TECHNOFORM

Upfront carbon footprint analysis

of New Zealand fenestration systems

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Executive summary

Embodied carbon is essential for the New Zealand ("NZ") construction industry to consider because some materials have high energy efficiency allowing for lower operational carbon, but have high embodied carbon. Having information on upfront and embodied carbon emissions could lead to different material choices. NZ's 2030 and 2050 carbon emissions reduction goals will only be achieved by transitioning towards sustainable renewable energy sources and reducing carbon intensive supply chains.

Energy efficiency should not be the only criterion when choosing fenestration frame material. Taking a fenestration system overall performance approach to sustainable design would require frame material selection to consider energy efficiency, frame material strength, service life and embodied carbon.

Due to NZ's inability to manufacture all products needed for the country, essential goods need to be transported from around the world. International shipping and transport is not usually included in carbon emissions calculations. However, the results for aluminium and uPVC fenestration systems undertaken in the following analysis show that including international transport emissions should influence fenestration material selection, including country of origin.

A desktop analysis undertaken for modules A1-A3 and A4, showed that shipping and transporting of internationally sourced aluminium or uPVC house lots of premanufactured fenestration systems increases emissions compared with containerised long lengths of aluminium or uPVC frame material. International shipping and transport emissions from Guangzhou, China are minor in comparison to the high aluminium smelting emissions of 20.00 kgCO_2-eq per kg (scope 1, 2 & 3) of aluminium compared to 5.09 kgCO_2-eq per kg (scope 1, 2 & 3) for aluminium sourced in NZ. When considering the upfront carbon emissions for modules A1-A3 and A4 the lowest kgCO_2-eq emissions came from NZ manufactured house lots, made from aluminium sourced in NZ.

Glossary

Aluminium	Aluminium thermally broken profiles (aluminium) with polyamide strips between two aluminium sections (not solid aluminium). See polyamide.
Argon	Low conductivity inert gas used in the air cavity between two panes of glass (see double glazing) – conductivity: 0.018 W/(mK).
Biogenic fuel	Fuel produced from combusting organic matter. When released into the atmosphere is absorbed over the course of the lifetime of the plant which replaces them.
Biomass	A renewable energy source that can be converted into liquid biogenic fuel. (see Biogenic fuel).
Carbon footprint	A measure of the amount of carbon dioxide released into the atmosphere due to human activities, such as the construction industry.
Container stuffing	The term used to describe when cargo is packed into a shipping container
COP	Conference of the parties.
Double Glazing	Windows with two panes of glass with a gap between the panes of glass designed to reduce heat loss and improve acoustic performance.
Embodied carbon	Embodied carbon is the carbon footprint of a material which considers how many greenhouse gases (“GHGs”) are released throughout the supply chain and is often measured from cradle to (factory) gate, cradle to site (of use) and cradle to grave. For this analysis the results are expressed as a material coefficient (see kgCO_2-eq).
Energy efficiency	The process of reducing the energy required to provide products and services. Good energy efficiency allows a building to use less energy.
Environmental product declaration	An “EPD” is a concise, readable, third-party verified document which reports environmental information via a quantitative technique called life cycle assessment (“LCA”). (See lifecycle assessment).
Extrusion profile (“aluminium”)	Refers to how aluminium is shaped during the extrusion process whereby an aluminium billet is heated to 600° C. The heated billet is pushed through a steel die to generate a cross section of the die pattern forming long lengths (see aluminium).
Extrusion profile (“uPVC”)	Refers to how uPVC is extruded by using large-scale automatic mixing equipment to churn a molten mix of plastic powder heated to 200-275° C. The mix is extruded in order to form long lengths. (See uPVC).
Fenestration	The arrangement of windows and doors in a building.
Fossil fuel	A natural fuel such as coal or gas. When released into the atmosphere contributes to global warming.
Frail	A frail is a demountable frame to speed up the process of loading and unloading window and door systems onto trucks or trailers. Frails save double handling the windows and doors during loading and unloading,reduces damage to window frames, addresses health and safety needs. Also known as an A-frame.
Global warming potential (“GWP”)	Quantifies the release of atmospheric GHG emissions with an evaluation time of 100 years.
Greenhouse Gasses (“GHG”)	Gases that, when released into the atmosphere, absorb and emit thermal infrared radiation trapping heat within the atmosphere, thereby contributing to global warming.
HS codes	Internationally recognised eight-digit codes identifying a product on importation paperwork, which sets the tariff rate for importing the products.
Kelvin (“K”)	Unit of thermodynamic temperature in the International System of Units (“SI”) equivalent in size to the degree Celsius.
kgCO_2-eq	Carbon dioxide equivalent (see “GWP”).
Kilograms (“kg”)	The SI unit of mass is equivalent to 2.205 pounds.

Krypton	Low conductivity inert gas used in the air cavity between two panes of glass (see double glazing) - conductivity: 0.00943 W/(mK).
Lifecycle assessment	Life cycle assessment ("LCA") is a tool that calculates the potential environmental impacts of building materials, building elements and whole buildings for production, use and disposal.
Model house	BRANZ developed house lots to allow for comparisons in thermal modelling.
Metric ton	A unit of weight equal to 1,000 kilograms.
Million ("M")	Millions (referencing dollars, population and kilograms).
Polyamide	PA 66 is a polyamide reinforced with glass fibers. The special, dry impact resistant mixture offers the best solution for window and door thermal insulation. PA 66 provides excellent mechanical performance, high precision processing and unlimited availability and recyclability.
Recycled billet	(See secondary billet)
R-value	A material's thermal resistance (R-value) is the capability to resist heat transfer. The higher the R-value, the better the thermal resistance of the material. The R-value is inversely proportional to U-value (R=1/U). (See U- value).
Secondary billet	Aluminium that is produced from recycled aluminium scraps.
Scope 1, 2 & 3	The GHG Protocol places emission sources into Scope 1, Scope 2 and Scope 3 activities. **Scope 1:** Direct GHG emissions from sources owned or controlled by the company (ie, within the organisational boundary). **Scope 2:** Indirect GHG emissions from the generation of purchased energy (in the form of electricity, heat or steam) that the organisation uses. **Scope 3:** Other indirect GHG emissions occurring because of the activities of the organisation but generated from sources that it does not own or control (eg, air travel).
Shipping	The analysis uses "shipping" as a term to cover all materials required to package goods ready for transport. See Transport.
Steel, galvansied	Reinforcement steel is inserted into uPVC structural profiles to control the expansion rate and provide rigidity; not all uPVC shapes require galvanised steel reinforcement.
Thermal modelling	A computer simulation providing the temperature of a junction at any given point, maximum and minimum frame temperatures, heat flux, and U-values
Tonne	Another term for Metric ton.
Transport	The analysis uses "transport" as a term to cover the movement of goods from one location to another.
Triple Glazing	Windows with three panes of glass with a space between the panes of glass designed to reduce heat loss and improve acoustic performance.
Upfront embodied carbon	Upfront embodied carbon is defined as the carbon footprint of construction materials from its extraction, through manufacture, to installation, and the emissions associated with the construction works.
uPVC	Unplasticised polyvinyl chloride as a fenestration frame material.
U-value	A material's thermal transmittance ("U-value") is the heat transfer rate through matter. The lower the number, the better the thermal insulation. The U-value is inversely proportional to R-value (U = 1/R). (See R-value)
Virgin billet	Virgin aluminium ingot obtained through electrolysis of alumina refined from bauxite, increasing the purity of the resulting aluminium.
W/(mK)	Watts per metre kelvin. Representing the heat conduction properties of a material, specifying the heat transfer rate.
Window schedule	Organised presentation of pertinent window characteristics.
Windows	(See fenestration).
Xenon	Low conductivity inert gas used in the air cavity between two panes of glass (see double glazing) – conductivity: 0.00565 W/(mK).

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Acknowledgements

The analysis was funded by **Technoform**, with data provided from **Profile Group** businesses (**APL Window Solutions** & **KLIMA**). Cover photo supplied by **Windowmakers**. Crate design for imported fenestration systems provided by Pope Packaging. Critical peer review was undertaken by **thinkstep-anz**.

Disclaimer

The following study is a high-level desktop analysis which uses publicly available emission factors for raw materials with the oldest emission factors being 12 years old. Overall, this analysis is a streamlined Life Cycle Assessment ("LCA") based on a desktop survey, with the focus on climate impacts. A detailed LCA analysis is required for full compliance of the ISO standards for LCA (ISO 14040/44) which is beyond the scope of this work. The analysis is for internal use to understand if more work needs to be completed to understand the impact of international shipping and transport when importing window and door products into NZ.

Scope of works

Technoform commissioned DPS Consulting to complete fenestration system upfront carbon emisison calculations for fenestration systems manufactured in NZ compared to fenestration systems premanufactured or shipped in long lengths by container and imported into NZ. The analysis and underlying calculations have been subjected to external peer review by thinkstep-anz.

This report uses two dwelling types; a single-story detached dwelling, model house 1 ("MH1") with 19 windows and doors and a townhouse, model house 2 ("MH2") with 16 windows and doors (refer to Appendix A). MH1 and MH2 house lots were calculated with frame materials of Unplasticized Polyvinyl Chloride ("uPVC") profiles and aluminium thermally broken profiles with polyamide strips between two aluminium sections ("aluminium").

Goal of works

This high-level desktop analysis was undertaken to provide a preliminary review of readily available information relating to the upfront carbon emissions of two house lots, MH1 and MH2, with frame materials of uPVC and aluminium, either premanufactured or in long lengths and shipped to NZ from China or Germany. The analsyis then compares MH1 and MH2 house lots with aluminium as the frame material, manufactured in NZ from aluminium sourced in NZ ("baseline").

The analysis was undertaken to determine if additional work may be needed in regards to understanding the CO_2-eq contributions of a house lot of windows manufactured locally compared to various internationally sourced fenestration options. The desktop analysis is attempting to highlight the upfront emissions of internationally sourced fenestration systems which may not currently be considered when importing products into NZ.

Our goal is to actively encourage the use of locally-manufactured windows and doors in order to reduce the upfront carbon emissions of the construction industry while simultaneously stimulating the local economy. The analysis is backed by data for support.

This analysis provides supporting data for current New Zealand Government ("NZ Govt") initiatives to reach 2030 and 2050 climate change goals set via:

- Kyoto Protocol (1997): an agreement among leaders of over 180 countries to reduce greenhouse gas emissions and limit the global temperature increase to below 2 degrees Celsius above pre-industrial levels by 2100.
- COP21 Paris Agreement (2015): an international treaty adopted in 1997 aimed at reducing emissions of six greenhouses contributing to global warming. Forty-one countries, including NZ Govt, signed the protocol, requiring the signatories to reduce emissions to 5.2% below 1990 levels.
- COP26 (2021): United Nations climate change conference reached an agreement whereby every country agreed to work together to limit global warming to below 2 degrees, intending to keep the warming below 1.5 degrees (United Nations Climate Change, 2021).
- COP27 (2022): United Nations climate change conference reached an agreement to provide a "loss and damage" fund which provides developing nations financial assistance with the climate crisis (United Nations Climate Change, 2022).

NZ has committed to reducing emissions to 50% below 2005 levels by 2030 and reaching net-zero emissions by 2050 (Gen Less, 2023). NZ is a small country in terms of population at 5.151M people (Stats

NZ, 2022), and therefore NZ's contribution to global emissions is small compared to other nations. However, NZ's gross average emissions in 2019 were 7.8 tonnes of CO_2 per capita, while the global average for CO_2 emissions in 2019 were 4.8 tons of CO_2 per capita (Ritchie, October 7, 2019).

Additionally, a spike in NZ emissions occured in 2021 due to poor hydro dam storage conditions and low natural gas supply leading to the importation of 1.8M tonnes of coal to fuel NZ coal-fired power plants which is a 69% increase in coal imports compared to 2020 (refer Appendix B). As of 2023, NZ needs to course-correct current emissions to achieve the goals of 5.2% below 1990 emissions levels by 2030.

Many types of greenhouse gases ("GHG") naturally occur in the Earth's atmosphere, absorbing different amounts of heat. Burning fossil fuels increases GHGs leading to climate change and global warming (Brander, 2012).

Global warming potential ("GWP") is a measure of how much a given amount of greenhouse gas is estimated to contribute to global warming over a particular time period, relative to the same amount of carbon dioxide (CO_2). It is a measure of the warming effect of a greenhouse gas, taking into account the fact that some gases can trap more heat than others, and that some gases remain in the atmosphere for longer periods of time than others. GWP is typically expressed as a factor relative to CO_2, with CO_2 having a GWP of 1. This report adopts the unit kgCO_2-eq for total GHG emissions, expressed in terms of the equivalent measurement of carbon dioxide (Asdrubali, Roncone, & Grazieschi, 2021).

System boundaries

The data used for the materials related to CO_2-eq calculations undertaken in this report are based on a house lot of windows and doors (refer to Appendix A, MH1 Figure 10 and MH2 Figure 11). The emissions factors contained in the analysis were sourced from a range of research papers which have different authors and underlying assumptions. The oldest of the sources is from 2011 making some of the data 12 years old.

Inclusions

EN15804, whole of life embodied carbon modules which are represented in this report:

- A1–A3 (product stage), representing manufacture of materials up to the factory gate including international shipping and transport.
- A4 (product distribution), which includes international and local transport.
- Refer Appendix C, Figure 13.

Emission source inclusions:

- Scope 1, 2, and 3 emissions included.
- Aluminium frame raw material sourcing, extrusion, scrap and powdercoating included.
- uPVC frame, extrusion, galvanised steel reinforcement and scrap included.
- Hardware and components included.
- Local and international transport included for internationally sourced uPVC and aluminium house lots and long lengths.
- Local transport for New Zealand manufactured house lots.
- Clear, toughened and low-E glass included.

Exclusions

EN15804, whole of life embodied carbon modules which are NOT represented in this report:

- A5 (construction stage).
- B1-B7 (use stage).
- C1 to C4 (end of life stage) .
- D (future reuse, recycling or energy recovery potential).
- Refer Appendix C, Figure 13.

Emission source exclusions:

- Packaging and transport from aluminium smelter to fenestration manufacturing factory has been excluded.
- Packaging and transport from uPVC extrusion plant to fenestration manufacturing factory has been excluded.
- Packaging and transport from primary float glass manufacturing plant to glass double-glazing factory has been excluded.
- Glass spacer and secondary sealant for double glazing has been excluded.
- Packaging and transport from glass double glazing factory to fenestration manufacturing factory has been excluded.
- Packaging and transport from hardware and components manufacturer to fenestration manufacturing factory.
- Timber reveals for uPVC and aluminium windows and doors have been excluded.
- Manufactured fenestration transport aids for local transport have been excluded.
- Waste removal and disposal for all scrap, waste and packaging products have been excluded.
- No calculations for frame material energy efficiency, material strength, durability or service life have been undertaken.

Inventory of source emissions

Figure 1 shows materials as emissions source, emissions coefficients in kgCO_2-eq per kg of material, and sources for where the coefficients were derived from. Where data was not available specifically related to materials used in the calculations, proxies have been used across the uPVC and aluminium materials to ensure consistency of results. See system boundaries section for inclusions and exclusions in this analysis.

Emission source	Coefficient kg CO_2-eq per kg	Source	Comments
Aluminium powder coating *	3.790	Sinha & Kutnar, (2012)	Table 3, powder coating, aluminium sheet.
Aluminium, bauxite mining, alumina refining and smelting (China)	20.000	International Aluminium, (2022)	Figure 16, scenario 1, with a supply chain from China. Includes bauxite mining, alumina refining and smelting.
Aluminium, bauxite mining, alumina refining and smelting (Hamburg, Germany)	7.400	International Aluminium, (2022)	Figure 16, scenario 3, with a supply chain from Africa to Europe. Includes bauxite mining, alumina refining and smelting.
Aluminium, bauxite mining, alumina refining and smelting (New Zealand)	5.090	NZAS, (2023)	Year-end results, December 2022, scope 1 and 2 calculations, with email confirmation from NZAS for mining and refining scope 3 results.
Aluminum extrusion	1.030	Sinha & Kutnar, (2012)	Table 3, section bar extrusion, aluminium.
Aluminum extrusion (scrap)	1.030	Sinha & Kutnar, (2012)	Table 3, section bar extrusion, aluminium.
Cardboard case outers	1.420	Sada & Figli (2021)	Environmental Product Declaration, Sada Plant, Italy.
Components injected moulded PVC	3.300	Hammond & Jones, (2019)	PVC injection moulding.
Components stainless steel, fasteners	6.150	Hammond & Jones, (2019)	Worldwide average, 304 stainless.
Components steel, wheels	1.460	Hammond & Jones, (2019)	Steel, general UK (EU) average.
Components, extruded aluminium	1.030	Sinha & Kutnar, (2012)	Table 3, section bar extrusion, aluminium.
Direct Thermal Labels	0.940	Teorra, (2023)	Paper products, based on material use only, does not include chemical layer required to produce thermal label.
Hardware, handles, zinc cast alloy	4.180	Hammond & Jones, (2019)	Zinc, virgin. No other processing data available.
Insulated glass units - clear glass	1.440	Hammond & Jones, (2019)	Glass general, per kg.
Insulated glass units - toughened & Low E glass	1.670	Hammond & Jones, (2019)	Glass toughened, no value found for Low-E.
International shipping packaging - cardboard cases shipping long lengths of aluminium**	16.841	Multiple sources.	Calculations based on a combination of 9 packaging materials, calculated in separate spreadsheet. Multiple materials all recorded in emissions Figure 1, Inventory source of emissions.
International shipping packaging - timber cases shipping long lengths of uPVC**	82.988	Multiple sources.	Calculations based on a combination of 9 packaging materials, calculated in separate spreadsheet. Multiple materials all recorded in emissions Figure 1, Inventory source of emissions.
International shipping packaging - timber for crates	0.493	Hammond & Jones, (2019)	Timber, average.
International shipping packaging - plywood for crates	0.681	Hammond & Jones, (2019)	Timber, plywood.
International transport **	0.016	MBIE, (2023)	Climate change toolbox, international shipping. Units tonnes/kilometre. Shipped from International port of departure to Ports of Auckland.
local transport - house lots, internationally made ***	0.135	MBIE, (2023)	Climate change toolbox, local transport. Units tonnes/kilometre. Shipped from Ports of Auckland to Bombay Hills Pokeno.
local transport - house lots, made in NZ ***	0.135	MBIE, (2023)	Climate change toolbox, local transport. Units tonnes/kilometre. Shipped from Silverdale to Bombay Hills Pokeno.
local transport - containerloads ***	0.135	MBIE, (2023)	Climate change toolbox, local transport. Units tonnes/kilometre. Shipped from Ports of Auckland to Silverdale.
local transport - containerloads, made in NZ ***	0.135	MBIE, (2023)	Climate change toolbox, local transport. Units tonnes/kilometre. Shipped from Silverdale to Bombay Hills, Pokeno.

Figure 1: Material emissions coefficients

Emission source	Coefficient kg CO_2-eq per kg	Source	Comments
Low density polyethylene	2.080	Hammond & Jones, (2019)	Low density polyethylene (LDPE) resin.
Newsprint Roll	0.940	Teorra, (2023)	Paper products, based on material use only.
Polyamide	7.140	Technoform, (2022)	Polyamide 66 GF25 EPD.
Polypropylene, orientated film	3.430	Hammond & Jones, (2019)	Packaging tape, chemical resistant labels.
Polystyrene	4.390	Hammond & Jones, (2019)	Thermoformed expanded polystyrene.
Polyurethane flexible foam roll	4.840	Hammond & Jones, (2019)	Polyurethane flexible foam roll.
Timber	0.493	Hammond & Jones, (2019)	Timber, average.
Steel, electrogalvanised steel	3.030	Hammond & Jones, (2019)	Worldwide average, electroplating cold rolled, galvanised steel.
Steel, electrogalvanised steel (scrap)	3.030	Hammond & Jones, (2019)	Worldwide average, electroplating cold rolled, galvanised steel.
Steel strapping	3.030	Hammond & Jones, (2019)	Worldwide average, electroplating cold rolled steel
uPVC, raw materials and extrusion	3.230	Hammond & Jones, (2019)	PVC pipe. Including raw materials and extrusion - excluding galvanised steel.
uPVC, raw materials and extrusion (scrap)	3.230	Hammond & Jones, (2019)	PVC pipe. Including raw materials and extrusion - excluding galvanised steel.

* aluminium powder coating units: $kgCO_2$-eq per m^2
** cardboard case units: $kgCO_2$-eq per case
*** transport units: $kgCO_2$-eq per ton / kilometer

Assumptions and limitations

Aluminium

When previous carbon emissions studies have occurred, uPVC was shown to provide lower carbon emissions than aluminium (refer to Figure 43). Alcorn (2003) calculated aluminium smelting cradle-to-grave emissions at 8 $kgCO_2$-eq per kg of aluminium produced and PVC extruded at 4.349 $kgCO_2$-eq per kg of uPVC produced. International Aluminium (2022) calculated Oceania scope 1, 2 and 3 bauxite mining, alumina refining and smelting as 11.50 $kgCO_2$-eq per kg of aluminiuim produced - refer to International Aluminium, (2022) (Figure 16, Scenario 2, page 41). Oceania is categorised as the combination of Australia and New Zealand (International Aluminium (2022). However, due to NZ's energy mix with a high renewable energy electricity grid, NZ-sourced aluminium has significantly lower embodied carbon than most internationally sourced aluminium.

Rio Tinto's New Zealand Aluminium Smelter (“NZAS”) reported a total discharge of 5.09 $kgCO_2$-eq per kg of primary aluminium produced, year ending 31 December 2022, GHC calculations scope 1, 2 and 3 (bauxite mining, alumina refining and smelting) (NZAS, 2023).

Aluminium mining, refining and smelting for China and Germany were sourced from the life cycle assessment figures in an International Aluminium report on environmental metrics for the primary aluminium industry (International Aluminium, 2022). The report shows primary aluminium production for China at 20.00 $kgCO_2$-eq per kg of aluminium produced refer to International Aluminium, (2022) (Figure 16, Scenario 1, page 41) and Germany at 7.40 $kgCO_2$-eq per kg of aluminium produced refer to International Aluminium (2022) (Figure 16, scenario 3 page 41).

The powdercoat square metre data was supplied by APL Window Solutions with underlaying calculations excluded from the report due to confidentiality requirements.

Aluminium and uPVC scrap

Aluminium and uPVC extrusion profiles are extruded in long lengths, which are then cut to size during the manufacturing process. When importing long length extrusion profiles, the scrap rate can be reduced by optimsing profile lengths across multiple house lots, rather than just one house lot. However, this report has not optimised the extrusion profile lengths for containerised long lengths and has instead used the data provided for manufacturing one house lot of MH1 or MH2.

International transport

Existing CO_2-eq reports for fenestration, such as the Bougher and Braunstein (2022) report only include local transport in the emissions calculations and, therefore, would not reflect additional kgCO_2-eq emissions due to international shipping and transport of fenestration systems. Windows imported into NZ travel a significant distance to reach NZ ports. Therefore, this report undertakes the calculation process of a premanufactured house lot of windows to compare the emissions results of uPVC and aluminium fenestration systems imported into NZ from Germany and China compared to a NZ manufactured aluminium house lot. For a balanced view, this report also undertakes emissions calculations for container loads of uPVC (Germany only) and aluminium (China only) long length extrusion profiles.

For international transport, two shipping ports were considered due to the availability of uPVC and aluminium fenestration systems and access to large international shipping ports (refer to Appendix D):

- Hamburg, Germany – Ports of Auckland (refer to Figures 14 and 15).
- Guangzhou, China – Ports of Auckland (refer to Figure 16).

The calculation of transport emissions for MH1 and MH2 uPVC and aluminium premanufactured house lots were carried out based on the total house lot weight combined with packaging weight. The calculation of transport emissions for MH1 and MH2 long lengths were carried out based on volume, as the maximum container volume was exceeded before the maximum container weight was exceeded. Full container loads of aluminium long lengths of extrusion profiles was only assessed coming from Guangzhou, China. Full container loads of uPVC long lengths of extrusion profiles was only assessed coming from Hamburg, Germany.

International shipping – aluminium long length, cardboard cases

This report uses non-reusable cardboard cases for long lengths of aluminium extrusion profiles for MH1 and MH2 shipped to NZ via 40ft sea freighted containers. Silva, (2023) concluded that cardboard increases the weight of packing cases and represented the highest carbon footprint compared to polypropylene ("EPP"), and expanded polyethylene ("EPE") packing cases. However, while EPP and EPE cases have lower embodied carbon, they can leach into the environment.

According to Silva (2023) shipping with reusable EPP or EPE packaging is preferred for shorter supply chains where the packaging is returned to origin (Silva, 2023). International long distance shipping chains prefer to use cardboard packaging as the packaging return distances are large (Silva, 2023).

- Cardboard case design and calculations for aluminium long lengths (refer to Appendix E, Figures 17 and 18).
- The shipping case design was provided by Profile Group.

International shipping – uPVC long lengths, timber crates

This report uses timber crates for long lengths of uPVC extrusion profiles for MH1 and MH2 shipped to NZ via 40ft sea freighted containers.

- Timber case design and calculations (refer to Appendix E, Figure 19 and 20).
- The shipping case design was provided by Profile Group.

International shipping – timber and plywood crates, house lots

This report uses timber crates for premanufactured aluminium or uPVC house lots of MH1 and MH2 and shipped to NZ via 40ft sea freighted containers.

House lots of fenestration systems are flat packed, without glass, to reduce transit losses. If the premanufactured units are glazed, shipping and transport must occur vertically which is the least efficient packing option. If premanufactured house lots are glazed and stacked vertically the timber crates cannot be jostled too vigorously, otherwise the frame mitres, glass and hardware of the fenestration systems can be easily damaged in transit. Glazing could occur during manufacturing, before shipping; however, this report considers imported uPVC and aluminium fenestration glazing to occur onsite by a local NZ glazier. Glazing in NZ ensures the glass complies with NZS:4223 parts 1, 2, 3 & 4 Glazing in buildings and AS:4666 Insulating glass units. The glass is not from any specific supplier, as generic data was used for the glass emissions factor (refer to Figure 1, clear, toughened and low-e glass).

Horizontal flat packing premanufactured house lots reduces container packing efficiency as the size of windows and doors in a house lot varies, therefore air takes up container volume. This report considers multiple house lots per container, but further packing improvements could increase the number of house lots per container.

The following parameters were used to calculate the timber packaging of premanfactured house lots of MH1 and MH2 with uPVC and aluminium frame material (refer to Appendix E):

- Timber crate design (refer to Figure 20).
- uPVC and aluminium house lots timber crate packing. Packed horizontally, unglazed, with similar sized units crated together allowing for improved volume maximisation and NZ glazing (refer to Figure 21).
- Calculations for timber crate packaging for premanufactured house lots (refer to Figures 22, 23, 24, and 25).

International transport – container sea freight

The maximum cargo capacity of a 20ft container is 21,640 kg and the maximum cargo capacity of a 40ft container is 26,500 kg (refer to Appendix E, Figure 27). However, NZ road limitations place a 24,000 kg gross weight limitation up to 30,000kg with permits, for container transport options. However, 90% of NZ import and export containers are sideloaded, which is not acceptable for use with the special permit requirements for 30,000kg loads, which brings the maximum container load back to 24,000 kg (refer to Appendix E, Figure 28). This report has used 40ft containers with a maximum gross weight of 24,000kg to stuff the premanufactured house lots of fenestration systems and long lengths of window extrusion profiles to calculate international transport emissions.

Local transport

This report uses the following parameters for local transport (refer to Appendix F).

- Ports of Auckland - Silverdale Auckland (refer to Figure 29).
- Silverdale, Auckland – Bombay Hills, Pokeno (refer to Figure 30)
- Silverdale, Auckland – Bombay Hills, Pokeno, photo of windows and doors are transported by frail on a truck or trailer (refer to Figure 32).
- Ports of Auckland – Bombay Hills, Pokeno. Windows and doors are transported inside a 40ft container (refer to Figure 32).

Onsite glazing

All glazing for MH1 and MH2 for all frame material options is generic and not from a specific glass supplier. Only the glass emission value was taken into consideration not the manufacturing, spacers or secondary sealant required for double glazing (see system boundaries section).

The emissions calculations have occurred assuming all glazing will occur onsite. The uPVC fenestration systems could be imported into NZ glazed, which would increase the weight and alter the method of shipping, as glazed units can only be transported vertically, not flat packed as per this report. Fenestrations systems manufactured in NZ usually have a mix of factory and onsite glazing aspects.

To ensure comparisons between the results can be undertaken, this report assumes all fenestration systems will be glazed onsite (refer to Appendix G, Figures 33, 34, 35 and 36).

Results

The analysis was completed using an Excel spreadsheet. To ensure the methodology is transparent, the source of the emissions coefficient has been noted (refer to Figure 4) and the section system boundaries presents the inclusions and exclusions in the analysis. The following results were completed for aluminium and uPVC frame material, sourced from Guangzhou, China or Hamburg, Germany in either premanufactured house lots or long length containerised extrusion profiles. Additionally, results for NZ sourced aluminium house lots manufactured in NZ are used for comparison.

Some of the spreadsheet cells have been hidden to maintain the confidentiality of the data provided for the analysis.

- Results of the analysis for MH1 can be seen in Figures 2 and 3 indicated by shades of turquoise.
- Results of the analysis for MH2 can be seen in Figures 4 and 5 indicated by shades of blue.
- Results for the breakdown of the emission source material results for MH1 and MH2 can be seen in Figures 2 and 4 indicated by the colours orange (all glazing), red (all shipping and transport), apricot (all components and hardware) and purple (all frame) and match the colour coding used for Figures 6, 7, 8 and 9.

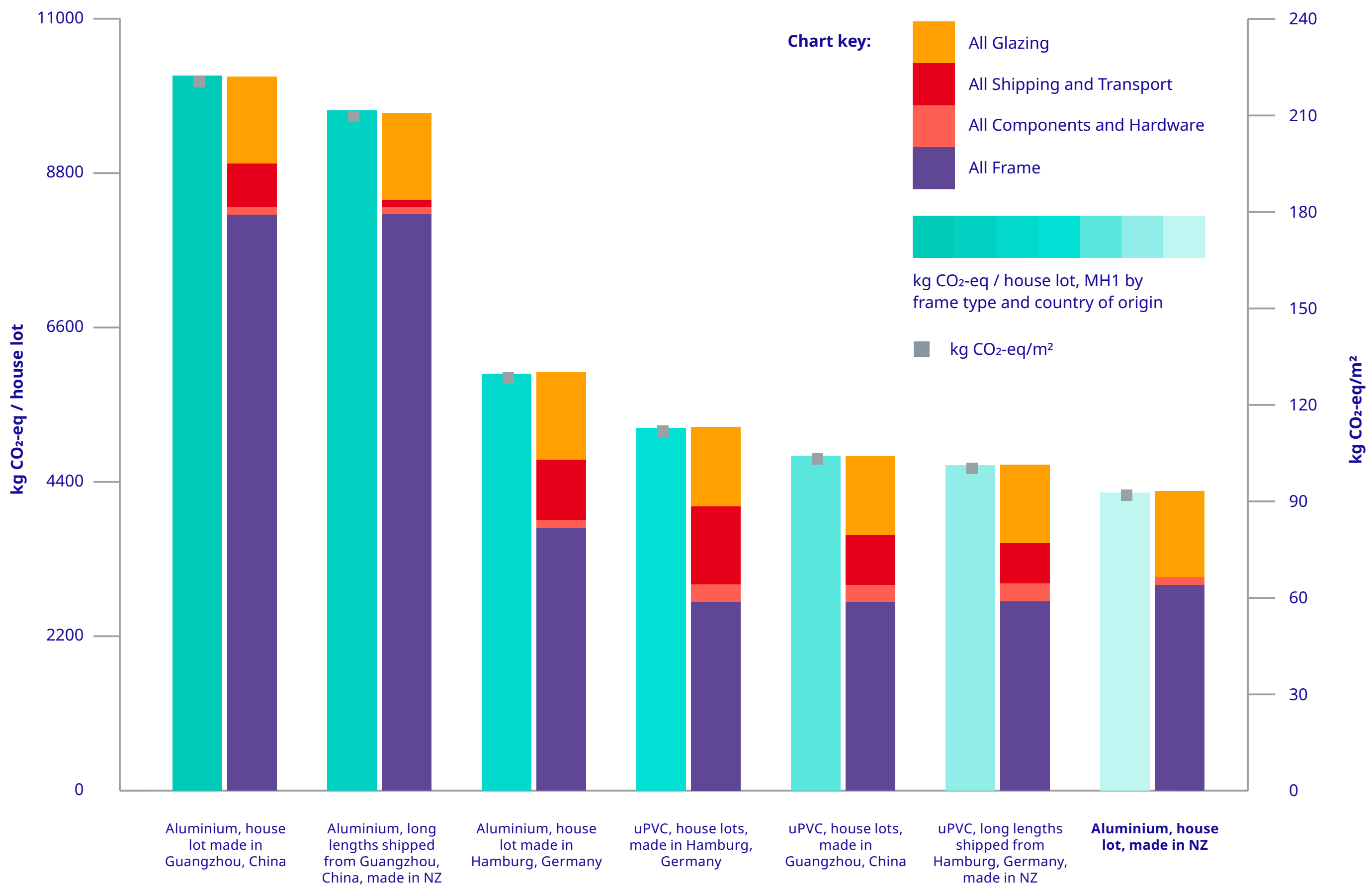

Figure 2: Chart of results. MH1, uPVC & aluminium, kg CO_2-eq per house lot or per m²

House lot label	Frame material	Country of origin	House lot description	Shipping method	House lot of windows and doors (m²)	kg CO_2-eq per house lot	kg CO_2-eq per m²	Percentage increase over NZ house lot
MH1	Aluminium	Guangzhou, China	Aluminium, house lot made in Guangzhou, China	House lot	46.208	10189	220.512	139.839%
MH1	Aluminium	Guangzhou, China	Aluminium, long lengths shipped from Guangzhou, China, made in NZ	Long lengths	46.208	9689	209.671	128.048%
MH1	Aluminium	Hamburg, Germany	Aluminium, house lot made in Hamburg, Germany	House lot	46.208	5935	128.430	39.686%
MH1	uPVC	Hamburg, Germany	uPVC, house lots, made in Hamburg, Germany	House lot	46.208	5166	111.803	21.602%
MH1	uPVC	Guangzhou, China	uPVC, house lots, made in Guangzhou, China	House lot	46.208	4770	103.235	12.284%
MH1	uPVC	Hamburg, Germany	uPVC, long lengths shipped from Hamburg, Germany, made in NZ	Long lengths	46.208	4633	100.265	9.052%
MH1	Aluminium	New Zealand	Aluminium, house lot, made in NZ	House lot	46.208	4248	91.942	Baseline

Figure 3: Table of results. MH1, uPVC & aluminium, kg CO_2-eq per house lot or per m²

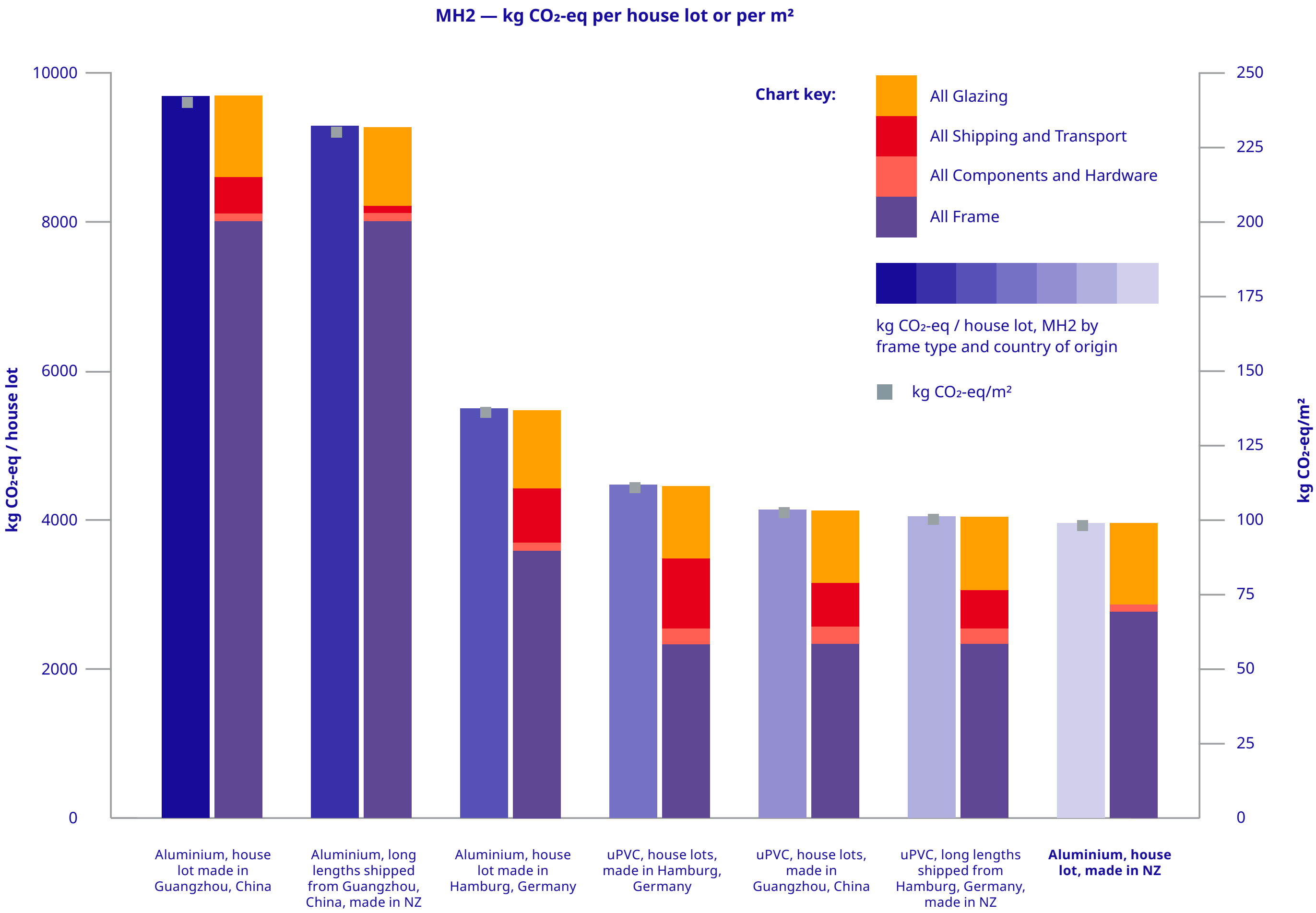

Figure 4: Chart of results. MH2, uPVC & aluminium, kg CO_2-eq per house lot or per m²

House lot label	Frame material	Country of origin	House lot description	Shipping method	House lot of windows and doors (m²)	kg CO_2-eq per house lot	kg CO_2-eq per m²	Percentage increase over NZ house lot
MH2	Aluminium	Guangzhou, China	Aluminium, house lot made in Guangzhou, China	House lot	40.341	9688	240.142	144.696%
MH2	Aluminium	Guangzhou, China	Aluminium, long lengths shipped from Guangzhou, China, made in NZ	Long lengths	40.341	9287	230.222	134.588%
MH2	Aluminium	Hamburg, Germany	Aluminium, house lot made in Hamburg, Germany	House lot	40.341	5494	136.186	38.769%
MH2	uPVC	Hamburg, Germany	uPVC, house lots, made in Hamburg, Germany	House lot	40.341	4474	110.893	12.996%
MH2	uPVC	Guangzhou, China	uPVC, house lots, made in Guangzhou, China	House lot	40.341	4137	102.555	4.500%
MH2	uPVC	Hamburg, Germany	uPVC, long lengths shipped from Hamburg, Germany, made in NZ	Long lengths	40.341	4049	100.358	2.261%
MH2	Aluminium	New Zealand	Aluminium, house lot, made in NZ	House lot	40.341	3959	98.139	Baseline

Figure 5: Table of results. MH2, uPVC & aluminium, kg CO_2-eq per house lot or per m²

The following results are the percentage breakdown of source material contributions in terms of emissions:

- uPVC fenestration systems percentage emissions for MH1, refer to Figure 6.
- uPVC fenestration systems percentage emisisons for MH2, refer to Figure 7.
- Aluminium fenestration systems percentage emissions for MH1, refer to Figure 8
- Aluminium fenestration systems percentage emissions for MH2, refer to Figure 9.
- The colour coding for Figures 6, 7, 8 and 9 match the breakdown of source material results shown for MH1 and MH2, refer to Figures 2 and 4.

All Glazing
All Shipping and Transport
All Components and Hardware
All Frame

Emissions source: uPVC frame material, MH1	uPVC, house lots, made in Hamburg, Germany		uPVC, house lots, made in Guangzhou, China		uPVC, long lengths shipped from Hamburg, Germany, made in NZ	
uPVC, raw materials and extrusion	26.502%		28.702%		30.143%	
uPVC, raw materials and extrusion (scrap)	0.530%		0.574%		0.000%	
Steel, electrogalvanised steel	21.178%		22.936%		27.623%	
Steel, electrogalvanised steel (scrap)	3.594%	51.804%	3.892%	56.104%	0.000%	57.766%
Hardware, handles, zinc cast alloy	1.677%		1.816%		1.870%	
Components injected moulded PVC	2.059%		2.230%		2.296%	
Components steel, wheels	0.547%		0.593%		0.610%	
Components stainless steel, fasteners	0.739%	5.023%	0.801%	5.440%	0.825%	5.601%
International shipping, cases (timber)	3.186%		3.450%		2.640%	
International shipping, cases (plywood)	5.576%		6.039%		0.000%	
International shipping, cases (cardboard)	0.000%		0.000%		0.000%	
International transport	12.394%		0.370%		9.363%	
local transport - house lots, internationally made	0.342%		5.124%		0.000%	
local transport - containerloads	0.000%		0.000%		0.258%	
local transport - containerloads, made in NZ	0.000%		0.000%		0.203%	
local transport - house lots, made in NZ	0.000%	21.497%	0.000%	14.983%	0.000%	12.464%
Insulated glass units - clear glass	6.653%		7.206%		7.419%	
Insulated glass units - toughened & Low E glass	15.022%	21.675%	16.268%	23.474%	16.750%	24.169%
	100.000%		100.000%		100.000%	

Figure 6: Breakdown of MH1, uPVC frame material, percentage contribution of emissions

Emissions source: uPVC frame material, MH2	uPVC, house lots, made in Hamburg, Germany		uPVC, house lots, made in Guangzhou, China		uPVC, long lengths shipped from Hamburg, Germany, made in NZ	
uPVC, raw materials and extrusion	26.605%		28.767%		30.133%	
uPVC, raw materials and extrusion (scrap)	0.666%		0.720%		0.000%	
Steel, electrogalvanised steel	21.260%		22.988%		27.897%	
Steel, electrogalvanised steel (scrap)	3.987%	52.518%	4.311%	56.787%	0.000%	58.030%
Hardware, handles, zinc cast alloy	1.529%		1.653%		1.689%	
Components injected moulded PVC	2.038%		2.204%		2.252%	
Components steel, wheels	0.586%		0.634%		0.648%	
Components stainless steel, fasteners	0.725%	4.878%	0.784%	5.274%	0.801%	5.390%
International shipping, cases (timber)	3.081%		3.331%		2.652%	
International shipping, cases (plywood)	5.291%		5.721%		0.000%	
International shipping, cases (cardboard)	0.000%		0.000%		0.000%	
International transport	12.160%		5.019%		9.407%	
local transport - house lots, internationally made	0.215%		0.233%		0.000%	
local transport - containerloads	0.000%		0.000%		0.166%	
local transport - containerloads, made in NZ	0.000%		0.000%		0.202%	
local transport - house lots, made in NZ	0.000%	20.747%	0.000%	14.304%	0.000%	12.428%
Insulated glass units - clear glass	6.214%		6.719%		6.867%	
Insulated glass units - toughened & Low E glass	15.644%	21.858%	16.915%	23.635%	17.286%	24.152%
	100.000%		100.000%		100.000%	

Figure 7: Breakdown of MH2, uPVC frame material, percentage contribution of emissions

Emissions source: Aluminium frame material, MH1	MH1, aluminium, house lot made in Guangzhou, China		MH1, aluminium, long lengths shipped from Guangzhou, China, made in NZ		MH1 - aluminium, house lot made in Hamburg, Germany		MH1, aluminium, house lot, made in NZ	
Aluminium, mining, refining and smelting	70.381%		74.020%		44.712%		42.960%	
Aluminum extrusion	3.280%		3.812%		5.632%		7.867%	
Aluminum extrusion (scrap)	0.345%		0.000%		0.592%		0.826%	
Aluminium powder coating	4.700%		4.943%		8.069%		11.272%	
Polyamide	2.249%	80.954%	2.365%	85.140%	3.861%	62.866%	5.393%	68.318%
Hardware, handles, zinc cast alloy	0.491%		0.516%		0.842%		1.177%	
Components injected moulded PVC	0.302%		0.318%		0.519%		0.725%	
Components steel, wheels	0.065%		0.068%		0.111%		0.155%	
Components stainless steel, fasteners	0.112%		0.117%		0.192%		0.268%	
Components, extruded aluminium	0.031%	1.000%	0.032%	1.052%	0.053%	1.718%	0.074%	2.399%
International shipping packaging - timber for crates	1.615%		0.000%		2.773%		0.000%	
International shipping packaging - plywood for crates	2.591%		0.000%		4.449%		0.000%	
International shipping packaging cardboard cases all materials	0.000%		0.326%		0.000%		0.000%	
International transport	1.594%		0.622%		7.170%		0.000%	
local transport - house lots, internationally made	0.074%		0.000%		0.127%		0.000%	
local transport - containerloads	0.000%		0.020%		0.000%		0.000%	
local transport - containerloads, made in NZ	0.000%		0.040%		0.000%		0.000%	
local transport - house lots, made in NZ	0.000%	5.874%	0.000%	1.008%	0.000%	14.519%	0.091%	0.091%
Insulated glass units - clear glass	3.793%		3.989%		6.513%		9.097%	
Insulated glass units - toughened & Low E glass	8.378%	12.171%	8.811%	12.801%	14.385%	20.898%	20.094%	29.192%
	100.000%		100.000%		100.000%		100.000%	

Figure 8: Breakdown of MH1, aluminium frame material, percentage contribution of emissions

Emissions source: Aluminium frame material, MH2	**MH2, aluminium, house lot made in Guangzhou, China**		**MH2, aluminium, long lengths shipped from Guangzhou, China, made in NZ**		**MH2, aluminium, house lot made in Hamburg, Germany**		**MH2, aluminium, house lot, made in NZ**	
Aluminium, mining, refining and smelting	72.424%		75.544%		47.252%		45.102%	
Aluminum extrusion	3.033%		3.891%		5.348%		7.421%	
Aluminum extrusion (scrap)	0.697%		0.000%		1.229%		1.706%	
Aluminium powder coating	4.480%		4.673%		7.900%		10.962%	
Polyamide	2.043%	82.677%	2.131%	86.239%	3.603%	65.332%	5.000%	70.191%
Hardware, handles, zinc cast alloy	0.495%		0.516%		0.873%		1.211%	
Components injected moulded PVC	0.297%		0.310%		0.524%		0.727%	
Components steel, wheels	0.068%		0.071%		0.120%		0.167%	
Components stainless steel, fasteners	0.117%		0.202%		0.207%		0.287%	
Components, extruded aluminium	0.032%	1.010%	0.021%	1.119%	0.057%	1.781%	0.079%	2.471%
International shipping packaging - timber for crates	1.423%		0.000%		2.508%		0.000%	
International shipping packaging - plywood for crates	2.279%		0.000%		4.018%		0.000%	
International shipping packaging cardboard cases all materials	0.000%		0.333%		0.000%		0.000%	
International transport	1.430%		0.635%		6.607%		0.000%	
local transport - house lots, internationally made	0.045%		0.000%		0.117%		0.000%	
local transport - containerloads	0.000%		0.020%		0.000%		0.000%	
local transport - containerloads, made in NZ	0.000%		0.037%		0.000%		0.000%	
local transport - house lots, made in NZ	0.000%	5.176%	0.000%	1.025%	0.000%	13.250%	0.087%	0.087%
Insulated glass units - clear glass	3.219%		3.357%		5.675%		7.876%	
Insulated glass units - toughened & Low E glass	7.918%	11.137%	8.259%	11.617%	13.962%	19.638%	19.375%	27.251%
	100.000%		100.000%		100.000%		100.000%	

Figure 9: Breakdown of MH2, aluminium frame material, percentage contribution of emissions

Interpretation of results

- Other international studies on uPVC and aluminium window and door systems CO_2-eq emissions likely exclude international transport in the calculations.
- uPVC and aluminium shipped internationally in premanufactured house lots or containerized long lengths resulted in higher kgCO_2-eq emissions than emissions from NZ manufactured house lots, made from aluminium sourced in NZ.
- Increases in emissions from international transport were dependent upon Country of Origin and whether house lots or long lengths were shipped.
- International shipping and transport emissions for a uPVC house lot premanufactured in Hamburg, Germany contributed emissions of 1110.5 kgCO_2-eq (21.5%) per house lot for MH1 and 928.2 kgCO_2-eq (20.75%) per house lot for MH2.
- International shipping and transport emissions for MH1 uPVC shipped in long lengths reduced to 577.45 kgCO_2-eq (12.46%) per house lot for MH1 and 503.3 kgCO_2-eq (12.42%) per house lot for MH2 if shipping and transporting long lengths of uPVC from Hamburg, Germany.
- International shipping and transport emissions for MH1, uPVC house lot premanufactured in Guangzhou, China contributed emissions of 714.7 kgCO_2-eq (14.98%) per house lot for MH1 and 591.8 kgCO_2-eq (14.30%) per house lot for MH2.
- International shipping and transport emissions for an aluminium house lot premanufactured in Hamburg, Germany contributed emissions of 861.7 kgCO_2-eq (14.52%) per house lot for MH1 and 728.1 kgCO_2-eq

(13.25%) per house lot for MH2.

- International shipping and transport emissions for an aluminium house lot premanufactured in Guangzhou, China contributed emissions of 598.5 kgCO_2-eq (5.87%) per house lot for MH1 and 501.5 kgCO_2-eq (5.18%) per house lot for MH2.
- International shipping and transport emisisons reduced if shipping long lengths of aluminium from Guangzhou, China to 97.7 kgCO_2-eq (1.01%) per house lot for MH1 and 95.2 kgCO_2-eq (1.03%) per house lot for MH2.
- Aluminium International (2022) calculated the average German bauxite mining, refining and smelting emisisons at 7.40 kgCO_2-eq per kg of aluminium produced.
- Aluminium International (2022) calculated the average Chinese bauxite mining, refining and smelting emisisons at 20.00 kgCO_2-eq per kg of aluminium produced.
- International Aluminium (2022) calculated Oceania's bauxite mining, refining and smelting emissions at 11.4 kgCO_2-eq per kg of aluminium produced.
- NZ's aluminium smelting options produce far lower emissions than the commonly available coefficients with NZAS producing 5.09 kgCO_2-eq per kg of aluminium produced scope 1, 2 and 3 (bauxite mining, alumina refining and smelting).
- Overestimating NZ sourced aluminium smelting emissions adversely affects local sourcing and manufacturing for the NZ Window and Door industry.
- **The lowest emissions calculated in this report came from fenestration systems manufactured in NZ from aluminium sourced in NZ which is referred to as the baseline house lot in the results.**
- All of the following results are percentage increases from the baseline house lots of MH1 and MH2 manufactured in NZ from aluminium sourced in NZ.
- Aluminium house lots of MH1 premanufactured in Guangzhou, China and shipped to NZ demonstrated a 139.84% increase in kgCO_2-eq per house lot which reduced to a 128.05% increase per house lot if shipping long lengths compared to the baseline house lot.
- Aluminium house lots of MH2 premanufactured in Guangzhou, China and shipped to NZ demonstrated a 144.70% increase in kgCO_2-eq per house lot which reduced to a 134.59% per house lot if shipping long lengths.
- Aluminium house lots of fenestration systems premanufactured in Hamburg, Germany and shipped to NZ demonstrated a 39.69% increase in kgCO_2-eq per house lot for MH1 and a 38.77% increase in kgCO_2-eq per house lot for MH2.
- uPVC house lots of MH1 premanufactured in Hamburg, Germany and shipped to NZ demonstrated a 21.60% increase in kgCO_2-eq per house lot which reduced to a 9.05% increase per house lot if shipping long lengths compared to the baseline house lot.
- uPVC house lots of MH2 premanufactured in Hamburg, Germany and shipped to NZ demonstrated a 13.00% increase in kgCO_2-eq per house lot which reduced to 2.26% kgCO_2-eq per house lot if shipping long lengths compared to the baseline house lot.
- uPVC house lots of MH1 premanufactured in Guangzhou, China demonstrated an increase in kgCO_2-eq of 12.28% per house lot and a 4.50% increase in kgCO_2-eq per house lot for MH2 compared to the baseline house lot.
- The galvanised steel reinforcement required inside of uPVC profiles for stiffening contributes emissions of an average of 28.54% per house lot for MH1 and 28.97% per house lot for MH2 averaged across house lots and long lengths.
- This report has not completed thermal modelling to compare the thermal performance of uPVC with internal galvanised steel reinforcement and aluminium frame materials for MH1 and MH2. Therefore, this report cannot interpret the affect galvanised steel reinforcement inserts have on the energy efficiency of uPVC fenestration systems compared with aluminium fenestration systems.

Further research

Further research could include a full LCA in accordance with ISO 14040 (ISO, 2023) which provides the principles and framework for LCA and ISO 14044 which specifiies requirements and provides guidelines for LCA work (ISO, 2023).

The analysis does not take into account the advantages of recycling aluminium. It is worth noting that the energy required to remelt used aluminium is a mere 5% of the original energy required to mine bauxite, refine alumina and smelt it into aluminium (Raabe et al., 2022). Therefore, it would be beneficial to conduct further research to understand the positive impacts of using a greater proportion of recycled material as primary inputs.

Durability and service life are important aspects in frame material selection as the effects of ultraviolet degradation could impact uPVC fenestration systems installed in NZ. This report did not undertake an indepth review of durability and service life of frame material options. Further research could be undertaken to understand whether ultraviolet degradation in uPVC as a frame material alters the frames durability and possibly affects the service life expectancy in a NZ context.

Thermal modelling is an important selection criteria for frame material options. This report did not undertake thermal modelling to understand the energy efficiency of uPVC or aluminium frames for MH1 or MH2. Further work could include understanding the impact of galvanised steel reinforcement in uPVC fenestration system thermal modelling calculations for MH1 and MH2 and compare the results to aluminium frames.

Having access to an easy to use embodied carbon calculator will be more important as the construction industry transitions towards an increase in carbon accounting. This report did not undertake a carbon emissions calculation for MH1 and MH2 using the BRANZ LCAQuick tool as the process seemed far more complicated than compared with using the NZGBC calculator. MH1 and MH2 were modelled in the NZBC calculator, for a summary refer to Appendix K, Figures 40 and 41 with full details shown in Appendix L, Figures 42, 43, 44 and 45. Further work could involve comparing the emissions calculations from LCAQuick for MH1 and MH2 to the emissions completed in this report.

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Appendix A – Window schedules

MH1 single-story, detached dwelling window schedule

MH1 - Detached dwelling
Building Type - 19 Units = 46.21m²

Unit size		2.222 x 1.585	1.330x 2.430	2.222 x 0.830	2.222 x 2.430	1.030 x 0.630	1.330 x 1.630	0.630 x 1.630	1.030 x 1.430	2.222 x 0.910	1.330 x 0.830
Unit area		3.522	3.232	1.844	5.399	0.649	2.168	1.027	1.473	2.022	1.104
		D1	W1	W2	D2	W3	W4	W5	W6	D3	W7
Units	19	1	4	3	2	2	3	1	1	1	1
Total Area	46.208	3.522	12.928	5.532	10.798	1.298	6.504	1.027	1.473	2.022	1.104

Figure 10: MH1,single-story, detached dwelling window schedule

MH2 - Townhouse
Building Type - 16 Units = 40.35m²

Unit size		2.222 x 1.585	1.330x 2.430	2.222 x 0.830	2.222 x 2.430	1.030 x 0.630	1.330 x 1.630	0.630 x 1.630	1.030 x 1.430	2.222 x 0.910
Unit area		3.522	3.232	1.844	5.399	0.649	2.168	1.027	1.473	2.022
		D1	W1	D2	W2	W3	W4	W5	D3	W6
Units	16	1	3	2	4	2	1	1	1	1
Total Area	40.352	3.522	9.696	10.798	8.672	1.298	1.027	1.473	2.022	1.844

Figure 11: MH2, townhouse window schedule

Appendix B – Coal statistics, imports and exports 1992-2022

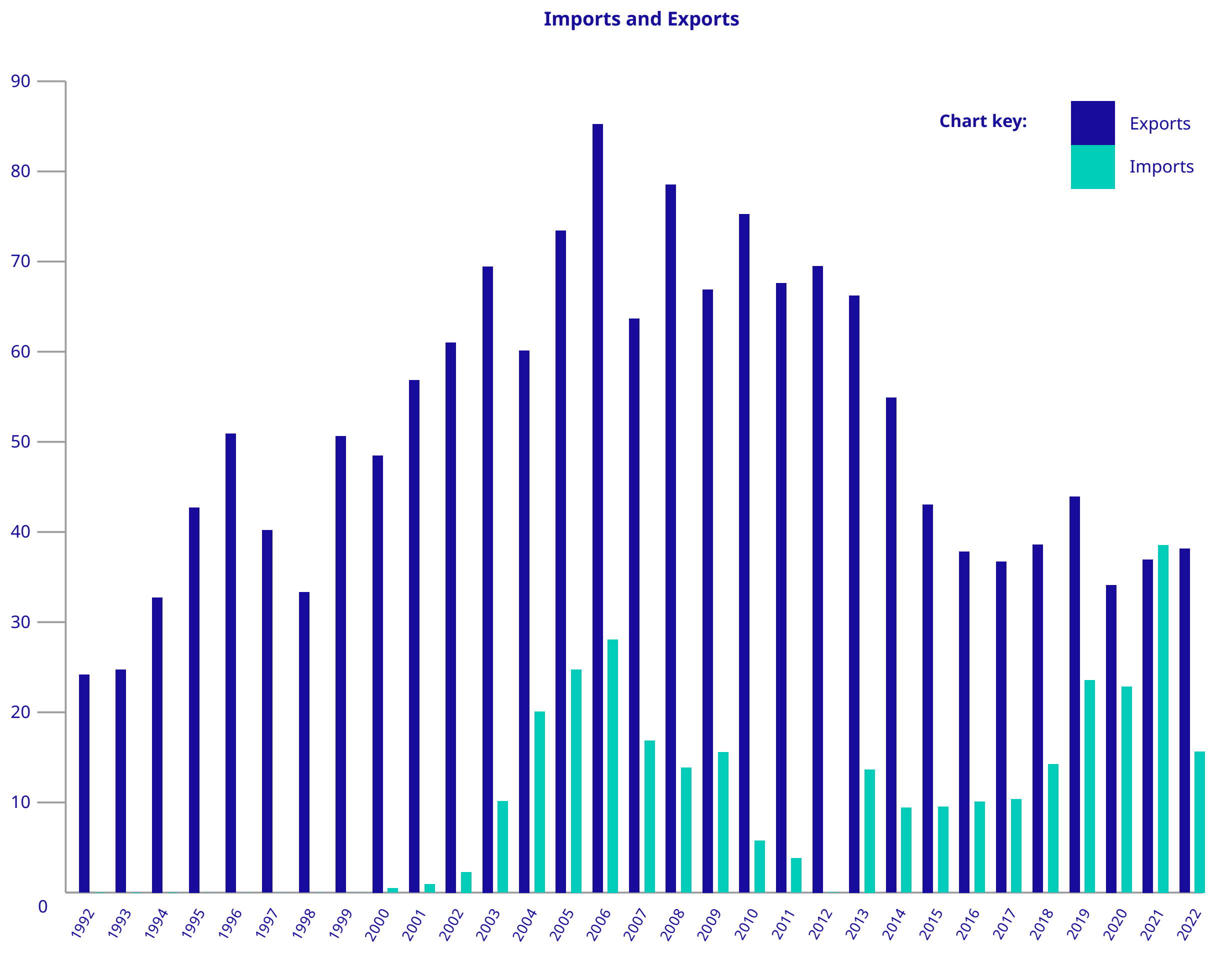


Figure 12 Coal statistics, imports and exports 1992-2022
Source: (MBIE, Coal statistics, 2023)

Appendix C – Whole of life embodied carbon modules

This appendix provides information about the data used for the materials related to CO_2eq calculations undertaken in this report based on a house lot of windows and doors (refer Figure 10, MH1 & refer Figure 11, MH2). The analysis is set out using the modular structure for describing the building life cycle in EN 15804 and illustrated in Figure 21 (Circular Ecology, 2023)

Figure 21, modules represented in this report:

- Modules A1–A3 (product stage), representing manufacture of materials up to the factory gate.
- Modules A4 (construction stage), representing international and local transport.

Figure 15, modules which are not represented in this report:

- Module A5 (construction stage), representing installation
- Modules B1-B7 (use stage)
- Modules C1 to C4 (end of life stage)
- Module D (future reuse, recycling or energy recovery potention)

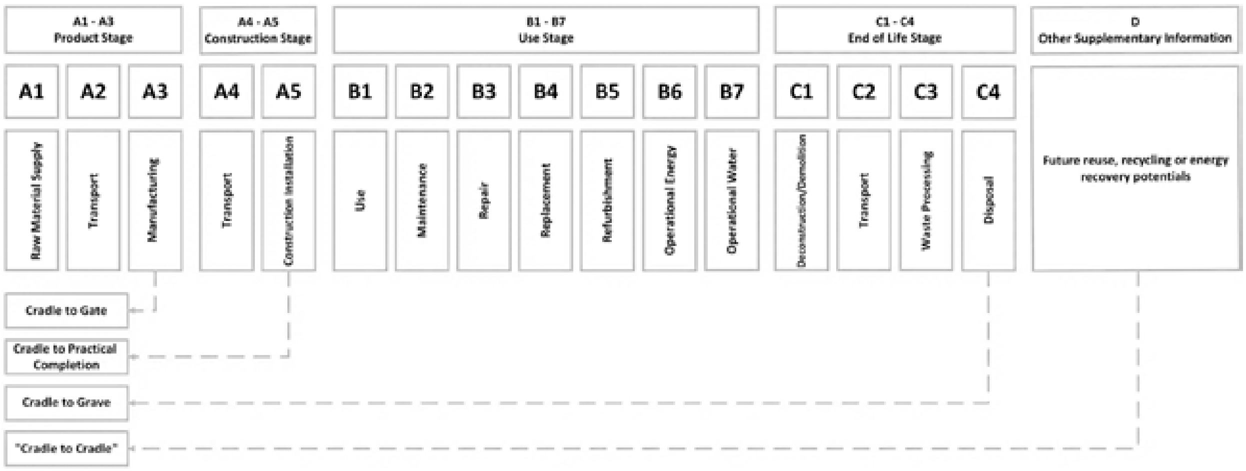


Figure 13: Whole of life embodied carbon for building products
Source: (Circular Ecology, 2023)

Appendix D – International transport distances

Hamburg to Auckland, New Zealand

Singapore is a stopover on the sea journey from Hamburg, Germany to Auckland, New Zealand.

Sea Journey – Hamburg, Germany – Singapore

15,718.23 km

Transit Time: 27 days 6 hours

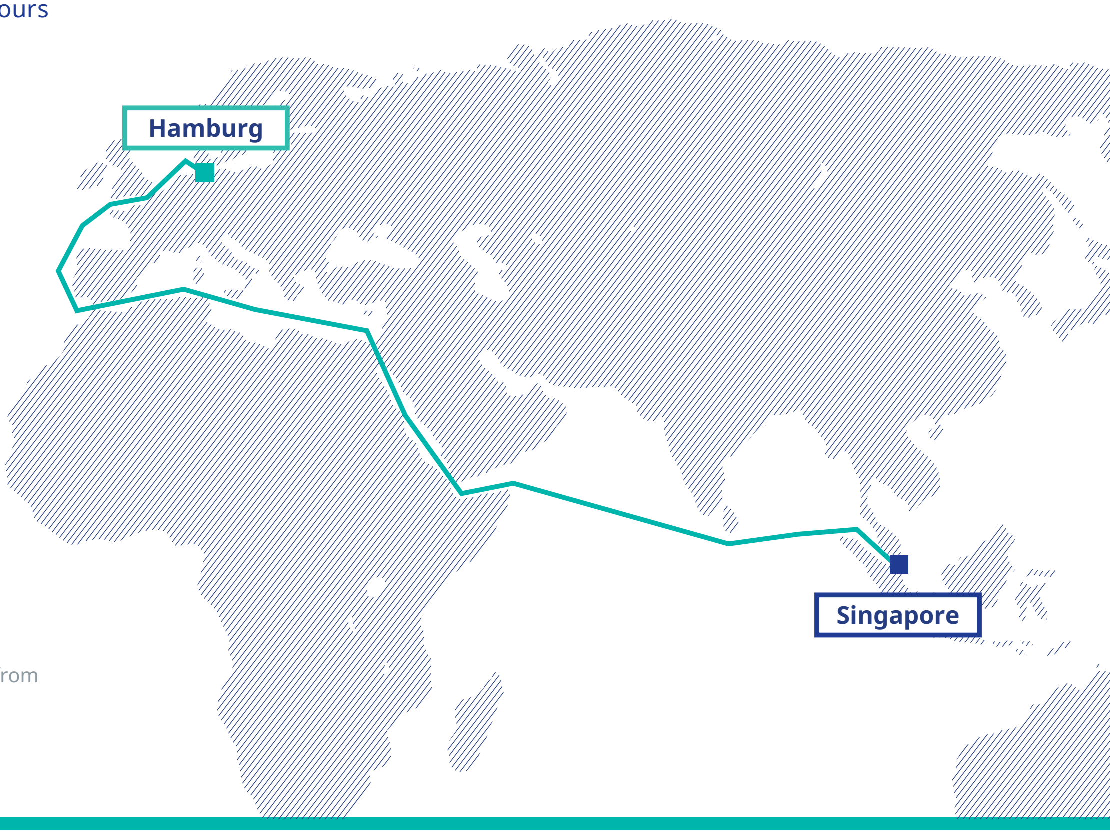


Figure 14: Map of sea journey from Hamburg to Singapore

Total sea journey from Hamburg, Germany to Auckland, New Zealand

15,718.23 km – Hamburg to Singapore

8,978.99 km – Singapore to Auckland

24,697.22 km

Transit time: 42 days, 19 hours

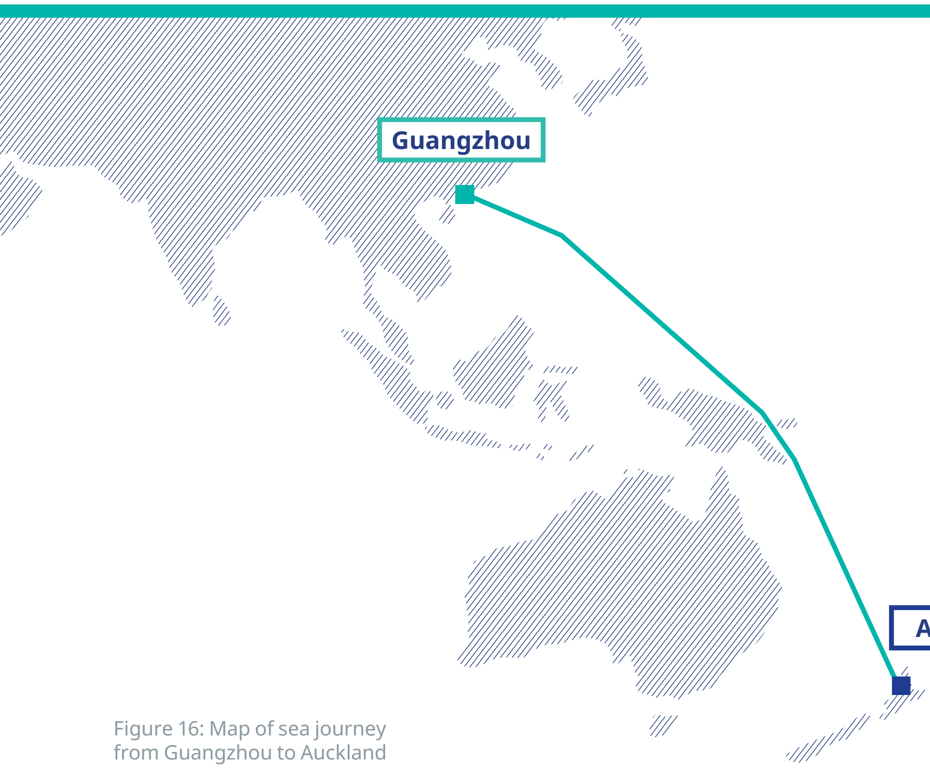
Sea Journey – Singapore – Auckland, New Zealand

8,978.99 km

Transit Time: 15 days 13 hours

Figure 15 Map of sea journey from Singapore to Auckland

Guangzhou to Auckland, New Zealand



Guangzhou, Guangdong, China – Auckland, New Zealand

(9427.18 km)

Transit Time: 16 days 7 hours

Figure 16: Map of sea journey from Guangzhou to Auckland

Appendix E – International transport

Cardboard cases (aluminium long lengths)

Emission source	kg CO_2-eq per case	Emissions percentage per case	Source	Comments
Rough sawn timber	9.022	53.570%	Hammond & Jones, (2019)	Timber, average
Cardboard case outers	2.556	15.177%	Sada & Figli (2021)	Environmental Product Declaration, Sada Plant, Italy.
Steel strapping	1.578	9.369%	Hammond & Jones, (2019)	Steel, organic coated sheet.
Polyurethane flexible foam roll	2.035	12.084%	Hammond & Jones, (2019)	Thermoformed expanded polystyrene.
Newsprint Roll	0.298	1.770%	Teorra, (2023)	Paper products, based on material use only
Low density polyethylene	0.429	2.545%	Hammond & Jones, (2019)	Low density polyethylene (LDPE) resin
Polystyrene	0.850	5.046%	Hammond & Jones, (2019)	Thermoformed expanded polystyrene.
Direct Thermal Labels	0.016	0.095%	Teorra, (2023)	Paper products, based on material use only, does not include chemical layer required to produce thermal label.
Polypropylene, orientated film	0.058	0.344%	Hammond & Jones, (2019)	Packaging tape, chemical resistant labels.
Emissions per 1 case	16.841	100.000%		

Figure 17: Cardboard case emissions per case

Figure 18: Aluminium cardboard case image

Timber crates (uPVC long lengths)

Emission source	kg CO_2-eq per case	Emissions percentage per case	Source	Comments
Timber	80.659	97.193%	Hammond & Jones, (2019)	Timber, average
Steel strapping	1.562	1.883%	Hammond & Jones, (2019)	Worldwide average, electroplating cold rolled steel
Newsprint Roll	0.693	0.835%	Teorra, (2023)	Paper products, based on material use only
Direct Thermal Labels	0.016	0.019%	Teorra, (2023)	Paper products, based on material use only, does not include chemical layer required to produce thermal label.
Polypropylene, orientated film	0.058	0.070%	Hammond & Jones, (2019)	Packaging tape, chemical resistant labels.
Emissions per 1 case	82.988	100.000%		

Figure 19: Timber crate emissions per crate.

Figure 20: uPVC timber crate image

International transport – timber crate, house lot, design, packing and weights (house lots)

International shipping crate design

Design was supplied by Pope Packaging, NZ
Similar design was supported by Anton, Klima NZ

Construction:

- Timber base 150 x 25mm rough sawn timber - window sits on it
- 90x45, timber bearers for forklight - 1m long x 6
- Plywood for the sides, end, top - 12-15mm
- Plywood – Monterey pine, kiln dried, maximum 20% moisture, 480 kg / m³
- Timber – Monterey pine, rough sawn, minimum moisture content 45%, 580 kg / m³
- Timber weights calculated (Timberpolis, 2023)
- Timber m³ calculated (Spikes menu, 2023)
- Multiple windows packed into one crate
- Plywood between each unit
- Units to be flat packed
- No glazing
- Hardware attached
- Crate screwed together

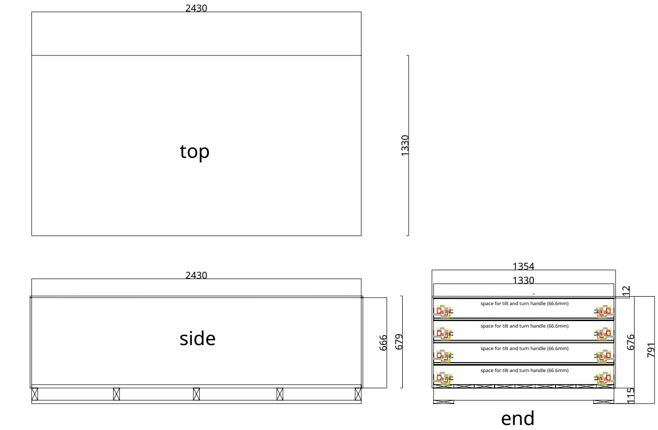
Figure 21: Representation of international shipping crate*
* not actual crate calculated, image simply represents a crate of similar design.

International transport – timber crates, packing, (house lots)

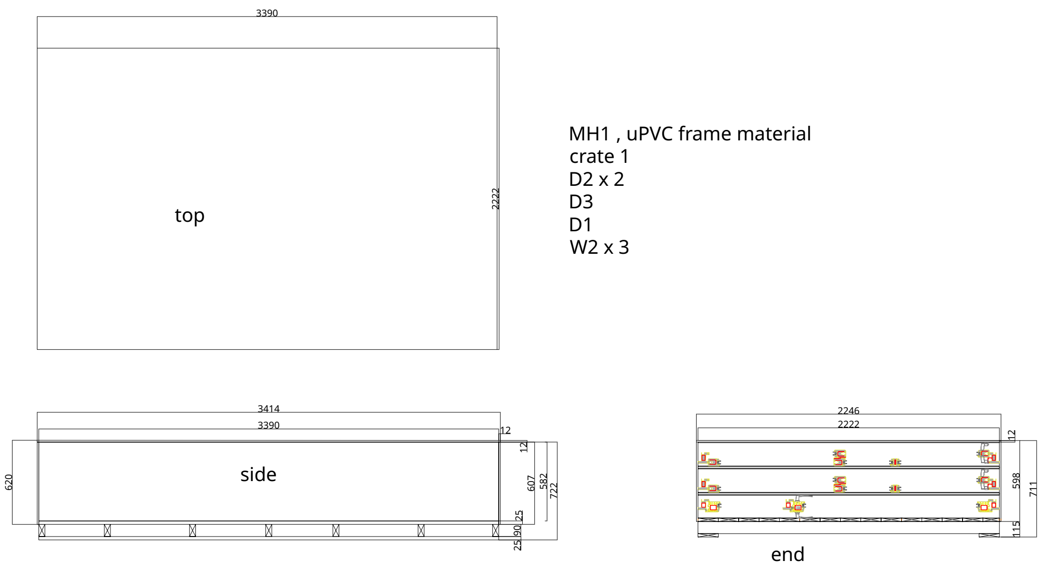
Similar crate design used for uPVC and aluminium house lots MH1 and MH2 for international shipping.

Figure 22: Example of uPVC crate design, crate 1, 2, & 3

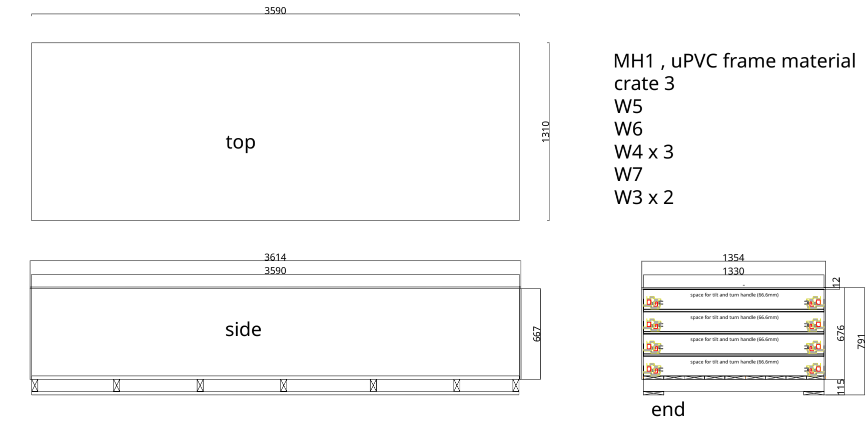
MH1 , uPVC frame material
crate 2 - W1 x 4



MH1 , uPVC frame material
crate 1
D2 x 2
D3
D1
W2 x 3



MH1 , uPVC frame material
crate 3
W5
W6
W4 x 3
W7
W3 x 2



International transport
– timber crates, weights (house lots)

MH1 and MH2 uPVC house lot international shipping, timber packaging weight calculations.

MH1, UPVC, CRATE 1

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	3.390	0.150	0.025	16.5	0.210	121.659
crate forklift bearers	2.222	0.090	0.045	7	0.063	36.536
plywood sides	3.414	0.607	0.012	2	0.050	23.873
plywood ends	2.222	0.607	0.012	2	0.032	15.538
plywood top	3.414	2.246	0.012	1	0.092	44.167
plywood inner linings between units	2.222	3.390	0.012	2	0.181	86.775
Total					0.628	328.548

MH1, UPVC, CRATE 2

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	2.430	0.150	0.025	10.5	0.096	55.495
crate forklift bearers	1.354	0.090	0.045	5	0.027	15.903
plywood sides	2.454	0.665	0.012	2	0.039	18.800
plywood ends	1.330	0.665	0.012	2	0.021	10.189
plywood top	2.454	1.354	0.012	1	0.040	19.139
plywood inner linings between units	2.430	1.330	0.012	3	0.116	55.847
Total					0.340	175.372

MH1, UPVC, CRATE 3

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	3.590	0.150	0.025	10.50	0.141	81.987
crate forklift bearers	1.354	0.090	0.045	7	0.038	22.264
plywood sides	3.614	0.667	0.012	2	0.058	27.769
plywood ends	1.330	0.667	0.012	2	0.021	10.220
plywood top	3.614	1.354	0.012	1	0.059	28.186
plywood inner linings between units	3.590	1.330	0.012	3	0.172	82.507
Total					0.489	252.93

Figure 23: MH1, uPVC house lot timber packaging

MH2, UPVC, CRATE 1

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	3.390	0.150	0.025	16.5	0.210	121.659
crate forklift bearers	2.222	0.090	0.045	7	0.063	36.536
plywood sides	3.414	0.607	0.012	2	0.050	23.873
plywood ends	2.222	0.607	0.012	2	0.032	15.538
plywood top	3.414	2.246	0.012	1	0.092	44.167
plywood inner linings between units	2.222	3.390	0.012	2	0.181	86.775
Total					0.628	328.548

MH2, UPVC, CRATE 2

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	2.430	0.150	0.025	10.5	0.096	55.50
crate forklift bearers	1.354	0.090	0.045	5	0.027	15.90
plywood sides	2.454	0.665	0.012	2	0.039	18.80
plywood ends	1.330	0.665	0.012	2	0.021	10.19
plywood top	2.454	1.354	0.012	1	0.040	19.14
plywood inner linings between units	2.430	1.330	0.012	3	0.116	55.85
Total					0.340	175.37

MH2, UPVC, CRATE 3

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	1.630	0.150	0.025	10.5	0.064	37.225
crate forklift bearers	1.354	0.09	0.045	4	0.022	12.722
plywood sides	1.654	0.665	0.012	2	0.026	12.671
plywood ends	1.330	0.665	0.012	2	0.021	10.189
plywood top	1.654	1.354	0.012	1	0.027	12.900
plywood inner linings between units	1.630	1.330	0.012	3	0.078	37.461
Total					0.239	123.168

Figure 24: MH2, uPVC house lot timber packaging

MH1 and MH2 aluminium international shipping, timber packaging weight calculations.

MH1, ALUMINIUM, CRATE 1

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	3.390	0.150	0.025	16.5	0.210	121.659
crate forklift bearers	2.222	0.090	0.045	7	0.063	36.536
plywood sides	3.414	0.567	0.012	2	0.046	22.300
plywood ends	2.222	0.567	0.012	2	0.030	14.514
plywood top	3.414	2.246	0.012	1	0.092	44.167
plywood inner linings between units	2.222	3.390	0.012	2	0.181	86.775
Total					0.622	325.951

MH1, ALUMINIUM, CRATE 2

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	2.430	0.150	0.025	10.5	0.096	55.495
crate forklift bearers	1.354	0.090	0.045	5	0.027	15.903
plywood sides	2.454	0.398	0.012	2	0.023	11.251
plywood ends	1.330	0.398	0.012	2	0.013	6.098
plywood top	2.454	1.354	0.012	1	0.040	19.139
plywood inner linings between units	2.430	1.330	0.012	3	0.116	55.847
Total					0.315	163.733

MH1, ALUMINIUM, CRATE 3

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	3.590	0.150	0.025	10.5	0.141	81.987
crate forklift bearers	1.354	0.090	0.045	7	0.038	22.264
plywood sides	3.614	0.297	0.012	2	0.026	12.365
plywood ends	1.33	0.297	0.012	2	0.009	4.551
plywood top	3.614	1.354	0.012	1	0.059	28.186
plywood inner linings between units	3.590	1.330	0.012	3	0.172	82.507
Total					0.446	231.859

Figure 25: MH1, aluminium house lot timber packaging

MH2, ALUMINIUM, CRATE 1

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	3.390	0.150	0.025	16.5	0.210	121.659
crate forklift bearers	2.222	0.090	0.045	7	0.063	36.536
plywood sides	3.414	0.567	0.012	2	0.046	22.300
plywood ends	2.222	0.567	0.012	2	0.030	14.514
plywood top	3.414	2.246	0.012	1	0.092	44.167
plywood inner linings between units	2.222	3.390	0.012	2	0.181	86.775
Total					0.622	325.951

MH2, ALUMINIUM, CRATE 2

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	2.430	0.150	0.025	10.5	0.096	55.495
crate forklift bearers	1.354	0.090	0.045	5	0.027	15.903
plywood sides	2.454	0.398	0.012	2	0.023	11.251
plywood ends	1.330	0.398	0.012	2	0.013	6.098
plywood top	2.454	1.354	0.012	1	0.040	19.139
plywood inner linings between units	2.430	1.330	0.012	3	0.116	55.847
Total					0.315	163.733

MH2, ALUMINIUM, CRATE 3

description	length	width	thickness	number of	m³	kg
floor timber + crate feet	1.630	0.150	0.025	10.5	0.064	37.225
crate forklift bearers	1.354	0.090	0.045	4	0.022	12.722
plywood sides	1.654	0.398	0.012	2	0.016	7.584
plywood ends	1.330	0.398	0.012	2	0.013	6.098
plywood top	1.654	1.354	0.012	1	0.027	12.900
plywood inner linings between units	1.630	1.330	0.012	3	0.078	37.461
Total					0.220	113.990

Figure 26: MH2, aluminium house lot timber packaging

International transport, container loads (long lengths)

SPECIFICATIONS	20' Dry Cargo Container 8'6" STANDARD		40' Dry Cargo Container 8'6" STANDARD	
Inside Cubic Capacity	32.8cu.m (1,158 cu.ft)		67.2cu.m (2,372 cu.ft)	
Cargo Capacity	21,640 kg (47,716 Ibs.)		26,500 kg (58,433 Ibs.)	
Tare weight	2,360 kg (5,204 Ibs.)		3,980 kg (8,776 Ibs.)	
	OUTSIDE:	**INSIDE:**	**OUTSIDE:**	**INSIDE:**
Length	6.05m (19.84 ft)	5.90m (19.35 ft)	12.19m (40.00 ft)	12.01m (39.39 ft)
Width	2.44m (8.00 ft)	2.35m (7.71 ft)	2.44m (8.00 ft)	2.35m (7.71 ft)
Height	2.59m (8.50 ft)	2.38m (7.80 ft)	2.59m (8.50 ft)	2.38m (7.80 ft)
DOOR SIZE:				
Height	2.28m (7.48 ft)		2.28m(7.48 ft)	
Width	2.33m (7.64 ft)		2.33m(7.64 ft)	

Figure 27: 20ft and 40ft container dimensions and usable container stuffing. Source: (PACCON, 2023).

We take it personally

Operational Restrictions

Road Limitation

- Standard road weight limitations:-

Road limitation is technically 24.0 tonne gross (container + cargo weight) per 20'/40'.

However, with a permit and appropriate trailer (chassis), road carriers can carry up to 30.0 tonne gross (container + cargo weight).

Note that containers of this weight may not be able to be sidelifted (most deliveries in NZ have containers placed on the ground with sidelifter / swinglift - and return for empty later).

A lot of customers cannot unpack cargo if container is left on the trailer, so if a container is heavy the shipper needs to check with the consignee re unpacking means.

  - 90% of import/export cartage jobs are with sideloader - NZ does not work on trailer/loading bay configurations - this is outdated in NZ.
  - Above 30 tonne, major problems are incurred, and special heavy haul rigs are required - we do not usually quote on this, as this exceeds the loading capacity of most containers.

Hazardous/Dangerous Cargo

- Regulations in respect to the importation of HZ and DG cargo into New Zealand are flexible. However, explosives of Class 1 demand specific attention and are subject to discharge at specified areas that may be away from the container terminal berth.

- All HZ and DG cargoes are to be handled, packed and transported in accordance with the recommendations of the IMO IMDG code, and must be accompanied by DG certificate which must be received prior to arrival of the vessel.

- In order to facilitate discharge and delivery in New Zealand, confirmation of acceptance by New Zealand Port is advisable prior to acceptance and shipment of the cargo.

Figure 28: New Zealand road maximum weight limitations. Source: (OOCL, 2023)

Appendix F – Local transport

MH1 & MH2, containerised long lengths, Ports of Auckland to Silverdale.

35.2 kilometres

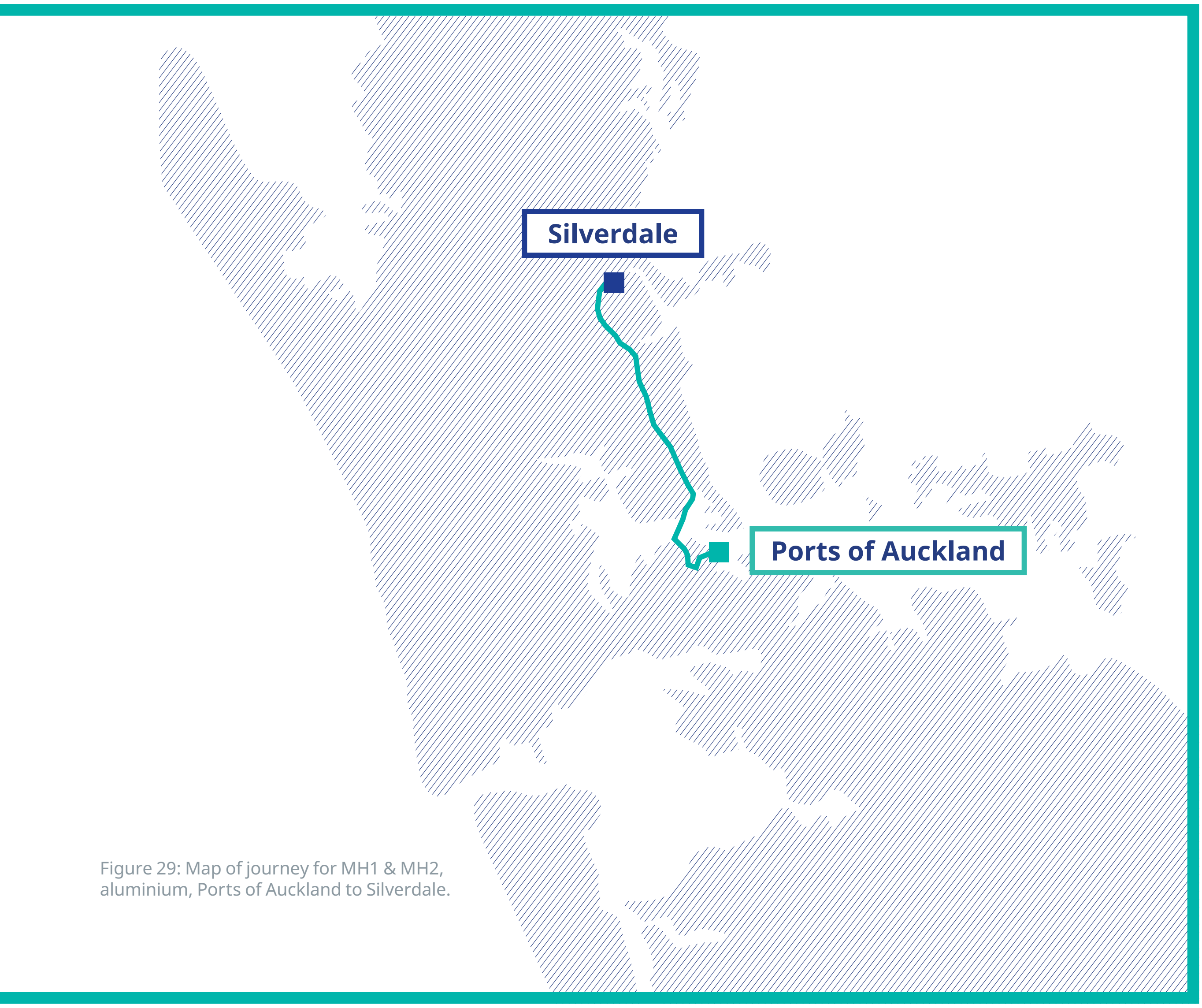


Figure 29: Map of journey for MH1 & MH2, aluminium, Ports of Auckland to Silverdale.

MH1 & MH2, manufactured units, NZ manufacturing facility, Silverdale to Bombay Hills, Pokeno.

80.7 Kilometres

Figure 30: Map of journey for MH1 & MH2, aluminium, Silverdale to Bombay Hills

MH1 & MH2 manufactured in NZ, local transport on a trailer frail.

Figure 31: Windows and doors loaded on a trailer frail

MH1 & MH2, uPVC and aluminium, internationally sourced premanufactured units, Ports of Auckland to Bombay Hills, Pokeno.

51.8 Kilometres

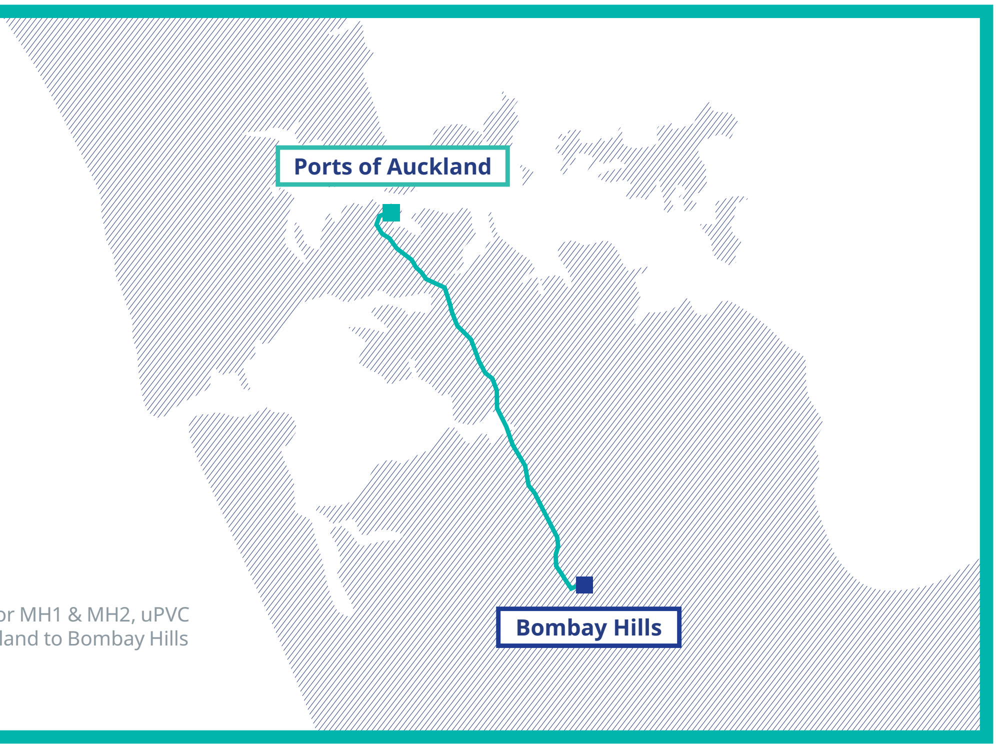


Figure 32: Map of journey for MH1 & MH2, uPVC & aluminium, Ports of Auckland to Bombay Hills

Appendix G – Onsite glazing

MH1 & MH2, uPVC

MH1 UPVC - HOUSELOT OF GLAZING						
Glass description	**Glass thickness**	**Area (m²)**	**Unit Weight (kg)**	**Coefficient $kgCO_2$-eq/kg**	**kg CO_2-eq / unit**	**Comments**
4mm Clr	4	7.620	76.200	0.910	69.342	Hammond and Jones, primary glass
4mm Clr	4	12.700	127.000	0.910	115.570	Hammond and Jones, primary glass
5mm Clr	5	2.840	35.500	0.910	32.305	Hammond and Jones, primary glass
			238.700		217.217	
4mm Clr Tgh	4	2.790	27.900	1.350	37.665	Hammond and Jones, toughened glass
4mm Clr Tgh	4	8.510	85.100	1.350	114.885	Hammond and Jones, toughened glass
4mm Solux-E	4	7.620	76.200	1.350	102.870	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E	4	12.700	127.000	1.350	171.450	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh	4	2.790	27.900	1.350	37.665	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh	4	8.510	85.100	1.350	114.885	No values found for Low-e, using Hammond & Jones Toughened glass
5mm Solux-E	5	2.840	35.500	1.350	47.925	No values found for Low-e, using Hammond & Jones Toughened glass
		68.920	**464.700**		**627.345**	
			703.400		**844.562**	**kg CO_2-eq / houselot**

Figure 33: MH1, uPVC, house lot of glazing emissions

MH2 UPVC - HOUSELOT OF GLAZING						
Glass description	**Glass thickness**	**Area (m²)**	**Unit Weight (kg)**	**Coefficient $kgCO_2$-eq/kg**	**kg CO_2-eq / unit**	**Comments**
4mm Clr	4	7.610	76.100	0.910	69.251	Hammond and Jones, primary glass
4mm Clr	4	9.720	97.200	0.910	88.452	Hammond and Jones, primary glass
5mm Clr	5	1.580	19.750	0.910	17.973	Hammond and Jones, primary glass
			193.050		175.676	
4mm Clr Tgh	4	2.790	27.900	1.350	37.665	Hammond and Jones, toughened glass
4mm Clr Tgh	4	8.510	85.100	1.350	114.885	Hammond and Jones, toughened glass
4mm Solux-E Tgh	4	2.790	27.900	1.350	37.665	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh	4	8.510	85.100	1.350	114.885	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E/	4	7.610	76.100	1.350	102.735	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E/	4	9.720	97.200	1.350	131.220	No values found for Low-e, using Hammond & Jones Toughened glass
5mm Solux-E/	5	1.580	19.750	1.350	26.663	No values found for Low-e, using Hammond & Jones Toughened glass
		60.420	**419.050**		**565.718**	
			612.100		**741.393**	**kg CO_2-eq / houselot**

Figure 34: MH2, uPVC, house lot of glazing emissions

MH1 & MH2, aluminium

MH1, ALUMINIUM - HOUSELOT OF GLAZING						
Glass description	**Glass thickness**	**Area (m²)**	**Unit Weight (kg)**	**Coefficient kgCO₂-eq/kg**	**kg CO₂-eq / unit**	**Comments**
4mm Clr	4	14.970	149.700	0.910	136.227	Hammond and Jones, primary glass
4mm Clr	4	8.020	80.200	0.910	72.982	Hammond and Jones, primary glass
5mm Clr	5	2.030	25.375	0.910	23.091	Hammond and Jones, primary glass
5mm Clr	5	1.050	13.125	0.910	11.944	Hammond and Jones, primary glass
			268.400		244.244	
4mm Clr Tgh	4	1.980	19.800	1.350	26.730	Hammond and Jones, toughened glass
4mm Clr Tgh	4	2.960	29.600	1.350	39.960	Hammond and Jones, toughened glass
4mm Clr Tgh	4	4.560	45.600	1.350	61.560	Hammond and Jones, toughened glass
4mm Clr Tgh	4	2.640	26.400	1.350	35.640	Hammond and Jones, toughened glass
4mm Solux-E	4	14.970	149.700	1.350	202.095	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E/	4	8.020	80.200	1.350	108.270	No values found for Low-e, using Hammond & Jones Toughened glass
5mm Solux-E	5	2.030	25.375	1.350	34.256	No values found for Low-e, using Hammond & Jones Toughened glass
5mm Solux-E	5	1.050	13.125	1.350	17.719	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh/	4	1.980	19.800	1.350	26.730	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux -E Tgh/	4	2.960	29.600	1.350	39.960	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh/	4	4.560	45.600	1.350	61.560	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh/	4	2.640	26.400	1.350	35.640	No values found for Low-e, using Hammond & Jones Toughened glass
		76.420	**511.200**		**690.120**	
			779.600		**934.364**	**kg CO₂-eq / houselot**

Figure 35: MH1, aluminium, house lot of glazing emissions

MH1, ALUMINIUM - HOUSELOT OF GLAZING						
Glass description	**Glass thickness**	**Area (m²)**	**Unit Weight (kg)**	**Coefficient kgCO₂-eq/kg**	**kg CO₂-eq / unit**	**Comments**
4mm Clr	4	11.470	114.700	0.910	104.377	Hammond and Jones, primary glass
5mm Clr	5	0.680	8.500	0.910	7.735	Hammond and Jones, primary glass
5mm Clr	5	1.050	13.125	0.910	11.944	Hammond and Jones, primary glass
4mm Clr	4	8.020	80.200	0.910	72.982	Hammond and Jones, primary glass
			216.525		197.038	
4mm Clr Tgh	4	1.980	19.800	1.350	26.730	Hammond and Jones, toughened glass
4mm Clr Tgh	4	2.960	29.600	1.350	39.960	Hammond and Jones, toughened glass
4mm Clr Tgh	4	4.560	45.600	1.350	61.560	Hammond and Jones, toughened glass
4mm Clr Tgh	4	2.640	26.400	1.350	35.640	Hammond and Jones, toughened glass
4mm Solux-E	4	8.020	80.200	1.350	108.270	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E	4	11.470	114.700	1.350	154.845	No values found for Low-e, using Hammond & Jones Toughened glass
5mm Solux-E	5	0.680	8.500	1.350	11.475	No values found for Low-e, using Hammond & Jones Toughened glass
5mm Solux-E	5	1.050	13.125	1.350	17.719	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh	4	1.980	19.800	1.350	26.730	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh	4	2.960	29.600	1.350	39.960	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh	4	4.560	45.600	1.350	61.560	No values found for Low-e, using Hammond & Jones Toughened glass
4mm Solux-E Tgh	4	2.640	26.400	1.350	35.640	No values found for Low-e, using Hammond & Jones Toughened glass
		66.720	**459.325**		**593.359**	
			675.850		**790.397**	**kg CO₂-eq / houselot**

Figure 36: MH2, aluminium, house lot of glazing emissions

Appendix H – Why consider upfront carbon emissions?

The New Zealand Building and Construction sector contributes 6.7% towards NZ's Gross Domestic Product ("GDP"), 10.5% of NZ's employment forces, representing 12.6% of NZ businesses (MBIE, 2022). The value of monthly importation of building products increased by 107% from January 2015 to June 2022 (MBIE, 2022). Understanding the upfront carbon emissions of imported products is essential to understanding the effect imported products have for NZ and global emissions. This report only considers the upfront carbon emissions of fenestration systems for uPVC and aluminium frame material.

A 2022 building and construction report (MBIE, 2022) analysed trends in NZ's importation of building products and identified 123 building product-related categories with a top 20 considered at a high level of the harmonised system ("HS codes"). The top 20 choices for building product importation codes with the most likely uPVC or aluminium fenestration system importation code being prefabricated products, structures & buildings (refer to Figure 37). Knowing what HS code a house lot of windows or long lengths of window extrusion profiles are imported with is challenging, as homeowners, builders, and architects may choose a different code to lodge the product import status. At the highest level, prefabricated products seemed the most likely fenestration system import code, with a current import value of $75M per month (MBIE, 2022).

Building and construction product categories
1. Aluminium structures and products
2. Base metal products and fittings
3. Bitumen-based products
4. Building stone, earth stone, brick and similar products
5. Cement, plastering and similar materials
6. Ceramic products
7. Glass and glassware
8. HVAC products
9. Insulation products
10. Iron and steel structures and products
11. Luminaires, light fittings and fire alarms
12. Machine, machine tools and equipment for building and construction
13. Paints and varnishes, carpet, flooring
14. Plastic products and builders' ware of plastics
15. Prefabricated products, structures and bu ildings
16. Putty, mastics, adhesives, sea lants and similar products
17. Sanitary ware, fixtures and plumbing
18. Wood and articles of wood
19. Multi-industry products
20. other (including elevators, escalators, extractor fans, hot water boilers, security devices, etc).

Figure 37: Building and construction product categories for imported products

Between 2005 and 2017, global CO_2 emissions increased by approximately 19%, and as of 2015, emissions from international trade contributed 27.2% of gobal CO_2 emissions (Guilhoto & Yamano, 2020). As of 2020, the NZ construction sector contributed 20% of NZ's emissions (MBIE, 2021) due to the energy consumption and materials used in the building process, and as of 2022, emissions reduced to 19.1% (Stats NZ, 2022). While NZ's emissions are decreasing, more than the current reduction pace is needed to ensure the country meets the requirements of the 2030 and 2050 emissions reduction targets.

In 2020 MBIE prepared a mandatory whole-of-life embodied carbon reporting framework to support the NZ construction industries' need to reduce emissions. The role of the emissions reduction framework is to achieve the Ministry's vision of the construction industry becoming accountable for carbon emissions by calculating and quantifying emissions from construction products and materials at all stages of the building life cycle (MBIE, 2020). With NZ emissions not reducing fast enough, and the importation of building products increasing, this report attempts to fill the gaps in current knowledge of fenestration carbon emissions because mandatory emissions reporting is coming soon.

When a transport plane is loaded with fuel, the fuel is used for that trip, howeever, calculating CO_2 emissions for sea freight is more difficult because fuel loaded in shipping ports is not fully used on each trip (Guilhoto & Yamano, 2020). Bunker fuel is the fuel used for international transport, however, bunker fuel is only reported as a memo item in NZ's Greenhouse Gas Inventory and does not have to meet NZ Govt's emissions reduction requirements (Ministry of Transport, 2023).

OECD material consumption refers to the tonnes of material used in an economy such as materials extracted or harvested in the country, plus materials and products imported, minus materials and products exported (OECD, 2023). NZ's net consumption of materials exceeds Germany and China and in the OECD NZ is the 6th highest consumer of materials per capita (OECD, 2023. Refer to Figure 38).

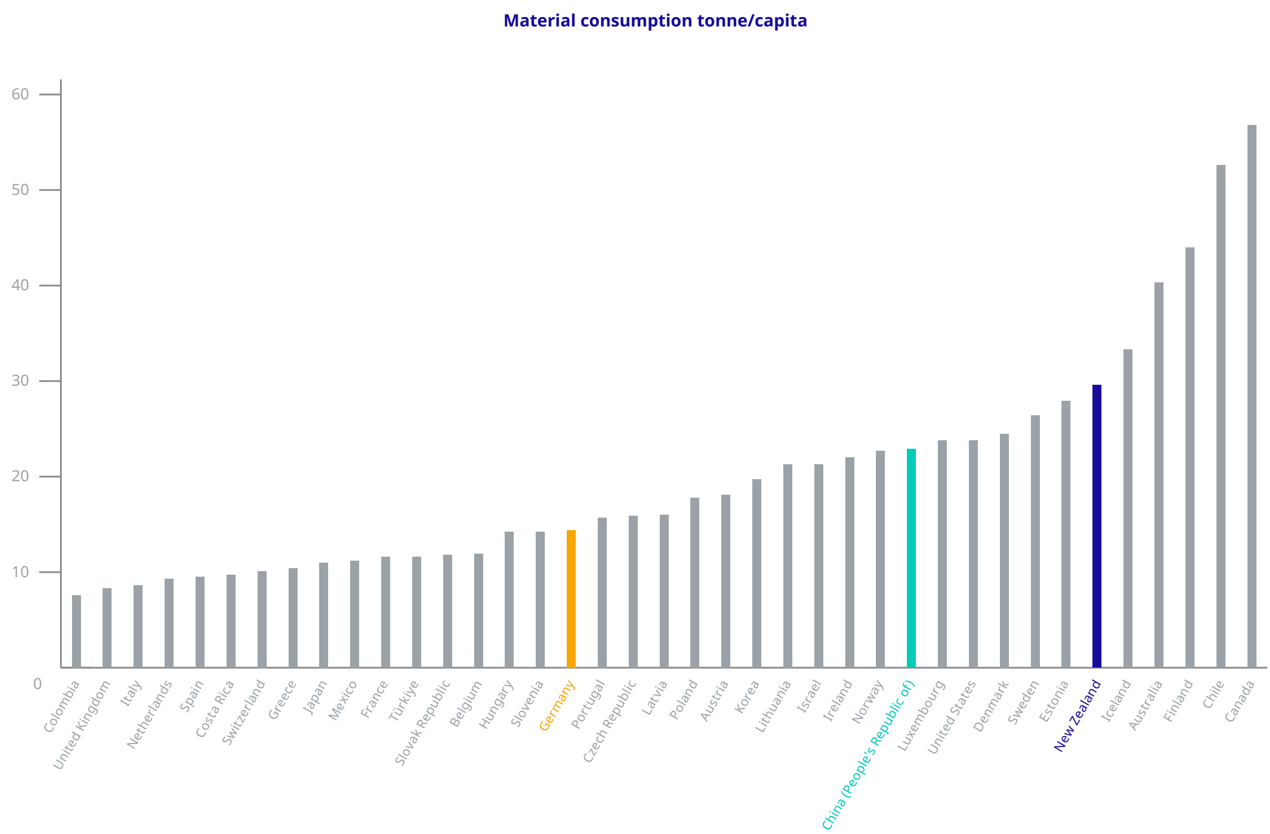


Figure 38: OECD material consumption tonne/capita, Germany, China and New Zealand highlighted
Source: OECD, (2023).

For the construction industry, importing products with international shipping and transport requires determining what is an essential product and what is better supported by a local supply chain. Not accounting for international shipping and transport emissions could cause unseen harm in NZ carbon emissions because globally, shipping contributes 11% to the total carbon dioxide emissions in the transport sector (refer to Figure 39). NZ specific local transport emisisons are also important to consider because the NZ Transport domestic sector energy consumption increased by 5% compared to 2020 (IEA, 2023), with a 17% increase in energy consumption from 1990 to 2019 (Hipgrave, 2021).

Transport sector distribution of carbon dioxide emissions worldwide

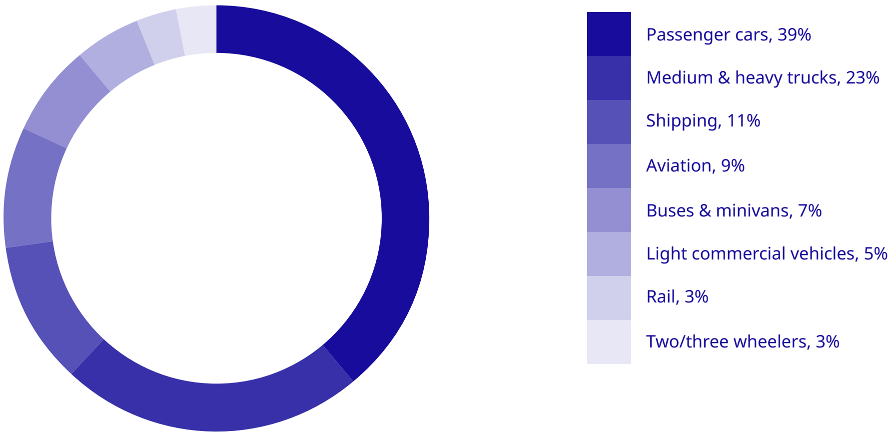


Figure 39: Distribution of global carbon dioxide emissions produced by the transportation sector in 2021, by subsector. Source: Tiseo, (2023).

Bougher and Braunstein (2022) researched the carbon footprint of an aluminium fenestration system and concluded that it is essential to include embodied and operational carbon calculations for buildings in the future. Upfront carbon is essential to consider because some materials have high energy efficiency allowing for lower operational carbon, but have high upfront carbon, and having information on embodied carbon emissions could lead to different material choices (Havre, 2022).

Analysing the upfront carbon results for modules A1-A3 & A4 (refer to Appendix C, Figure 13) including international transport but excluding waste disposal plays a vital role in understanding the actual carbon cost of importing premanufactured house lots or long lengths of fenestration systems into NZ.

Energy supply mix

Bougher and Braunstein (2022) indicated that CO_2 emissions differed depending on which State was assessed due to differences in energy sources such as hydroelectric power, wind, natural gas, nuclear, and coal. A 2020 study of NZ's renewable energy showed that renewable electricity generation is 82.1% (Jaques, Sullivan, Dowdell, Curtis, & Butler, 2020).

Overall, NZ has the third highest primary renewable electricity grid supply (after Norway and Iceland) in the OECD (MBIE, 2021). The NZ Government aims to achieve 50% of total energy consumption from renewable sources by 2035, and high electricity production from renewable energy puts NZ's energy consumption in a seemingly good light. However, NZ's total energy use from renewables is currently at 28.4% (MBIE, 2021). Therefore, NZ would be remiss if renewable energy was the only method to reach the 2030 and 2050 emissions reduction targets. It will only be through a transition towards sustainable renewable energy sources and reducing carbon intensive supply chains that the 2030 and 2050 carbon reduction goals will be reached. However, because NZ's electricity grid is 82.1% renewable, the carbon emissions coefficient for NZ aluminium smelting will reflect emissions from NZ's renewable energy.

Appendix I – Fenestration systems overall performance

Energy efficiency should not be the only criterion when choosing a frame material. Taking a fenestration system overall performance and whole-of-life approach to sustainable design would require frame material selection to consider energy efficiency, frame material strength, service life and embodied carbon (Sinha & Kutnar, 2012).

Energy efficiency

Recent changes to the NZ acceptable solution H1/AS1, energy efficiency, has seen the requirement for frame material to provide higher R-values with climate zone 1 increasing from R0.26 to R0.46 for windows and doors (MBIE, 2023). Frame conductivity (refer to Figure 40) shows that aluminium has high conductivity, with PVC having low conductivity, however, uPVC requires galvanised steel reinforcement inserts for structural integrity. This report has not undertaken further research to understand the impact of energy efficiency in a NZ context.

Frame material	Conductivity W/(mK)
Aluminium	205
PVC	0.200
Steel	50.200

Figure 40: Fenestration frame material conductivity
Source: Georgia State University, (2023)

Durability and service life

The fenestration market share of uPVC as a frame material differs around the world. Asif, Muneer and Kubie (2005) found that uPVC windows had a mean durability and service life of 24.1 years with aluminium having a mean durability and service life of 43.6 years. Asif et al (2005) also found that Southern Europe (Spain, Portugal, Italy and Greece) preferred aluminium as a frame material. A comparison of Italy's and NZ's annual climate values indicates similar average daily maximum and minimum temperatures (refer to Appendix J, Figure 42). This report has not undertaken further research to understand the impact of durability and service life in a NZ context.

Frame material strength

Aluminium is three times lighter than steel but is strong, tough and elastic (refer to Figure 41). As a fenestration system material, uPVC requires galvanised steel reinforcement as an internal stiffening device inside various structural parts of frames, mullions, and panels. This report has not undertaken further research to understand the impact of material strength in a NZ context.

Material	Metric density
Aluminium, 6060, T5	2.720 grams per cm^3
PVC	1.440 grams per cm^3
Steel	7.860 grams per cm^3

Figure 41: Fenestration frame material metric density
Source: Engineers Edge, (2023)

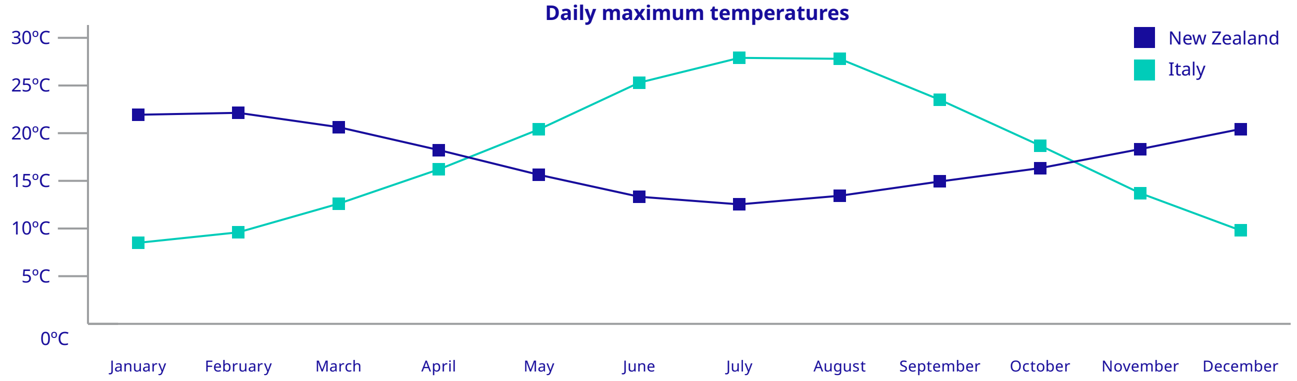
Appendix J – Daily temperatures

	Italy	New Zealand
Climate zone	Temperate zone to Subtropics	Subtropics to Temperate zone
Latitudes	46° 60' N to 35° 30' N	34° 60' S to 46° 36' S
Distance to equator	4,000 - 5,200 km	3,900 - 5,200 km

Annual Values	Italy	New Zealand
Ø Daytime maximum temperature	17.80 °C	17.40 °C
Ø Daily low temperature	10 °C	9.1 °C
Ø Humidity	70 %	82 %
Precipitation	4,698 mm	1,223 mm
Rain days	73.2 days	127.2 days
Hours of sunshine	2,227 hrs.	2,081 hrs.

Daily maximum temperatures

The highest daytime temperatures in Italy are reached in July with an average of 27.9 °C. The coldest month, on the other hand, is January, with an average of just 8.5 °C. In New Zealand, February is the warmest month, with 22.2 °C. There, it is coolest in July with an average of 12.6 °C.



Night time lows

At night, it cools down to varying degrees depending on the country and altitude. In Italy, temperatures drop as low as 2.2 °C in January. The warmest nights are in July at 18.6 °C. In New Zealand, it is coolest at night in July at 4.7 °C and warmest in February at 13.3 °C. This corresponds to a cooling of 6.2 to 9.3 °C in Italy and 7.8 to 8.9 °C in New Zealand.

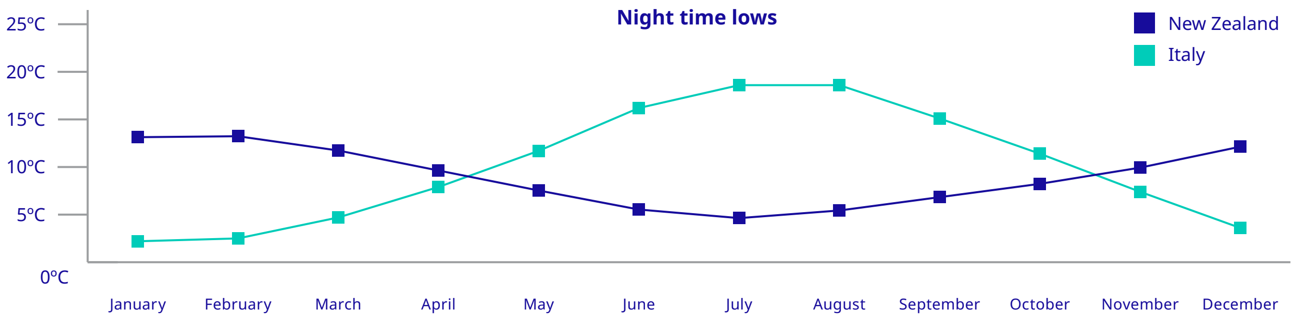


Figure 42: Comparison between Italy and New Zealand climate. Source: (World data, 2023)

Appendix K – Existing CO_2-eq data for windows and doors

The analysis of previously completed carbon emissions reporting shows that carbon emissions vary greatly across various reports (refer to Figure 43).

Asdrubali, Roncone, and Grazieschi (2021) reviewed 116 EPDs reporting that 100% of the EPD's contained A1-A3 modules, 70% contained A1-A4 modules, and only 50% contained A1-A5 modules. A1-A3 is a cradle-to-gate analysis from raw materials manufacture to factory gate (refer to Appendix C). None of the reporting in Figure 39 refers to modules A1-A5. Module A4 is transport to site, if calculated, would most likely only calculate local transport, and A5 being construction and installation processes (refer to Appendix C).

Teenou (2012) calculated uPVC and aluminium frame materials on a larger unit with triple glazing and gas fill options of Argon, Krypton and Xenon, with Xenon having very high embodied carbon due to the amount of energy required to create the inert gas (refer to Figure 43).

Recently published EPDs for locally manufactured aluminium windows and doors result in A1-A3 emissions for house lots MH1 and MH2 ranging from 75 to 86 kgCO_2-eq per m^2 (APL Window Solutions, 2023: Altus Industrial Aluminium & Windows Systems, 2023 respectively) compared to the baseline aluminium windows calculated in this analysis A1-A3 emissions of 92 to 98 kgCO_2-eq per m^2 (refer to Figures 3 and 5).

Report authors	Frame material	Unit type	Glazing	Functional unit size ("FU") (m^2)	Lifecycle phase	Embodied Carbon ($kgCO_2$-eq/FU)	Embodied Carbon ($kgCO_2$-eq/m^2)
Altus Industrial Aluminium & Window Systems EPD	Aluminium *	Fixed window	Double glazed	1.000	A1-A3	78.100	78.100
APL Window Solutions EPD	Aluminium	Fixed window	Double glazed	1.000	A1-A3	61.500	61.500
Asdrubali, Roncone, and Grazieschi, (2021)	Aluminium **	Fixed window	Double and triple glazed	1.200	A1-A3	105.000	87.500
	uPVC *	Fixed window	Double and triple glazed	1.200	A1-A3	68.400	57.000
Brougher and Braunstein (2022)	Aluminium	Fixed window	Double glazed	1.820	A1-A3	130.000	71.429
New Zealand Green Building Council (2023)	Aluminium	Single opening window	Double glazed	1.298	A1-A3	93.000	71.649
New Zealand Green Building Council (2023)	uPVC	Single opening window	Double glazed	1.298	A1-A3	86.000	66.256
Sinha and Kutnar, (2012)	Aluminium	Fixed window	Double glazed	1.000	A1-A3	486.000	486.000
	uPVC	Fixed window	Double glazed	1.000	A1-A3	258.000	258.000
Teenou (2012)	uPVC	Fixed window with opening sash	Triple glazed with Argon	2.145	A1-A3	205.000	95.571
	uPVC	Fixed window with opening sash	Triple glazed with Krypton	2.145	A1-A3	396.000	184.615
	uPVC	Fixed window with opening sash	Triple glazed with Xenon	2.145	A1-A3	1896.000	883.916
	Aluminium	Fixed window with opening sash	Triple glazed with Argon	2.145	A1-A3	502.000	234.033
	Aluminium	Fixed window with opening sash	Triple glazed with Krypton	2.145	A1-A3	692.000	322.611
	Aluminium	Fixed window with opening sash	Triple glazed with Xenon	2.145	A1-A3	2192.000	1021.911

Figure 43: CO_2-eq per functional unit for aluminium and uPVC frame materials

* Aluminium thermally broken profiles with thermosetting resin between two aluminium sections (not solid aluminium nor aluminium with polyamide strips).

**116 various EPDs with different window sizes and glazing types were homogenized to generate the results

New Zealand Green Building Council Homestar: embodied carbon calculator

The New Zealand Green Building Council ("NZGBC") introduced a carbon calculation tool to provide a Homestar methodology for calculating embodied carbon (NZGBC, 2023). BRANZ Ltd developed the tool which can be used to compare the impacts of wall, window, roof and flooring material selections. NZGBC calculator results are shown below on Figure 44 and Figure 45. For additional workings, refer to Appendix L for the MH1 (refer to Figures 46 and 48) and MH2 (refer to Figures 47 and 49) house lots of windows and doors.

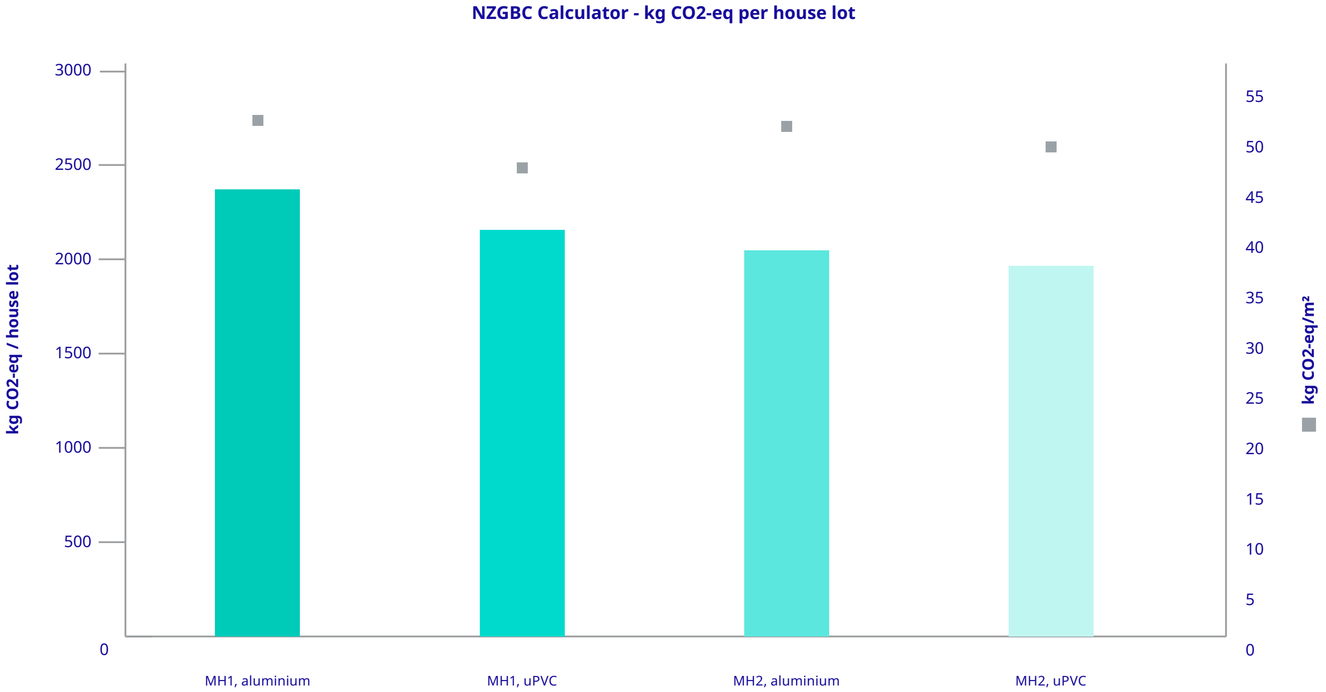


Figure 44: Chart of results, NZGBC calculated per house lots or per m² of MH1 & MH2, aluminium & uPVC frame materials

NZGBC CALCULATOR RESULTS

House lot label	Dwelling description	Windows and doors (m²)	Frame material	Kg CO_2eq per house lot	Embodied carbon per m²
MH1	Single story, detached house	46.210	Aluminium	2371	51.309
MH1	Single story, detached house	46.210	uPVC	2154	46.613
MH2	Townhouse	40.340	Aluminium	2064	51.165
MH2	Townhouse	40.340	uPVC	1965	48.711

Figure 45: Table of results, NZGBC calculator per house lots or per m² of MH1 & MH2, aluminium & uPVC frame materials

BRANZ LCAQuick calculator

BRANZ LCAQuick is a free tool developed by BRANZ to assist architects, designers and structural engineers in making design decisions to evaluate the carbon footprint within a building design and other environmental impacts that can affect the design (BRANZ, 2023). This report did not undertake a carbon footprint anaylysis for MH1 and MH2 using the LCAQuick tool as BRANZ developed the NZGBC Homestar calculator and the tool is particularly easy to use and provides enough detail to make an informed decision.

Appendix L – NZGBC emissions calculator results

MH 1, uPVC windows and doors embodied carbon results for - 19 units

Summary Sheet

Options

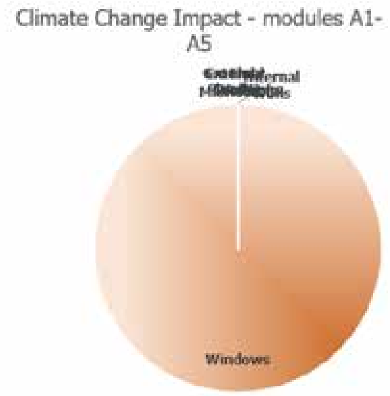
Concrete Carbon Content ◉ lower ○ higher

Building Gross Floor Area 242 m²

Results

Total Climate Change Impact (A1-A5) 2,154 kg CO_2 eq

Climate Change Impact Intensity 9 kg CO_2 eq/m²



	Climate Change [kg CO2 eq]				
	A1-A5	B	C	D	Total
Roofs	0	0	0	0	0
External Walls	0	0	0	0	0
Internal Walls	0	0	0	0	0
Windows	2,154	3,440	34	-533	5,095
Ground Floors	0	0	0	0	0
Midfloors	0	0	0	0	0
Floor Coverings	0	0	0	0	0
PV	0	0	0	0	0
Total	2,154	3,440	34	- 533	5,095

Windows

Climate Change impact 2,154 kg CO_2 eq

Instructions:
First enter the window type details in the top table
Then enter the dimensions for each window in the bottom table

Consider your Window Type Names carefully.
They must be unique and if you change them later you will have to re-assign all the windows which you had assigned to that name.

Window Type Name	Framing	Glazing		Manufacturing	Transport and installation	Maintenance and replacement	End-of-life	Potential benefits/ loads beyond the building life cycle	Climate Change [kg CO2 eq] (modules A1-A5)
uPVC Window	Material: uPVC; Frame Type: solid; Coating/Paint: uncoated, unpainted	Layers: Double Glazed; Glass Type: 4mm, float glass, low E; Gap: 12mm gap, Argon	Framing Impact [per m]	7.7	0.1	8.1	0.2	-4.5	8
			Glazing impact [per m²]	26.4	0.2	53.6	0.2	0.0	27
uPVC Door	Material: uPVC; Frame Type: solid; Coating/Paint: uncoated, unpainted	Layers: Double Glazed; Glass Type: 5mm, heat strengthened glass, low E; Gap: 12mm gap, Argon	Framing Impact [per m]	7.7	0.1	8.1	0.2	-4.5	8
			Glazing impact [per m²]	33.0	0.2	66.9	0.2	0.0	33

ID	Window Name	Window Type Name	Width	Height	External Wall Name	Count						
1	W1	uPVC Window	2.43	1.33	Wall 1	4	573	5	936	9	-135	578
2	W2	uPVC Window	0.83	2.222	Wall 1	3	287	3	445	5	-82	289
3	W3	uPVC Window	0.63	1.03	Wall 1	2	85	1	123	2	-30	86
4	W4	uPVC Window	1.63	1.33	Wall 1	3	308	3	492	5	-79	311
5	W5	uPVC Window	1.63	0.63	Wall 1	1	62	1	92	1	-20	62
6	W6	uPVC Window	1.43	1.03	Wall 1	1	77	1	119	1	-22	77
7	W7	uPVC Window	0.83	1.33	Wall 1	1	62	1	94	1	-19	63
8	D1	uPVC Window	1.585	2.222	Wall 1	1	152	1	250	2	-34	153
9	D2	uPVC Window	2.43	2.222	Wall 1	2	428	3	729	6	-83	432
10	D3	uPVC Window	0.91	2.222	Wall 1	1	102	1	159	2	-28	102

Figure 46: NZGBC emissions calculator, MH1, uPVC windows and doors embodied carbon results - 19 units

MH 2, uPVC windows and doors embodied carbon results – 16 units

Summary Sheet

Options

Concrete Carbon Content (•) lower ( ) higher

Building Gross Floor Area 205 m²

Results

Total Climate Change Impact (A1-A5) **1,965** kg CO_2 eq

Climate Change Impact Intensity **10** kg CO_2 eq/m²

	Climate Change [kg CO2 eq]				
	A1-A5	B	C	D	Total
Roofs	0	0	0	0	0
External Walls	0	0	0	0	0
Internal Walls	0	0	0	0	0
Windows	1,965	3,197	29	-452	4,740
Ground Floors	0	0	0	0	0
Midfloors	0	0	0	0	0
Floor Coverings	0	0	0	0	0
PV	0	0	0	0	0
Total	1,965	3,197	29	- 452	4,740

Windows

Climate Change impact **1,965** kg CO_2 eq

Instructions:
First enter the window type details in the top table
Then enter the dimensions for each window in the bottom table

Consider your Window Type Names carefully.
They must be unique and if you change them later you will have to re-assign all the windows which you had assigned to that name.

Window Type Name	Framing	Glazing		Manufacturing	Transport and installation	Maintenance and replacement	End-of-life	Potential benefits/ loads beyond the building life cycle	Climate Change [kg CO2 eq] (modules A1-A5)
uPVC Window	Material: uPVC; Frame Type: solid; Coating/Paint: uncoated, unpainted	Layers: Double Glazed; Glass Type: 4mm, float glass, low E; Gap: 12mm gap, Argon	Framing Impact [per m]	7.7	0.1	8.1	0.2	-4.5	8
			Glazing impact [per m²]	26.4	0.2	53.6	0.2	0.0	27
uPVC Door	Material: uPVC; Frame Type: solid; Coating/Paint: uncoated, unpainted	Layers: Double Glazed; Glass Type: 5mm, heat strengthened glass, low E; Gap: 12mm gap, Argon	Framing Impact [per m]	7.7	0.1	8.1	0.2	-4.5	8
			Glazing impact [per m²]	33.0	0.2	66.9	0.2	0.0	33

Climate change stages (kg.CO_2 eq.)

ID	Window Name	Window Type Name	Width	Height	External Wall Name	Count	Manufacturing	Transport and installation	Maintenance and replacement	End-of-life	Potential benefits/ loads beyond the building life cycle	Climate Change [kg CO2 eq] (modules A1-A5)
1	W1	uPVC Window	2.43	1.33	Wall 1	3	430	4	792	7	-101	433
2	W2	uPVC Window	1.63	1.33	Wall 1	4	411	4	656	7	-106	415
3	W3	uPVC Window	0.63	1.03	Wall 1	2	83	1	123	2	-30	86
4	W4	uPVC Window	1.63	0.63	Wall 1	1	62	1	92	1	-20	62
5	W5	uPVC Window	1.43	1.03	Wall 1	1	77	1	119	1	-22	77
6	W6	uPVC Window	0.82	2.222	Wall 1	1	95	1	147	2	-27	96
7												
8	D1	uPVC Door	1.585	2.222	Wall 1	1	175	1	297	2	-34	176
9	D2	uPVC Door	2.43	2.222	Wall 1	2	500	4	874	6	-83	504
10	D3	uPVC Door	0.91	2.222	Wall 1	1	115	1	186	2	-28	116

Figure 47: NZGBC emissions calculator, MH2, uPVC windows and doors embodied carbon results - 16 units

MH 1, aluminium windows and doors embodied carbon results for – 19 units

Summary Sheet

Options

Concrete Carbon Content (•) lower ( ) higher

Building Gross Floor Area 242 m²

Results

Total Climate Change Impact (A1-A5): **2,371** kg CO_2 eq

Climate Change Impact Intensity: **10** kg CO_2 eq/m²

	Climate Change [kg CO2 eq] A1-A5	B	C	D	Total
Roofs	0	0	0	0	0
External Walls	0	0	0	0	0
Internal Walls	0	0	0	0	0
Windows	2,371	4,653	38	-2,032	5,029
Ground Floors	0	0	0	0	0
Midfloors	0	0	0	0	0
Floor Coverings	0	0	0	0	0
PV	0	0	0	0	0
Total	2,371	4,653	38	- 2,032	5,029

Windows

Climate Change impact **2,371** kg CO_2 eq

Instructions:
First enter the window type details in the top table
Then enter the dimensions for each window in the bottom table

Consider your Window Type Names carefully.
They must be unique and if you change them later you will have to re-assign all the windows which you had assigned to that name.

Climate change stages (kg CO_2 eq.)

Window Type Name	Framing	Glazing		Manufacturing	Transport and installation	Maintenance and replacement	End-of-life	Potential benefits/ loads beyond the building life cycle	Climate Change [kg CO2 eq] (modules A1-A5)
Aluminium Window	Material: Aluminium; Frame Type: thermally broken; Coating/Paint: Powder Coated, painted	Layers: Double Glazed; Glass Type: 4mm, float glass, low E; Gap: 12mm gap, Argon	Framing impact [per m]	9.1	0.2	17.6	0.2	-17.1	9
			Glazing impact [per m²]	22.6	1.1	47.8	0.2	0.0	24
Aluminium Door	Material: Aluminium; Frame Type: thermally broken; Coating/Paint: Powder Coated, painted	Layers: Double Glazed; Glass Type: 5mm, heat strengthened glass, low E; Gap: 12mm gap, Argon	Framing impact [per m]	9.1	0.2	17.6	0.2	-17.1	9
			Glazing impact [per m²]	33.0	1.3	69.2	0.2	0.0	34

ID	Window Name	Window Type Name	Width	Height	External Wall Name	Count						
1	W1	Aluminium Window	2.43	1.33	Wall 1	4	566	19	1147	10	-514	585
2	W2	Aluminium Window	0.83	2.222	Wall 1	3	292	9	587	5	-313	301
3	W3	Aluminium Window	0.63	1.03	Wall 1	2	90	3	179	2	-113	92
4	W4	Aluminium Window	1.63	1.33	Wall 1	3	308	10	623	5	-303	318
5	W5	Aluminium Window	1.63	0.63	Wall 1	1	64	2	129	1	-77	66
6	W6	Aluminium Window	1.43	1.03	Wall 1	1	78	2	157	1	-84	80
7	W7	Aluminium Window	0.83	1.33	Wall 1	1	64	2	129	1	-74	66
8	D1	Aluminium Door	1.585	2.222	Wall 1	1	185	6	378	3	-130	191
9	D2	Aluminium Door	2.43	2.222	Wall 1	2	526	18	1075	7	-318	543
10	D3	Aluminium Door	0.91	2.222	Wall 1	1	124	4	250	2	-107	127

Figure 48: NZGBC emissions calculator, MH1, aluminium windows and doors embodied carbon results - 19 units

MH 2, aluminium windows and doors embodied carbon results for – 16 units

Summary Sheet

Options

Concrete Carbon Content (•) lower ( ) higher

Building Gross Floor Area 205 m²

Results

Total Climate Change Impact (A1-A5) **2,064** kg CO_2 eq

Climate Change Impact Intensity **10** kg CO_2 eq/m²

	Climate Change [kg CO2 eq] A1-A5	B	C	D	Total
Roofs	0	0	0	0	0
External Walls	0	0	0	0	0
Internal Walls	0	0	0	0	0
Windows	2,064	4,052	32	-1,722	4,426
Ground Floors	0	0	0	0	0
Midfloors	0	0	0	0	0
Floor Coverings	0	0	0	0	0
PV	0	0	0	0	0
Total	2,064	4,052	32	- 1,722	4,426

ID	Window Name	Window Type Name	Width	Height	External Wall Item	Count						
1	W1	Aluminium Window	2.43	1.33	Wall 1	3	424	14	860	7	-385	**439**
2	W2	Aluminium Window	1.63	1.33	Wall 1	4	411	13	831	7	-404	**425**
3	W3	Aluminium Window	0.63	1.03	Wall 1	2	90	3	179	2	-113	**92**
4	W4	Aluminium Window	1.63	0.63	Wall 1	1	64	2	129	1	-77	**66**
5	W5	Aluminium Window	1.43	1.03	Wall 1	1	78	2	157	1	-84	**80**
6	W6	Aluminium Window	0.83	2.222	Wall 1	1	97	3	196	2	-104	**100**
7												
8	D1	Aluminium Door	1.585	2.222	Wall 1	1	185	6	378	3	-130	**191**
9	D2	Aluminium Door	2.43	2.222	Wall 1	2	526	18	1075	7	-318	**543**
10	D3	Aluminium Door	0.91	2.222	Wall 1	1	124	4	250	2	-107	**127**

Windows

Climate Change impact **2,064** kg CO_2 eq

Instructions:
First enter the window type details in the top table
Then enter the dimensions for each window in the bottom table

Consider your Window Type Names carefully.
They must be unique and if you change them later you will have to re-assign all the windows which you had assigned to that name.

Window Type Name	Framing	Glazing		Climate change stages (kg CO_2 eq.): Manufacturing	Transport and installation	Maintenance and replacement	End-of-life	Potential benefits/ loads beyond the building life cycle	Climate Change [kg CO2 eq] (modules A1-A5)
Aluminium Window	*Material:* Aluminium; *Frame Type:* thermally broken; *Coating/Paint:* Powder Coated, painted	*Layers:* Double Glazed; *Glass Type:* 4mm, float glass, low E; *Gap:* 12mm gap, Argon	*Framing Impact [per m]*	9.1	0.2	17.6	0.2	-17.1	9
			Glazing impact [per m²]	22.6	1.1	47.8	0.2	0.0	24
Aluminium Door	*Material:* Aluminium; *Frame Type:* thermally broken; *Coating/Paint:* Powder Coated, painted	*Layers:* Double Glazed; *Glass Type:* 5mm, heat strengthened glass, low E; *Gap:* 12mm gap, Argon	*Framing Impact [per m]*	9.1	0.2	17.6	0.2	-17.1	9
			Glazing impact [per m²]	33.0	1.3	69.2	0.2	0.0	34

Figure 49: NZGBC emissions calculator, MH2, aluminium windows and doors embodied carbon results - 16 units. Source: (NZGBC, 2023)

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