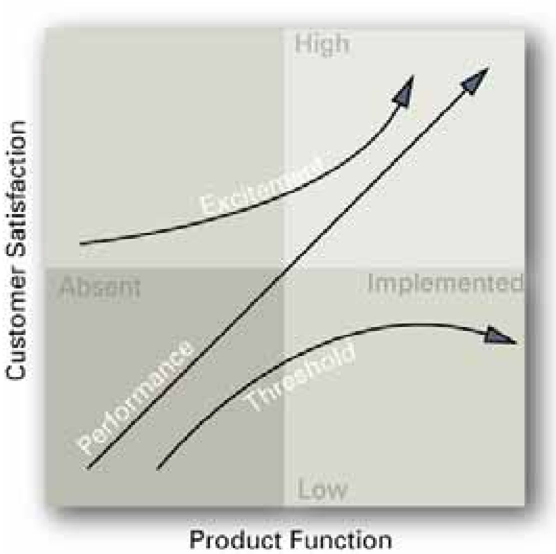
It has also demonstrated the potential of science and design working closely together, resulting in a range of ideas that are project specific and others that have application outside of the current envelope of work. The ‘holistic framework’ is an example of the collision of these ideas generating new and interesting concepts.

Market Context

From a performance, perspective timber weatherboards meet the specified requirements and have been doing so for many years. However, it does not currently excite the consumer, purchaser or specifier.

The Kano model of customer satisfaction, pioneered by Noriaki Kano, classifies product function as it relates to customer satisfaction.

Figure 37 Kano Model



Firstly, there are basic functional requirements (Threshold) that a customer will expect. Secondly, there are satisfiers or variable requirements - these are extras that if present, makes a customer happier. Thirdly, there are delighters or latent requirements (Excitement) - These are things that a customer is not expecting at all but is delighted to get. The ‘exciters’ are important to a successful product and are the aspect that would appear lacking in the timber cladding products currently.

It is also important to pay attention to these requirements, as over time new functions become basic threshold requirements, lifting the entry-level requirements of a product or service. An example of this in the cladding context is ‘Maintenance’. Low maintenance has become a basic threshold expectation of the consumer.

Timber weatherboards are in the middle of the pack in terms of performance when compared to other products on the market. The key weaknesses are; maintenance, total cost, acoustics and thermal attributes.

Current pricing of timber weatherboards position it in the mid-upper end of the market. This restricts the volume of the product that can be sold, a fact compounded by the difficulty of telling the difference between painted timber weatherboard and other cheaper products. For example a house constructed from Linea fibre cement weatherboards, and another with timber weatherboards would be very difficult to tell apart.

Natural timber is perceived, when used well, as a premier product. To achieve the look of natural timber it requires a stained finish to be utilised, otherwise it is impossible to tell the difference and therefore mitigates the fact it is timber. This key area could be translated into a clearly scoped project to create a durable, integral finishing and colouring system to decrease the finishing and maintenance required, thereby creating an exciter for the consumer.

The changing urban landscape is projected become increasingly intensified, with a growing number of apartment buildings displacing conventional housing. This is both an opportunity and the threat for timber based cladding systems. Weatherboards are not currently well suited for deployment in this type of construction, but a new product designed to meet these requirements might provide an exiting new option for specifiers and developers.

Commercial and industrial cladding are key markets that timber exterior cladding does not participate in. Developing a sheet form cladding system would enable timber-based products to compete favourably against fibre cement sheet and sheet metal products.

If a broad view of timber based cladding is taken it is possible to create a hypothetical product range structure (see Figure 38). This would encompass solid timber products, composite, and timber-derived materials through a range of mechanical forms such as solid, thin wall profile, and sheet products.

Figure 38 Product Structure

Residential Cladding		Cross Over	Commercial Market	
Solid Form	Profile Form	Sheet Form	Sheet Form Med	Sheet Form Hi
Solid Timber product High quality Top end of market Internationally competes against top timber cladding systems.	Composite product. Mass market large volume product. Competing against mainstream residential cladding systems with existing and new shape concepts.	Bio plastic sheet product for mid to lower price point residential housing. Target new and existing style concepts.	Medium rise sheet cladding system. Medium performance requirements.	Hi Rise sheet cladding system. High Performance requirements.

Impact of Maintenance

The life cycle thinking approach used in this project has illustrated the current timber cladding products have deficiencies in the area of maintenance and total cost of ownership. In addition to this, the key environmental impact appears to be the acrylic coating required to maintain the product over its lifespan.

Maintenance is also key customer factor. Although not proven conclusively here, it is believed to be one of the influential factors in the consumer preference of clay brick as a cladding system. It is one of the very few systems that can survive effectively with a very low or no maintenance regime.

A reduction in maintenance in timber based cladding systems would increase customer perception and sales, and decrease both total cost of ownership and environmental impact.

Testing

Anecdotally it would appear there is no real 'system' testing to enable accelerated life cycle testing of a complete cladding solution. This is a critical element to benchmark existing solutions and rapidly test new ideas for efficacy and performance. Without a mechanical means to accelerate the lifespan, the testing timeframes of new products and materials are unacceptably long and result in project timeframes that do not allow reaction to market, legislative and environmental changes.

Life cycle information available from BRANZ would appear to contradict the statements of a variety of manufacturers stipulate that they have a superior lifespan to timber cladding. This would be more easily rebutted with a clearly benchmarked performance.

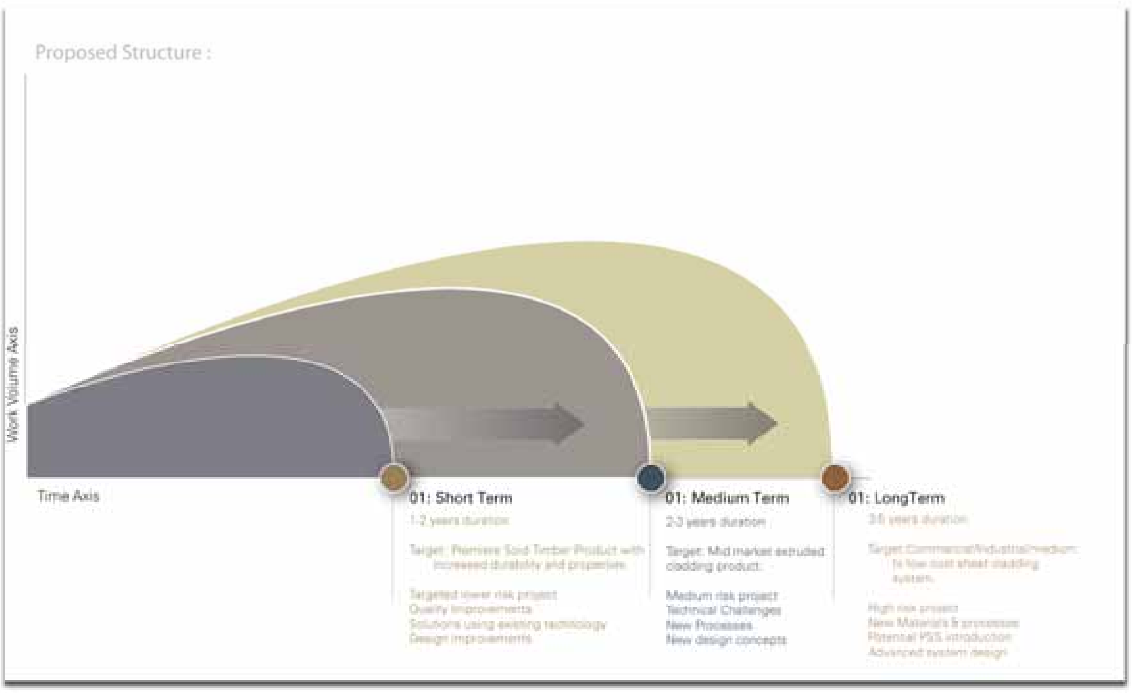
It is proposed that an engineering PHD TIF project be put forward for the design and development of an advanced exterior cladding 'system' testing facility.

Path forward

It is proposed that three projects be created. These would be divided into short, medium, and long-term product developments (see Figure 39). These projects would be undertaken concurrently with the aim of releasing the products sequentially into the market in a timeframe that would make it difficult for the competition to respond effectively.

If undertaken in a traditional linear manner the projects would take 10 or more years to complete, compared to five if approached concurrently. This ensures continuity in the project team and the commercial partnerships. It also captures the efficiencies of using a single project team to work on once product context, creating in depth product knowledge.

Figure 39 Proposed Project structure (Please refer to Appendix 14)



This would be achieved by creating a small multi-disciplinary team. The team should be relatively autonomous and be focussed on project deliverables, reporting directly to the senior management of Scion. This approach could generate significant time and resource efficiency, as well as generate good critical mass for the development. The team would ideally function in a similar vein to Kelly Johnson's well-known 'Skunk works' design team from Lockheed Martin (refer to Appendix 15)

The key skills the team would ideally consist of:

- Mechanical Engineer (Design oriented)
- Structural Engineer (Testing & Analysis)
- Production Engineer (Plastics & Extrusion/wood)
- Chemist (Coatings & Wood Modification)
- Product Designer (Architectural experience)
- Environmental Scientist (LCA technician)

Commercially, a collective of research and manufacturing interests that were well balanced could be bought together to develop a cohesive product range. This would ideally be made up of:

- Research and development team (Scion)
- Forestry and processing company (Cladding marketing experience preferred)
- Plastics manufacturer and processor (extrusion)

The manufacturing companies would be involved early to develop strong ownership in the project. The forestry and processing company would provide strategic market knowledge and pre-existing distribution, whilst the plastics company would provide manufacturing experience in the areas of plastics.

It is viewed as essential that the research and development team retain involvement in the products development after initial commercialisation. This would unlock the benefit on continuous improvement by retaining the scientific and design engagement after the initial development to further optimise and improve the product. This may be achieved by the collective forming an independent body to undertake the research and development; thereby Scion would retain an interest in the commercial viability of the range.

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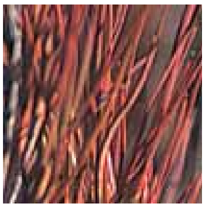
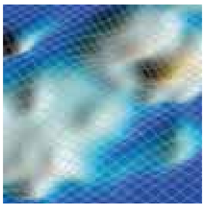


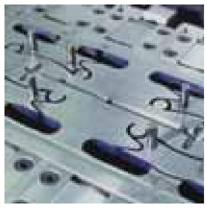



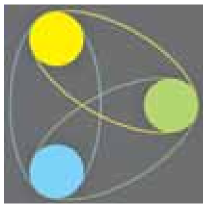


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In the six years since Locus was started we have built a reputation for deep research, original design and effective implementation. Our approach to sustainability has been pragmatic and practical, we simply aim to address these issues on a daily basis for both ourselves and our clients benefit.

This is achieved with simple design strategies, through to more advanced analysis using life cycle assessment and systemic analysis. As a team we have an overarching commitment to sustainable product design (SPD) from research into SPD through to commercial applications of the products that we design.

Our focus has been on research and development rather than just design; we drive to deliver a basic point of difference by using research to build a platform for product development and engineering. We believe in the strategic use of design on a short, medium and long term basis.

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