TE180/3

Multi-paned Windows

Final

A report prepared for Beacon Pathway Limited
April 2006

The work reported here was funded by Beacon Pathway Limited and the Foundation for Research, Science and Technology

Confidential to Beacon – not to be distributed without General Manager's approval

About This Report

Title

Multi-paned Windows

Authors

John Burgess, J. Bennett (BRANZ)

Reviewer

Nigel Isaacs (BRANZ)

Abstract

This report outlines the international and local window technologies following a general discussion of window technology. It reviews the New Zealand fenestration market and presents its structure and main stakeholders. It also lists a number of technologies which could be developed to achieve Beacon's goal.

Reference

Burgess, J. and Bennett, J. April 2006. Multi-paned Windows.Report TE180/3 for Beacon Pathway Limited.

Disclaimer

The opinions provided in the Report have been provided in good faith and on the basis that every endeavour has been made to be accurate and not misleading and to exercise reasonable care, skill and judgment in providing such opinions. Neither Beacon Pathway Limited nor any of its employees, subcontractors, agents or other persons acting on its behalf or under its control accept any responsibility or liability in respect of any opinion provided in this Report.

Contents

Tables

Figures

Error! No table of figures entries found.

1 Introduction

This report outlines the international and local window technologies following a general discussion of window technology. It presents a conspectus of the New Zealand fenestration market and presents its structure and main stakeholders. It concludes by listing a number of technologies which could be developed to achieve the aims of Beacon Pathway.

BRANZ Ltd senior scientist, John Burgess is heading the team to present this report to Beacon Pathway. The other team members are Albrecht Stoecklein (thermal performance, non-energy benefits), and Jessica Bennett (Sustainability). Nigel Isaacs (HEEP, thermal performance) has peer reviewed the report. Input was obtained from a variety of other BRANZ staff members and industry players, with summaries of this interaction presented in the below.

2 Method

The current technologies used in multi-pane residential glazing systems will be investigated through industry contacts, visits and literature. An understanding of these technologies will be developed, discussed with the team, stakeholders, and other New Zealand industry and government members, and encapsulated in a report. The view of international industry participants will be sought, and reflected on, as above.

An assessment of the market for new insulating glazing systems in the domestic sector will be included from data obtained in a previous survey, on the basis of separation by climate zone. The structure of the New Zealand market for new and retrofit framing and insulating glazing systems will be investigated, to reveal the companies with major market share, and those players who have significant local impact.

The potential of latent, new, and developing technologies which are uncovered during the above will be discussed among the team and stakeholders (where IP permits) and presented as technical opportunities for Beacon to develop into a second stage of work.

This last section of the report will include the development of a plan to strategically target areas where more research is needed, and investigate the conversion of opportunities for sustainable development into market realities for Beacon.

A variety of glazing technologies are used in the New Zealand residential market, with some practices following international procedures. A conspectus of these technologies is presented in the below, with the international technologies discussed first before the component glazing materials are discussed, followed by an assessment of the domestic technologies.

3 International Glazing Technologies

A précis of the main glazing technologies up until the end of 2000 is included in the below, following a general discussion of the development of window technology. The approximate thermal advantages from the main technologies that are beneficial for thermal performance are presented in Table 1.

3.1 Early Windows

When self-built housing developed from early times, homes had no windows, but only doors to keep people in or out. The windows we have today were developed from the door and have been continuously developed throughout history, with the smoke hole being the first step towards today's windows. This hole was a means of letting the smoke and heat from the fire out, while letting air and daylight in, to an otherwise dark room.

Eventually the single shutter opening was developed, consisting of an opaque covering that could be opened or closed as the user wished. However, while it let in air and light, it meant there was no protection against unwanted intruders, insects, or the weather.

Oiled papers or animal skins were the next step in creating windows. Translucent materials mean that windows could now be operable and offer more control for the indoor environment.

In Roman times when transparent glass was first created, the indoor living space was changed dramatically as glass was used in windows. The biggest recorded piece of glass from the Roman world was 0.9 x 1.2m and was found in a public bath house in Pompeii.

In the Middle Ages, Venice became the centre of glass production for both building and ornamental pieces. A technique of blowing glass was developed that involved blowing a bubble or cylinder, then cutting it open while still hot and rolling it flat to create small panes of glass. This 'rolled' glass was widely used by European and American pioneers in multiple frames; and it is now a lasting icon of colonial times around the world.

3.2 French Glass

During the 1600's a new way of casting flat glass was developed in France, which allowed the glass for the Hall of Mirrors at Versailles Palace to be made, and coined the term for what is now known as a 'French door'.

However glass really came of age in the 19th Century. New techniques where developed in the production of glass that really made it accessible and affordable for the masses. Glass became larger, stronger, better in quality and cheaper, however until the 20th Century, the window was still a simple single pane.

Other innovations in window control were still separate to the window i.e. overhangs, shutters, security grates, shades etc. The window and its extra parts remained a decorative feature on the wall that controlled the elements at the opening in the wall.

3.3 Modern Window Developments

The 1950's and post war development saw the innovation of float glass which was made by floating a thin layer of molten glass on flat tin. Now glass had very flat surfaces with an even thickness and few visual deformations, which is needed for the thin covering applied to today's specially designed glasses.

Before 1965, anything more than single-glazed glass was very rare, although there had been patents as early as the turn of the 19th century for welding the edges of two adjacent glass sheets to form insulating glass. However 1965-1980 saw the development and widespread use of insulating-glass. (Double glazed glass.) The energy crisis of the late 1970's in the United States saw the further development of triple paned glazing. By 1980 the window industry was transformed. Only 50% of glass sales in the US and Europe were single glazing with 45% being double glazing and 5% triple glazing in the US.

This demand for insulating glass has not eased through the cold climate countries of Europe and North America, with up to 90% of sales for insulating glass of 2 more layers. The demand for triple glazing has however slowed as further innovations have developed better energy saving windows, which mean that the thermal performance of triple glazing can be achieved with specially treated double glazing.

3.4 Technological Improvements in the 20th Century

Unlike the window systems of the 19th Century, now the environmental control methods were being incorporated into the glazing from the time of production. The main thermal benefits are summarised in Table 1.

- Multiple layers of glass or plastic films were assembled to increase the thermal resistance and reduce the heat loss caused by convection between the layers.
- Low-emittance coatings were developed that are highly transparent and give very high reflectance (or low emittance) to long-wavelength infrared radiation, reducing the heat transfer between glass layers.
- Low density gases such as argon, or krypton were placed between the glass layers of double glazing to reduce the heat transfer by conduction between layers, as they have lower conductivities than air.
- 'Warm edge spacers' were developed which incorporate new materials to reduce the effect of heat loss and condensation caused from heat transfer through the spacer at the edge of double glazing units.
- New materials and designs for sashes were developed which would reduce the rate of heat loss from conventional sash and frame systems.

- Tinted glass while still providing a view out, was been developed that counteracted heat gain, in order to lower cooling loads.
- Improved weather-strips were developed that reduce air leakage that led to unwanted heat loss in opening windows.

3.5 Technological Improvements in the 21st Century

The 21st century has seen a continued advance in the development of window systems with the likes of self cleaning glass, more developments in spectrally selective glass and insulating spacers, holographic glazing, specialized designs of light-shelves and light-pipes, while advances in dynamic systems include automatically-operated Venetian blinds between the panes of double glazing, and hybrid composite photochromic and electrochromic glazing. Frame and glazing has been integrated with minimal framing constructed of translucent glass reinforced plastics (GRP), and other efforts have made framing a structural part of the building envelope to reduce the heat transfer around windows. Many of these developments are in the early stages of commercialisation and the market is yet to respond to their presence.

While advancements in the Northern hemisphere take less time to permeate through to the New Zealand market than they have in previous centuries since glass is no longer made in New Zealand, our climate is generally not severe enough, nor energy prices (for home heating) high enough to warrant the introduction of some of the higher cost, higher technology solutions. The expectations, sociology or demographics pertinent in our market sometimes reduce the use that we can make of these technologies. However, this is not the case in all areas, with several exciting new technologies being developed in New Zealand, as outlined later in this report.

Technology	**Approximate Thermal Improvement from the base-case – combination of technologies are not necessarily additive**
4mm clear glass in aluminium frame	Base case
Composite frame	5-20%
Thermally broken Al frame	20-40%
PVC/timber frame	30-50%
Insulated fibreglass frame	40-70%
Engineered timber frames	30-60%
6mm clear glass	5%
Airtight weather-stripping	10%
Plastic panes	10%
Tinted glass	Nil
Electrochromics	0-70%
Reflective glass	-20%
Spectrally selective glass	0-20%
Clear double glazing (IGU)	70-100%
Gas fill	105-120%
Low emissivity glass in an IGU	120-150%
Vacuum in an IGU	200%
Triple glazing	90-220%
Warm edge spacers	105%
Aerogel	150%
SuperWindow (incorporating many of the above)	500%

Table 1: Approximate thermal effects

Note: The above table is indicative of the order of improvement in the thermal performance of a glazing system that may be achieved through the application of the noted technologies. It is ***only*** presenting the thermal performance, and does not mention the trade-offs that are due to favouring weight, optical performance, condensation, visual disturbances, fading performance, privacy.

4 Component Glazing Materials

4.1 Glass

Glass today has a huge variety of uses and comes in many different forms. Traditional windows of clear glass, originating from the original blown glass of early techniques to today's common production technique of floating the glass over a bed of molten tin. This technique gives a very uniform thickness and the only visual distortion being a slight greenish tinge. However this can be minimised with reduced iron content.

Glass can be used for both providing a view and for privacy, such as the obscure glass used in bathrooms where either designs or frosted surfaces break up the view in and out. Glass can be a huge range of different colours by adding different chemicals into the mix during production. Clear glass is still the most widely used glass in the residential building industry, but grey tinted glasses are also very common as they alter the perceived colour of light the least.

The properties of glass can be changed so that it has better resistance against heat and breaking. This is called either heat-strengthened glass or tempered glass, which breaks into small harmless pieces rather than long sharp shards. Laminated glass is also very common today especially for security doors as when it is held together by the plastic interlayer.

4.2 Plastics

Plastics are usually used for specialty installation and skylights. The most commonly used for building today are clear acrylics which are widely available and relatively cheap. This can come in many colours and tints with good transparency but are susceptible to scratching as they are relatively soft.

Frosted acrylic is similar to clear acrylic except that it diffuses the light and offers more privacy. Skylights are often made from this material. Clear polycarbonate has performance like acrylic sheet but is much more hardwearing and unfortunately more expensive. Fibre-reinforced plastic is tough, transparent, and flexible and has very good light diffusing properties. Formed into either flat or ribbed sheets, it is especially used in roofing, but has limited glazing applications.

Extruded multicell sheet is made from acrylic or polycarbonate plastic, being a translucent or tinted plastic extruded into sheets. Polyester is a thin film used to carry specialised coatings or to divide the air space between layers of glass. It is very transparent and can be tinted or be in a coating form as a film for existing windows.

4.3 Tinted Glazing

All plastics and glasses are available in a wide range of tints. Tints are particularly useful as they absorb a portion of the heat and light as well as changing the colour of the window and may create more privacy. Tinted window panes may be used singularly or in multi-layer applications.

The tinting works by reducing bright outdoor glare and the solar energy that is transmitted through the glass. The advantage of using this type of glass is that there is little to no maintenance for the life of the window; however tinting does not change in response to climate conditions. In summer and winter it stops the same amount of light and solar gain, that in winter it would be useful to retain.

Tinted windows are most commonly found in commercial applications in comparison to residential windows. This is due to the fact that solar gain is often stopped through aesthetic means in homes, through the use of curtain and drapes. In retrofit situations often tinted coatings or films may be applied.

The beauty of tinted windows is that they offer an unhindered view from inside, but typically offer privacy from the outside. However at night time, this effect is reversed and when the lights are turned on inside, it proves very difficult to see outside and very easy to see in through the window.

Tinted glass is also known as heat absorbing glass as it provides effective sun control when it is on the outside layer or included in multi layered glazing. Tinting is achieved by altering the chemical formula of glass, with every change resulting in different transmittance, reflectivity, and solar heat gain.

There are two types of tinted glass, the first is conventional tint which diminishes both light and heat gains and comes in bronze and gray tints. The second is called spectrally selective tints. These are more advanced and while they reduce heat gain they allow much more light to be transmitted through the glass into the interior. They typically come in blue and green tints.

4.4 Reflective Coatings and Films

If bigger reductions in heat or light are required, a solution is to apply a reflective coating or film to an either pre tinted or clear pane of glass. This works by increasing the surface reflectivity on the plastic or glass. These coatings or films are generally thin metallic layers that are available in a wide range of colours. One of their properties is in the reduction of ultra violet (UV) penetration.

The major problem however is that while they provide good control depending on the location and thickness, they are not overly durable in comparison with glass and plastics.

It must be remembered however that the heightened surface reflectivity will act as a mirror to the outside making glare a large factor causing momentary blindness for passers-by and possibly overheating and killing vegetation, with a similar effect to tinted glasses, in reversing at night.

4.5 Double Glazing

Second panes in front of standard glazing known as 'Storm windows' were the first type of double glazing, (now called 'Secondary glazing') with the intent to reduce air infiltration with a tight air seal. Improving the insulating value was a secondary effect. Double glazing was made by fusing the glass at the edges of two glass panes together. Today spacers and polymers have replaced this traditional glass to glass edge seal and are much more durable. These systems should last for decades if good quality control is used in production. Also available today are the additional non sealed removable glazing panels, i.e. a blind or shade that is positioned between the glazing layers and may be removed in summer. Typically, glass panes had an organic edge seal, which was an advance on the earlier welded glass-metal edge, or a fused glass edge and various types of organic seal edge are still being developed today.

4.5.1 Glass Coatings and Tints in Double Glazing

Double pane units often incorporate different glass types with clear glass usually used in the inner pane and tinted on the exterior pane. Types of coatings are also varied depending on the type and location where they are applied.

There is flexibility in reducing heat transfer by changing the gap width between two or more layers of glazing. About 12mm thickness is the optimum insulating value when either air or argon is installed in the cavity. The rule is that as the gap increases so does convection and therefore heat transfer.

4.5.2 Divided Lights

People often prefer the look of the colonial windows with the small panes of glass in the muntins. With single paned glass this is often an advantage as the timber of the framing has a higher insulation value than the glass used. So the divided light was created but it is very expensive and hard to fabricate with the small panes of insulated glass. Fakes are often used for the aesthetics and ease of production, with fake muntins glued onto the interior and exterior glazing.

4.6 Special Products

Glass blocks provide double glazing while letting in light and providing privacy.

Plastic blocks are very similar but depending on the fixing materials used i.e. metal bars for the structure and the grout used it can have considerably lower thermal performance.

4.7 Multiple Panes of Glass

When a double paned window is installed the insulation value is effectively doubled compared to that of a single paned window. However adding a 3rd or 4th layer also increases the insulating value but in diminishing value.

There is a serious trade-off between a more energy efficient system, as the more layers used mean that the VT and SHGC decreases and there is a heavier weight over the unit. There are physical and economic limits to the use of multi layer glazing. Instead a plastic layer is often installed between two layers. It is much thinner and lightweight. It effectively does the same job as another layer of glazing but it does not increase the width of the unit while still dividing the air cavity in two.

4.8 Low Emittance and Spectrally Selective Coatings

Spectrally selective coatings were developed from the need to include and exclude certain parts of the visible and infrared spectrum. Glazing materials can be manufactured to, for example, allow most of the solar spectrum in through the window but block the re-radiation of heat back out when designing to maximise solar gains for winter. Windows designs can now optimize energy flows for heating, cooling and day lighting.

High-transmission low-E systems are best for buildings situated in heating-dominated climates, while selective-transmission low-E incorporates spectral selectivity, which is best for buildings situated in climates that have both heating and cooling load needs. Low-E coatings reduce heat loss in winter and allow day lighting and blocking of solar infrared energy in summer, decreasing cooling loads. Low-transmission low-E systems are best suited for buildings situated in cooling dominated climates as the combination of a low-E coating with dark tinted glass and/or increased solar reflectance reduces solar heat transfer and glare while still providing insulation.

The coating placement and location of different low-e coatings in a multi-layered glazing unit will **not** have an effect on the units U-value; however it will change the value of the solar heat gain coefficient. For example placing a coating on the outside surface of the interior pane (facing into the cavity) is best when trying to minimise passive solar gain.

4.8.1 Sputtered or Soft Coats

This is a multi-layered coating, usually put onto the glass or plastic film in a vacuum. It is very thin, not particularly durable, fragile, and must be protected from humidity. Uncoated clear glass has an e value of 0.84 which means that 16% of radiant heat energy is reflected whereas sputtered glass e = 0.20, 80% is reflected.

4.8.2 Pyrolytic or Hard Coats

This type of coating is very hard and very durable and maybe exposed to air, it maybe cleaned with everyday cleaning products without any significant failure. As a result it is available for single layer, multi-layer and storm windows. The e value ranges from 0.4-0.15.

4.8.3 Spectrally Selective Coatings

These are modified developed version of sputtered coatings, and are generally not available with pyrolytic coatings.

These coatings may be applied to retrofits. Due to the rapid development of this industry since the 1980's it is now common to find these coatings in residential windows.

4.9 Gas Fills

When a multi paned unit is used, a way to improve the performance of it is to reduce the conductance of the air cavity. This basically involves filling the space with a slower moving, more viscous gas which minimises the convection current from top to bottom. This then lowers conduction through the gas and provides heat transfer reduction method, across a multi layered unit. The use of argon and krypton gas fills shows the most improved thermal performance so far. While argon is a much cheaper, clearer gas that works best with a 10-12mm thick cavity, krypton is a more expensive gas, but works better with only a 6mm cavity. Gas fills work very well at lowering the heat transfer, but when used in combination with other measures there can be up to a 20% reduction in heat transfer through the glazing unit.

There are concerns about gas leakage but in reality leakage that does occur is very low - only about 0.5% a year when good quality design and assembly is adhered to.

4.10 Thermally Improved Edge Spacers

In multi-layered window units the spacer plays a vital role. It is there not only to keep the glass or plastic panes at the required thickness but also to act as a moisture barrier, a gas tight seal, an insulating barrier, and also to accommodate stress brought on by thermal expansion.

The originally spacer used in wooden double glazing units were made from wood however these could not create an air tight seal and had to be vented to the outside. The current technology that is being used has developed this much further. There are generally two types of system for modern day insulating glazing units (IGU's); the single seal system or the double seal system. The first is not overly reliable as it lets the low-conductive gases leak. The second system uses one seal to stop moisture entry and gas loss and a second seal for structural strength, whereas the single seal system uses one seal for all these things.

It was found early on in the development of edge spacers that aluminium was a poor metal for use in this situation. This is due to the fact that it conducts heat too well at the edges, effectively reducing the improved insulating qualities of other innovations in the unit. There are a few

different developments for this. The first is to use a less conductive metal like stainless steel. Another is to take away the use of metal altogether, using a better insulating material like silicone, extruded vinyl, or pultruded fibreglass instead. The basic idea in the design of thermally improved edge spacers is to stop or minimise the heat transfer pathway at the edge of the glazing unit between two or more layers. Spacers being used internationally now include composites of Aluminium, PVC, Stainless steel, silicone foam, and profiled metals, and are chosen for their specific performance.

4.11 SuperWindows

This term has been coined to refer to the commercially available systems that take advantage of a lot of the different energy saving measures available. While they are very expensive, they do create a translucent window with remarkable energy performance, which can be 100% better than standard double glazing. The loss of heat is very low and sunlight that is gained though the window is diffused but is still greater than any heat loses even in colder periods of the year. It may become possible in the near future for windows to become energy saving elements of house design not energy losing elements especially as the main impact of super windows occur in winter not summer.

Not only do Super windows save energy but they are also proven to improve interior user comfort. There are often high interior temperature even in winter and when there are large window spaces. Some systems that are currently widely available in the colder parts of US America include triple glazed glass panes with two low e coatings with the gaps filled with Krypton gas. There are also quadruple paned panels with two layers of flexible plastic that are low-e coated and suspended between structural spacers.

5 Emerging and Future Developments of the 21st Century

5.1 Evacuated Windows

Gases and air between the panes of a window are thermally efficient; however the most effective method would be to enclose a vacuum with two panes of glass. The idea is that if the vacuum is low enough then no conductive or convective heat exchange would be present between the glass layers, reducing the U-value, since there are no molecules to transfer heat. This would not address the radiative heat transfer however, so low emissivity surfaces must be used in conjunction with it to minimize radiative heat transfer. A very similar idea to thermos bottle used commonly today.

The main problem with evacuated windows though is that there are often substantial thermal pressures on large panes on windows. In contrast to the cylindrical surface of a thermos the flat planes of a window are inclined to bend and flex under pressure. Therefore the structure is very important and the pillars used in between the glass layers are small but visible making the transparency of evacuated windows a problem. This technology[1] has been commercialised in Japan following developments at Sydney University in the last 10 years.

5.2 Aerogel

Another new innovation in the world of transparent insulation is that of Aerogel. This product is a silica-based, open-cell, foam-like material around 4% silica and 96% air. It works through the foam cells that trap gas which in turn reduces convection however it still lets light through. The only difference being that due to the diffusing nature of the cells it creates a soft blue haze like the sky.

It is not only insulating but also see-through making it a highly effective material in terms of energy efficient windows. However currently it may only be produced in small batches so it use has been limited. In the long-term Aerogel may find its use even more limited, due to its diffusing nature it provides a much more reduced view out in comparison to standard glass. Pilkington Glass have commercialised this technology as Nanogel, where the company's U-channel glass is augmented with 16mm polycarbonate inserts that contain this Aerogel.

1 Evacuated windows work at Sydney University that has been commercialised in Japan for their narrow spacer windows.

5.3 Smart Windows

Smart windows are a term developed for new technology that allows windows to react to the environments and change their own solar-thermal properties. There are two types – passive devices that react directly to the environment, and active devices which can be controlled to respond to the user requirements.

5.3.1 Passive - Photochromics

Photochromic technology allows sheets of glass to change their transparency in reaction to the changing light around them, similar to sunglasses that develop a dark tint in bright situations. This new technology may help in cutting out glare and overheating problems while still letting in enough light and providing a view out. Currently the product is still far too costly to be used widely, although developments are continuing internationally.

5.3.2 Passive - Thermochromics

Thermochromics change transparency due to changes in temperature. They consist of gel between glass and plastic layers which range from being clear in cold situation and white in hotter situations. If this technology became an affordable option it would allow the control of 'cool daylight', allowing the ingress of light into indoor spaces, but not the associated heat. This would provide an appropriate alternative in skylights as views would not be minimized due to the changing colours.

5.3.3 Active - Liquid Crystal Glazing

Similar to the technology used in watches, liquid crystal glazing has become a real substitute for traditional glass panes and is very effective in terms of privacy and security. It allows a glass assembly to be switched between two different states, the first when the power is off, providing a diffused state which renders the assembly opaque, and the second when power is connected to the pane which provides clear vision through the glass seconds after the power is connected. Currently it is only used in commercial buildings as it is highly expensive.

5.3.4 Active - Particle Dispersed Glazing

Similarly to the liquid crystal technology, this innovation has two states, either unpowered or powered. When unpowered the particles of a liquid media trapped between two panes are randomly scattered, blocking sunlight transmission and the view. When powered, the particles align in a chemical reaction which creates a more transparent surface. However, like liquid crystal glazing it too is still very costly.

5.3.5 Active - Electrochromic Glazing

This technology is formed by the deposition of very thin layers of rare metals in specific layers on clear glass. Electrochromic surfaces are becoming increasingly cheaper, while their performance, cost and manufacturing requirements are also improving through continued research. These materials are able to change translucency of about 10 – 70% in fewer than 60 seconds. Unlike the previous innovations, switching only needs around 1 – 2 volts compared to

12 volts with the others; this should mean that it is much cheaper and readily accessible to the general public much sooner. The electrochromic process may be stopped at any time without changing its state by removing the power, or reversed to its initial state by reversing the polarity of the power. The Japanese are the world leaders in these innovations and examples of its use are available in many commercial buildings there.

5.4 Laser-cut panels

This technology involves the use of laser cutting equipment being applied to clear plastic sheets, which allows variable shading effects to be created which either retain orientation independence, or have a varying orientation dependence. This technology will help to address the need for skylights to pass light and heat in the early morning, but only light in the later hours.

5.5 Self-cleaning glass

This technology was released by Pilkington International Ltd in 2004 where a special surface treatment to the glass allows ultraviolet light to energise the decomposition of organic materials which lodge on the glass surface. This has the effect of loosening them from the glass surface such that rain is more likely to wash them off. While the chemical deposition process of achieving the right layers on the glass surface is energy intensive, the potential energy saved through reduced maintenance costs of hard-to-reach commercial facades must be factored into the cost equation.

6 Frame Materials

It was not until relatively recently that prefabricated windows frame were available internationally. Up to the 1920's window frames were still being made on site by the residential builder. From the 1920's to during World War II, prefabricated steel-framed windows were very fashionable until prefabricated wood framed windows were introduced into the market during the 1940's and 1950's. The use of aluminium window frames mushroomed after World War II as aluminium producers changed from wartime fabrication to domestic construction. By the 1980's and 1990's, 50% of window frames used in domestic building in US America were prefabricated aluminium frames. From the 1990's onwards new innovations such as vinyl frames, fibreglass frames, engineered thermoplastic frames and modified wood framed windows have been produced. The new materials used in window frames dramatically alter the physical characteristics of the window and progressively more manufacturers are using creating different combinations of materials to increase the thermal properties and performance requirements of windows frames.

6.1 Wood Frames

Wooden framed windows are a very versatile window frame system that is still in use today. Not only is it a readily available, sustainable resource but also it is easy to repair and maintain. It is able to be modified easily with a wide range of paints and finishes that are available and is able to be manufactured for almost all types of windows.

It is favoured not only for its aesthetic qualities and time-honoured use but also because it performs very well thermally. That is to say that the thicker the frame the higher the insulating quality of the window frame.

Perhaps the only concern with the use of wooden window frames is that un-modified wood is not the most resilient material used in window framing. This is due to the fact that it may succumb to rot easily and weathertightness can be a real issue. As a result kiln drying and chemical treatments are often applied to make the timber have a much longer life.

6.2 Aluminium Frames

From the end of World War II till around the end of the 1980's aluminium frames were a very common type of window frame, used about 50% of the time in US America. However after the 1980's their use has declined and is currently around 25% in US America, whereas it is over 90% in New Zealand (See later). This is because of the low thermal performance of aluminium window frames.

Aluminium frames pose a difficult problem for the window industry. While they are highly durable, light, strong and able to be extruded into many different shapes and profiles unlike timber, the thermal performance is much lower. This is due to aluminium's high thermal

conductance meaning that it is not very insulating; conducting heat too quickly across the opening and similarly produces condensation too easily.

The most readily available answer to the problem is to use what is called a thermal break between the two parts of the interior and exterior frames. The thermal break is usually a kind of plastic that is inserted between the two parts, and then left to harden. The result is that the plastic slows the heat flow between the aluminium extrusions on the interior and the exterior. It is possible to produce a thermal break that halves the U-value, however this is difficult for manufacturers to achieve evenly over the whole surface and it is also very costly.

6.3 Vinyl Frames

Vinyl window frames are similar to both wooden and aluminium window frames. It is produced similarly to aluminium but performs much closer to that of wooden framing. Vinyl is a very useful plastic, it provides high insulation, little colour degradation, resistance to corrosion, low maintenance, little painting is required and it also has very good moisture resistance. Its lifetime is similar to that of aluminium, with the componentry and assembly degrading before the material itself, provided adequate UV stabilisation from polymer modification has been made.

These types of window frames are manufactured by using standard extrusions and assembling these to create a standard window frame. They are used commonly in both residential building and retrofitting as the production process easily leads to production of custom sizes.

Thermally vinyl performs similar to that of wood, in some cases better. Often an insulating material is added to the vinyl to prevent any unwanted convection within the frame.

6.4 Fibreglass and Engineered Thermoplastics

Like Vinyl frames, fibreglass and engineered thermoplastic frames are becoming a viable part of the window industry. The beauty of these two products is that like vinyl they too are able to be extruded into many different profiles. Fibreglass especially is much stronger and therefore able to be produced into much smaller sections and profiles. Both of these two new materials have very good insulating qualities but are unfortunately much more expensive hence the smaller use in the window industry.

Aluminium is a stiff material, approximately 20 times stiffer than vinyl, and 7 times stiffer than soft wood. While dependent upon its makeup, fibreglass can be pultruded into lengths of similar stiffness, which means that larger doors can be constructed with this material without the need for additional steel reinforcement, which reduces the thermal effectiveness of PVC windows.

6.5 Wood Composites

The use of wood composites in window frames is fast becoming a viable part of the window market. This type of system is very similar to the traditional wood frames but with the added advantage of being able to be formed into different shapes similar to extruded vinyl, fibreglass and thermoplastics. The wood composite extrusions have the same thermal performance seen in wood frames but have improved moisture and decay resistance. They can be stained and made to look like anything. Also they are a very sustainable type of window frame as their production sees the reuse of sawdust and otherwise useless wood scraps.

6.6 Hybrid and Composite Frames

What window manufactures are beginning to provide more and more are hybrid and composite frames that are made up of two or more types of frames from the ones above. This innovation sees the combination of two different elements such as a wood interior frame and a vinyl exterior frame. This way the manufacturers are able to produce products that make use of the best elements of different materials, e.g. the appearance of wood, thermal properties of vinyl, extrusion qualities of fibreglass etc.

7 New Zealand Technologies

Most of the international glass technologies are available in New Zealand, and are only limited by market demand, since the glass and frame market is an international one. The limitations of access to this international market that New Zealand faces are due to the transportation time required to supply our market with product by cost effective surface transport. Some glasses are only available in limited amounts in New Zealand, or not at all, due to the limited shelf life of soft-coat low-e glass, for example. Vacuum glazing and many of the smart glass technologies are also not available due to transport requirements increasing their cost beyond market viability, and our moderate temperate climate which can be serviced by lower technology options.

7.1 New Zealand Framing

The window/door framing technologies that are currently available in New Zealand include Aluminium, composite timber-clad Aluminium, thermally broken Al, timber (with imported cedar being predominant, but with many imported timbers being available through to locally sourced pinus radiata) laminated timber, a limited range of imported engineered timbers, PVC, and specialist steel windows.

New Zealand has also been an innovative nation, which is represented in the developments in window framing that are identified at the end of this report.

7.2 New Zealand Glazing

Glass is readily available in New Zealand includes clear float, tint, low emissivity, reflective, spectrally selective, combinations, and self-cleaning varieties. This reflects the international availability of glazing products.

Other glass treatments that are not directly related to their thermal performance include obscure, patterned, screenprinted; wired, toughened, heat treated, and laminated glasses, sourced from Asia, China, US, Europe, and Australia.

The New Zealand residential glazing market is not a commodity market. It is only recently that the market has had the option to 'upgrade' its windows from timber to aluminium; however this has not normally been a performance upgrade, as happens in the large renovation markets of US America and Europe. Our temperate maritime climate has limited the perceived necessity of significant internal climate control as is the case in these international western markets, such that New Zealanders live with their windows open. However, as increasing demand-side management of energy becomes an issue in the residential market, energy efficiency is becoming more important. Sustainability is also becoming a significant issue, resulting in some changes to the way the market operates, although much of this has been in response to international trends in more developed markets.

It is in the area of window framing that New Zealand has had some development success, where stakeholders such as Scion have been addressing the uses of radiata pine, aluminium extruders have been converting international developments to suit the New Zealand market, and individuals or small companies have been investigating niches that may be able to develop into significant markets. The particular ones that have been identified all have IP issues, and are summarised in the later section.

8 Structure of the New Zealand Window Market

Up until the 1960's, the New Zealand residential window/door market was dominated by timber and steel with 3 or 4mm clear glass panes puttied into sashes. Wooden windows were constructed in joinery factories or on site from imported timbers, such as western red cedar, or from locally sourced redwood, cedar, rimu, totara or other similarly durable timbers. Steel windows were fabricated in factories and commonly used where fire rating was an issue, or heritage appearance was valued. Aluminium did not arrive as a significant player in the window industry until the mid 60's, whereupon it rapidly gained market share due to its lower pricing structure and lower maintenance requirements. Aluminium framing allowed glazing to be rapidly installed with aluminium beads with vinyl or plastic wedges and seals, rather than relying upon glazing putties, and it meant that windows were now all manufactured in factory conditions which allowed considerably better quality control and process automation.

8.1 PVC Framing

PVC has been a recent entrant into the New Zealand domestic market following its huge use in Europe and north America where it has captured over 80% of the window market, and over 90% in the UK (See report [2]). The retrofit window market is significant in Europe and North America, where houses are typically built to outlast their components.

Several attempts have been made to introduce PVC into the domestic market in New Zealand, with the most successful inroads being made with the current attempts by several large European PVC window extrusion companies including Kommerling, Dei Koenig, Veru and Homerit targeting the Australian and New Zealand markets.

8.1.1 PVC extrusion in New Zealand

In the 1990's an attempt to extrude PVC window sections in New Zealand was made by personnel from the Aluminium industry based in Hamilton. This attempt was not successful, however the importation of lengths of PVC extrusion from Europe and North America continued at very low levels, never gaining more than half a percent of the residential market. Now however, there are between 6 and 10 companies who are fabricating windows in New Zealand from imported PVC extrusion, with support from major European brands. The increase in the use of insulating glazing units has helped PVC to gain a foothold in Christchurch, where NK windows have gained 1% of the residential window market in the last five years with their windows which readily accept wide double glazing units, sourced from MetroGlassTech in Christchurch. Their aim is to follow the lead of the Australian PVC window market, and capture a significant portion of the Christchurch market and make inroads into the market in the remainder of the South Island through local suppliers. PVC is aiming to capture 10% of the Australian domestic window market in the next five years, where windows are more of a

2 Report from Stephen Garvin of the Building Research Establishment Ltd, Scotland.

commodity item, although they have been priced significantly lower due to their stock sizes and limited colour options in aluminium.

8.1.2 Thermal performance of PVC

PVC has a significantly better thermal performance than the standard aluminium-based windows and the thermally improved aluminium windows available in New Zealand, and as the South Island continues to grow in its adoption of thermally efficient window systems, there will be growth in the PVC market. PVC is favoured by expatriate Europeans and North Americans who are familiar with this technology, and is able to compete on price with thermally improved aluminium windows. NK windows currently supply several companies in the North Island with built up windows, as these companies develop their own fabrication facilities. The issues that the New Zealand market has with PVC is that all the profiles are oriented to use in Europe where internally opening windows are used, external shutters may be operated from the inside, and security is a big issue. In New Zealand, consumers are used to having internal window sills, being able to open their windows outwards, having internal drapes and curtains, have little demand for the security offered by five point locking, and are not yet seeing windows as a consumable commodity item. PVC has had a chequered history with its durability in New Zealand when used in exterior uses such as gutters, where our elevated UV exposure levels steadily increased the ductile-brittle transition temperature (DBTT) of the PVC polymers, meaning that the older PVC elements would shatter when impacted. Since the introduction of polymer-modifiers, a hot-country-mix of PVC has been designed, which has largely eliminated this problem. New Zealand has not seen the PVC colour change problems that were prevalent in the UK due to the instability of the coloured PVC polymers, since the chemistry was altered to develop a UV-stable polymer.

PVC windows have also suffered from the New Zealand penchant for larger windows, coupled with our more severe wind environment, meaning that structural strength and stability of the PVC sections has had to be augmented through the insertion of galvanised steel or aluminium bars/angles in the PVC sections. Our highly saline coastal exposure has also led to rust-bleeding problems in some inappropriately specified joinery installations in extreme maritime exposures.

8.2 Aluminium

The New Zealand market for windows is largely represented by the aluminium window frame market. A 1995 report [3] set the domestic aluminium market share at 93%. A 2002 report [4] shows that 96% of the New Zealand domestic market has been captured by the standard aluminium window frame industry, with 1% captured by the thermally improved aluminium market, and the other 3 percent divided between PVC, timber, steel and other composite window framing technologies. Developments within the timber window market (discussed later) indicate that the aluminium window market share is likely to be still holding at this level; so for the purposes of this report we will accept the approximate value of 95% as the domestic window market share in 2006 for the accumulated total of both standard and thermally improved aluminium.

Given this market delineation, discussion in this 'market structure' section will centre on the aluminium-based frame market, with a cursory explanation of the other window frame technologies. Since the glazing side of the market is integrated with the aluminium-based frame manufacture, it will also be covered here.

The New Zealand residential aluminium window market is serviced by four main players, referred to as proprietary system suppliers (PSS) who are generally own their own dies for extrusion, and are sometimes known as the Prime Die Holders (PDH's). These PSS group members each extrude aluminium sections from their own dies, and each licence numerous local fabricators to build these aluminium extrusion sticks into window frames. These companies are: Aluminium Systems Ltd (ASL) who owns the brands Fairview, Elite, and TimberView. Aluminium Profiles Ltd (APL) who own the brands Altherm, First, Vantage, Smartwood and Architectural. Fletcher Aluminium Ltd (FAL) who own the brands Oakley, Alti, Fisher, Nebulite, Rylock, and Vistalite (and are part of Fletcher Building) and National Aluminium Ltd (NALCO) who own the brands NULOOK, Millennium, and Bradnams.

There are a few other smaller players who such as L.W. Hoyle Ltd (Omega) who also produce aluminium window systems through similar arrangements.

3 Sage, A. 1995 Glass and Insulation. Centre for Advanced Engineering, Energy Efficiency Project Workshop, residential Buildings Section, Appendix B, Christchurch 1995.
4 BRANZ report, EC0567, Surveys of Insulating window Systems in the New Zealand Residential Construction Sector, 1994-2002, 9 July 2002.

8.2.1 Aluminium-based window fabrication

The aluminium window fabricator takes orders for windows/doors from group builders, builders, architects, specifiers or homebuilders, and then typically assembles the finished product from the framing, glass (or glazing unit); glazing wedges/seals, reveal liners, operating hardware, and ancillary products.

Aluminium framing: surface finished aluminium framing is supplied in 6m lengths from the PSS's extrusion plant, in any of over 300 colours in a powdercoated, anodised or mill-finish condition. The sticks of extrusion are mitre-cut and jointed with gussets and screws into a frame and sashes of any shape or size.

Assembly: the aluminium frames are assembled together with hardware as required by the client, in configurations of awning, casement, bifold, sliding, single hung, double hung, hopper, greenhouse, fixed, or other opening type.

Glazing: Glass or glazing units is ordered from a glass merchant, and glazed into the frames and sashes with vinyl wedges and seals, on setting and retention blocks.

Accessories: Virtually all New Zealand aluminium windows and doors are supplied with timber reveal liners, which typically form the sill and internal jambs on the inside of a window. These are typically made from H3.1 treated timber, since customwood and untreated timbers have been unsuccessfully used as reveal liners in the past. These liners are supplied from a timber yard, and together with operating hardware, supplied from the major New Zealand supplier Interlock, or with other imported hinges, stays, handles and hardware, are assembled into a completed window unit, and delivered to the site.

Installation: windows/doors are typically received by the building contractor and are installed by the builder according to the method described in the acceptable solution to clause E2 of the New Zealand Building Code, E2/AS1.

Unlike most other developed countries, New Zealand aluminium windows are available in several hundred colours, in any size that is desired, in a large number of different configurations. Glazing options are likewise almost unlimited, with panes of clear, tinted, toned, reflective, low emissivity, spectrally selective, toughened, and laminated in single or double configurations with almost any combination of the above glazing available in toughened glass. This propensity for variation has protected the window market from losing market share to imported windows which are available in a limited number of colours, sizes, materials and types.

There is only a limited variety of hardware available in New Zealand however, with the European 'tilt and turn' and 'five-point-locking' options not being readily available in aluminium.

8.3 Timber

Timber no longer has a significant proportion of the New Zealand domestic window market, however its use is increasing in high-value homes for its aesthetic requirements, however its main benefits are those of sustainability and energy efficiency, for which it is not yet seriously sought after.

Most timber windows used in New Zealand are constructed in small joinery factories from imported timbers of suitable durability, with western red cedar being the most commonly specified timber. Since the availability of non-renewable timbers from our own or international rainforest sources has been successfully reduced, the search for ongoing supplies from sustainably harvested sources has led to interest in the engineered timbers that are common in Northern European construction. Investigation of the multiple-laminate timbers has so far been stymied by the low cost and low performance expectations of the market.

In the 1970's timber windows were made to a single set of designs that were included in NZS3610 which were generically tested for their weathertightness and airtightness. Since this time, all but one of the New Zealand timber joinery firms have made modifications to their timber profiles that mean they are no longer are compliant with New Zealand standards, and so will either need to be modified again, or will lose market share as compliant frame technologies overtake them.

8.4 Modified Timber

Exotic timbers such as radiata pine and Douglas fir are a major sustainable resource in NZ. Douglas fir does not accept chemical treatment very well, while radiata pine does. While very little of these timbers are used in the construction of NZ residential windows because they do not currently have good dimensional stability or durability, (as is discussed elsewhere in this report), there is potential for radiata pine in particular to be engineered into a form with suitable properties for exterior joinery timbers. As the issue of the disposal of treated wood is a major environmental concern, the Life Cycle Assessments (LCA) for preservatives and preservative-treated timber may well become the norm for selecting the appropriate treatment or chemicals to achieve the desired durability requirements.

In future, waste disposal and recycling potential at the end of the service life of treated product will dictate what preservative chemicals or treatments may be necessary to use.

Disposal of preservative treated timber in land fills causes potential hazard as the water soluble preservative elements may leach into the groundwater. Alternatively, if the timber is incinerated one has to consider the consequence of the toxic contaminants in the smoke or ash on human health and the environment. An alternative choice for the industry is to substitute safer chemicals in favor of the traditional wood preservatives. In this context wood modification using non-toxic chemicals offers a future scenario for the industry. Radiata pine's easy

treatability makes it an ideal biomaterial for tailoring products to suit the market requirements of high value products.

If suitably engineered for enhancing specific properties, radiata has the potential to bring enormous monetary benefits to the New Zealand wood industry as the world demand for such products is rapidly growing.

8.5 Steel

The use of steel window framing for domestic window systems has reduced to a greater degree than has timber. This material has been effectively replaced with aluminium except for fire-rated windows and those few that are needed in the replacement market to retain the heritage value of old steel-windowed construction. Steel has poor thermal performance and while having strength and ductility, suffers from the need for treatment to enhance durability, and possesses significantly greater weight. New Zealand never had the market penetration of steel that North American markets achieved.

8.6 Glass

There are two main players in the New Zealand window glass industry, and a number of smaller operators. MetroGlassTech has rapidly grown in the last decade to rival Pilkington New Zealand Ltd as the largest importer and supplier of glass for window and door joinery in New Zealand. Typically they source their flat glass from Asia, Australia, Europe or North America, then cut stock sheet to size on demand. Both MetroGlassTech and Pilkington, together with other of these glass importing companies also run toughening furnaces, laminating, screen printing or insulating glazing unit manufacturing facilities, which allows a manufactured glazing unit to be delivered to the fabricator for inclusion in a window/door system. Other surface treatments of the glass (such as polyvinyl butrate lamination, low emissivity coating, or spectrally selective coatings as discussed elsewhere in this report) are not performed in New Zealand.

8.7 Double glazing

There are currently 9 manufacturers of insulating glazing units for the residential market in New Zealand. These companies are Glass Specialists (Christchurch), Mainland Glass and Glazing, MetroGlassTech (with manufacturing operations in Mt Maunganui, Christchurch, Wellington, and Auckland), Pilkington New Zealand Ltd (with manufacturing in Hamilton, Christchurch and Wellington), Otago Glass (Dunedin), Southland Glass (Invercargill), Thermaseal (Christchurch), Total Glass and Glazing (Palmerston North), and Ultraglass (Wellington). All of these companies use the same IGU manufacture technology with an aluminium spacer bar an internal airtight seal , and an external structural seal of polyurethane, silicone or polysulphide, except for Pilkingtons who also manufacture units with the warm-edge 'Swiggle strip' technology, and the Mt Maunganui branch of MetroGlassTech. There are several other manufacturers who have been manufacturing with warm-edge spacer technology primarily in the refrigerated cabinet market, although these warm-edge spacers are available in the residential market to customers who are prepared to pay $2 or $3 per metre for spacer, instead of a standard aluminium spacer, at $1/metre.

9 New Zealand domestic market issues

The domestic window market in New Zealand is around a 0.7 billion dollar industry. Around 25 000 building consents are issued annually for new residential building work, each containing around 40m² of glazing. Each houselot of installed glazing is worth between $10 and $30K. In addition there are the alterations and additions which add another few percent to the market, as does the renovation market.

9.1 Aluminium-based Market

The capital cost of standard aluminium framed exterior window joinery is around $8K for single glazing, and $11K for clear double glazing. Composite aluminium framing (timber inside, aluminium outside) has a capital cost of $18K in single and $20K in double for an average houselot, while access to cheaper thermally broken aluminium technologies for window systems in China may soon reduce the price of this option to below a capital cost of $15K for clear double glazing. PVC framing is also reducing in cost as their market share rises, with a houselot of PVC-framed windows having a capital cost of around $14K in single and $17K in double glazing.

9.2 Group Building

Group builders are now reported to be servicing up to 60% of the NI market residential construction market, with much of their construction in speculative development where a purchaser has not been involved in any decisions about the construction of the house. Group builders are now large companies that are able to fully employ all the sub-trades required to construct a house with specific teams that travel between many housing sites to complete only one specific task (such as installing the gutter, or erecting timber framing), before moving on to the next site. Consequently, the selection of window joinery is often now performed by the specifier for the group builder, rather than by the occupier or purchaser. This has modified the market strategy for window companies wishing to upsell window systems, although several of the group builders, including Golden Homes which operates nationally, have made the decision to only specify double glazing, in place of the standard industry practice in the North Island of specifying clear single glazing.

9.3 IG Market size

The market for insulating glazing in the early 1990's was fragmented, but has now become a lot more defined with major players emerging, as identified in the previous section. The market for IG in the New Zealand domestic market has risen from 9% in 1994 to 28% in 2005, with the South Island market currently at 82%, and the NI market at 9%. This information comes from the 2005 BRANZ survey [5], with the results of the 2006 survey not yet available. The use of low-emissivity glass is also growing, and a survey may soon expand to include this technology. Informally, the market for low-e glass is reported to be around 10% in the South Island with variations from 2 to 20% in regions of the North Island.

9.4 Legislative issues

NZS4218:2005 is soon to be implemented in clause H1 of the NZBC, which will require IG as the acceptable solution to meet energy efficiency targets in zone three (the South Island and NI volcanic plateau), since cost benefit work has shown that the use of IG is economic in the NI, and as soon as non-energy benefits are considered, IG also becomes viable in the top of the North island.

[5] ***BRANZ report, DC0995, Double Glazing in New Zealand, 1994-2005, 2 August 2005.***

10 Life Cycle Assessment

No attempt in this report has been made to incorporate a Life Cycle Analysis for the technologies that have been identified, and this report recognizes that a ranking of all the opportunities on the basis of LCA is unlikely to be a wise use of resources. However this report does recommend that the promising technologies be assessed further to allow some rank order to be given in order to assess their potential.

The most significant issues for Life Cycle costing appear to be those of the embodied energy in the major window components of aluminium, glass and PVC, together with the transportation requirements from offshore manufacture for imported components, and the disposal of elements such as treated wood. Recycling options for Aluminum and glass are readily available, with the new MetroGlassTech IG facility in Christchurch which opened in March 2006 being locating alongside the Christchurch Tasman Insulation plant, to allow waste glass to be transferred immediately into the production of 'Pink Batts'. PVC suffers from having a limited recycle lifetime, while aluminium can theoretically be recycled indefinitely, however there is no waste stream coordination to allow this to happen for product other than cans.

11 Technical Opportunities

A number of technical opportunities have been identified in the work pursued for this report, and they are presented in the order of their discovery. A conspectus of these opportunities is presented in the below, indicating technologies that have already been captured, and those that are still available for appropriate capture.

Since most have these technologies have IP issues, they have been summarised into a common format below, and most are not discussed in the above. The technologies vary from research developments or products or systems, to varied applications of existing technology, market leveraging, legislative modifications and incentive programs.

11.1 Ranking of Opportunities

Initially it was assumed that the below opportunities would be identified in this report, together with a proposal to fully expand the opportunities ranked in terms of their LCA's in a further report. However it has become apparent that the further work to achieve this ranking on the basis of LCA is not likely to provide value for money. Therefore, this is not recommended. Rather, it is recommended that the opportunities identified below which Beacon are interested in, be developed in further work on the basis of the following rationale:

- Potential time to market
- Potential market uptake
- Potential market benefit (Qualitative)

Currently, an overview of the identified technologies is presented below, drawn from the information discovered during the preparation of this report. Favour has been given to those technologies that are, or appear to, demonstrate the ability to reduce, renew or recycle materials, are sustainable, and reduce energy use for the occupant.

Some of the opportunities include sufficient information to allow a presentation of the research work required without further investigation, although the majority will still need some investment into investigating the cost benefit of pursuing them.

A summary of these opportunities is presented in Table 2 at the end of this section.

11.2 Acetylated timber

11.2.1 Situation

This technology has just been commercialised under the names of 'Titan' and 'Accoya' by an overseas investor, following development from SCION in Rotorua. Licenses for this technology will soon be being offered back to NZ parties, as licensing is still being completed. (March 2006)

11.2.2 Description

Acetylation is a process which starts with radiata pine, improving its dimensional stability and resistance to weathering and biodegradation via chemical reactions and modification of wood cell wall macromolecules. In the process, polymer hydroxyl groups, which provide "weak spots" in wood from the perspective of dimensional changes and durability, are chemically blocked. The wood cell wall is thus "water-proofed", the extent depending upon the degree to which wood cell walls are acetylated.

Acetylated wood has a life cycle of a natural wood and its disposal or recycling will not pose any problem. It may be incinerated with no more harmful byproducts than normal radiata pine.

11.2.3 Opportunities

The high-cost, high-risk, high-return phase of this technology has been taken up by another party, so Beacon now has the opportunity to investigate the viability of utilizing this technology to construct sustainable timber-framed window systems from acetylated radiata pine in partnership with a local manufacturer. There is market research required based upon the outcomes of research into the suitability of this technology for application in future proofing the domestic New Zealand timber window joinery industry.

It is recommended that Beacon investigate the application of this technology with an existing timber joinery company.

11.2.4 Process

Investigate this opportunity in detail, including assessments of the potential time to market, the potential market uptake, and a qualitative analysis of the potential market benefit, together with the potential development pathway and partners. This would culminate in a five page report as an opportunity plan to be presented to Beacon.

Cost $7K

Time: 2 months.

11.3 Indurite™ Wood Hardening Technology

11.3.1 Situation

The Indurite™ process has been developed by Scion and fully commercialised and operated by Fibre7 Limited, Tauranga (www.fibre7.com). They have licensed the technology to Fletcher Building allowing the use of this process to provide suitable timbers for the internal timber lining of aluminium-based window systems.

11.3.2 Description

The Indurite™ process is a chemical wood modification technology which uses aqueous chemistry to modify principally the hardness of radiata pine wood. It is also applicable to any timber species which can be treated with aqueous formulations, although *this* applicability has not been commercialised in New Zealand. The consequences of the hardening process also bring about other property enhancements such as some improvement to dimensional stability and stiffness, of about 12% on average.

The chemistry is based on condensation polymerisation of maltodextrins (a chemical commodity derived from enzyme hydrolysis of starch) and commercial melamine resins. The concept behind the chemistry was to use the maltodextrins to mimic the hemicellulose components of wood and the melamine to mimic the lignin. The technology became known as 'pouring wood into wood'.

The process of wood hardening using the Indurite™ technology is carried out in water. The maltodextrin component is water-soluble, but the melamine is not, so some 'pre-polymerisation' chemistry is carried out first. The formulation derived is used to treat wood using conventional wood processing and kiln drying plant and machinery.

11.3.3 Opportunities

Fibre7 have developed the technology further than the original Indurite™ patent for both interior and exterior applications. To date only the interior applications have been commercialised, leaving the potential for its application in exterior use in window systems.

11.3.4 Process

Investigate this opportunity in detail, including assessments of the potential time to market, the potential market uptake, and a qualitative analysis of the potential market benefit, together with the potential development pathway and partners. This would culminate in a five page report as an opportunity plan to be presented to Beacon.

Cost $7K

Time: 2 months.

11.4 BT timber - Beyond tallow timber

11.4.1 Situation

This technology has not been commercialised. The objective of the development work performed at Scion was to treat radiata pine to mimic the properties of tallow wood, a dense and strong Eucalypt wood used for electrical applications because of its electrical resistance properties and strength.

11.4.1.1 Description

BT timber utilises a process used nonylphenol (a commodity product from petroleum) for preparing nonylphenol-formaldehyde resin in a hydrocarbon solvent. Radiata wood was treated with this and heated to distil the solvent and to form the polymer in the wood. The result was a dense wood material with unusual rupture behaviour, more like a rubber than a brittle material such as wood. Using 50% resin solution for wood modification, the modified wood showed only 9% water absorption, compared with 42% for radiata pine wood over an hour time period. The modified wood showed 79% water repellency effectiveness for both dimensional swelling and water absorption.

The BT timber was also durable against both white-rot and brown-rot fungi using rapid laboratory assessment methods.

For this chemical modification system, a flame-proof treatment vessel is required as hydrocarbon solvents, such as those used in LOSP wood treatments, is used. The solvent would be recovered as part of the polymerisation process, as heat is used to form the polymer.

11.4.2 Opportunities

It appears that this technology provides a pathway to achieving some of the functional parameters necessary for use of endemic-sourced framing material for sustainable exterior joinery, which has not been commercialised, but is still at concept stage and needs a lot of development to bring to market.

11.4.3 Process

Phase 1: Prepare a proposal for the research questions yet to be answered, and a viable funding and resource path to achieve these outcomes. Cost $5K, time 2 months.

Phase 2: Undertake the remaining application research with a Scion/BRANZ collaboration, at a cost that is likely to exceed $100K.

Phase 3: Negotiate an IP MOU, then investigate the application of this opportunity in detail, including a LCA with benefit-cost analysis, development pathway and partners, and present a commercialisation plan to Beacon.

11.5 PVC framed windows

11.5.1 Situation

PVC framed windows are available in New Zealand and the technology has been fully commercialised offshore. Like aluminium framed windows, they offer durability, and weathertightness, but they offer better thermal control and security than aluminium windows with different operability options (i.e. tilt and turn, chain wound) but have a limited market since their benefits are not widely recognised, and New Zealand parties are not currently contributing to much of the supply chain.

11.5.2 Description

Many European, North American and Asian suppliers are entering the New Zealand market with PVC windows and struggling to gain market share in a low-cost market.

11.5.3 Opportunities

This technology offers greatly enhanced thermal performance, security, operability and durability, which benefits are currently being marketed in New Zealand by commercial interests. The sustainability of PVC has been addressed in other work (not sourced) but no information about the sustainability of PVC window technology in the domestic New Zealand market is available. The value that Beacon would add to this market would be the determination of the LCA for PVC-framed windows in comparison to the aluminium market.

11.5.4 Process

Prepare a comparative Life Cycle Analysis between PVC and aluminium windows.

Prepare a report on the market support that Beacon should offer to this market segment.

Cost $40K

Time: 3 months.

11.6 TRIG – Timber retrofit with IGU's

11.6.1 Situation

There are over 800 000 domestic residences in New Zealand with single glazed timber framed joinery. Much of this joinery is in poor condition, and is likely to be replaced with single glazed aluminium window framing.

11.6.2 Description

The TRIG technology has been developed at BRANZ (in parallel with an independent company) which allows existing timber single glazed exterior joinery to be renovated and upgraded with insulating glazing units, seals and paint. The technology is currently being utilised in Canterbury whereby the exterior joinery of a single glazed timber house can be retrofitted with IG over several days with no loss of occupancy. (The technology is also applied to Aluminium, but this has fewer benefits so is not discussed). BRANZ Ltd is unable to commercialise this technology in competition with the other company

11.6.3 Opportunities

Beacon has the opportunity to leverage this technology to achieve greater market penetration and prevent the unsustainable removal of glass and timber window framing and its replacement with aluminium and new glass or glazing units. The overall thermal performance of existing window systems could be doubled with a small householder investment, which significant ongoing benefits in the reduction of space heating energy for the householder and the nation.

11.6.4 Process

It is recommended that this opportunity be investigated in detail to provide an accurate assessment of the benefit of this technology to the NZ domestic housing sector, and the value that can be added through Beacon. This technology is already at market in New Zealand in a limited form, although its IP has not been captured, and there is potential for research to develop improvements in both the application and understanding of the limitations of the technology. An MOU would be negotiated between Beacon Pathway and the company to allow BRANZ/others to partner in this development. BRANZ Ltd would then work with this company and necessary other partners to provide the application research and assess the best means for increasing the market penetration of this technology.

Cost $15K

Time: 3 months.

11.7 TTJ – Traditional timber joinery enhancement

11.7.1 Situation

Timber joiners manufacture windows for the NZ domestic market that are unsuitable for double glazing with poor air leakage handling, and unknown weathertightness, according to old designs. Acceptance of these timber windows by local councils is based upon an often erroneous reference to window testing and designs from the early 1970's, encapsulated in New Zealand standards such as NZS3610. A technology has been developed by BRANZ in partnership with MetroGlassTech and the timber joinery industry which allows new timber window joinery to be constructed with sufficient space to install double glazing, possessing good air leakage handling, and good weathertightness. There has been no capture of IP.

11.7.2 Description

A sloped timber rebate and sloped glazing setting block has been designed and commercialised by BRANZ Ltd to allow the durable double glazing of new timber windows. Designs for the insertion of airseals within the closing sashes of traditional timber joinery have been identified, and the parameters influencing the weathertight installation of timber joinery into common wall cladding types has been assessed.

11.7.3 Opportunities

Increase the market penetration of timber windows into the residential sector through market research, testing and research into window installation processes, culminating in the leveraging of building control authorities, energy efficiency codes and the policy of government agencies.

11.7.4 Process

Perform market research to size the New Zealand domestic timber joinery market.

Test the weathertightness of the installation of timber joinery into the five main New Zealand domestic cladding types, perform research into the optimal installation methodologies for timber windows in these cladding systems, and develop an installation guidance document.

Investigate the best means to leverage the market for the use of timber rebates to accept double glazing units, airtightness and weathertightness.

Cost $95K

Time 18 months.

11.8 Al-clad - Aluminium-clad timber joinery

11.8.1 Situation

Composite aluminium or PVC clad timber joinery is available overseas and is imported in very limited quantities into New Zealand. A New Zealand company has just acquired a New Zealand patent for an aluminium-clad timber joinery system specifically designed for New Zealand conditions, and is in the process of patenting this technology in Australia.

11.8.2 Description

The technology augments the durability of a timber-framed window system by coating the external structural elements of a window with durable aluminium, allowing less durable locally-sourced timbers to provide the structure. Developed from other international advancements, this technology will allow significantly more-durable exterior joinery systems to be designed and constructed in New Zealand for the New Zealand domestic market while allowing the installation of double glazing systems and advanced glazing types to provide other benefits to security, fading of furnishings, durability, reduced interior condensation and improved thermal performance.

11.8.3 Opportunities

The patent holder is seeking a funding partner to complete the product development, and commercialise this technology in New Zealand to allow an indigenous, durable, sustainable, timber-based window technology to be incorporated into our domestic building stock. This has the potential to reduce our reliance upon imported timbers, reduce our space heating energy through the use of a more thermally efficient window framing material, and develop an alternate market for locally-sourced less durable timbers.

11.8.4 Process

Define the potential involvement of Beacon Pathway and its stakeholders in discussions with the patent-holder, and establish future potential.

11.9 RAF – Recessed Aluminium Framing

11.9.1 Situation

A New Zealand entrepreneur has developed a thermally efficient aluminium-based window framing technology that is currently being patented for offshore use since it incorporates window functionality that is not typically demanded in New Zealand.

11.9.2 Description

A method for recessing the highly thermally conductive elements of an aluminium-based fenestration system within elements of lower conductivity has been designed by a New Zealand entrepreneur who has a long history of involvement in the New Zealand domestic aluminium market. This technology allows double hung vertical sliders, horizontal sliders and casement windows to be designed with greatly improved thermal performance and condensation resistance.

11.9.3 Opportunities

While much of the existing opportunity is offshore, use of the existing aluminium window fabricator network would allow this window technology with enhanced thermal performance to reduce the contribution of New Zealand residential glazing to the 13% of the national energy demand which is taken for residential energy use. The New Zealand market does not currently perceive windows as a commodity product, so this technology would need leverage to enable the market to be willing to support advancements in window operability and function.

11.9.4 Process

Partner with this entrepreneur to complete the market research and help leverage market share through policy developments, potential use of the WERS tool, and developments in New Zealand codes and standards, following a definition from Beacon as to their potential involvement.

11.10 Low-e and gas filled IGU's

11.10.1 Situation

There is low uptake of the available and inexpensive technologies of low emissivity glasses and gas filling within double glazing units in the New Zealand domestic market.

11.10.2 Description

Low-e glasses and insulating gasses have a small market share within the New Zealand domestic market, but both significantly contribute to the thermal performance of IG units. They are both fully commercialised technologies internationally, but have little market leverage in New Zealand.

11.10.3 Opportunities

To leverage the market with a rating system, incentives or legislative initiatives to increase the penetration of these existing technologies. (A separate opportunity details a grander plan which could incorporate this opportunity. This opportunity deals only with the added value of existing aluminium window double glazing)

11.10.4 Process

Partner with a large New Zealand glazing company to allow BRANZ Ltd to investigate this opportunity in detail, including the best method to increase the market penetration of this technology, including assessments of the potential market uptake, and a quantitative analysis of the market benefit. This would involve BRANZ undertaking the research and preparing a ten page report as an opportunity plan to be presented to Beacon.

Cost $7K

Time: 2 months.

11.11 WERS – the Window Efficiency Rating System

11.11.1 Situation

A star rating tool for comparing the performance of window systems in the New Zealand climate has been developed by the Australasian Window Council, with BRANZ developing the New Zealand end of this technology. The tool was launched in New Zealand in 2000, and is imbedded in New Zealand standards and advisory documents, but does not have widespread acceptance.

11.11.2 Description

WERS provides a robust consistent means of comparing the performance of a window framing system constructed of any material, with any glazing, installed in an average house in one of the three New Zealand climate zones. It provides a star rating for the winter heating performance, the summer cooling performance, the effect on internal condensation and on the fading of internal components. It has been incorporated into Australian house energy rating legislation, but does not have process control documentation for its New Zealand use, and is only available for the generic rating of fenestration systems.

11.11.3 Opportunities

Provide public access to a custom window rating process to allow robust comparison between different window technologies with a window labelling scheme.

11.11.4 Process

Develop a process control system for the publicly available WERS to allow custom rating of window products.

Investigate the integration of WERS with a national home energy rating scheme in NZ.

Leverage the market to adopt this technology with legislative requirements.

Cost $85K

Time 18 months.

11.12 Incentivised window upgrading

11.12.1 Situation

The Pacific NW of the USA has recently pursued a successful market transformation program to increase the market penetration of energy efficient window technology. The opportunity for New Zealand to do likewise exists with incentives offered through a consortium of government, energy retailers and window manufacturers.

11.12.2 Description

The Northwest Energy Efficiency Alliance in US America began offering a residential Energy star rated windows rebate plan in 1998, and successfully grew market penetration of thermally efficient windows from a 15% baseline in 1997 to 70% by 2001 with a $1.8 million budget.

11.12.3 Opportunities

To replicate this incentive program in New Zealand to increase the market penetration of thermally efficient windows in both new and existing housing.

11.12.4 Process

Investigate this opportunity in detail, including discussions with government policy advisors in EECA and DBH to pull together the potential consortium and outline a marketing plan.

This would culminate in a ten page report as an opportunity plan to be presented to Beacon.

Cost $10K

Time: 3 months.

Title	Situation	Description	Opportunity	Process	Cost/Time
Acetylated timber	Technology commercialised overseas yet to be sold in NZ	Chemical improvement of pinus.	Implementation in NZ	Partnership and market review	$7K 2 months
Indurite Wood Hardening Technology	Technology partially commercialised in NZ	Chemical improvement of pinus.	Market creation and entry.	Partnership and market review	$7K/2 mo.
BT timber - Beyond tallow timber	New Zealand technology yet to be commercialised	Chemical improvement of pinus.	Research and development	Determine research questions, + funding	$5K/2 mo + 100K/?
PVC framed windows	Commercialised, but with unknown impact	Framing material assessment	Market definition	Determine LCA in comparison to Aluminium	$40K/3 mo
TRIG – Timber retrofit with IGU's.	800K houses soon to need window renovation	Retrofit IGU's	Promotion of re-use, low household investment	Partnership and identification of further development	$15K/3 mo
TTJ – Traditional timber joinery enhancement	Timber windows non-compliant with NZBC	Timber will lose market share unless it is NZBC compliant	Restore market penetration of timber-based joinery	Market size assessment, product testing, installation limitation	$95K/18 mo
Al-clad - Aluminium-clad timber joinery	New patent for commercialisation	New market for Al-clad timber.	Provide investment funding partner	Partnership for market development	?
RAF – Recessed Aluminium Framing	New patent for product commercialisation	New market for recessed aluminium frame.	COM modification, market creation and entry.	Partnership for market development	?
Low-e and gas filled IGU's	Commercialised, beneficial, but with low uptake	Commercialised technology needing a push	Leverage market share	Partnership and market definition	$7K/2 mo

WERS – the Window Efficiency Rating System	Rating system with low market uptake	Multi-parameter rating system	Leverage market share	Develop POC	$85K/18 mo
Incentivised Window Upgrading	Piggyback on USA scheme for upgrading windows	Incentives offered for performance enhancement	Leverage market share	Develop program and consortium	$10K/3 mo

Table 2: Summary of Opportunities

12 Conclusion

The above report has assessed the international and local glazing markets, and has concluded with a number of opportunities that are believed to be currently viable, and likely to meet the objectives of Beacon Pathway in this area.

The opportunities broadly fall into two categories:

a) Technical opportunities that need further assessment prior to execution.
b) Technical opportunities that need no further assessment prior to execution.

In the cases where no further assessment is necessary, the future work is scoped, although this is not always possible where considerable development is needed prior to market. The opportunities range from the need for a financial investor, to the need for fundamental research. BRANZ is capable of developing most of these opportunities, and receptive to progressing any of the above opportunities with other partners, as will often be necessary to adequately capture their inherent value.

Many of the opportunities have already had some IP captured, and there would need to be agreements established as to the ownership of this IP.

13 References

Carmody, J et al. 1996. Residential Windows. WW Norton & Co. New York

BRANZ report, EC0567, Surveys of Insulating window Systems in the New Zealand Residential Construction Sector, 1994-2002, 9 July 2002.

BRANZ report, DC0995, Double Glazing in New Zealand, 1994-2005, 2 August 2005.

Jennings, J, et al. 2002. Residential Windows in the Northwest: A market transformation Success, Residential Buildings: Program Design and Implementation – 2.147. Report to the DoE, by the Northwest Energy Alliance, Tacoma Washington.

Sage, A. 1995 *Glass and Insulation.* Centre for Advanced Engineering, Energy Efficiency Project Workshop, residential Buildings Section, Appendix B, Christchurch 1995.