STUDY REPORT

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Window thermal enhancement: the development of a rating process

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Preface

This report was developed by BRANZ Ltd in cooperation with the Window Association of New Zealand (WANZ) and the Energy Efficiency and Conservation Authority (EECA) to justify and record the development of a window thermal performance rating tool.

Existing information about the thermal performance of windows in housing in New Zealand is not readily available to the market, is contradictory and is not easily incorporated into energy efficiency metrics.

Although a previous attempt to develop a window energy rating system was successful, the system was overly complex and lacked any drivers for both uptake and consequent market acceptance.

The Building Research Association of New Zealand (BRANZ) recognised in 2010 that a robust means to compare the thermal performance of domestic window systems was lacking and commenced a programme to address this issue. This report is a result of that research activity, undertaken with funding from the Building Research Levy and WANZ with contributions from the EECA and support from the Building and Housing Group (BHG) of the Ministry for Business, Innovation and Employment (MBIE).

The support of the technical group from WANZ is gratefully acknowledged, as this group ensured that the work stayed grounded in the realities of the market for domestic windows in New Zealand.

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1. INTRODUCTION

This report is in two parts.

Part 1 addresses the justification for a Window Energy Efficiency Rating System (WEERS) for housing in New Zealand. It is from the perspective of understanding and implementing a means of improving the energy efficiency of domestic windows in the New Zealand market.

This part of the report discusses the regulatory drivers for improving energy efficiency in New Zealand and the role that windows can play, including the barriers and opportunities for improving their own energy efficiency. Part 1 of the report concludes by describing a tool (WEERS) that should be developed to address these issues.

Detailed issues are discussed in the Appendices, including the following:

- WERS – a first generation window energy rating tool
- Australian interactions
- International window energy rating schemes

Part 2 of this report presents the WEERS that was developed as a result. The WEERS is currently being implemented for rating the thermal performance of windows. The report confirms that this can provide the infrastructure to include windows as a product category within the ENERGY STAR® endorsement programme.

Detailed issues from Part 2 are also discussed in the Appendices, including the following:

- Use of flixo™ to calculate U_f values of sub-assemblies and ψ values of spacer systems
- Use of Window/Therm 7 to calculate U_f values of sub-assemblies and ψ values of spacer systems
- Use of surface coefficients in the LBNL Window modelling software.

1.1 Key stakeholders

Key stakeholders in this work are:

- BRANZ – the author. A research, testing and consultancy agency specialising in the built environment, which develops research outputs that meet the needs of the industry. BRANZ authored this document and jointly funded this work
- WANZ – this trade association group includes representation from all parties representing framing and glazing used for windows in the housing market, including aluminium, timber, steel and uPVC window sectors. They are co-funders of this work
- EECA – the central government agency which is including windows in a product energy labelling programme and funded a small part of this work
- BHG of MBIE – which is interested in ensuring continued compliance of windows to the New Zealand Building Code (NZBC) and appropriate cost-effective performance specifications for windows

All four organisations involved in this project are represented on the governance and/or technical group, although BHG joined the guidance committee during the development of Part 1.

2. SELECT GLOSSARY AND ACRONYMS

A_w	total area of the window in m² – including the glass area and the frame area
ASHRAE/NFRC	American Society of Heating Refrigeration and Air Conditioning Engineers/National Fenestration Rating Council
AWA	Australian Window Association
BHG	Building and Housing Group of MBIE
BCA	Building Consent Authority
CBA	cost benefit analysis
CEN	European Committee for Standardization (French: Comité Européen de Normalisation)
CO_2-e	carbon dioxide equivalent – measure of the effect of a greenhouse gas in tonnes of CO_2, which would have the equivalent effect over a 100-year timeframe
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
EECA	Energy Efficiency and Conservation Authority
E2/AS1	Acceptable Solution 1 from Clause E2 (external moisture) from the New Zealand Building Code
flixo™	thermal modelling software used for modelling the U values of sections of window systems, including sub-assemblies and producing ψ values – flixo™ performs the same function as the Therm software within the Window/Therm package, but not the calculation of the IGU U_g value or the area-weighting provided by Window 6 for R_w
FRST	Foundation for Research Science and Technology
GHG	green house gas, contributing to climate change
IGU	insulating glazing unit – previously known as double glazing
MBIE	Ministry of Business Innovation and Employment
MEPS	minimum energy performance standards
NZBC	New Zealand Building Code
NZEECS	New Zealand Energy Efficiency and Conservation Strategy
NZES	New Zealand Energy Strategy
NZETS	New Zealand Emissions Trading Scheme
PJ	petajoule – 1 x 10^{15} joules – one thousand million, million joules
PVC	poly vinyl chloride – more correctly known as uPVC or PVCu, being unplasticized (rigid) PVC.
R_e	external surface coefficient in terms of a thermal resistance in m²K/W
R_g	thermal resistance of the glazing in m²K/W, including the external and internal surface coefficients – also known as R_{cog}
R_i	internal surface coefficient in terms of a thermal resistance in m²K/W

R_w	thermal resistance of a complete window – reciprocal of the U_w value in m²K/W (see "U value")
R value	thermal resistance in m²K/W
SHGC	solar heat gain coefficient – a measure of the amount of energy that passes through a window by radiation from the sun – a dimensionless number
Thermal envelope	roof, wall, IGU and floor construction, between unconditioned external spaces and conditioned spaces, enclosing all habitable spaces likely to require conditioning
TPM	technical procedures manual for the WEERS programme, published in confidence to the stakeholders
TTMRA	Trans-Tasman Mutual Recognition Agreement between New Zealand and Australia
U value	a measure of heat loss or thermal transmittance in a building element measured as W/m²K. It can also be referred to as a "heat transfer co-efficient" and measures how well parts of a building transfer heat. This means that the higher the U value the more heat travels through the building element. A low U value usually indicates high levels of insulation. The reciprocal is the R value, measured in m²K/W
U_f	thermal transmittance of sections of the framing (sub-assemblies) in W/m²K
U_g	thermal transmittance of the IGU glazing (centre of glass)
USA	United States of America
VLT	visual light transmission – a measure of the amount of light visible to humans that passes through a window
WANZ	Window Association of New Zealand
The WEERS	the Window Energy Efficiency Rating System
WERS	Window Energy Rating Scheme – initially developed for New Zealand in co-operation with Australia before 2000
Windows	used to refer to windows and doors in vertical building elements, excluding rooflights, horizontal and sloped glazing
Window/Therm	thermal modelling software used for modelling the U or R values of sections of window systems, including sub-assemblies, IGUs and complete windows. These are two pieces of software which are normally used together. There have been various version of the software, known as W5, W6 and W7 (Window 5, 6 and 7), Therm 1, 2, 5, 6 and 7, although W7 and Therm 7 are the versions recommended in this work
ψ	Greek letter "y", pronounced "sy", in W/mK – is the compensation factor for the edge effects of installing an IGU with a particular spacer in a sub-assembly, as calculated by flixo™ at the sight line

PART 1

UNDERSTANDING THE NEED FOR A WINDOW ENERGY RATING SYSTEM

3. BACKGROUND

Energy efficiency and conservation play an important role in promoting economic growth and helping New Zealand meet its energy challenges, such as enhancing security of supply and reducing greenhouse gas emissions from energy. There are a range of policies and drivers that exist to improve energy efficiency.

3.1 Current policies and drivers for improving energy efficiency

The Government's direction for the energy sector is outlined in the New Zealand Energy Strategy 2011-2021[1]. This sets out the role that energy will play in the economy. "Achieving efficient use of energy" is one of the priorities and requires better consumer information to enhance energy choices. In association with Australia, New Zealand is committed to informing consumer choices by providing energy efficiency labelling and standards for products.

The New Zealand Energy Efficiency and Conservation Strategy 2011-2016 (NZEECS)[2] is a companion to the Energy Strategy. This is a statutory document prepared under the Energy Efficiency and Conservation Act 2000. Objectives of this strategy include "greater business and consumer uptake of energy efficient products" through "extending minimum energy performance standards, labelling and ENERGY STAR® product coverage to remain in line with major trading partners".

The use of energy conservation and more energy efficient technology and practices will:

- Enhance economic growth through increased productivity
- Improve energy security by reducing energy demand, including for imported sources of energy
- Assist with energy affordability by reducing consumer energy costs
- Defer the need for more expensive energy supply by making better use of existing energy
- Reduce greenhouse gas emissions from energy
- Improve people's health, well-being and productivity through warmer and more energy efficient homes

The NZEECS promotes a mix of interventions, which includes information to target consumer and business needs, and codes and standards to underpin confidence in energy efficient products and practices. It also affirms that: "Having common standards and energy labelling information supports closer economic relationships with Australia. It reduces compliance costs for product manufacturers and suppliers who are often trading in both countries."

The Government is aiming for a 50% reduction in greenhouse gas emissions by 2050, compared to a 1990 baseline. If there is a comprehensive global agreement to reduce greenhouse gas emissions, New Zealand will commit to a reduction of up to 20% below 1990 levels by 2020.

The New Zealand Emissions Trading Scheme (NZETS) is the primary intervention to reduce emissions across all energy-intensive sectors of the economy, including the

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1 More information on the New Zealand Energy Strategy is available from: http://www.med.govt.nz/templates/ContentTopicSummary____46214.aspx, accessed August 2012.

2 The New Zealand Energy Efficiency and Conservation Strategy is available here: http://www.eeca.govt.nz/node/13339, accessed August 2012.

energy generation sector. One of the benefits of such a scheme is that it puts a price on carbon emissions which can be factored into investment decisions and improve the business case for lower emission alternatives.

Additional policies to help lower New Zealand greenhouse gas emissions involve focusing on developing more renewable energy. The New Zealand Energy Strategy has an aim of 90% of grid electricity needs coming from renewable resources by 2025, so long as this does not disrupt the security and reliability of supplying electricity. Around 75% of New Zealand's electricity is currently generated from renewable resources, (August 2012).

3.2 Energy efficiency in products

Energy-using products that are sold in the New Zealand market do not necessarily assist in meeting the Government's objectives for energy efficiency, so instruments need to be adopted to encourage this.

One means of encouraging the energy efficiency of products to comply with Government objectives is through the use of minimum energy performance standards. Energy performance test standards and regulatory requirements (e.g. MEPS [Minimum Energy Performance] levels) are set out in joint Australia-New Zealand standards. In New Zealand, the relevant standards are incorporated by reference into the Energy Efficiency (Energy Using Products) Regulations 2002[3].

Another means is through voluntary product energy labelling, whereby a declaration of the energy performance of the product is determined and a label attesting to this fact is made available with the product. Where suitable international standards exist, these are used as the basis of the energy performance test standards. For internationally-traded products, the regulatory levels for New Zealand are usually based on the most stringent regulatory levels currently in force with major trading partners, but may be adapted to suit local market conditions.

To be included in a regulatory programme, products must satisfy certain criteria relating to the feasibility and cost-effectiveness of Government intervention. These include:

- The potential for energy and greenhouse gas emissions savings
- Environmental impact of the fuel type
- Opportunity to influence purchase
- The existence of market barriers
- Access to testing facilities
- Considerations of administrative complexity

Policy proposals are subject to a rigorous cost-benefit analysis and consideration of whether the measures are generally acceptable to industry stakeholders and the wider community[4]. Any regulatory proposals must undergo a formal Regulation Impact Assessment (RIA) process and be agreed by the New Zealand Cabinet before they can come into effect.

[3] The energy-using products regulations are available here: http://www.legislation.govt.nz/regulation/public/2002/0009/latest/DLM108730.html.

[4] The New Zealand Energy Strategy states that the New Zealand Government will be judicious in its use of energy labelling and standards for the energy performance of selected commercial and consumer products that use relatively large amounts of energy, and that it will ensure robust economic analysis, including consultation with industry and consumers, informs standards development.

Stakeholders are provided with opportunities to comment on specific measures as they are developed by reviewing issued reports, attending meetings and seeking consultation with other key stakeholders. The process usually commences with a product profile which is a detailed technical, market and regulatory analysis of the equipment in question – and will then proceed to the development of a Regulatory Impact Statement (RIS) if it is agreed to consider the feasibility of implementing regulations.

3.3 Windows as energy-using products

Windows designed for use in housing in New Zealand are a particular product group which have been identified as providing an opportunity for reducing national energy use and increasing energy efficiency. While windows in housing do not directly use energy (as a television uses energy to operate) windows are responsible for the loss and gain of space heating and cooling energy when space conditioning is used. Given that the energy used for space cooling is estimated at 0.1% of the energy used for space heating of housing[5], cooling energy will be ignored in this work.

The only regulatory driver for the improvement of the energy efficiency of windows in housing is provided by the minimum thermal performance requirements of Clause H1 (energy efficiency) of the NZBC. However, there are other regulatory clauses (non-energy) that impact windows.

These regulatory requirements are performance-based, with their stringency determined through the NZBC by the BHG and their implementation under the guidance of the local Building Consent Authority (BCA). These thermal performance requirements are not necessarily focused on windows as a building element, but on the contribution that windows make to the thermal performance of a house, within the complete building thermal envelope.

3.4 Code compliance

The New Zealand standard relevant to the thermal performance of windows in housing is NZS 4218:2004 Energy efficiency – small building envelope, which is cited as a means of compliance with Clause H1 of the NZBC. This standard includes default generic R values for window systems, and also includes the WERS ratings. Clear IGUs in non-thermally-broken (standard) aluminium frames are deemed to meet the default NZBC requirement for thermal performance for an R_w value of 0.26 m²K/W.

There is a later version of the standard (NZS4218:2009) which has updated the minimum R value requirements, however the text of the 2004 version is still the cited requirement according to the Acceptable Solution of Clause H1 of the NZBC.

Windows have to meet other requirements of the NZBC, including durability and weathertightness performance standards (Clauses B2 and E2), which calls up standards determining the air and water leakage, structural performance and dimensional accuracy, among other things. Windows are expected to be operable to provide passive ventilation as well as offering a view to the outside. Compliance with the health and safety requirements in Clause F2 of the NZBC are also required which include reference to the use of safety glazing.

There are usually no fire requirements (NZBC Clause C) for windows within standalone housing, although where there are multiple tenancies or housing is located close to property boundaries, Clause C of the NZBC may be invoked.

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[5] Taken from the EECA energy end use database http://enduse.eeca.govt.nz/default.aspx, accessed 8 August 2012.

3.5 International standards

International standards impact upon the assessment of the performance of windows in New Zealand.

Standards of interest are:

- EN 673:2011 Glass in building – Determination of thermal transmittance (U value) – Calculation method
- EN 410:2011 Glass in building – Determination of luminous and solar characteristics of glazing
- EN ISO 10077-1:2006 Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: General
- EN ISO 10077-2:2012 Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames
- ISO 15099:2003 Thermal performance of windows, doors and shading devices – Detailed calculations

Of particular note is the use of the boundary conditions to assess the convective and radiative surface heat transfer coefficients between the solid material of the window and the fluid material of the adjacent air. Different assumptions are made in different countries about how this impacts upon the thermal performance of window systems (this is addressed in Section 12.)

3.6 Supporting information

A number of reports have been completed as part of the investigation to understand and determine the market and benefit of a window rating system. These include:

- Burgess, J.C., *Critique of existing WERS,* Task report 1 to the Window Energy Efficiency Ratings System committee, July 2012.
- Burgess, J.C., *Support for a tool,* Task report 2 to the Window Energy Efficiency Ratings System committee, July 2012.
- Burgess, J.C., *Determination of tool restrictions,* Task report 3 to the Window Energy Efficiency Ratings System committee, July 2012.
- Burgess, J.C., *Description of products,* Task report 4 to the Window Energy Efficiency Ratings System committee, July 2012.
- Burgess, J.C., *The New Zealand window market,* Task report 5 to the Window Energy Efficiency Ratings System committee, July 2012.
- Burgess, J.C., *Representative windows,* Task report 6 to the Window Energy Efficiency Ratings System committee, July 2012.
- Burgess, J.C., *Window thermal modelling,* Task report 7 to the Window Energy Efficiency Ratings System committee, July 2012.
- Burgess, J.C., *Window energy savings,* Task report 8 to the Window Energy Efficiency Ratings System committee, July 2012.
- Burgess, J.C., *Potential greenhouse gas savings,* Task report 9 to the Window Energy Efficiency Ratings System committee, July 2012.

- Burgess, J.C., *Other energy efficiency options,* Task report 10 to the Window Energy Efficiency Ratings System committee, July 2012.
- Burgess, J.C. BRANZ study report, SR274 2012. Product Profile for Windows in New Zealand Housing. 2012.

Due to containing confidential information supplied by individual WANZ member companies, these reports have not been made publically available. However, key results have been reported within this document where possible.

4. WINDOWS – THE PRODUCTS AND THE MARKET

What are windows and what is included in the scope of this work?

Before determining the impact that energy efficient windows can have on housing, we need to understand the products and the market. This has been undertaken in a series of documents commissioned by EECA, including a Product Profile, a Technical Procedures manual (TPM) and a Cost Benefit Assessment (CBA).

These have had a positive outcome, which has encouraged the development of a Window Energy Efficiency Rating System, described here.

4.1 Windows – scope

Windows include all types of openings in the external walls of housing between the outdoors and indoors that contain some glazing and which exist to provide access, light and/or ventilation to occupants. Doors are included, while skylights and openings without some glazing are excluded. The detail, including the technical description of windows and their components, is presented in the confidential reports.

The thermal resistance (R value) of windows dictates the rate at which space heating energy is lost through them by conduction to the outdoor environment in the heating season and the rate at which energy passes inside (by conduction) during the cooling season. Windows with high R values have a high ability to restrict energy from passing through them by conduction, while windows with low R values provide little resistance to energy flow, in either direction.

4.2 Frame and glazing R value variation

The NZS 4218 standard provides default window R values for various options of frames and glazing systems. These R values are actually dependent upon the size and type of the window, and variations in the glazing and framing, solar heat gain through the glazing (SHGC) and air leakage. The variation in window R value due to changing proportions of frame and glazing is presented in Figure 1 for common windows. The variation with airtightness and SHGC raises or lowers the lines in the graph.

Here it can be seen that the glazing percentage (the proportion of glass in comparison to the total area of the window) has an effect on the R value of the window for all the frame types shown, with the largest impact on the R value of IGUs installed in standard aluminium framing. In this case the R_w value of an aluminium-framed IGU with a small glazing percentage (a window with a small amount of glazing and comparatively large amount of framing) is below 0.15 m²K/W (this requires a very small window of around 300 mm by 400 mm, whereas a small toilet window may be 400 x 600 mm). When the glazing percentage rises to the feasible maximum of 90% (a window with a large amount of glazing and a comparatively small amount of framing) the R_w value rises to 0.3 m²K/W (this requires a picture window of about 2400 by 2400 mm).

Reducing the energy loss through windows is therefore a matter of manipulating these parameters, as allowed by the market. This supports the decision of the window industry to include window size in the rating of energy efficiency.

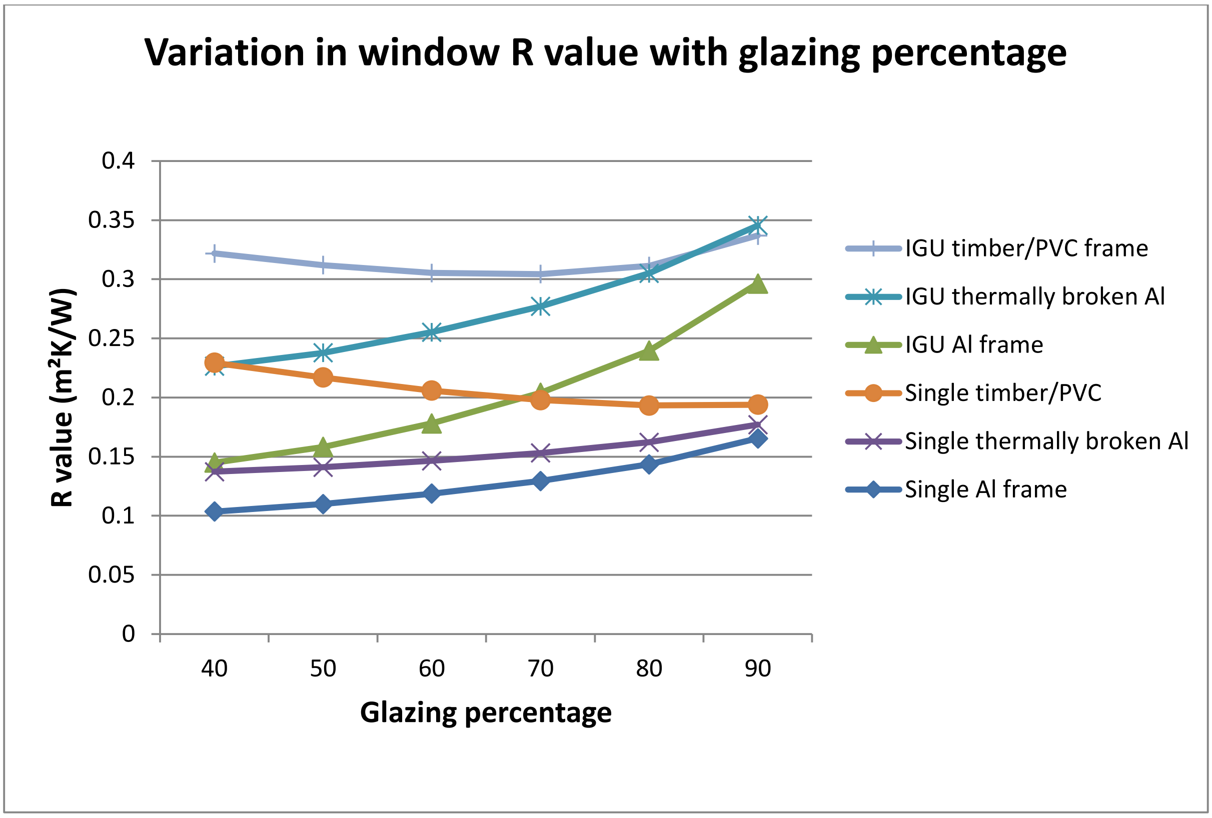

Figure 1: Representative variation in window R value with glazing percentage for a "typical" window, with modified sizing and changed frame and glazing types

4.3 Energy Efficiency and Greenhouse Gas (GHG) emissions

Are there improvements in energy efficiency in housing and reductions in GHG emissions from energy use that can be obtained through the use of windows with higher thermal performance?

Investigation of the energy use and GHG emissions related to windows and doors in the New Zealand housing stock show that improvements in energy efficiency and GHG emissions are available.

If all the windows manufactured in the 2011/12 year were installed into housing which was maintained at an internal temperature of 18°C on a 24-hour heating schedule over the winter period without the use of curtains, then they would be responsible for the use of 87 GWh (0.31 PJ) of space heating energy over the year. This would cost $13.9 million, at an average price of energy of 15.9c/kWh. A further 0.31 PJ of energy would be needed every year that the windows remain in the houses.

Without market intervention, it is projected that the energy lost in the 2014/15 year through new windows installed in that year will be 0.56 PJ, given the number of new windows needed to service the Christchurch rebuild and the demand for new housing stock in Auckland. It is projected that this extra annual energy demand will level out at around 0.5 PJ of energy per year for the windows installed in each year, for the 15 years after that.

If no interventions are made into the window market in 2014, nearly 100 PJ of energy could be lost through the new windows installed in New Zealand homes over the next 20 years, rather than only 80 PJ if interventions are made.

This would also contribute to the release of three million tonnes of CO_2-e to the atmosphere and consequent global climate change.

However, if interventions are made in the window market, 20 PJ of energy, $730 million of utility bills, and 600 000 tonnes of CO_2-e emissions can be saved over the next 20 years.

4.4 Future Trends

The New Zealand window sector is unlikely to remain static as it is increasingly being exposed to the international market. Understanding the likely trends in this market will help to understand how the Government objectives of improved energy efficiency can be achieved.

While there has been an expectation that, with appropriate maintenance, windows would last the lifetime of the house, this has not been a requirement of the NZBC since the introduction of durability requirements (Clause B2) in the NZBC[6]. This requires components such as windows to remain durable for 15 years. This legislative requirement should not be confused with "lifetime", which can be considerably more than the NZBC B2 requirement.

Without intervention, the market will continue to dictate what products are available to the consumer based largely on operation, price and standards compliance[7].

It is expected that the introduction of a market driver that requires, rewards or encourages the use of more energy efficient windows in houses will substantially increase the market penetration of energy efficient windows. The rapid increase in the uptake of IGUs once a legislative driver was put in place in 2007/8 is a relevant precedent, where the national market penetration for IGUs rose from 30% in 2007 to 90% in 2011[8].

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[6] This was the 1992 version (first version) of the New Zealand Building Code, being the first schedule of the 1991 Building Act where durability requirements of five, 15 and 50 years were set in place. See http://www.legislation.govt.nz/regulation/public/1992/0150/latest/DLM162570.html. This has been superseded by the 2004 Building Act and Schedule.

[7] This is largely compliance with Clause H1 of the NZBC through the NZS 4218 standard, but also includes compliance with minimum (15-year) durability requirements and window performance requirements according to NZS 4211.

[8] Information from unpublished analysis of building consent data and BRANZ quarterly material surveys regarding the increased stringency of Clause H1 of the NZBC, progressively introduced through 2007 and 2008.

5. BARRIERS TO THE ADOPTION OF ENERGY EFFICIENT WINDOWS

What is preventing the market from accepting more energy efficient window products?

Barriers to the adoption of more energy efficient windows include:

- Market awareness – where the market does not comprehend the thermal performance range available. While marketing literature could provide the opportunity to influence purchase decisions, an independent source of verified data is lacking
- Capital cost – the initial cost of purchase of more energy efficient windows comes at a premium
- Absence of improvement drivers – the lack of voluntary or regulatory requirements/incentives for installing windows that exceed the Building Code minimum R value
- Bounded rationality – where incomplete market understanding means responses are made without full information, in such cases as –
    - The benefit of reduced space heating costs in comparison to increased capital costs, where there is no whole-of-life costing tool to assist in purchasing decisions
    - The benefits of improved health for the occupants
    - The benefits of reduced condensation and damage to interior furnishing and fitments
    - Poor understanding of the total performance expectation of window products means that thermal performance is not optimised
- Split incentives where drivers applied to one market segment are realised in a different market segment, such as –
    - A builder or designer specifying windows while the householder/occupant pays the consequent space heating bills
    - Landlords influenced to purchase lowest cost windows, with tenants paying higher operating costs
- Thermal modelling – although thermal performance verification is available, implementation of an agreed single modelling methodology with the software flixo™ is still being rolled out (see Section 15.4 for an explanation of the operation of this software)
- Complexity of previous schemes – the infrastructure required to implement a previous scheme (WERS[9]) in New Zealand was significant

These barriers need to be avoided or overcome to enable the aim of increasing the energy efficiency of window systems in housing.

[9] See Section 15.1.

6. OPPORTUNITIES FOR ENERGY EFFICIENCY IMPROVEMENTS

What opportunities exist that could address these market barriers and provide a means whereby windows in housing could help New Zealand achieve the energy efficiency aims of the NZEECS?

This work identifies 15 major options for driving increased uptake of windows and doors with higher thermal performance in Table 1, and assesses options which could assist to address these barriers. Restrictions in their application have been identified through the work.

Energy efficiency opportunities		
Option to improve energy efficiency of windows	Main restriction	Option?
Whole house energy rating – where the thermal performance of the house envelope is measured or modelled	Not targeted to windows	N
Sectional house energy rating – where the thermal performance of a portion of the thermal envelope of a house is measured or modelled	Not targeted to windows	N
Elemental energy rating – where the thermal performance of an element (such as the glazing in a window) of a house is measured or modelled	**Option – insufficient by itself**	Y
MEPS for windows – where the minimum energy performance of a window is set with a legislative tool, with the stringency potentially raised incrementally as the market adjusts	Already implemented in NZBC, although the stringency levels could be increased, this is insufficient in itself to drive increased uptake	N
Mandatory disclosure – where the thermal performance of a window must be disclosed to the market at a certain point – for example at the sale of a product	**Option – needs labelling first**	**Y**
NZBC stringency increase – where the requirement for the thermal performance of windows or the thermal envelope are increased through the NZBC	Partial option, although it targets new build only, unless a WOF for existing housing is implemented	N
Building WOF – where a Warrant of Fitness is obtained regularly to confirm the ongoing thermal performance of a building	Not currently required for housing and not targeted to windows	N
Solution package marketing – where several products that impinge upon window energy use are packaged and marketed together – such as heat pumps, insulation and energy efficient windows	**Option — currently available to the market and not being used**	**Y**
Education/awareness – where existing or new education channels are used to advise and inform the stakeholders of the issues pertaining to the energy efficiency of window systems	**Option – a delivery mechanism rather than a means**	**Y**
Research and development – where there are areas of need for research into the	**Option – insufficient by itself**	**Y**

thermal performance of window systems that could be developed in the New Zealand market		
Fee remission – where a financial arrangement is entered into between a house owner and a local authority or supplier whereby rates, utility charges or other imposed levies are increased to pay back the capital cost of installing more energy efficient windows	**Option – needs window energy labelling first**	**Y**
Standardised window sizing – where there is a commercial opportunity for an existing market actor to standardise the window size or types offered into the market and so obtain economies of scale in the manufacture of stock-size windows	**Option – this is currently available to the market, but has not been commercialised**	**Y**
Value transference – where an instrument is introduced to allow higher-priced window systems with higher thermal performance to be traded against reduced operating costs – similarly to the "fee remission" option	**Option – needs window energy labelling first**	**Y**
Lifecycle costing – where the actual environmental impact and cost of a product is not recognised in economic value judgements. A tool could be introduced to provide this value based upon the manufacture, installation, operation and retirement of windows	Option – needs considerable development, which the industry is not yet ready for.	**Y**
Window energy labelling – where the actual thermal resistance of the specific window is voluntarily disclosed at point of sale	**Option – needs rating first**	**Y**

Table 1: Options for improving the energy efficiency of new windows for housing in New Zealand

6.1 Option assessment

The 15 options identified in this work have been assessed, with a summary shown in Table 1. The discussion below recommends that window energy **labelling** is the most likely means of achieving a market intervention to improve the energy efficiency of windows installed in New Zealand housing. This must be based on a window energy **rating** process.

Option assessment:

- Five of the options identified in this work are not targeted to windows or are targeted only to part of the new window market. So while they could achieve the desired aim, they are complicated by such factors and therefore will be discounted
- A further two options (solution package marketing and standardised window sizing) firmly sit in the market and while they could be incentivised by an outside party, they are not seen as viable options for further investigation or Government intervention
- A significant gap has been identified in the knowledge of the performance of thermally broken window frames that are installed into cladding systems incorporating batten cavities, for which some research and development is required. However, this is a fundamental issue that needs to be separately addressed, rather than used as the sole means for improving market uptake of energy efficient windows. Other research and development initiatives could improve thermal performance, but need to be packaged with additional initiatives to achieve the aim
- MEPS is already effectively implemented in the NZBC through the minimum energy performance requirements of the schedule method in the NZS 4218 standard, as called up by Clause H1, therefore is excluded from further investigation
- Elemental energy rating is an option which needs to be built into a complete package since it is a basic tool which cannot achieve the outcome of improving the energy efficiency of new windows without being part of a procedure
- The Building Warrant of Fitness is not required for single family homes, although will be applied in some circumstances where windows are used in housing[10]
- Education/awareness is a delivery mechanism, rather than a means
- Fee remission is already available to EECA and Building Consent Authorities, and could be built into a tool in conjunction with "value transference". However, as with mandatory disclosure, these options need to be built on a means for robustly and transparently determining the energy efficiency of the windows, before they could operate

This leaves the option of window energy efficiency labelling, which can address the barriers and provides a means for differentiating the performance of windows. It also serves as a prerequisite for several other options for improving the energy efficiency of windows designed for the New Zealand housing stock and must therefore be implemented as a step in any market transformation programme for windows. Window labelling does, however, need a robust window rating programme as a prerequisite.

[10] Buildings which require a compliance schedule are required to have an annual Warrant of Fitness. However, single family homes are typically exempt from this requirement – see the NZBC 2004 Clause 100 http://www.legislation.govt.nz/act/public/2004/0072/latest/DLM306860.html?search=sw_096be8ed80827318_compliance+schedule_25&p=1.

7. WINDOW ENERGY RATING SCHEMES

Are there existing schemes that could be adapted to allow window energy labelling to help achieve the NZEECS objectives for the windows of housing in New Zealand?

The Window Energy Rating Scheme (WERS)[11] was developed for Australian use in the 1990s by a group led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and including the Australian Window Association (AWA). New Zealand joined the programme in the mid-1990s and BRANZ developed the technical aspects to allow use of WERS in this country. Unlike in Australia, where WERS was integrated into building energy compliance paths, WERS in New Zealand did not have any regulatory drivers and did not obtain significant market uptake. WERS was a difficult and complex scheme (as described in Section 15.1) as it relied on difficult and convoluted software.

The Trans-Tasman Mutual Recognition Agreement (TTMRA) encourages the implementation of joint Australian/New Zealand programmes (see Appendix, Section 15.2). WERS has not succeeded in New Zealand due in part to the lack of local drivers and the complexity of the scheme. Consequently, other international window energy rating schemes have been investigated to ascertain their relevance to meeting the needs for improving window energy efficiency.

7.1 Overseas window energy rating schemes

Are there overseas programmes that could be adopted for improving the energy efficiency of windows for housing in New Zealand?

There are a number of overseas programmes that make use of window energy rating and labelling, and are shown[12] in Table 2.

International window energy rating schemes
Australian Window Energy Rating Scheme
British Energy Rating Scheme
Canadian Window Energy Rating Scheme
Chinese Window Ecolabel
Dutch VKG and VRMG Keurmark Programmes
Hong Kong Green Label Scheme
Korean Ecolabel
Nordic Swan Ecolabel
USA Window Energy Rating Systems

Table 2: International window energy rating schemes assessed for compliance with the needs of a programme in New Zealand

[11] The detail of WERS and its issues in the New Zealand environment are discussed in the Appendix, Section 15.1.

[12] The programmes listed here have been selected for assessment with pre-evaluation criteria drawn from decisions of meetings of the WEERS governance committee.

The features of a WEERS in New Zealand were agreed by the project stakeholders and are provided in Table 3[13]. These were used to assess the applicability of the international schemes from Table 2.

Requirements for a window energy efficiency rating system for homes	
1	Produces a user-acceptable measure of the energy performance of domestic window systems in New Zealand
2	Window-specific and not dependent upon the whole house
3	Includes consideration of glazing and framing
4	Includes all framing materials
5	Rating dependent on window size
6	Uses the thermal resistance of the whole window as the rating metric
7	Independently verified
8	Incorporates windows and doors
9	Referenced in national standards or code
10	Applicable to residential and non-residential windows
11	Uses SI (Systeme Internationale) units
12	Does not vary with climate zones
13	Supported by central government
14	Is accessible to consumers
15	Includes declaration of R_w and SHGC[14] and potentially the VLT[15]

Table 3: Requirements for a New Zealand energy efficiency rating system

Detail on the assessment of these schemes is included in the Appendix, Section 15.3.

This assessment found that there are no overseas protocols that are directly applicable to improve the energy efficiency of windows for use in New Zealand housing, although attributes of some of the schemes can be used. Consequently, a rating programme to assist in improving the energy efficiency of windows in the New Zealand market will need to be built, as informed by the schemes identified in Table 2.

[13] The justification for these requirements is contained in Table 8 in the Appendices.

[14] Where the SHGC is the solar heat gain coefficient. SHGC is not part of WEERS but may be declared on window rating labels.

[15] Where the VLT is the visible light transmission.

8. CONCLUSIONS FROM PART 1

The work undertaken in Part 1 of this research has shown that:

- About 100 PJ of space heating energy could be lost through the 20 million square metres of windows which are projected to be added to the New Zealand housing stock over the next 20 years
- A window energy labelling system that includes a window energy efficiency rating programme is the best current option to improve the energy efficiency of new windows to be installed in New Zealand housing
- Implementation of a window energy efficiency rating system could assist in saving 16 PJ of energy, 500,000 tonnes of CO_2-e and $730 million over the next 20 years
- Window energy efficiency improvement in housing is consistent with the objectives of the National Energy Strategy (NES) through the National Energy Efficiency and Conservation Strategy (NZEECS)
- There is no international programme that is currently able to meet the needs of the New Zealand window industry

Consequently, Part 2 of this work was commenced to determine a response to the issues discovered in this work

PART 2

THE NEW ZEALAND WINDOW ENERGY EFFICIENCY RATING SYSTEM

9. INTRODUCTION TO PART 2

Domestic window systems contribute to the thermal performance of the New Zealand housing stock. The thermal performance of windows affects the amount of space heating and cooling energy that is required to maintain our housing at comfortable temperatures.

WEERS is a means to rate the conductive thermal performance of windows that are installed in homes. This rating system is internationally unique, as it allows the conductive thermal performance of windows of any size to be calculated precisely, rather than relying on approximations for predetermined standard sized windows. Each window system gets a WEERS star rating dependent upon the lengths of sub-assemblies used, as well as the thermal performance of the other components. The rating is dependent upon the following items:

- The thermal performance of the sub-assemblies (Uf)
- The ψ value – compensation for the spacer and edge effects
- The thermal performance of the IGUs (U_{cog})
- The area of the window (A)

There are also thermal effects from air infiltration and solar heat gain through windows. However, since this work concerns windows that are built to meet minimum air infiltration standards (of 2 litres/second.metre^2 NZS 4211) and are available with clear glazing with a SHGC of 0.7, these factors are not considered further in this work.

This report outlines the technical information necessary to operate the WEERS. The detail, including the algorithms, application and auditing to allow the production of robust WEERS star ratings, are available to the stakeholders.

For WEERS to be successful, it must :

- Require that windows comply with the relevant clauses of the New Zealand Building Code
- Manifest verified thermal performance ratings as a product energy label
- Support reduction of energy for space conditioning in housing
- Encourage the reduction in greenhouse gas emissions from domestic space heating energy use
- Provide an opportunity to influence purchase decisions
- Help to avoid or overcome market barriers
- Provide the infrastructure for including windows in the ENERGY STAR® endorsement scheme
- Be simple and easy to implement

Initial assessments have identified the costs and benefits of implementing a window energy labelling scheme. These show energy savings of up to $730 million (in 2011 dollars) are available over the 20-year period assessed.

This work has allowed EECA to add windows to the suite of products that are subject to ENERGY STAR® labelling in the New Zealand market.

9.1 ENERGY STAR®

ENERGY STAR® is the trusted, Government-backed symbol for energy efficiency. ENERGY STAR® is industry-neutral, providing an endorsement label that is awarded by EECA to the most energy efficient products – typically the top 25% best performing products in the New Zealand market. Products can earn the ENERGY STAR® label by meeting the energy efficiency requirements set forth in ENERGY STAR® product specifications.

EECA has agreed to promote energy efficient windows as a product category within the ENERGY STAR® programme and facilitate the use of the WEERS rating within the ENERGY STAR® website, but will not separately promote the WEERS programme.

The WEERS will be promoted and operated by WANZ and provide a compliance path for WANZ members towards meeting the requirements for qualified products within the ENERGY STAR® programme.

EECA will allow alternative paths for earning the ENERGY STAR® label for windows if the paths meet all of the requirements and specifications prescribed by EECA, at their discretion.

9.2 Background to the programme

The work to develop the WEERS is a partnership between WANZ, BRANZ, EECA and MBIE. Direct funding has been provided from WANZ, and from BRANZ, through the Building Research Levy, with contributions from EECA and support from MBIE. The programme leverages from an earlier Window Efficiency Rating System (WERS – established in 2000), in order to deliver a means to compare the conductive thermal performance of windows designed for New Zealand housing and small buildings.

The objective of the WEERS is to supply robust, accurate and useful information about the conductive thermal performance of window systems, with a rating system using one to six stars. This will provide guidance for design, manufacture, supply and purchase decisions for windows with all types of frame materials, sizes and IGUs.

The technical development of the WEERS programme has been undertaken by BRANZ and WANZ with direction from both governance and technical committees, whose membership comprises WANZ, BRANZ, EECA and MBIE.

There is already a range of products that have energy or efficiency labelling – including refrigerators, freezers, dryers, dishwashers, washing machines, heat pumps, air conditioners and vehicles – although these programmes require mandatory rating, which is not currently being considered for windows.

10. SCOPE OF WEERS

The primary aims of WEERS are to:

- Increase the uptake of energy efficient windows in the New Zealand housing and small building stock
- Reduce space heating and cooling energy needs of the New Zealand housing and small building stock
- Contribute to meeting the Government's objectives of –
    - Warm, dry and energy efficient homes to reduce related ill-health and lost productivity
    - Greater business and consumer uptake of energy efficient products, as per the New Zealand Energy Efficiency and Conservation Strategy 2011-2016 (EECA, 2011)

The WEERS has been designed to be relevant to the thermal performance of windows in the scope of NZS 4218:2004 – small building envelope. Items not included are:

- Complex framing systems such as curtain walling[16]
- Window systems that extend over more than one floor or include spandrel panels
- Sloped glazing, rooflights and any other windows that are not installed vertically[17]
- Or any window system that cannot be accurately modelled with the verification software flixo7™[18], irrespective of the use of the window

This means that there is no building height restriction on the use of windows in this programme, with the WEERS stars designed only for comparing the conduction of heat through windows, not radiative effects. Other performance parameters such as the solar heat gain coefficient (SHGC), ultraviolet light transmission (T_{uv}) or the visual light transmittance (VLT) could provide additional information on window performance, but are not a part of this work.

Any thermal influence from structural framing beyond the window perimeter is also outside the scope of this work. The installation of the window is assumed to follow the Acceptable Solution 1 of Clause E2 (E2/AS1) of the New Zealand Building Code.

EECA intends to use the output of the WEERS programme to provide an ENERGY STAR® endorsement for windows, meeting certain qualification criteria. To this end, EECA has provided technical assistance for this work, to ensure that the ENERGY STAR® programme for windows has a robust foundation.

[16] However, the scope of the WEERS could be extended to windows in these situations at a later date.

[17] Where "vertical" has the definition from the window industry of "within 15° of vertical".

[18] Note that flixo™ effectively replaces the Therm software. The Window 5/6/7 software has no direct replacement, but can be configured to assemble the results from flixo™.

11. CALCULATION OF THERMAL PERFORMANCE

The thermal resistance of windows (R_w) to be rated under the WEERS programme shall be determined by modelling, with the materials used in a window declared by the customer.

While many software packages including the Window/Therm package or the flixo™ software can be used for thermal modelling, the approach must implement the methods (EN conditions) from “Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames (EN ISO 10077-2:2012)”. This accommodates the use of the New Zealand surface coefficients, (see Section 12) and aligns with the European glazing surface conditions from “Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 1: General (EN ISO 10077-1:2006)”.

The following aspects of thermal performance must be considered:

- The U value of sub-assemblies (Uf)
- The ψ value (adjustment factor for the spacer and edge of glass thermal performance)
- The length of the sub-assemblies
- The U value of the centre of glass of the IGU (Ug)

These allow the calculation of:

- The total U value of the window (Uw)
- The WEERS star rating

The flixo™ software has been accepted as the primary means of verifying the accuracy of thermal modelling performed with any other means.

Methods to calculate these performance parameters must be developed by users of the WEERS and verified by an independent party to ensure the results are accurate and the programme remains robust.

12. SURFACE COEFFICIENTS

The thermal performance of windows is affected by the thermal and optical properties of that product. This is particularly the case when products are required to provide thermal insulation as part of their design specification. The degree to which glazing products provide thermal insulation to buildings has frequently been disputed, as there are different approaches internationally to the calculation of this thermal performance of glazing products.

The R value of a glazing system is the sum of the thermal resistance of the material(s) plus the effective thermal resistance of the thin layer of still air that "sticks" to the inside and outside surfaces of any glazing sheets. The insulating effects of the layers of air are referred to as surface coefficients and add to the R value of the material. In normal use, the actual thermal resistance of an element or system is constantly changing as the air film changes in response to air currents and radiation. The surface coefficients are merely an arbitrary set of pre-defined values, which allow a single static number to represent a dynamic R value and are chosen as appropriate for the situation.

For a wall insulation product (e.g. with an R value of 1.9 m²K/W) the surface coefficients (of value 0.12 m²K/W) may be 6% of the R value. However, for IGUs (e.g. with an R value of 0.26 m²K/W) the surface coefficients (of value 0.16 m²K/W) can be 60% of the insulation value. For single glazing (e.g. with an R value of 0.17 m²K/W) the surface coefficients can be 95% of the R value.

Table 4 displays the three most common sets of surface coefficients used for the U/R values of glazing systems[19] in New Zealand.

Surface coefficients			
Method	**Outdoor coefficient (m²K/W)**	**Indoor coefficient (m²K/W)**	**Total coefficient (m²K/W)**
NZS 4214, NZS 4243	0.03 m²K/W (h_o = 33W/m²K)	0.09 m²K/W (h_i = 11 W/m²K)	0.12
ASHRAE/NFRC (USA)	0.038 m²K/W (h_o = 26 W/m²K)	0.12 m²K/W (h_i = 8.3 W/m²K)	0.16
EN (Europe)	0.04 m²K/W (h_o = 25W/m²K)	0.13 m²K/W (h_i = 7.7 W/m²K)	0.17

Table 4: Surface coefficients[20]

[19] Where the U value is the reciprocal of the R value. Note, however, that both IP and SI units are in use for R and U values.

[20] The situation is complicated when low emissivity surfaces are present on the outer face of a glazing layer, which alters the coefficients for these surfaces. For example h_i = 3.6 + 4.1 ε_i/0.837 under EN conditions, where ε_i is the emissivity of the indoor surface. When ε_i = 0.84 (normal glass) then h_i = 7.7 W/m²K, contributing an R value of 0.13. However, when ε_i = 0.3 (a specific low–E glass) then h_i = 5.1 W/m²K, contributing an R value of 0.20 for the centre of glass.

12.1 How are surface coefficients used?

Glazing was introduced into the housing insulation standard (NZS 4218) in 2004, when the ASHRAE/NFRC values for surface coefficients were adopted to match the Australian choice. This conflicted with the surface coefficients used for opaque insulation materials in the New Zealand market and in the New Zealand building standards, such as NZS 4214 and NZS 4243. The coefficients used for glazing in the United States and Europe have also changed over the years, although they currently align with each other quite well (0.16 versus 0.17 m^2K/W).

Using different surface coefficients means that the resulting R values for the declared thermal resistance of the centre of glass of an identical single glazing system may be over 40% different. When the R value of the frame is incorporated with the R value of the glazing to calculate a total product R value (R_w) the effect of using different surface coefficients for the glazing is reduced, but with highly conductive window frame materials (such as non-thermally broken aluminium) they can still have a significant effect.

Industry has often used surface coefficients from the United States or Europe given the software modelling programmes and glazing products have originated in these locations. While it is possible to convert from one set of surface coefficients to another and to use a variety of surface coefficients in the various R value modelling programmes, this process is not always straightforward and needs to be clearly stated when any claims are being made.

A version of the Window Efficiency Rating Scheme (WERS[21]) used in Australia was launched in New Zealand in 2000 and used a complex process to rate window products. However, WERS was oblivious to the choice of surface coefficients as it used hourly calculations including wind speed and solar radiation to calculate R values. The second-generation Window Energy Efficiency Rating System (WEERS) does need surface coefficients, as it uses these to define the R value of glazing products, so it has become important to determine what they should be.

12.2 Implications for New Zealand

Of the three sets of values available (Table 4), the values in Table 5 (the EN values) were chosen by the WEERS technical committee as suitable for use in New Zealand, with the following basis:

- The climatic and internal conditions (wind, temperature range, internal space heating practices) on which the EN coefficients pertaining to R values were based were assumed to be a closer match than the climatic conditions upon which the ASHRAE/NFRC conditions were based
- The United States ASHRAE/NFRC surface coefficients (as implemented in the W5/6/7[22] software) are designed to provide accurate numbers for glazing that is 600 mm in height, with the EN coefficients[23] for windows up to 1.23 x 1.48 m. While the size recommendations from the United States and EN are not directly comparable (as glazing height is compared to window size), the average New

[21] WERS is a method for rating the thermal performance of domestic window systems in Australia which has been superseded in New Zealand by WEERS – to be launched in 2014.
[22] This is a reference to the Window 5, Window 6 and Window 7 versions of the thermal modelling software developed by LBNL in California, widely used internationally for modelling the thermal performance of window systems.
[23] Annex F of ISO 10077-1:2006 makes reference to the window size which is used in the standard.

Zealand window has been found in the WEERS development work to be 1430 mm x 1410 mm high[24]. This is a better match to the EN window size

- A method for altering the impact of a low emissivity surface facing the inside of a building is available in a nationally published standard EN 12898, which is referenced in the EN standards. In contrast, the ASHRAE/NFRC approach (NFRC 300-2001) for addressing emissivity has not been adopted as a national standard yet in the United States
- The EN values are close to the ASHRAE/NFRC values of the United States method (see Table 4) so the choice between these two sets of coefficients is not highly significant. It should be noted that Section 9.1 of EN 673 requires that U values be expressed in W/m².K rounded to one decimal place. The implication for R values for glazing purposes is that these should be rounded to two decimal places and the use of more than two decimal places does not provide any further information
- Glazing that is currently imported into New Zealand reports R or U values using either EN or ASHRAE/NFRC surface coefficient values
- Current New Zealand standards (NZS 4243, NZS 4214) allow the use of surface coefficients for glazing, which vary from the surface coefficients used for opaque building materials

NZC surface coefficients			
Name	**Outdoor coefficient**	**Indoor coefficient**	**Total surface coefficient**
U value coefficients for use with NZC (NZ conditions)	0.04 m²K/W (h_o = 25 W/m²K)	0.13 m²K/W (h_i = 7.7 W/m²K)	0.17 (m²K/W) (h = 5.88 W/m²K)
		(varies with ε_i)	

Table 5: The values used for the calculation of the R value of windows and doors subject to horizontal heat flow, as presented in ISO EN 10077-1:2006 (using the values for determining the U value of the centre of glass contained in Section 7 of EN 673:2011) and in Table B1 of ISO EN 10077-2:2012

These surface coefficients can be implemented in the Window 7 software in the manner described in the Appendices, Section 15.6, and are used as the default situation in the flixo™ software.

[24] Unpublished commercial in confidence work by BRANZ for WANZ.

13. CONCLUSIONS FROM PART 2

An internationally-unique energy efficiency rating system has been constructed by BRANZ for windows in New Zealand housing (WEERS), based upon the justification for such a scheme as described in Part 1 of this work.

- WEERS calculates the unique conductive thermal performance of window systems for housing dependent upon window size and the thermal performance of the window elements
- EECA can use the WEERS to provide infrastructure for the ENERGY STAR® endorsement of domestic window systems
- Surface coefficients for the U value of glazing components are calculated using the EN surface coefficients, being h_o = 25 W/m²K (outside coefficient) and h_i = 7.7 W/m²K (indoor coefficient), which are implemented in W7.
- A star rating with WEERS is achieved by calculating the total window R value (where R = 1/U) from the following parameters –
    - The U value of sub-assemblies (U_f)
    - The ψ value (adjustment factor for the spacer and edge of glass thermal performance)
    - The length of the sub-assemblies
    - The U value of the centre of glass of the IGU (U_g)
    - The size of the glazing pane(s)
- WEERS allows a unique star rating to be determined based on the thermal performance of an actual complete window

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Note: technical documentation has been developed in the form of task reports as part of the WEERS research stream to support the data in this report. Additional reports from BRANZ and other parties have also been published to the stakeholders. These reports are commercially sensitive and are not publicly available, so are not included in this list of references.

15. APPENDICES

15.1 WERS – a first generation window energy rating tool

A means of rating the performance of window systems was developed for the Australasian market. This was known as WERS – the Window Energy Rating Scheme. It allowed domestic window systems to be compared on the basis of the modelled energy required for heating and cooling a house as well as the fading of furnishings. It used a five star rating scale for each of the three metrics. The original New Zealand WERS logo is shown in Figure 2 on the left hand side, being a modification of the Australian WERS logo (with an early version shown on the right hand side). WERS in New Zealand was launched in July 2000 at a conference of the New Zealand Window Association (WANZ) by the then Minister of Energy, the Hon Pete Hodgson.

Figure 2: New Zealand (left) and Australian (right) WERS labels

The New Zealand WERS used stars to represent the thermal effect of a window system on an average house in one of the three New Zealand climate zones (as defined in NZS 4218). It included consideration of both the U/R values (the thermal conductivity/resistance of the system) and the SHGC (solar heat gain coefficient) of both the glazing and the window frame as input to a computer program, initially known as CheNath, built by the CSIRO (Commonwealth Scientific and Industrial Research Organisation) in Australia. The New Zealand WERS was based on climate files developed in the early 1980s by Victoria University of Wellington, which used hourly climate records extending back into the 1960s.

The New Zealand-specific WERS was developed in the 1990s by BRANZ with funding from the Foundation for Research Science and Technology (FRST), Building Research Levy funding and WANZ. The scheme built on the development funded by the Australian industry and government sources for the Australian WERS. WERS included the space heating and cooling energy need of the whole home. While a thermal model of a whole house was used, only the window-specific parameters were changed, which allowed the effect of the fenestration on the energy need of the complete building to be assessed.

The technical process took nine steps:

1. Modelling of the thermal performance of glazing components
2. Modelling of the thermal performance of the glazing system
3. Modelling of the thermal performance of framing components
4. Modelling of the thermal performance of the framing system
5. Modelling of the thermal performance of a complete window
6. Selection of house parameters, air infiltration, user behaviour, internal gains, window data file, HVAC setpoints, climate data and insulation levels
7. Modelling of the thermal performance of the complete house
8. Comparison of thermal performance on the basis of window selection
9. Allocation of stars to the windows

The result of this approach to window efficiency rating was a set of technically robust parameters which described the performance of standard sized windows in houses. However, the WERS programme required a complex and complicated set of input parameters and systems, for which the New Zealand market was not ready.

While the original WERS is consistent with the approach being taken in Australia, the modelling tool used is not suitable for use in a New Zealand Window Energy Efficiency Ratings System because it does not deliver outputs appropriate to the energy rating of domestic windows in New Zealand.

15.2 Australian interactions

The TTMRA requires that there are no trade barriers introduced by governments between Australia and New Zealand, such that most goods able to be legally sold in one country can be legally sold in the other without having to meet further sales-related requirements.

The Australian approach to window energy ratings has imbedded WERS within Building Code requirements, while the New Zealand Building Code (NZBC) uses R values to assess windows, following an earlier unsuccessful attempt to introduce WERS.

The development of a different Window Energy Rating Scheme to Australia does not discount the future integration of Window Energy Rating Schemes across the Tasman. The proposed declaration of the fundamental thermal parameters of R_w and SHGC on New Zealand windows means that these values can be used in whole-house energy modelling, as is performed in Australia. The NZBC already possesses the ability to incorporate whole building energy modelling within its compliance assessment for Clause H1 (energy). While this compliance path is infrequently used, the BHG of MBIE or other central New Zealand government agencies could introduce instruments to increase the uptake of whole building thermal modelling prior to domestic building consents being issued.

On the other hand, the development of window energy labelling as a product efficiency rating system could be extended to Australia, making use of the thermal performance data that is already declared on the Australian WERS labels.

15.3 International Window Energy Rating Schemes

The pre-evaluation criteria to be used to assess international Window Energy Rating Schemes were developed, as in Table 6, based upon decisions from the meetings of the WEERS governance committee.

Initial evaluation criteria	
1	Be capable of rating the whole window thermal performance (R_w) not just the performance of the glazing separate from the framing
2	Use reputable means to calculate or model the physical parameters
3	Be available in English
4	Not have significant barriers to use by industry sectors
5	Be independently developed
6	Have an identifiable output as a label or logo
7	Be developed, accepted or funded by a national government or representative national trade association
8	Be available to a range of window frame or glazing types
9	Not be captured by any industry sector
10	Fairly compare products in a transparent manner
11	Be adopted by more than one sector of the market

Table 6: Initial evaluation criteria for detailed assessment of international window rating schemes

The schemes that have been identified as meeting the initial evaluation criteria of Table 6 are shown in Table 7, as follows:

Schemes for assessment	
1	Canadian Window Energy Rating Scheme
2	USA Window Energy Rating Systems
3	British Energy Rating Scheme
4	Australian Window Energy Rating Scheme
5	Nordic Swan Ecolabel

Table 7: Schemes meeting the initial evaluation criteria

The requirements for a Window Energy Efficiency Rating System in New Zealand have been declared by the stakeholders and are summarised in Table 8, together with their justification.

Requirements (and justification) for a New Zealand window energy efficiency rating system		
	Requirement	Reason
1	Produces a user acceptable measure of the energy performance of domestic window systems in New Zealand	The Window Energy Efficiency Rating System requires this
2	Window-specific and not dependent upon the whole house	Separating the energy impact of the window from the energy use of a house simplifies the operation of the programme. WANZ requires this
3	Includes consideration of glazing and framing	Windows are sold in New Zealand containing both glazing and framing, so the rating must be relevant to this market. Avoids confusion between R_g and R_w measures. This is a WANZ requirement
4	Includes all framing materials	The programme must be material-neutral, as it is the performance of the material that is of importance, not the constitution of the product. EECA requires this
5	Rating dependent on window size	The accuracy of the rating for a window is significantly affected by the range of sizes of that window. New Zealand has a wide range of domestic window sizes so representing them accurately requires a programme which has size dependency. WANZ requires this
6	Uses the thermal resistance of the whole window as the rating metric	The WANZ technical committee determined that a New Zealand Window Energy Rating Scheme should have the output metric based solely upon the thermal resistance of the whole window, with the size and configuration of all components taken into account. WANZ requires this
7	Independently verified	A credible rating programme needs to be technically correct and so needs independent verification processes. BRANZ requires this
8	Incorporates windows and doors	As there is little difference between the materials, design, fabrication, operation and installation of windows and doors in the New Zealand market, both should be included. Skylights have similar construction, but have a significantly different implication for energy use, so their inclusion in the programme needs more consideration. WANZ requires this
9	Referenced in national standards or code	Referencing in national standards or compliance documents of the NZBC means that the programme has wide accessibility

		and demonstrates national acceptance. This is a BRANZ expectation
10	Applicable to residential and non-residential windows	As windows designed for residential use can be installed in non-residential and high-rise residential situations, the programme should consider application beyond the use in low-rise residential situations
11	Uses SI units	SI units are routinely used in New Zealand and are accepted internationally, whereas the United States uses imperial units, which create confusion in the market place and should be replaced with SI units
12	Does not vary with climate zones	Given the small size of the New Zealand market, separation of climate zones and the national representation of window supply companies, it is impractical to market the same window with different rankings in different regions. This leaves open the option of requiring different window performance levels in different regions
13	Supported by central government	The role of central government in promoting a Window Energy Efficiency Rating System is important since there is the opportunity for the programme to be integrated with existing marketing programmes. The original WERS did not have significant support from central government, which contributed to its low uptake
14	Is accessible to consumers	Practically, a programme needs to be available to consumers so that it has some uptake and is not limited to use for complying with legislative requirements of larger labelling schemes
15	Includes use of R_w, and potential declaration of SHGC, and the VLT.	These key thermal performance parameters provide basic information that can be used by sectors of the market to further differentiate window performance, as needed

Table 8: Justification of the requirements for a New Zealand Window Energy Efficiency Rating System

The five schemes from Table 7 have been assessed in detail, with the results shown in Table 9.

International window energy rating scheme attributes					
Parameter	**Jurisdiction**				
	Canada	USA	Norway Sweden Finland Iceland Denmark	Australia	UK
Scheme name	ER Scheme	NFRC	Nordic Swan	WERS	Energy Rating
Glazing and frame included	Y	Y	Y	Y	Y
Available to all framing materials	Y	Y	Y	Y	Y
Fee for access to scheme	Y	Y	?	Y	Y[25]
Fee for performance parameters	Y	Y	Y	Y	Y
Supported by central government	Y	Y[26]	Y	Y	Y
Independent verification	Y	Y	?	Y	Y
Windows, doors and skylights	Y	Y	Y	Y	Y
Residential and non-residential	N	Y	Y	N	N
Independent of whole building	Y[27]	Y	Y	N	Y
Voluntary	Y	Y[28]	Y	Y	Y
QMS required	N	N	?	N	Y
Referenced in national standards or codes	Y	Y	?	Y	Y[29]
Rating change with size of window	N[30]	N	N	Y[31]	N
Varies with climate zone	Y	N	N[32]	Y	Y[33]
Uses SI units	Y	N	Y	Y	Y
Stars used in label	N	N	N	Y	N[34]

Table 9: Summary of relevant attributes of international Window Energy Rating Schemes

[25] A registration fee is payable to the BFRC to make use of the BFRC logo and window energy label
[26] Supported by the DoE but not run by the central government.
[27] But can be applied to a nationally accepted programme that includes whole house energy rating.
[28] Many states in the United States have adopted mandatory labelling for which the NFRC process can be used.
[29] Compliance with Part L (conservation of fuel and power) can be demonstrated through the energy rating.
[30] Seven different window types are rated in the ER process in Canada, each with a standard size.
[31] Windows are marketed based on a single size rating, however, Building Code compliance is on the basis of the actual size of the product used.
[32] However, different variations for the climate zone could be introduced.
[33] However, only one climate zone is currently used in the United Kingdom.
[34] The A-G rating is similar to a star rating.

Comparing the list of requirements for a New Zealand Window Energy Efficiency Rating System in Table 8 with the summary of attributes of the international schemes evaluated in Table 9, shows that there is no perfect match between existing schemes and New Zealand programme requirements.

Specifically: requirements 2, 5, 6, 10, 12 and 15 from Table 8 discount the Australian WERS; requirements 5, 6 and 12 discount both the British and Canadian schemes; requirements 2, 5, 6, 14 and 15 discount the Nordic Swan Ecolabel; and requirements 6 and 10 discount the United States NFRC scheme.

Consequently, there is no existing window energy labelling scheme that is immediately available for use in New Zealand without modification.

15.4 Use of flixo7™ to calculate U_f values of sub-assemblies and ψ values

The following provides the significant information required to ensure that consistent results are obtained from flixo™ version 7.0.597.1 and is consistent with EN ISO 10077-2, except where noted. The actual construction of a window shall be used, with characteristics of all elements noted, and verified. This includes stiffeners and any other continuous elements, but does not include intermittent elements such as hardware, packers etc, unless they extend for more than half the length of the sub-assembly or provide a thermal bridge. Where elements cannot be confirmed or are unknown, the conservative default values shall be used. This process does not include the possible variation of other selections within the flixo™ process, but assumes all the default settings remain, other than noted below.

Developed by John Burgess of BRANZ in August 2013.

Confirmed by Walter Schmidli of software support for flixo™7, August 2013.

15.4.1 flixo™ calculation of the U_f value of a sub-assembly

1. Model each sub-assembly as it would be used in a window – e.g. for a combination awning aluminium window, three models are required: the frame; frame/sash; and sash/mullion, as for the former WERS system
2. Model the system horizontally for mullions, with the inside surface at the top, and vertically for frame and sash sections, with the internal surface and timber liner on the right hand side (RHS)
3. Insert a 250 mm long panel in place of the IGU, by default this shall be of 24 mm width[35]
4. The thickness of the air cavity between the panel and the frame shall be at least 6 mm
5. The thermal conductivity of the panel (λ) shall be 0.035 W/mK
6. Model the timber liner where it is used to install windows (this is a departure from EN ISO 10077-1). When default values are needed, these shall be 19 mm x 114 mm and made of softwood of density 450 kg/m³ and conductivity 0.12 W/mK
7. Use materials from the "EN ISO 10077-2: Frame" directory in flixo™ and create any materials that are not available, with independent verification provided
8. Model stiffeners where these are needed to comply with the maximum wind zone that the product is marketed for – by default this should be the "Extra High" level from NZS 4211
9. Retain any exterior weathering fin/flange – this is a New Zealand-specific departure from the EN ISO 10077-2 standard
10. Model the character of the air under the sill as "Slightly ventilated air" – this is a New Zealand-specific departure from the EN ISO 10077-2 standard and accounts for the standard window installation detail from E2/AS1
11. The emissivity of 0.9 (suitable for painted materials and anodised aluminium) shall be used for the aluminium surfaces of all extrusions, given all current aluminium sections can be anodised, which confers the emissivity of 0.9 to all surfaces, including hollows. While it is recognised that when Al sections are powder coated, hollows and some portions between thermal breaks can be left

[35] The EN ISO 10077-2 process requires that to calculate the U_f, IGUs with two panes are compared to a system with a 24 mm thick panel.

as mill finish which actually confers a value of 0.3 to the emissivity, this value shall **not** be used in the modelling. The appropriate emissivity shall also be used for PVC, timber and fibreglass, as verified by the WANZ Verification Group

12. Use boundary conditions from the EN ISO 10077-2 standard, with surface coefficients of 0.04 m²K/W for the outside, 0.13 m²K/W for the inside, (using “Interior Frame”) and temperatures of 0°C for the outside and 20°C for the inside (ΔT = 20). Ensure that flixo™ automatically alters some of the interior conditions to account for different surface effects
13. Calculate the U_f value of the sub-assembly with the panel and use this value to represent the U value of the sub-assembly. The U_f value is calculated from the bottom of the timber reveal liner (not from the bottom of the flange) to the sightline. The equation used within flixo™ is –

    $U_f = \frac{\frac{\Phi}{\Delta T} - U_p b_p}{b_f}$, where Φ is the calculated heat flow through the system with the panel in W/m, U_p is the U value of the panel in W/m², b_p is the exposed length of the panel in m and b_f is the length of the frame from the bottom of the reveal liner. See Figure 3

15.4.2 flixo™ calculation of the ψ value of a sub-assembly

14. The ψ value shall be calculated between the bottom of the timber reveal liner and the sight line of the IGU for sections including outer frames, and between the sight lines for systems without exterior frames. This requires that an IGU of 250 mm length is used to replace the panel. If a default value is needed, a U value for the centre of glass (U_g) of 2.9 W/m²K (rounded up from 2.86) shall be used (an R_g value of 0.35 m²K/W). The R_i value of 0.13 m²K/W (0.2 if reconfigured by flixo™) and R_e value of 0.04 m²K/W are retained
15. Modify the size of wedges and seals in the sub-assembly if the IGU has a different thickness than the panel
16. If needed, by default use the 12 mm “Spacer Aluminium 2” as used in the flixo™ component library, as the IGU edge spacer in a 4/12/4 IGU
17. Calculate the ψ value of the sub-assembly using the “Edge/Spacer” option in W/mK. flixo™ uses the equation $\psi = \frac{\Phi}{\Delta T} - U_g b_g - U_f b_f$ to calculate ψ, where U_g is the U value of the glass, U_f of the frame and b_g is the length of the exposed glazing (250 mm – edge bite) and b_f is the height of the frame from the bottom of the reveal liner, as shown in Figure 3. This is a departure from EN ISO 10077-2
18. Use these values to calculate the U_w value of the window according to the formula

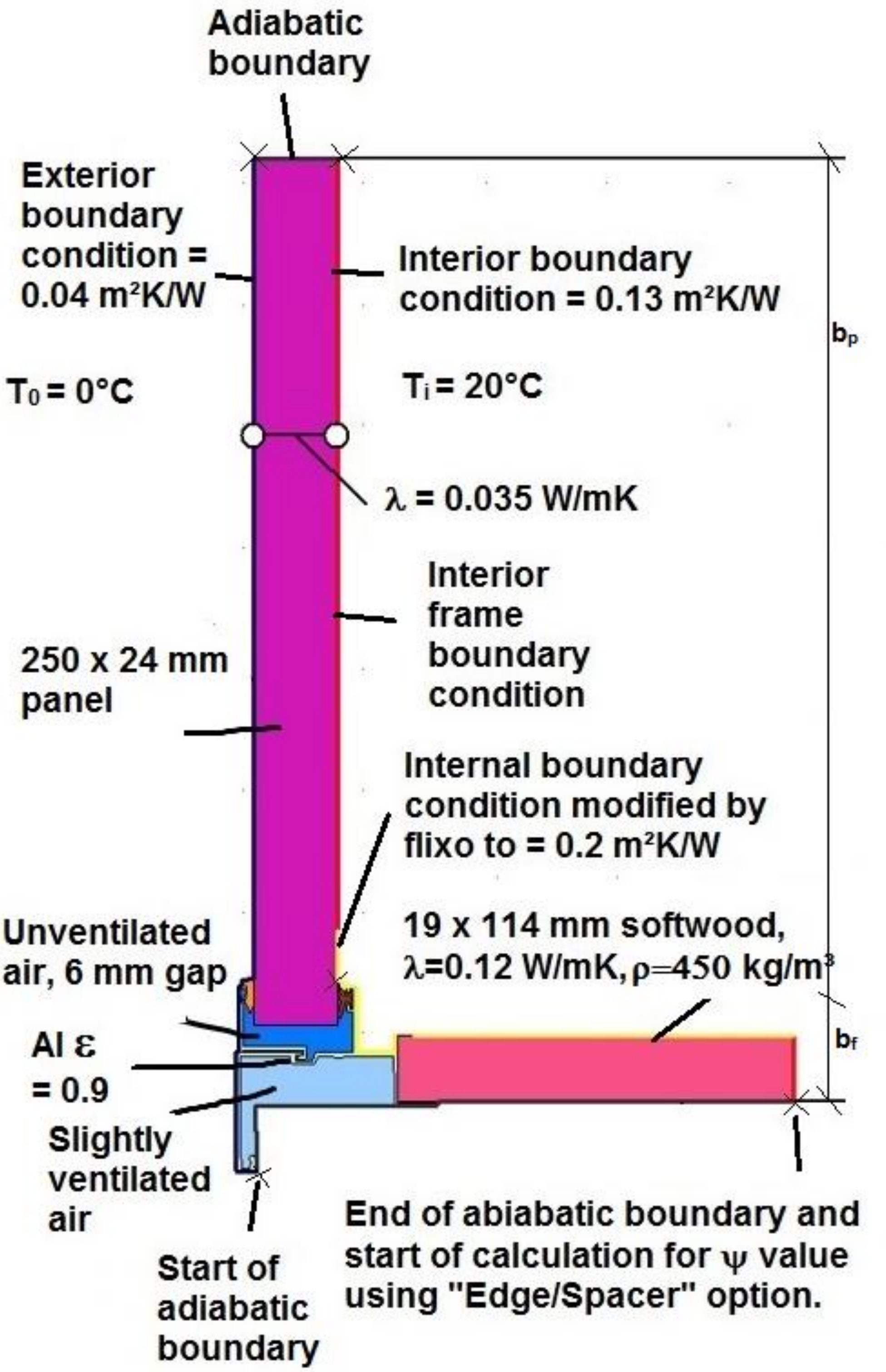


Figure 3: Presentation of significant information required to ensure consistent results are obtained from the thermal modelling of window sections with the flixo™ or Window/Therm software using CEN/NZ surface coefficients

15.5 Use of Window/Therm v7 to calculate U_f values of sub-assemblies and ψ values of spacer systems

Developed by John Burgess of BRANZ in October 2013.

Confirmed by WEERS technical committee and EECA, November 2013.

Overview: The thermal performance of window systems are modelled to enable their thermal performance to be converted into a star rating. This rating compares the transport of energy through windows by conduction. Several different methods are available to model this thermal performance and one of them is the Window/Therm version 7 software package. Note that this package does not currently calculate values that are completely consistent with the EN 673 and ISO 10077-2 standards.

For WEERS purposes, the U_w value of window systems is calculated according to EN ISO 10077-2, with minor process modifications noted below. The sub-assemblies of windows are first modelled with a highly insulating panel to provide a "best possible" U value, which is then used to represent the U_f value of the sub-assembly. The effect of installing an IGU with edge spacer in the sub-assembly (rather than the panel) is then modelled and the difference is termed the ψ value. This may involve changing the shape of the seals to allow the panel and IGU to be properly glazed, but does not affect the frame size or the U_f value.

15.5.1 U_f calculation process with Therm

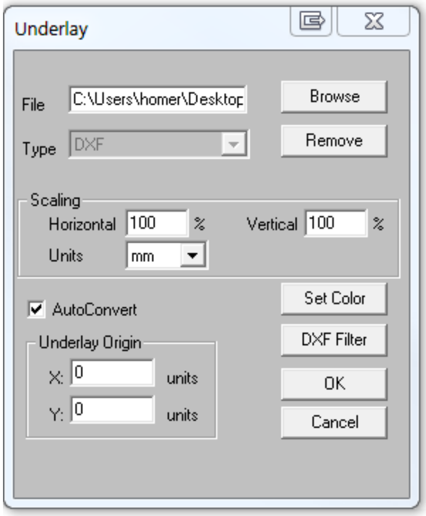
The following instructions provide the significant information required to ensure that results for the U_f and ψ value consistent with EN ISO 10077-2 are obtained from the Window/Therm software, version 7, for WEERS purposes in New Zealand. Window and Therm are designed to calculate the U_f value of systems using the ASHRAE/NFRC method according to ISO 15099 by default, but they can be configured to calculate the U_f value of systems according to EN ISO 10077-2, which is required here.

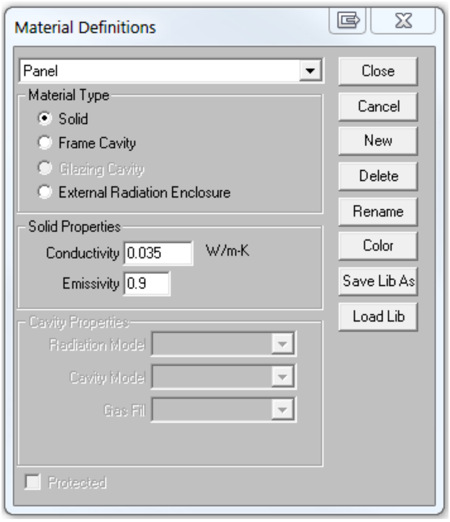
While flixo™ calculates U_f (of sub-assemblies) and the ψ value, and allows the specification of a U_g value, Therm calculates the U_f and ψ values and imports the U_g value from a calculation in Window. Hence, there are references to Window in this set of instructions for the calculation of the ψ value. Window is also able to calculate U_w values according to EN ISO 10077-2.

When modelling with the Window/Therm 7 package, the actual construction and size of a window shall be used, with characteristics of all elements noted and verified. This includes stiffeners and any other continuous elements, but does not include intermittent elements like hardware, packers etc, unless they extend for more than half the length of the sub-assembly or provide a thermal bridge. Where elements cannot be confirmed or are unknown, the conservative default values noted here shall be used. This process does not include the possible variation of other selections within the Therm modelling process, but assumes all default settings remain.

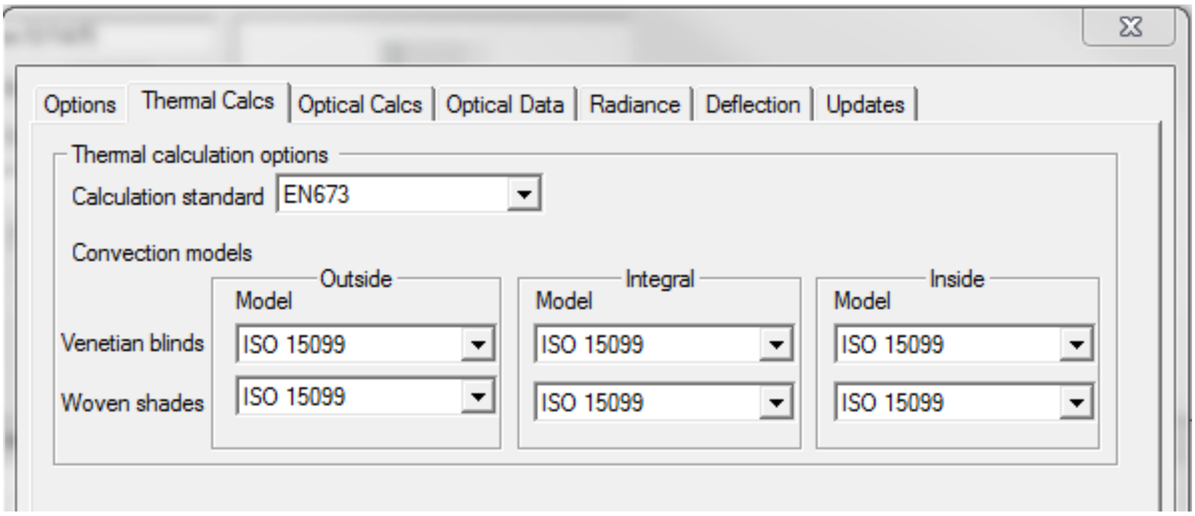
1. Model each sub-assembly as it would be used in a window – i.e. for a combination awning window three sub-assembly models are typically required: the frame; frame/sash sub-assembly; and the sash/mullion sub-assembly, as for the former WERS system. However, up to seven models could be needed for a combination awning window where different sub-assemblies are used at the head, jamb and sill
2. Model the system horizontally for mullions, with the inside surface at the top, and vertically for frame and sash sections, with the internal surface and timber liner on the right hand side (RHS)

3. Ensure that the calculation units are set to SI under the Options tab
4. Import a sub-assembly underlay with the "Autoconvert" option checked, as below
5. Draw a rectangle of 250 mm long and 24 mm wide to be the pane, and assign this a conductivity of 0.035 W/mK (using the Material Definitions as below) to replace the normal IGU(s)





6. Model in accordance with ISO 15099:2003(E), using the options for EN673, as below



7. Follow the guidelines in the Therm 6.3/Window 6.3 NFRC simulation manual, (available here http://windows.lbl.gov/software/NFRC/SimMan/NFRCSim6.3-2013-07-Manual.pdf) which refers to the "Therm user's manual" (available here http://windows.lbl.gov/software/therm/Docs/Therm2.pdf) with the following particulars (note the instructions have not yet [November 2013] been updated for version 7 of Window or Therm)

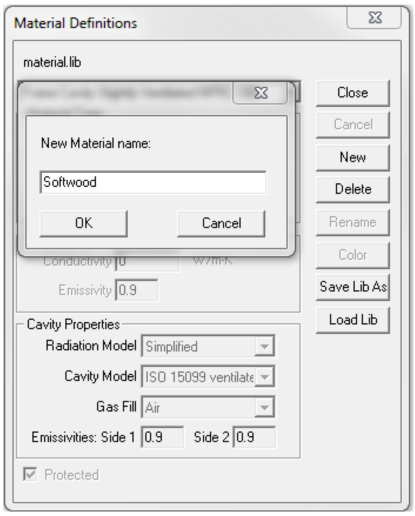
8. Retain the external weathering flange in the model, as this is critical for weathertight window installation in New Zealand. This is a departure from EN ISO 10077-2

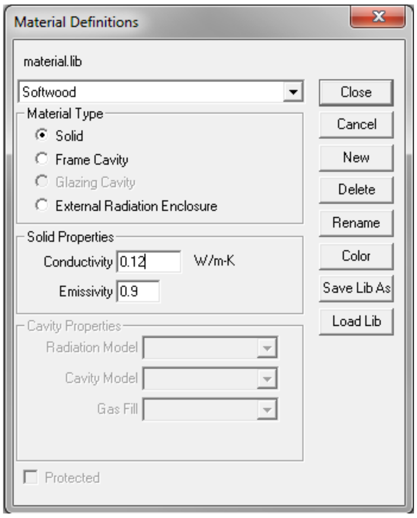
9. Set the thickness of the air cavity between the panel and the frame to be 6 mm (see Figure 3)

10. Modify the size of wedges and seals in the sub-assembly to fit the 24 mm panel, if the seals in the glazing rebate do not allow for a panel that is precisely 24 mm wide

11. Use default materials from the Therm "Material Library" and create other materials that are not available, with independent verification provided

12. Include the timber liner for sub-assemblies which use the timber liner to install windows. Create a new solid material called "Softwood" with a conductivity of 0.12 W/mK and emissivity of 0.9. When sizes are needed, these shall be 19 mm x 114 mm



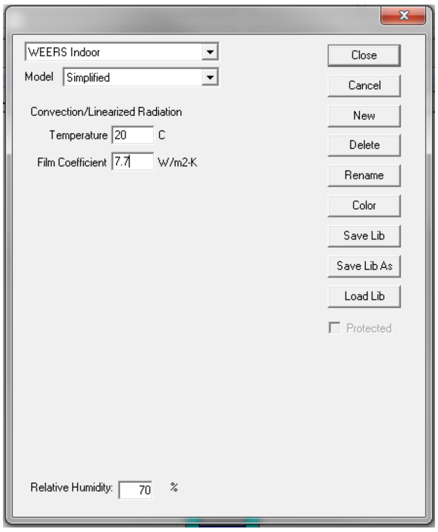


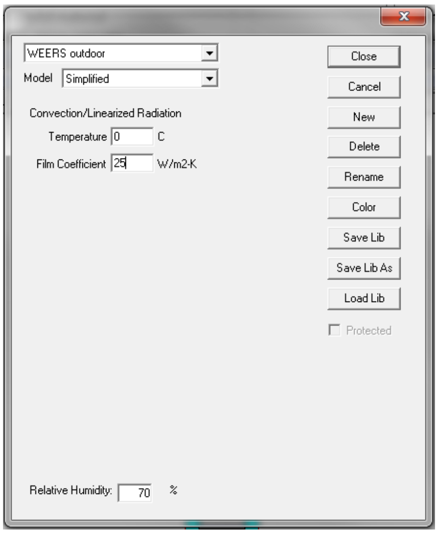
13. By default model the stiffeners required for the largest size window offered to comply with the "Extra High" wind zone of NZS 4211 – or the maximum wind zone that the product is marketed for, unless different U_f values are used for the same sub-assembly with different amounts of stiffening, for different wind zones and/or sizes

14. Model the character of the air under the sill as "Slightly Ventilated Air" – this is a New Zealand-specific departure from the EN ISO 10077-2 standard and accounts for the standard window installation detail from E2/AS1

15. The emissivity of 0.9 (suitable for painted materials and anodised aluminium) shall be used for the surfaces of all sub-assemblies of all materials, unless other values can be proven. While it is recognised that when Al sections are powder coated, hollows and some portions between thermal breaks can be left as mill finish with an emissivity of 0.3, this value shall **not** be used in the modelling, given anodised aluminium has an emissivity of 0.9 which will be applied to all surfaces. The only exception is if the manufacturer explicitly disallows anodising or other processing which reduces the emissivity of the surface and can prove that the emissivity of the surfaces of their products is lower

16. Use boundary conditions from the EN ISO 10077-2 standard, with surface coefficients of 0.04 m²K/W for the outside (25 W/m²K), 0.13 m²K/W for the inside (7.7 W/m²K), and temperatures of 0°C for the outside and 20°C for the inside. Manually alter portions of the interior conditions to 0.2 m²K/W to account for surface sheltering effects, as specified in the “Therm 2” instruction manual

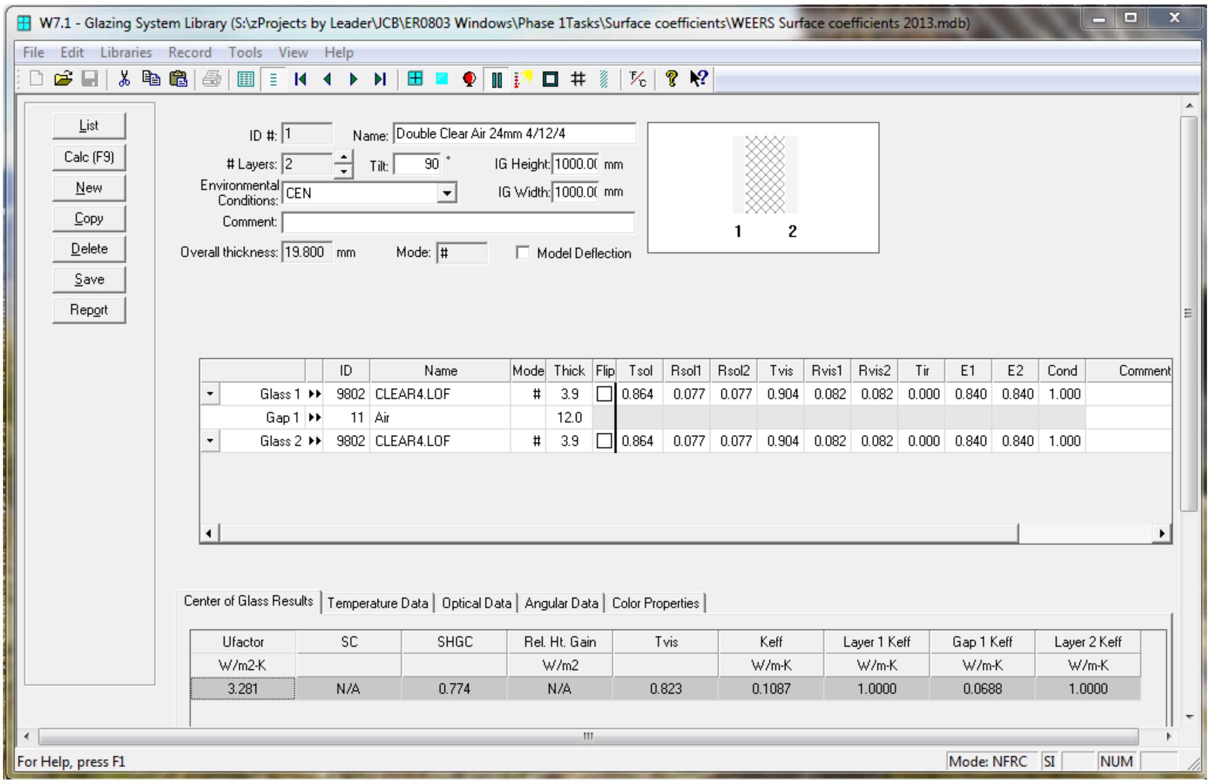




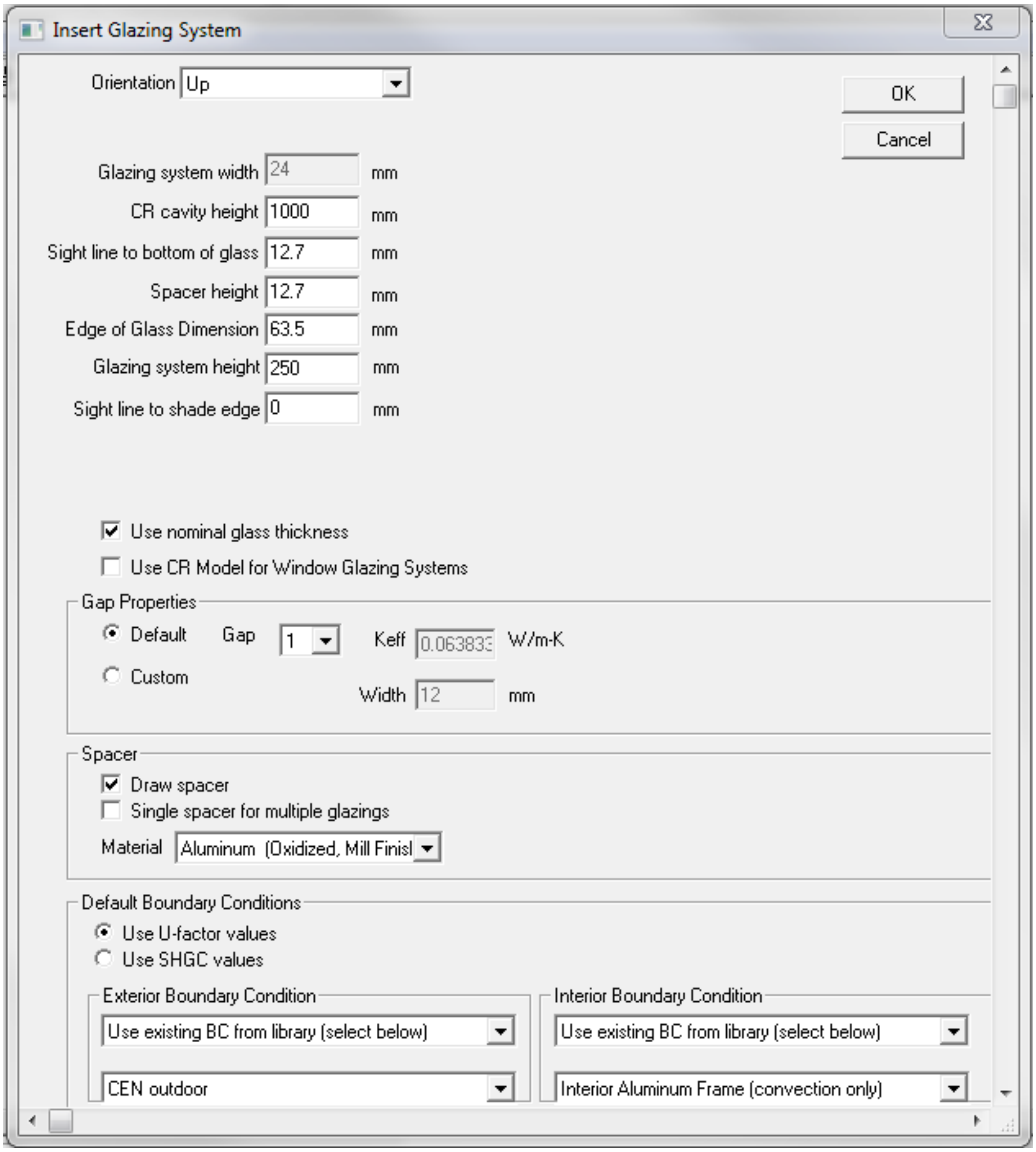
17. Calculate the U value of the sub-assembly with the panel in accordance with EN ISO 10077-2 and use this value to represent the U_f value of the sub-assembly. The U_f value is calculated from the bottom of the timber reveal liner (not from the bottom of the flange) to the sightline. The following equation can be used – $U_f = \frac{\frac{\Phi}{\Delta T} - U_p b_p}{b_f}$, where Φ is the heat flow through the system (with the panel) in W/m, U_p is the U value of the panel in W/m², b_p is the exposed length of the panel in m and b_f is the length of the frame from the bottom of the reveal liner, as shown in Figure 3

15.5.2 ψ value calculation process with Window/Therm

18. The ψ value shall be calculated between the bottom of the timber reveal liner and the sight line of the IGU for sections including outer frames, and between the two sight lines for systems without exterior frames. This requires that an IGU of 250 mm length is used to replace the panel
19. Modify the seals and wedges in the previous **Therm** model to fit the IGU if it is not precisely 24 mm wide
20. **In Window**, model the relevant IGU(s), importing glazing panes from the IGDB, using the “CEN” environmental conditions (as shown below) with a 90° tilt, IGU height and width of 1000 mm, an overall thickness to match the required system, and the “Air” option or the “Air (10%) / Argon (90%) Mix” for Argon gas-filled units. Alternatively, use values provided by GANZ
21. If a default value is needed for a spacer, use a 12 mm aluminium spacer



22. In **Therm**, insert the relevant IGU(s) from **Window**, with a default 12.7 mm spacer height, 63.5 mm edge of glass dimension, 250 mm glazing system height, using the “Nominal glass thickness” option, with the exterior and interior boundary conditions appropriate for the frame material, using the “Convection only” option, as below
23. If a default value is needed for standard clear-glazed IGUs, a U value for the IGU (U_g) of 2.9 W/m²K for a 4/12/4 IGU shall be used and 2.7 for a 4/16/4 IGU



24. Calculate the ψ value of the sub-assemblies using the equation $\psi = \frac{\Phi}{\Delta T} - U_g b_g - U_f b_f$ to calculate ψ, where U_g is the U value of the glass, U_f is the U value of the frame from the previous step, bg is the length of the exposed glazing (250 mm – edge bite) and bf is the height of the frame from the bottom of the reveal liner, as shown in Figure 3.
25. Calculate the total product U value (U_w) using Window 7 or alternatively create your own model to calculate this and have it verified by an independent expert

15.6 Use of surface coefficients in the LBNL Window modelling software

The implementation of the surface coefficient values in the LBNL Window software version 6 and 7 is provided below. Note that:

- the Window 5 (W5) software has been superseded
- the SHGC is not part of WEERS, however has been included in this discussion.

15.6.1 Modelling in Window 6 or Window 7

See Figure 4 through to Figure 7, noting that:

- The CEN gas fill must be used to get correct values from Window 6
- When calculating the R value of glazing including a low-E surface on an inside surface, the equation ($h_i = 3.6 + 4.1\ \varepsilon_i/0.837$) must be employed and the result used to replace the value of 7.7 for the internal combined coefficient
- There is no correction made to the convective heat transfer due to a low-E surface used on the outside of a glazing layer – this is purely the convention used in the EN standards and does not necessarily give an accurate result if a low-E surface is used on the outer face of a glazing system. The implication is that no benefit for improved R value can be claimed when a low-E surface is used on a glazing surface facing outside

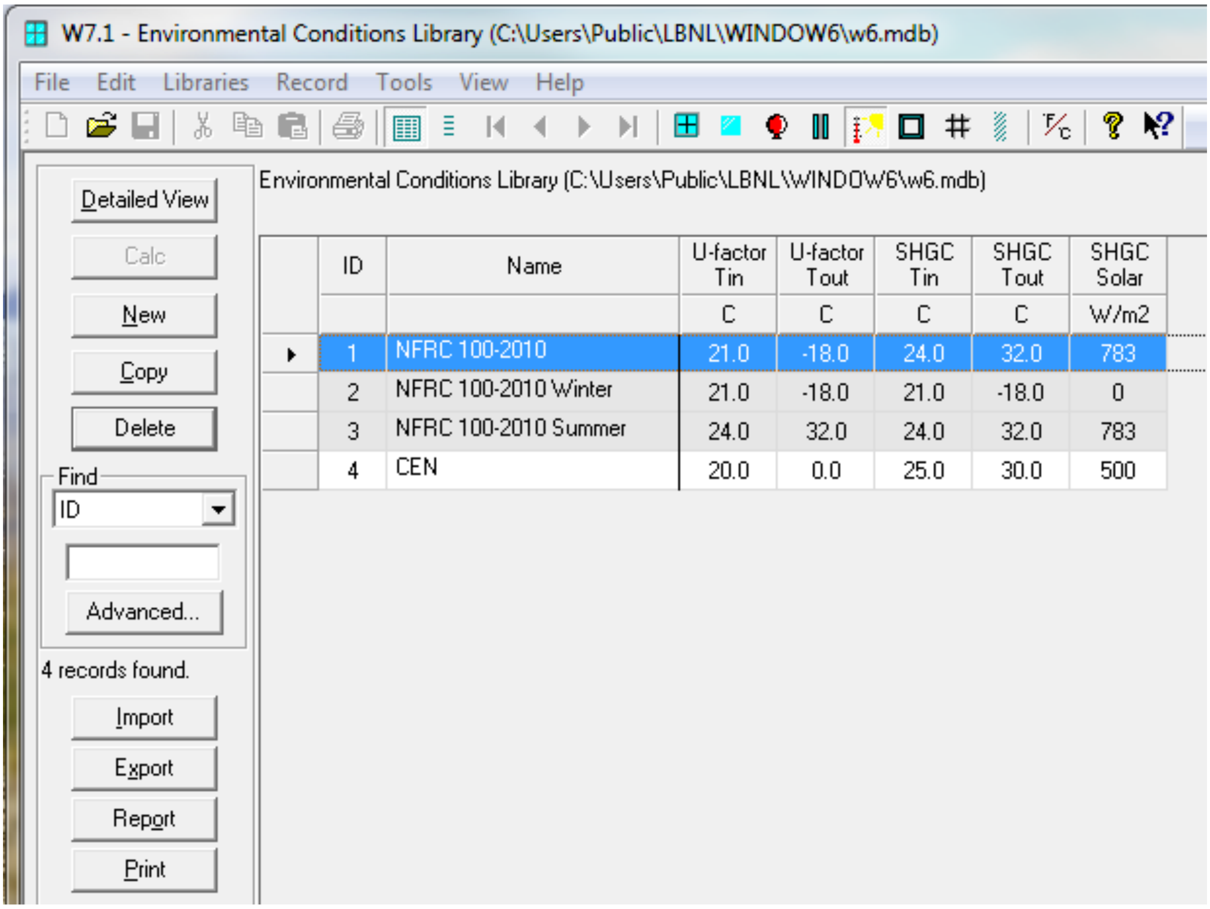


Figure 4: Screenshot of environmental conditions main screen in Window 6 (similar in W5 and W7)

In Figure 4, the values of 20, 0, 24, 32 and 783 are used given:

- 20°C is the inside air temperature which is used in EN standards and in the LBNL paper[36]
- 0°C is the outside air temperature which is used in EN standards and in the LBNL paper
- 24°C is the inside temperature used for NFRC/ASHRAE modelling purposes in W5/6/7
- 32°C is the outside temperature used for NFRC/ASHRAE
- 783 W/m² is the direct solar radiation value used for NFRC/ASHRAE

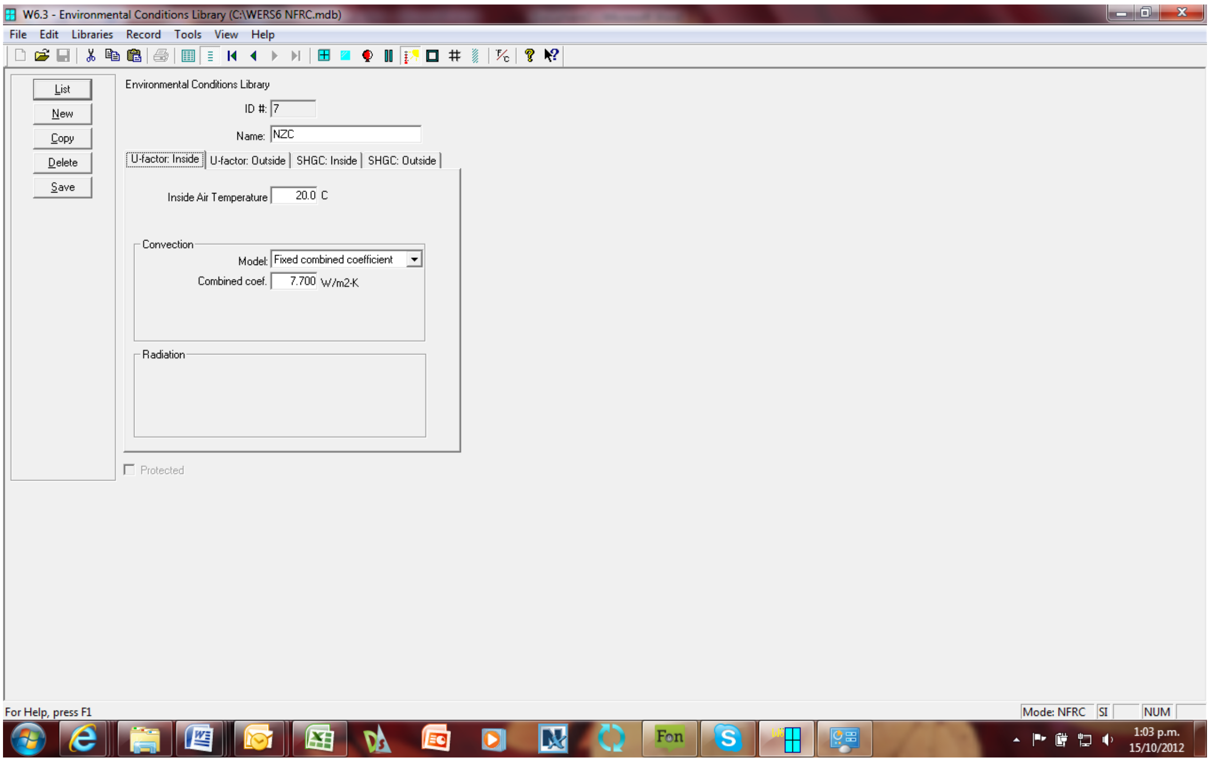


Figure 5: NZC conditions for the U factor inside conditions implemented in Window 6 software

In Figure 5, the values of 20 and 7.7 are used given:

- 20°C is the inside air temperature which is used in EN standards and in the LBNL paper
- 7.7 W/m²K is the inside fixed combined surface coefficient including both radiative and convective coefficients which is used in all of EN 673/410/10077 standards and in the LBNL paper, although 8 W/m²K is used in W5/6/7

[36] This is the paper by Kohler, referenced in the Bibliography.

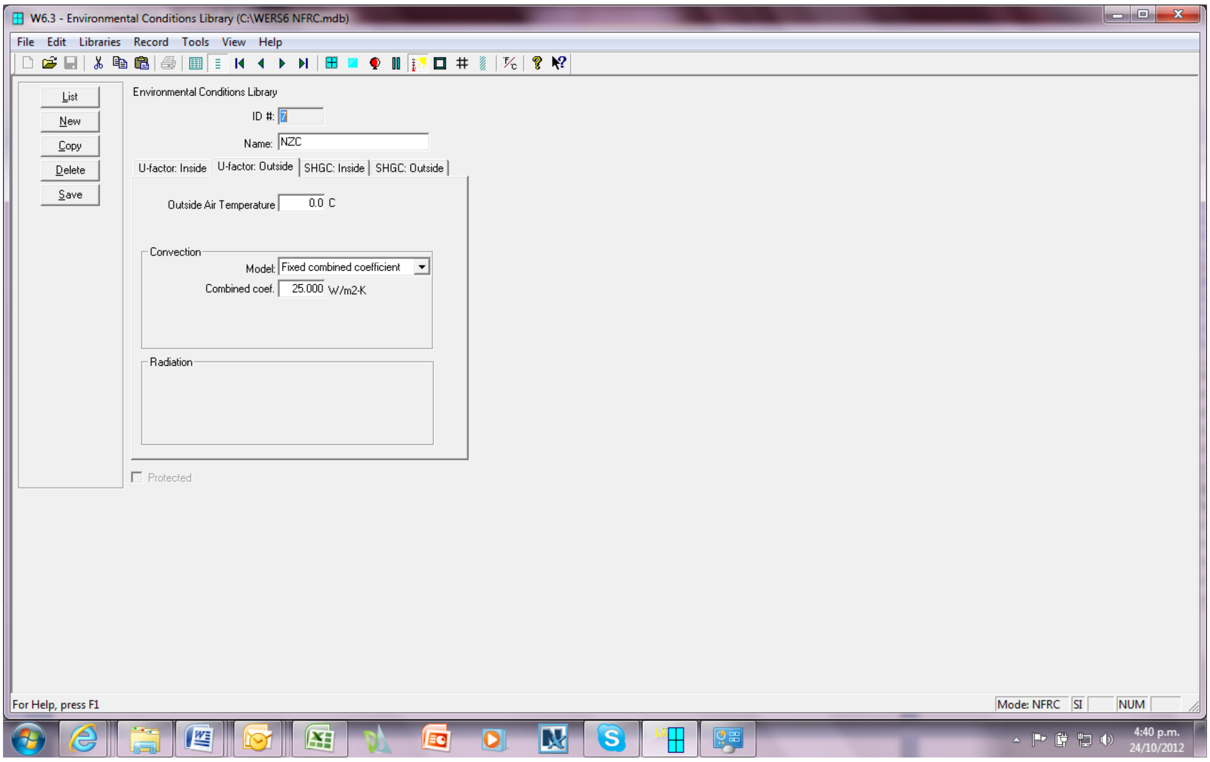


Figure 6: NZC conditions for the U factor outside conditions implemented in Window 6 software

In Figure 6, the values of 0 and 25 are used given:

- 0°C is the outside air temperature which is used in EN standards and in the LBNL paper
- 25 W/m²K is the fixed combined coefficient which is used in all of EN 673/410/10077 standards although 23 is used in the LBNL paper and in W5/6/7

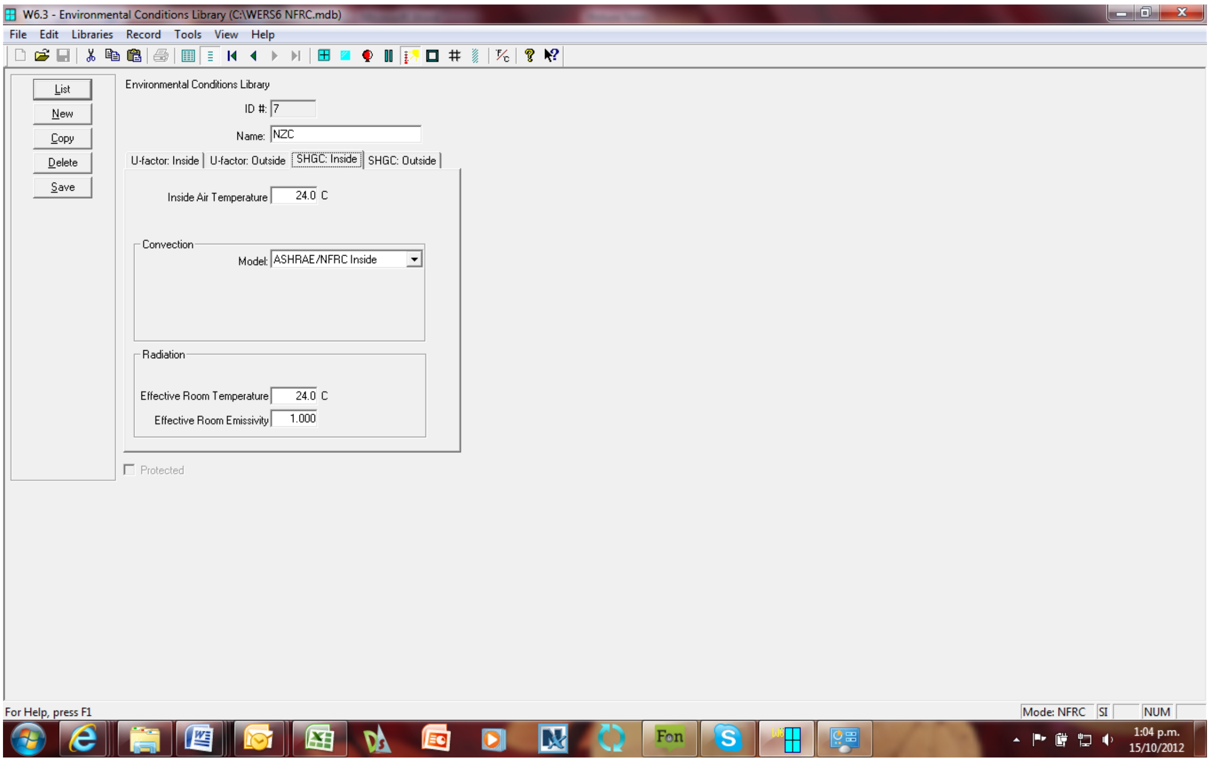


Figure 7: NZC conditions for the SHGC inside conditions implemented in Window 6 software

If using EN boundary conditions, make sure to set the Thermal Calculation standard to EN673. This can be done from File / Preferences, then going to the Thermal Calcs tab and setting the Calculation standard pulldown to "EN673".