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Development of an Embodied CO_2 Emissions Module for AccuRate

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www.fwpa.com.au
FWPA Level 4, 10-16 Queen Street,
Melbourne VIC 3000, Australia
T +61 (0)3 9927 3200 F +61 (0)3 9927 3288
E info@fwpa.com.au W www.fwpa.com.au

Development of an Embodied CO_2 Emissions Module for AccuRate

Prepared for

Forest & Wood Products Australia

by

D. Chen, M. Syme, S. Seo, W. Y. Chan, M. Zhou and S. Meddings

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Principal Researcher:

D. Chen, M. Syme, S. Seo, W. Y. Chan, M.Zhou and S. Meddings
CSIRO Sustainable Ecosystems

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Forest & Wood Products Australia Limited
Level 4, 10-16 Queen St, Melbourne, Victoria, 3000
T +61 3 9927 3200 F +61 3 9927 3288
E info@fwpa.com.au
W www.fwpa.com.au

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CSIRO Sustainable Ecosystems

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EXECUTIVE SUMMARY

In order to understand whole building life cycle CO_2 emissions, it is important that we take into account both the embodied and the operational CO_2 emissions of the house. In this project, with the co-investment from Forest and Wood Products Australia Ltd (FWPA) and CSIRO's National Climate Adaptation Flagship, an ECO_2 module has been developed and integrated into AccuRate.

The term "Embodied CO_2" (ECO_2) is defined here as the total Greenhouse Gas (GHG) emissions caused from resource extraction, transportation, manufacturing and fabrication of a product or system (cradle-to-factory gate). Emissions from the construction, operation & maintenance and the end of life disposal phases of the building life cycle were not included in the current ECO_2 module implementation.

SimaPro was used to calculate ECO_2 for the building materials included in AccuRate's material library. SimaPro requires a number of product manufacturing process parameters such as energy sources, goods, transportation distance and quantity of input materials etc. It was difficult to collect all the data required for SimaPro modelling within the project time frame and resources. In this study, whenever possible, Australian data were used for SimaPro modelling. For parameters which are very difficult to obtain or unavailable in Australia, the LCI data available in SimaPro (e.g. European databases such as Ecoinvent, ETH etc) were used. These parameters can be updated in the future when Australian data become available.

It is noted that the building construction information available in AccuRate is mainly limited to those which affect the building thermal performance. Information regarding foundations, frames, internal doors and staircases for example, may be not available in AccuRate, while these components may contribute significantly to the ECO_2 emissions of the house. To avoid/minimise additional user input effort, the ECO_2 module estimates the ECO_2 emissions from these 'missing' components based on the existing AccuRate building construction information. At the same time, a flexible ECO_2 module implementation approach was adopted for users to put in the missing construction information if it is available. However, it must be noted that there is a trade off in the current ECO_2 module implementation between accuracy and usability of the software.

The establishment of an ECO_2 module provides AccuRate users with a tool for assessing the impact of ECO_2 when using various construction materials and is one step toward a broader life cycle approach in building sustainability assessment.

1. BACKGROUND

In order to reduce the risk of catastrophic changes in future climate, policy makers are increasingly focussed on reducing CO_2 emissions from all sectors of the economy to assist in meeting the national emissions reduction targets. Currently, building regulations in Australia focus on assessing the thermal performance of the building envelope which impacts upon the operating energy used to run residential buildings over the use phase of their lifecycle. Whilst this helps to curtail increasing emissions, the focus of these regulations with respect to CO_2 emissions is indirect and therefore fails to provide a consistent and complete indication of CO_2 emissions in two ways:

(i) Different fuels and different efficiencies in heating, cooling, hot water and lighting appliances used in residential buildings produce different quantities of CO_2 emissions for the same level of performance; and

(ii) The ECO_2 impact of the building materials used in the construction of residential buildings is currently ignored by the regulations.

Issues regarding the first deficiency in the regulations are currently being addressed through the introduction of heating, cooling, lighting and other assessment tools that take into account the efficiency of the appliances as well as CO_2 intensities of the fuels used to run them. On the other hand, there are currently no Australian assessment tools or modules for existing tools under development that can be used to provide good quantitative estimates of the ECO_2 impact from the building materials.

In 2009, it was decided that an ECO_2 module should be developed and integrated into AccuRate with co-investment from Forest and Wood Products Australia Ltd (FWPA) and CSIRO’s National Climate Adaptation Flagship. The module was to be used to calculate the ECO_2 emissions for the materials planned for use in the construction of new homes in urban centres of Australia. Emissions occurring during the construction phase; those caused by maintenance and repair during the use phase and those occurring at the end of life of the building were not to be considered. These emissions are generally smaller than the embodied emissions in residential constructions. Also, the uncertainties associated with the construction, maintenance/repair and end of life emissions are much greater. Further significant effort would therefore be required to obtain good definition for the emissions associated with these phases before they could be included.

It is intended that this module be used:

- by building assessors, to provide assessments of ECO_2 emission impacts of material choices;
- by builders and designers to allow them to assess the ECO_2 impacts of different house designs and assist them in their design process to minimise CO_2 emissions (e.g. towards the ‘zero carbon’ home);
- by the building design and construction industry to undertake assessment of different materials to achieve an improved environmental performance; and
- to assist government and regulators in assessing the impact of taking a broader life cycle approach to building sustainability assessment.

This report details the development and the implementation of the ECO_2 module in AccuRate.

2. GENERAL METHODOLOGY OF THE EMBODIED CO_2 MODULE

The total ECO_2 emissions of a house can be calculated as the aggregation of the ECO_2 emissions of individual construction materials and systems. In developing the AccuRate ECO_2 module, the following three steps were involved for the house ECO_2 emission estimation:

1) Based on the information available, an average value of the ECO_2 per unit volume or area, i.e. the ECO_2 emission factor for each material or system used in AccuRate is obtained as the default in a look up table similar to Table 1. In this project, all the construction materials defined in AccuRate were considered. Altogether there are about 150+ different materials in the AccuRate material database.

   Table 1 ECO_2 emission factor lookup table

Material	**Unit**	**ECO_2 factor**
Concrete (Standard)	kg CO_2-e /m^3	333.6

   It is understood that the ECO_2 emission calculation for a material is a complex issue and there are different methodologies available. Also, the ECO_2 emission factor for individual materials or systems can vary among different manufacturers and even different periods and locations from the same manufacturer. Consequently, in the ECO_2 module, the users are allowed to modify the default ECO_2 emission factors if the users have appropriate ECO_2 emission factors available for particular materials or systems.

2) Determine ECO_2 emissions for each material or system used in the house by multiplying the total quantity (volume) of each material or system by its corresponding ECO_2 emission factor.

3) The total ECO_2 of the building is calculated as the sum of the ECO_2 emissions of individual construction materials or systems, i.e.

$$ECO_2 = \sum_{Material_i} Quantity_{Material_i} \times ECO_2\, factor_{Material_i}$$

It is noted that the building construction information available in AccuRate is limited to that which affects the building thermal performance. Information regarding foundations, frames, doors and staircases for example, may be not available in AccuRate, while these components may contribute significantly to the ECO_2 emissions of the house. It is understood that excessive user inputs are undesirable for building sustainability assessment. To avoid/minimise user input effort, the ECO_2 calculation should be seamless; the user would not need to provide additional input than already required for thermal assessments. The module should estimate the house ECO_2 emissions based on the existing AccuRate input information if defaults and assumptions approximately match the house construction. At the same time, the ECO_2 module implementation should be flexible for users to put in missing information if it is available. However, it must be noted that there is a trade off in the current ECO_2 module implementation between accuracy and usability of the software.

3. EMBODED CO_2 EMISSION FACTORS FOR MATERIALS IN ACCURATE

Seo (2010) described in detail the methodologies, assumptions and establishment of the ECO_2 emission factors for the materials used in AccuRate. The general methodologies and assumptions are included here for completeness. The ECO_2 factors for the materials used in AccuRate can be found in Appendix A.

3.1 Definition of Embodied CO_2

The term “embodied carbon” is defined as “Embodied CO_2” emitted at all stages of a product’s manufacturing process, from the extraction of raw materials through the distribution process, to the final product provided to the consumer (Kejun et al, 2008). It is noted that “Embodied CO_2” can be referred to in two ways: CO_2 only and CO_2 equivalent which includes CO_2 and other greenhouse gases (GHGs). In this study, we included all GHGs (i.e., CO_2, CH_4, N_2O etc) in the “Embodied CO_2” since this is a more common measure than CO_2 emissions only.

Consequently, in this study, the term “Embodied CO_2 (ECO_2)” is defined as the total GHG emissions caused from resource extraction, transportation, manufacturing and fabrication of a product or system (cradle-to-factory gate).

3.2 Reference Unit

The purpose of an ECO_2 module is to quantify the emission of GHGs produced in the manufacturing of a material or product. In the case of building products, this involves the assessment of the overall GHGs emitted from extraction of raw material and manufacturing of products including transportation. The ECO_2 value for a particular building material/product is known as the ECO_2 coefficient (or intensity) and is usually expressed in terms of CO_2-e per material mass (or in the case of this ECO_2 module implementation, per volume).

The reference unit provides a reference to which the input and output (as CO_2 equivalent) data are normalized. The reference unit for each of the products is set as volume considering that AccuRate has the volume information for most thermal related building construction materials and also the fact that this information is commonly available in the building industry.

3.3 System Boundary

The system boundary determines which unit processes shall be included within a whole life cycle of building products. The selected system boundary has to be clearly defined since it influences the final ECO_2 value.

GHGs are emitted during the whole life cycle of a building (extraction of raw material, transportation, construction and operation & maintenance, refurbishment and end-of-life). Among these life cycle phases, emissions from the building construction and operation & maintenance phases are not considered in this study. The system boundary therefore is limited to 'cradle-to-gate' for these building materials (Figure 1). This includes extraction of raw materials, transportation and manufacturing of building materials (prior to the factory gate before transportation to the construction site).

'Recurring embodied carbon', which covers maintenance and refurbishment, is also important and should be included in the full life cycle (cradle-to-grave). However, it is beyond the scope of this study and is not considered in this report.

Some building materials have carbon emissions from both fuel related and non-fuel related processes. In this case, both emissions (from fuel related and non-fuel related) are considered for the embodied carbon calculation.

For timber products, carbon sequestration effects are also considered in the embodied carbon calculation.

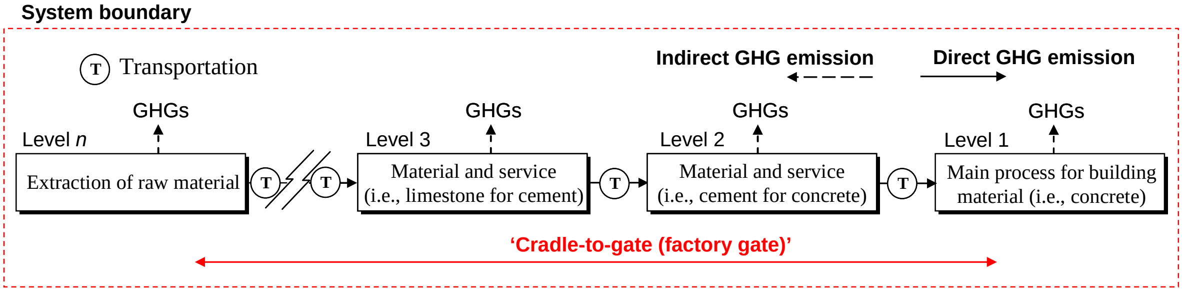


Figure 1 'Systems' view of embodied CO_2 emissions

3.4 Selection of Implementation Tool: SimaPro Model

SimaPro (Pré Consultants, 2008) is a professional tool to collect, analyse and monitor the environmental performance of products and services. It is a tool with which it is easy to model and analyse complex life cycles in a systematic and transparent way, following the ISO 14040 series recommendations.

SimaPro comes with several inventory databases and thousands of processes. The Australian database (as process approach) is also included in this data group. The most useful part of the Australianised database which is supplied with SimaPro is the sources of energy (e.g. electricity generation – all by State, and other fuels used in Australia). The SimaPro database is also a source of models for common processes, such as transport modes and imported products that were modified to suit Australian usage.

In this study, the SimaPro model was used to calculate ECO_2 for the building materials included in AccuRate's material library.

3.5 Data for SimaPro Model

To calculate ECO_2 using SimaPro, a number of product manufacturing process parameters are required such as energy sources, goods, transportation distance and quantity of input materials etc. It was difficult to collect all the data required for SimaPro modelling within the time frame and given the resources allocated to the current study. In this study, whenever possible, Australian data were used for SimaPro modelling. For parameters which were very difficult to obtain or unavailable in Australia, the LCI data available in SimaPro (e.g. European databases such as Ecoinvent, ETH etc) were used. In these specific cases, it was assumed that the manufacturing process for building materials/products in Australia was similar to that of European countries, however, incorporating Australia energy sources and transportation as well. These parameters can be updated in the future when Australian data become available.

3.6 Data Selection Criteria

When calculating embodied carbon for building materials, the following criteria for data requirements are considered.

3.6.1 Compliance with agreed methodologies/standards

Preference was given to data sources that complied with accepted methodologies. In this study, the process based ECO_2 calculation methodology is consistent with the AusLCI methodology guideline (AusLCI, 2009).

It is anticipated that ECO_2 data will be updated in the future. The following hierarchy is preferred (starting from the top of the list):

1. Data from the AusLCI and BPIC databases;

2. From other acknowledged Australian data sources (documented for source, age, representativeness and data quality assessment);

3. From authoritative sources (for example, Ecoinvent, USNLCI) adapted for relevance to Australian conditions (energy sources, transport distances and modes and so on, documented to show how the data is adapted for relevance in Australia);

4. From sources with sensitivity analysis reported to show the significance of this data for the results and conclusions drawn.

3.6.2 Recycling

Currently different methodologies are available for recycling (different scope and boundary rules etc). In this case, it is important to use a consistent methodology. However, allocation for recycling at end of life is not yet defined within the AusLCI guidelines.

Thus, in this study, the closed-loop method of allocation for recycling based on the metals' ability to maintain its inherent metallic properties during recycling, which is one of the employed approaches for aluminium recycling in LCA by the European Aluminium Association (EAA, 2005). According to ISO 14044 (2006), closed-loop allocation applies to closed-loop product systems. In this case, the need for allocation is avoided since the use of secondary materials displaces the use of virgin (primary) materials (ISO, 2006) and the boundary comprises the secondary material production as well (shown in Figure 2).

As shown in Figure 2, for example, aluminium product is manufactured with 40kg of primary aluminium and 60kg of recycled aluminium. In the recycling loop, 80kg of EOL (End-of-Life) aluminium is recycled to produce 60kg secondary aluminium. The total CO_2 emissions associated with this product can be worked out as follows:

$$E_{Tot} = E_{\mathrm{Pr}} + E_{Sc} + E_{Pc} + E_{Wa}$$

Where, E_{Tot} is total emission for aluminium product, E_{Pr} and E_{Sc} are emissions for manufacturing primary and secondary aluminium respectively. E_{Pc} *and* E_{Ws} are emissions from manufacturing process and waste (assumed 0 value and 0 emission), respectively.

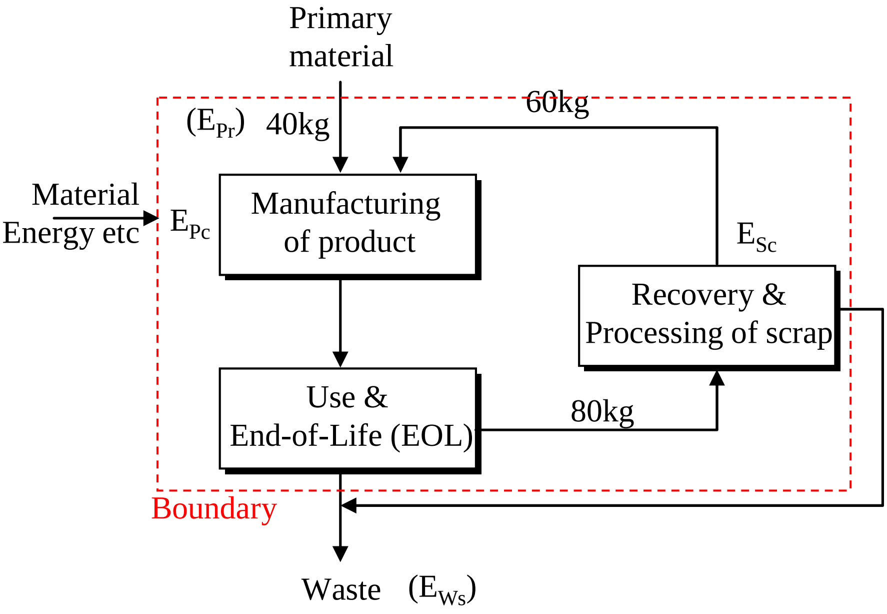


Figure 2 Aluminium recycling allocation (example)

3.6.3 Regional Boundary

Ideally the embodied carbon data would have all been obtained from Australia. However, when the required information is very difficult to obtain or unavailable in

Australia, the best available source for embodied carbon data was adopted from abroad (e.g. Ecoinvent database).

3.6.4 Time Boundary

Many building material manufacturers adopt advanced technologies to reduce energy consumption and carbon emissions. Consequently, in this study, modern data sources are preferred for building materials.

3.7 Assumptions

The general assumptions used in this study were:

- Energy used is reported by energy source (e.g. coal, diesel fuel and electricity) and the upstream modelling assumes Australian average energy production for all energy sources (i.e. Australian average energy production data was used instead of using state energy production data);
- No emissions from the infrastructure in the manufacturing process were considered;
- The European manufacturing process is similar to that used in Australia.

In this study, data uncertainties were not considered. For more detailed information on specific materials and products, please refer to Seo (2010).

4. IMPLEMENTATION OF EMBODIED CO$_2$ MODULE IN ACCURATE

As mentioned in Chapter 2, the implementation of an ECO$_2$ module in AccuRate should consider at least the following three aspects:

- The ECO$_2$ emission calculation for a material is a complex issue and there are different methodologies available. Also, the ECO$_2$ emission factor for individual materials or systems can vary among different manufacturers and even different periods and locations from the same manufacturer. Consequently, the ECO$_2$ module should allow the users to modify the default ECO$_2$ emission factors if the users have appropriate ECO$_2$ emission factors available for particular materials or systems.

- The building construction information available in AccuRate is limited. Information regarding foundations, frames, internal doors and staircases for example, may be not available in AccuRate, while these components may contribute significantly to the ECO$_2$ emissions of the house. Currently, the common understanding is that excessive user inputs are undesirable for building sustainability assessment. To avoid/minimise additional user input effort, the ECO$_2$ calculation should be seamless; the user would not need to provide any additional input than already required for thermal assessments. The module should estimate the house ECO$_2$ emissions based on the existing AccuRate building construction information.

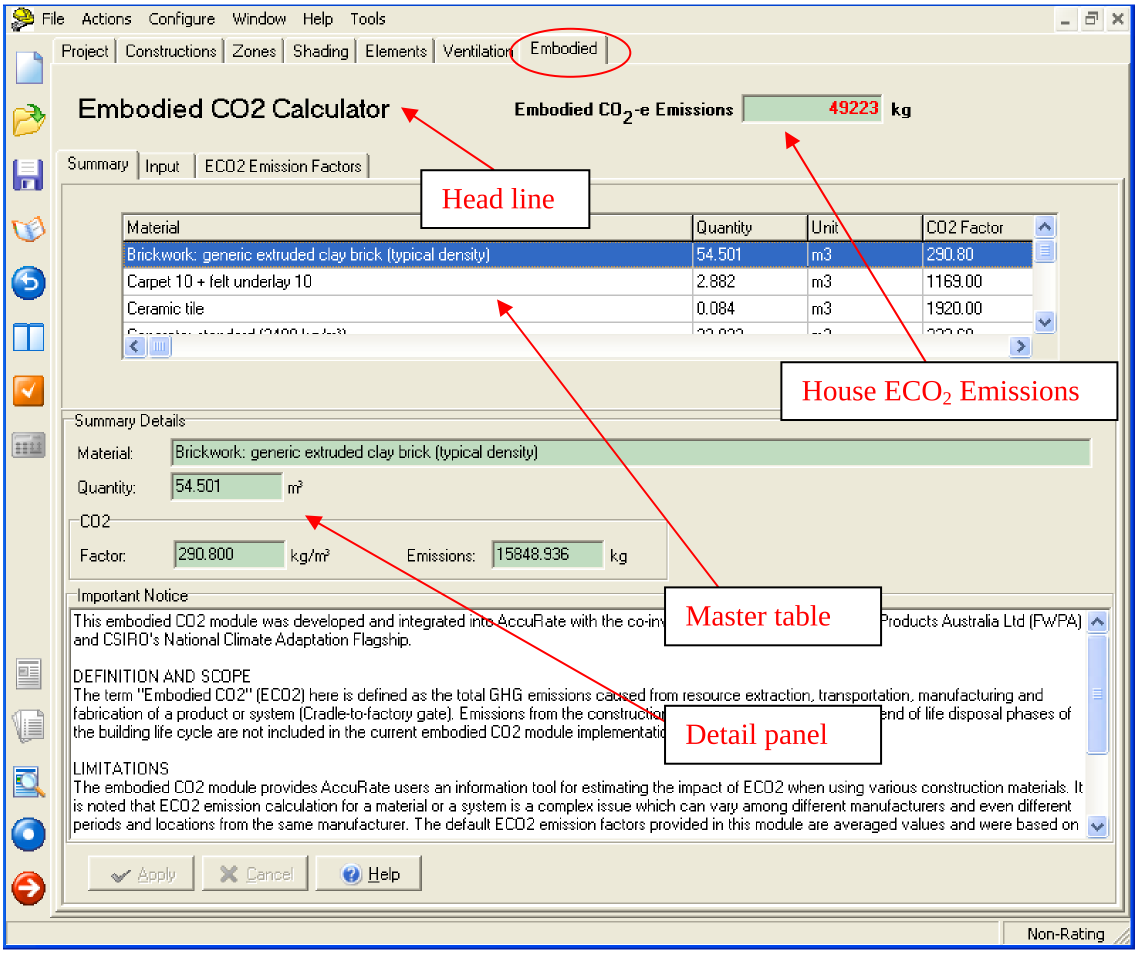
- At the same time, a flexible ECO$_2$ module implementation approach should be adopted to allow users to input the missing construction information if it is available.

The implementation of the ECO$_2$ module in AccuRate described in the following sections addresses these aspects.

4.1 The Embodied CO_2 Module in AccuRate

The user interface of the ECO_2 module follows a similar design style to other modules in AccuRate. As shown in Figure 3, the user interface includes a Head line, a Master table and a Detail panel for data entry. The Head line displays the calculated total house ECO_2 emissions in kg. The middle section occupied by the Master table and the lower section occupied by the Detail panel (some pages may also include an Information section in the detail panel) as shown in Figure 3.

Information displayed in the Master table is non-editable. Data editing is mainly done in the Detail panel. Apply/Cancel buttons appear on the bottom left hand corner of the page as shown in Figure 3. The ‘Apply’ button updates the changes to the model while the ‘Cancel’ button reverts the model to the step before the change. The ‘Help’ button invokes the on-line help for the specific topic currently in consideration.



Embodied CO_2-e Emissions 49223 kg

Material	Quantity	Unit	CO2 Factor
Brickwork: generic extruded clay brick (typical density)	54.501	m3	290.80
Carpet 10 + felt underlay 10	2.882	m3	1169.00
Ceramic tile	0.084	m3	1920.00

Summary Details

Material: Brickwork: generic extruded clay brick (typical density)

Quantity: 54.501 m³

CO2

Factor: 290.800 kg/m³ Emissions: 15848.936 kg

Important Notice

This embodied CO2 module was developed and integrated into AccuRate with the co-inv Products Australia Ltd (FWPA) and CSIRO's National Climate Adaptation Flagship.

DEFINITION AND SCOPE

The term "Embodied CO2" (ECO2) here is defined as the total GHG emissions caused from resource extraction, transportation, manufacturing and fabrication of a product or system (Cradle-to-factory gate). Emissions from the constructio end of life disposal phases of the building life cycle are not included in the current embodied CO2 module implementatio

LIMITATIONS

The embodied CO2 module provides AccuRate users an information tool for estimating the impact of ECO2 when using various construction materials. It is noted that ECO2 emission calculation for a material or a system is a complex issue which can vary among different manufacturers and even different periods and locations from the same manufacturer. The default ECO2 emission factors provided in this module are averaged values and were based on

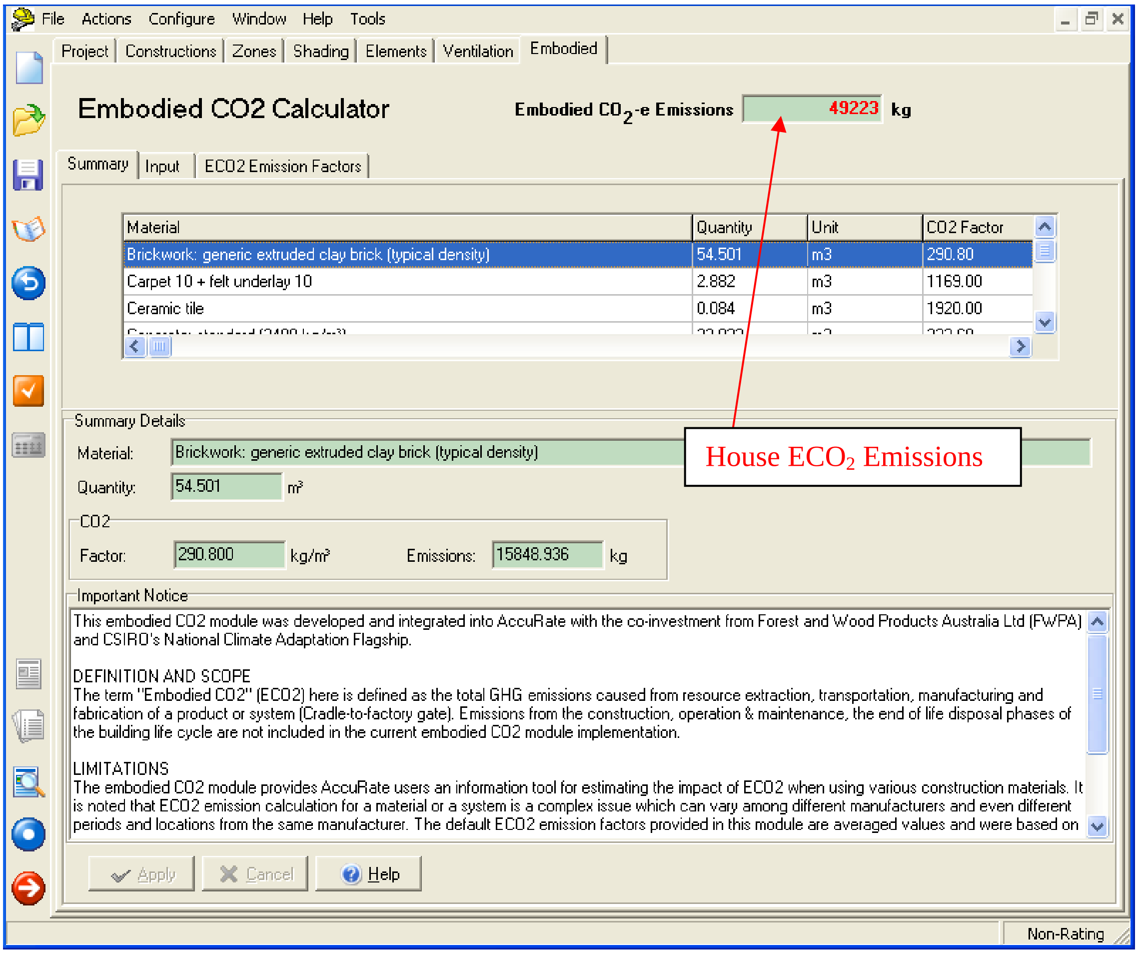
Figure 3 Embodied CO_2 module in AccuRate

As shown in Figure 3, the ECO_2 module contains three sub-pages:

- A 'Summary' page - displays the ECO_2 emissions from each material or system;
- An 'Input' page - allows estimation and specification of various construction components which are currently not handled by existing AccuRate user input; and
- An ECO_2 'Emission factor' page – allows users to choose or change the ECO_2 emission factors for the materials used in AccuRate.

4.2 The Embodied CO_2 Module Summary Page

The Summary page displays the ECO_2 emissions from each material or system (refer to Figure 4). The Master table lists the material quantity used, the ECO_2 emissions factor and the ECO_2 emissions from each material or system. The Detail panel in the Summary page shows the summary information of each material. In the current implementation, the summary information in the Detail panel is for display only and no changes can be made by the users.



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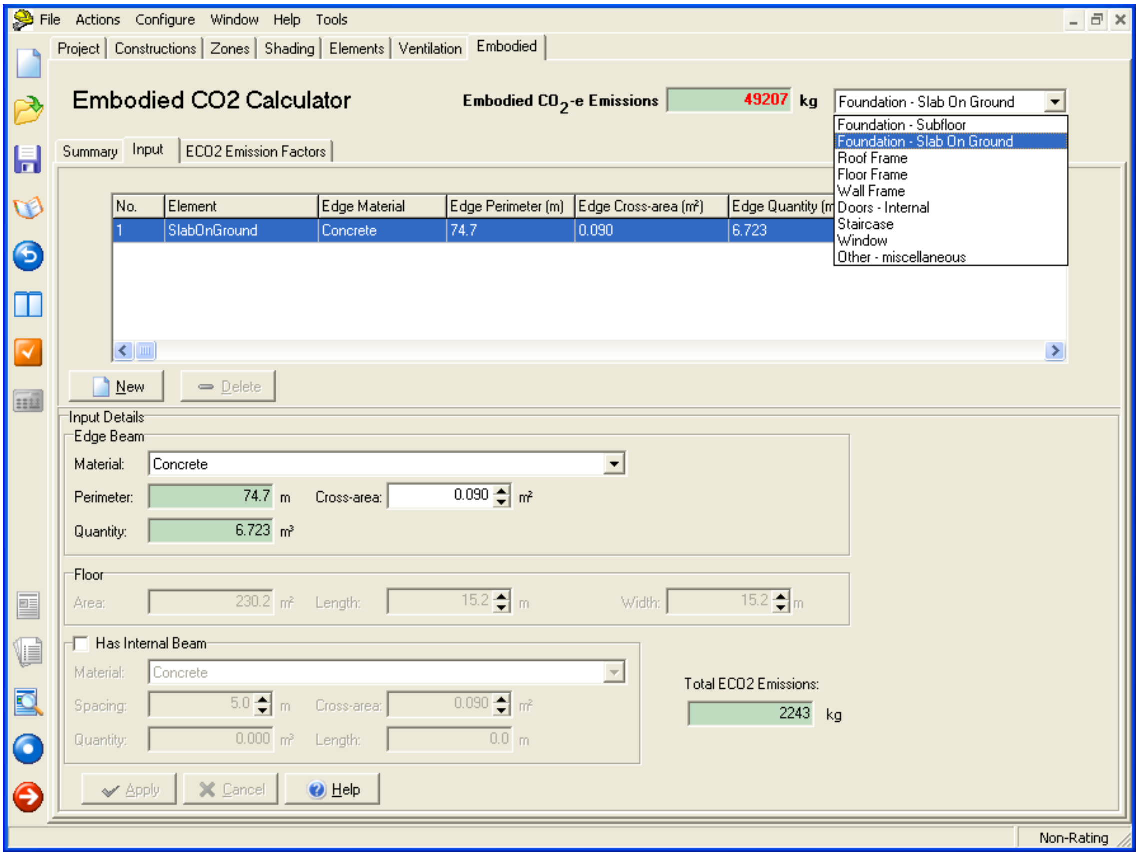
LIMITATIONS
The embodied CO2 module provides AccuRate users an information tool for estimating the impact of ECO2 when using various construction materials. It is noted that ECO2 emission calculation for a material or a system is a complex issue which can vary among different manufacturers and even different periods and locations from the same manufacturer. The default ECO2 emission factors provided in this module are averaged values and were based on

Figure 4 Summary page of the Embodied CO_2 module in AccuRate

4.3 The Embodied CO_2 Module Input Page

The Input page includes a number of building components such as foundations, frames, internal doors, staircases, windows etc which are not specified or fully specified in the existing AccuRate software. For each component, the ECO_2 module makes assumptions for estimating the material quantities used in the building and then calculates the ECO_2 emissions from the component.

At the same time, modifications to some assumptions are allowed for better representation of the house components, e.g., the cross-section area of the Edge Beam of a slab-on-ground concrete floor, the length and width of the concrete floor and whether or not internal beams exist (refer to Figure 5). The Input page includes an ‘Other – miscellaneous’ component category which allows the users to include other ‘missing’ components which are not specifically considered in the current embodied CO_2 module implementation. Detailed assumptions and implementation of these ‘missing’ components in the input page are described in Appendix B.



Embodied CO2 Calculator

Embodied CO_2-e Emissions: 49207 kg

Foundation - Slab On Ground

- Foundation - Subfloor
- Foundation - Slab On Ground
- Roof Frame
- Floor Frame
- Wall Frame
- Doors - Internal
- Staircase
- Window
- Other - miscellaneous

No.	Element	Edge Material	Edge Perimeter (m)	Edge Cross-area (m²)	Edge Quantity (m
1	SlabOnGround	Concrete	74.7	0.090	6.723

Input Details

Edge Beam

Material: Concrete

Perimeter: 74.7 m Cross-area: 0.090 m²

Quantity: 6.723 m³

Floor

Area: 230.2 m² Length: 15.2 m Width: 15.2 m

☐ Has Internal Beam

Material: Concrete

Spacing: 5.0 m Cross-area: 0.090 m²

Quantity: 0.000 m³ Length: 0.0 m

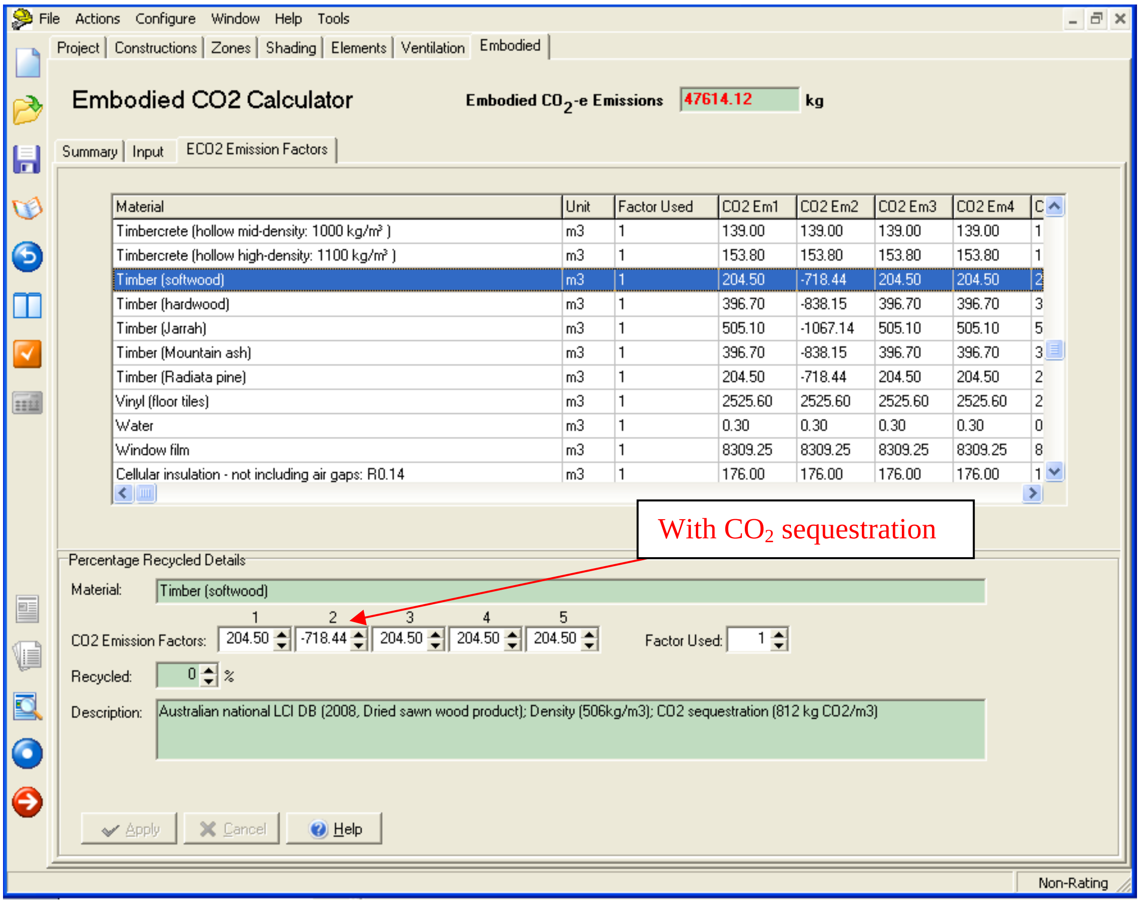
Total ECO2 Emissions: 2243 kg

Figure 5 Embodied CO_2 module input page in AccuRate

4.4 The Embodied CO_2 Module Emission Factor Page

As shown in Figure 6, five ECO_2 emission factors (or coefficients) are allowed in the ECO_2 emission module implementation for potential future expansion of ECO_2 emission factors developed by other methodologies or with different boundaries (for example, ECO_2 emission factors developed by considering the building construction phase, maintenance phase etc). Currently, ECO_2 Emission Factor 1 is used as default. ECO_2 Emission Factor 2 for timber products is the ECO_2 emission factor with the consideration of CO_2 sequestration (refer to Figure 6).

The ECO_2 emission factor page allows users to choose, change and save (at exit) the ECO_2 emission factors for the materials used which facilitates the flexibility and expandability of the ECO_2 module.



Embodied CO2 Calculator

Embodied CO_2-e Emissions: 47614.12 kg

Material	Unit	Factor Used	CO2 Em1	CO2 Em2	CO2 Em3	CO2 Em4	C
Timbercrete (hollow mid-density: 1000 kg/m³)	m3	1	139.00	139.00	139.00	139.00	1
Timbercrete (hollow high-density: 1100 kg/m³)	m3	1	153.80	153.80	153.80	153.80	1
Timber (softwood)	m3	1	204.50	-718.44	204.50	204.50	2
Timber (hardwood)	m3	1	396.70	-838.15	396.70	396.70	3
Timber (Jarrah)	m3	1	505.10	-1067.14	505.10	505.10	5
Timber (Mountain ash)	m3	1	396.70	-838.15	396.70	396.70	3
Timber (Radiata pine)	m3	1	204.50	-718.44	204.50	204.50	2
Vinyl (floor tiles)	m3	1	2525.60	2525.60	2525.60	2525.60	2
Water	m3	1	0.30	0.30	0.30	0.30	0
Window film	m3	1	8309.25	8309.25	8309.25	8309.25	8
Cellular insulation - not including air gaps: R0.14	m3	1	176.00	176.00	176.00	176.00	1

With CO_2 sequestration

Percentage Recycled Details

Material: Timber (softwood)

CO2 Emission Factors: 1: 204.50; 2: -718.44; 3: 204.50; 4: 204.50; 5: 204.50

Factor Used: 1

Recycled: 0 %

Description: Australian national LCI DB (2008, Dried sawn wood product); Density (506kg/m3); CO2 sequestration (812 kg CO2/m3)

Figure 6 Embodied CO_2 module Emission Factor page in AccuRate

5. CONCLUSIONS

With the co-investment from Forest and Wood Products Australia Ltd (FWPA) and CSIRO's National Climate Adaptation Flagship, an ECO_2 emission module has been developed and integrated with AccuRate. The "Embodied CO_2" here is defined as the total GHGs emissions caused from resource extraction, transportation, manufacturing and fabrication of a product or system (cradle-to-factory gate).

SimaPro was used to calculate ECO_2 for the building materials included in AccuRate's material library. SimaPro requires a number of product manufacturing process parameters such as energy sources, goods, transportation distance and quantity of input materials etc. It was difficult to collect all the data required for SimaPro modelling within the current project time frame and with the resources allocated. In this study, whenever possible, Australian data were used for SimaPro modelling. For parameters which were very difficult to obtain or unavailable in Australia, the LCI data available in SimaPro (e.g. European databases such as Ecoinvent, ETH etc) were used. These parameters can be updated in the future when Australian data become available.

It is noted that the building construction information available in AccuRate is limited to that which affects the building thermal performance. Information regarding foundations, frames, internal doors and staircases for example, may be not available in AccuRate, while these components may contribute significantly to the ECO_2 emissions of the house. To avoid/minimise additional user input effort, the module estimates the ECO_2 emissions from these 'missing' components based on the existing AccuRate building construction information. At the same time, a flexible ECO_2 emissions module implementation approach was adopted for users to put in the missing construction information if it is available. However, it must be noted that there is a trade off in the current ECO_2 module implementation between accuracy and usability of the software.

The establishment of the ECO_2 emissions module provides AccuRate users a tool for assessing the impact of ECO_2 when using various construction materials and is one step forward for a broader life cycle approach in building sustainability assessment.

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APPENDIX A - EMBODIED CARBON DATA TABLE

Embodied CO_2 emissions from different building materials used in AccuRate are presented in Table 2. The table is constituted with four columns. The first column describes the building materials which correspond to the AccuRate building material library. The second column is the reference unit for each building material. The embodied carbon (as kg CO_2 equivalent) for the building material per reference unit is represented in the third column. Column four briefly describes the methodology and assumptions in calculating the embodied carbon. More detailed information on the methodology and assumptions for each building material is described in Seo (2010).

Table 2 Embodied carbon for building materials

Materials	Unit	Embodied CO_2 (kg CO_2 eq./unit)	Comments
Aerated autoclaved concrete block	m^3	196.9	• Adopt European data from Ecoinvent (2004, autoclaved aerated concrete block, at plant/kg/CH) • Assumed raw material are transported within 100km • Density is 550 kg/m^3 (Hebel, 2009)
Aluminum	m^3	35804.8	• Employ closed-loop method for recycling allocation (EAA, 2005; ISO 14044, 2006) • Assumed 70% recovery rate • Assumed mixing as virgin (70%) and scrap aluminum (30%) (Koltun and Tharumarajah, 2006)
Bituminous roof membrane	m^3	1012.5	• Adopt European data from Ecoinvent (2007, bitumen sealing, polymer EP4 flame retardant, at plant/kg/RER)
Brickwork with extruded clay brick	m^3	290.8	• Density 1580kg/m^3 • Standard brick size (110 (W)×230 (L)×76 (H) • 3.3kg of clay brick (extruded)
Brickwork with pressed clay brick	m^3	344.8	• Density 2097kg/m^3 • Standard brick size (110 (W)×230 (L)×76 (H) • 4.1 kg of clay brick (pressed)
BST lightweight concrete	m^3	1332.0	• Density 2000kg/m^3 (25-30MPa) sourced from Kirkside Products (2009)
Carpet (Nylon)	m^3	2337.9	• Assumed 50% for cut pile (0.175 g/cm^3) and 50% for loop pile (0.150 g/cm^3) • surface pile mass for Nylon BCF carpet (25.2/100mm gauge) is 580g/m2 cut pile and 475 g/m2 loop pile (CIAL, 2009)
Carpet underlay (rubber)	m^3	739.5	• Rubber underlay • Thickness 7.5mm (1.830±55 kg/m2) • Sourced from NFA (2009)
Carpet 10 + felt underlay 10	m^3	1169.0	• Felt underlay data unavailable • Only carpet is considered; • Assumed 50% for cut pile (0.175 g/cm^3) and 50% for loop pile (0.150 g/cm^3) • surface pile mass for Nylon BCF carpet (25.2/100mm gauge) is 580g/m2 cut pile and 475 g/m2 loop pile (CIAL, 2009)
Carpet (10) + rubber underlay (8)	m^3	1186.6	• 0.018m thickness (10mm carpet (nylon) with 8mm rubber underlay)

			• Density 185kg/m^3
Ceramic tile	m^3	1920	• Adopt European data from Ecoinvent (2003, ceramic tiles, at regional storage/kg/CH) • Assumed raw material are transported within 100km
Concrete block 190 dense-weight (not core-filled)	m^3	153.9	• Adopt Boustead data (UK dense concrete block) • Thickness 190mm • Density 1101kg/m^3
Concrete block 190 dense-weight (core-filled at 1800 centres)	m^3	186.3	• Adopt Boustead data (UK dense concrete block) • Thickness 190mm • Density 1332kg/m^3
Concrete block 190 dense-weight (core-filled at 1500 centres)	m^3	189.5	• Adopt Boustead data (UK dense concrete block) • Thickness 190mm • Density 1355kg/m^3
Concrete block 190 dense-weight (core-filled at 1400 centres)	m^3	190.6	• Adopt Boustead data (UK dense concrete block) • Thickness 190mm • Density 1363 kg/m^3
Concrete block 190 dense-weight (core-filled at 1000 centres)	m^3	199.4	• Adopt Boustead data (UK dense concrete block) • Thickness 190mm • Density 1426 kg/m^3
Concrete block 190 dense-weight (core-filled at 600 centres)	m^3	219.3	• Adopt Boustead data (UK dense concrete block) • Thickness 190mm • Density 1568 kg/m^3
Concrete block 190 dense-weight (fully core-filled)	m^3	313.1	• Adopt Boustead data (UK dense concrete block) • Thickness 190mm • Density 2239 kg/m^3
Concrete block 190 light-weight (not core-filled)	m^3	189.7	• Adopt Boustead data (UK lightweight concrete block) • Thickness 190mm • Density 909kg/m^3
Concrete block 190 light-weight (core-filled at 1800 centres)	m^3	237.3	• Adopt Boustead data (UK lightweight concrete block) • Thickness 190mm • Density 1137 kg/m^3
Concrete block 190 light-weight (core-filled at 1500 centres)	m^3	242.3	• Adopt Boustead data (UK lightweight concrete block) • Thickness 190mm • Density 1161 kg/m^3
Concrete block 190 light-weight (core-filled at 1400 centres)	m^3	243.8	• Adopt Boustead data (UK lightweight concrete block) • Thickness 190mm • Density 1168 kg/m^3
Concrete block 190 light-weight (core-filled at 1000 centres)	m^3	257.1	• Adopt Boustead data (UK lightweight concrete block) • Thickness 190mm • Density 1232 kg/m^3
Concrete block 190 light-weight (core-filled at 600 centres)	m^3	286.8	• Adopt Boustead data (UK lightweight concrete block) • Thickness 190mm • Density 1374 kg/m^3
Concrete block 190 light-weight (fully core-filled)	m^3	427.4	• Adopt Boustead data (UK lightweight concrete block) • Thickness 190mm • Density 2048 kg/m^3

Concrete block 140 dense-weight (not core-filled)	m^3	174.2	• Adopt Boustead data (UK dense concrete block) • Thickness 140mm • Density 1246 kg/m^3
Concrete block 140 dense-weight (core-filled at 1800 centres)	m^3	201.8	• Adopt for Boustead data (UK dense concrete block) • Thickness 140mm • Density 1443 kg/m^3
Concrete block 140 dense-weight (core-filled at 1500 centres)	m^3	204.7	• Adopt Boustead data (UK dense concrete block) • Thickness 140mm • Density 1464 kg/m^3
Concrete block 140 dense-weight (core-filled at 1400 centres)	m^3	205.7	• Adopt Boustead data (UK dense concrete block) • Thickness 140mm • Density 1471 kg/m^3
Concrete block 140 dense-weight (core-filled at 1000 centres)	m^3	212.7	• Adopt Boustead data (UK dense concrete block) • Thickness 140mm • Density 1521 kg/m^3
Concrete block 140 dense-weight (core-filled at 600 centres)	m^3	230.7	• Adopt Boustead data (UK dense concrete block) • Thickness 140mm • Density 1650 kg/m^3
Concrete block 140 dense-weight (fully core-filled)	m^3	312.0	• Adopt Boustead data (UK dense concrete block) • Thickness 140mm • Density 2231 kg/m^3
Concrete block 140 light-weight (not core-filled)	m^3	214.8	• Adopt Boustead data (UK lightweight concrete block) • Thickness 140mm • Density 1029 kg/m^3
Concrete block 140 light-weight (core-filled at 1800 centres)	m^3	254.8	• Adopt Boustead data (UK lightweight concrete block) • Thickness 140mm • Density 1221 kg/m^3
Concrete block 140 light-weight (core-filled at 1500 centres)	m^3	259.4	• Adopt Boustead data (UK lightweight concrete block) • Thickness 140mm • Density 1243 kg/m^3
Concrete block 140 light-weight (core-filled at 1400 centres)	m^3	260.9	• Adopt Boustead data (UK lightweight concrete block) • Thickness 140mm • Density 1250 kg/m^3
Concrete block 140 light-weight (core-filled at 1000 centres)	m^3	272.8	• Adopt Boustead data (UK lightweight concrete block) • Thickness 140mm • Density 1307 kg/m^3
Concrete block 140 light-weight (core-filled at 600 centres)	m^3	298.2	• Adopt Boustead data (UK lightweight concrete block) • Thickness 140mm • Density 1429 kg/m^3
Concrete block 140 light-weight (fully core-filled)	m^3	420.3	• Adopt Boustead data (UK lightweight concrete block) • Thickness 140mm • Density 2014 kg/m^3
Concrete block 110 dense-weight (not core-filled)	m^3	230.3	• Adopt for Boustead data (UK dense concrete block) • Thickness 110mm • Density 1647 kg/m^3
Concrete block 110 dense-	m^3	304.8	• Adopt Boustead data (UK dense concrete

weight (solid)			block) • Thickness 110mm • Density 2180 kg/m^3
Concrete block 110 light-weight (not core-filled)	m^3	283.8	• Adopt Boustead data (UK lightweight concrete block) • Thickness 110mm • Density 1360 kg/m^3
Concrete block 110 light-weight (solid)	m^3	375.7	• Adopt Boustead data (UK lightweight concrete block) • Thickness 110mm • Density 1800 kg/m^3
Concrete block 90 dense-weight (not core-filled)	m^3	230.3	• Adopt Boustead data (UK dense concrete block) • Thickness 90mm • Density 1647 kg/m^3
Concrete block 90 dense-weight (solid)	m^3	304.8	• Adopt Boustead data (UK dense concrete block) • Thickness 90mm • Density 2180 kg/m^3
Concrete block 90 light-weight (not core-filled)	m^3	283.8	• Adopt Boustead data (UK lightweight concrete block) • Thickness 90mm • Density 1360 kg/m^3
Concrete block 90 light-weight (solid)	m^3	375.7	• Adopt Boustead data (UK lightweight concrete block) • Thickness 90mm • Density 1800 kg/m^3
Concrete (standard)	m^3	333.6	• Density 2400 kg/m^3 • SimaPro (Australian LCI data, 2007)
Conpolcrete	-	-	• Density 395kg/m^3 • Data not available
Copper (tube)	m^3	55262.7	• Assume extruded • Adopt European data from Ecoinvent (2007, cold impact extrusion, steel, 1 stroke/kg/RER) • Density is 1490kg/m^3 from AccuRate (default value)
Cork tile	m^3	861	• Adopt European data from Ecoinvent (2003, cork slab, at plant/kg/RER) • Density is 593 kg/m^3 from AccuRate default
Fibre-cement sheet	m^3	1668.6	• Adopt European data from Ecoinvent (2004, fibre cement facing tile, at plant/kg/CH) • Flat tile type • Density (1490kg/m^3) • Transport within 200 km by truck for freight
Compressed fibre-cement sheet	m^3	2239.7	• Assumed that manufacturing process is similar to fibre-cement sheet (but density is different with fibre cement sheet) • Density (2000kg/m^3) • Transport within 200 km by truck for freight
Glass (flat)	m^3	1380.5	• Adopt European data from Ecoinvent (2007, flat glass, uncoated, at plant/kg/RER) • Only flat glass considered (uncoated) • Assumed raw material are transported within 200km
Granite	m^3	386.9	• Adopt Dolomite from Australian data 2007 (Dolomite/AU U in SimaPro DB) • Assumed raw material are transported within 500km • Density is 2650 kg/m^3 from AccuRate default
Hollow-core precast concrete panel (200mm)	m^3	302.5	• Assumed to be similar to general precast concrete production (50MPa general purpose

			concrete) • Assumed transport within 100km • Density (1680kg/m^3)
Hollow-core precast concrete panel (150 mm)	m^3	302.5	• Assumed to be similar to general precast concrete production (50MPa general purpose concrete) • Assumed transport within 100km • Density (1680kg/m^3)
Lead	m^3	30894	• Adopt European data from Ecoinvent (2003, sheet rolling chromium steel/kg/RER) • Assumed scrap use percentage 50%. • Process includes lead from mining, concentrating and melting.
Linoleum	m^3	1461.2	• Adopt European data from IDEMAT (1998, Linoleum production) • Input data considering Australian conditions
Marble	m^3	397.1	• Assumed to be similar to dolomite mining process • Process considered mining process (limestone) and transportation • Assumed raw material are transported within 500km • Density is 2720 kg/m^3 from AccuRate default
Masonite (soft) without carbon sequestration	m^3	231.8	• Adopt European data from Ecoinvent (2003, fibreboard hard, at plant/m^3/RER and fibreboard soft, at plant/m^3/RER) • Assumed raw material are transported within 200km • Density is 1025 kg/m^3 from AccuRate default
Masonite (soft) with carbon sequestration		-853	
Mud brick	m^3	36.4	• Assumed that mixing energy consumption is similar to clay brick. • Mixing data adopt European data from Ecoinvent (2004, plaster mixing/kg/CH) • Assumed raw material is transported within 100km.
Particleboard (for flooring) without carbon sequestration	m^3	513.8	• Data is take from AusLCI data (2008, Particleboard, 19mm, Australia, AU/U) • Density is 640kg/m^3 from AccuRate (default value)
Particleboard (for flooring) with carbon sequestration	m^3	-1322	
Plaster (cement : sand, 1:4)	m^3	418	• Adopt European data from Ecoinvent (2004, cement cast plaster floor, at plant/kg/CH) • Assumed raw material are transported within 200km • Density is 2000 kg/m^3 from AccuRate (default value)
Plasterboard	m^3	301.8	• Adopt European data from Ecoinvent (2004, gypsum plaster board, at plant/kg/CH) • Process includes production of plasterboard including drying process. • Assumed raw material are transported within 200km • Standard 10 mm thickness is considered
Plywood (softwood) without carbon sequestration	m^3	650.1	• Data taken from AusLCI data (2007, Plywood Structural, at mill, Australia /AU U) • Density is 530kg/m^3 from AccuRate (default value) • Carbon sequestration (747kg of CO$_2$-e/m^3)
Plywood (softwood) with carbon sequestration	m^3	-96.9	

Polycarbonate	m^3	6944.3	• Adopt European data from Ecoinvent (2007, polycarbonate, at plant/kg/RER) • Process includes aggregated data for all processes from raw material extraction until delivery at plant • Density is 1150 kg/m^3 from AccuRate default
Rammed earth	m^3	0.000	• Assumed '0' until information available
Reflective blind	m^3	3745.6	• Assumed Polyester is PET (polyethylene terephthalate) • PET data taken from Australian LCI database from SimaPro (2008) • Assumed transport within 200km
Roof tile (clay)	m^3	422.8	• Adopt European data from Ecoinvent (2005, roof tile, at plant/kg/RER). • Assumed transport within 100km • Density is 1922 kg/m^3 from AccuRate default
Roof tile (concrete)	m^3	564	• Adopt European data from Ecoinvent (2007, concrete roof tile, at plant/kg/CH) • Assumed transport within 100km • Density is 2400 kg/m^3 from AccuRate (default value)
Sand	m^3	51	• Data taken from Australian LCI DB in SimaPro (2007, sand) • Assumed that sand processing operations take place at the mining site or nearby, and for this reason • Assumed transport within 400km (NSW, QLD and VIC ACI plants)
Sandstone	m^3	190	• Adopt Dolomite from Australian data 2007 (Dolomite/AU U in SimaPro DB) • Density is 2000 kg/m^3 from AccuRate (default value)
Slate	m^3	198.8	• Adopt Dolomite from Australian data 2007 (Dolomite/AU U in SimaPro DB) • Assumed transport within 200km • Density is 2650 kg/m^3 from AccuRate (default value)
Soft-board (MDF, 12mm)	m^3	627.7	• Australian national LCI DB (2008) • MDF, 12mm, Australia, AU/U • Carbon sequestration of MDF is 1096 kg of CO_2-e/m^3.
Soft-board (MDF, 12mm, with carbon sequestration)	m^3	-468.3	
Soil (average)	m^3	0.000	• Assumed '0' in this stage
Steel	m^3	12207	• Australian LCI DB in SimaPro (2004, Steel, Bluescope Port Kembla, 20% recycled content/AU U)
Straw board	-	-	• Data not available
Straw bale rendered	-	-	
Styrocon	m^3	697	• Adopt Ecoinvent (2005, Lightweight concrete block, polystyrene, at plant/CH U)
Timbercrete (solid low-density, 900kg/m^3)	m^3	125.9	• Assumed timbercrete manufacturing is similar to normal concrete blocks (even though Portland cement portion for timbercrete is slightly higher as 17% to normal concrete blocks). • Assumed ingredient portion for solid low (or mid, high) density is similar to hollow low (or mid, high) density
Timbercrete (solid mid-density, 1000kg/m^3)	m^3	139.0	
Timbercrete (solid high-density, 1100kg/m^3)	m^3	153.8	
Timbercrete (hollow low-density, 900kg/m^3)	m^3	125.9	

Timbercrete (hollow mid-density, 1000kg/m^3)	m^3	139.0	
Timbercrete (hollow high-density, 1100kg/m^3)	m^3	153.8	
Timber (softwood)	m^3	204.5	• Australian national LCI DB (2008, Dried sawn wood product) • Density (506kg/m^3) • CO_2 sequestration (922.944 kg CO_2/m^3)
Timber (softwood, with carbon sequestration)	m^3	-718.4	
Timber (hardwood)	m^3	396.7	• Australian national LCI DB (2008, Dried sawn wood product, softwood) • Density (677kg/m^3) • CO_2 sequestration (1234.848kg CO_2/m^3)
Timber (hardwood, with carbon sequestration)	m^3	-838.1	
Timber (Jarrah)	m^3	505.1	• Australian national LCI DB (2008, Dried sawn wood product, hardwood) • Density (862kg/m^3) • CO_2 sequestration (1572.288kg CO_2/m^3)
Timber (Jarrah, with carbon sequestration)	m^3	-1067.1	
Timber (Mountain Ash)	m^3	396.7	• Australian national LCI DB (2008, Dried sawn wood product, hardwood) • Density (677kg/m^3) • CO_2 sequestration (1234.848kg CO_2/m^3)
Timber (Mountain Ash, with carbon sequestration)	m^3	-838.1	
Timber (Radiata Pine)	m^3	204.5	• Australian national LCI DB (2008, Dried sawn wood product, softwood) • Density (506kg/m^3) • CO_2 sequestration (922.944 kg CO_2/m^3)
Timber (Radiata Pine, with carbon sequestration)	m^3	-718.4	
Vinyl tile (for flooring)	m^3	2525.6	• Data taken from Australian LCI DB in SimaPro (2004, PVC compound for vinyl flooring) • Density (2050kg/m^3)
Water	m^3	0.3	• Data taken from Australian LCI DB in SimaPro (1999, Water delivery in Australia)
Window film	m^3	8309.25	• Adopt PET film data from Ecoinvent (2000, PET film production (average) A)
Cellular insulation (without air gap)	m^3	176	• Assumed cellular insulation made from polyethylene (94%) and aluminum foil (6%) • Assumed transport within 200km
Cellulose fibre: loose fill (k=0.04)	m^3	76.4	• Assumed cellulose fibre made from recycled newspaper (except for phone books or glossy paper is used) • Assumed transport within 200km • Density is 38.6kg/m^3 from AccuRate (default value)
Cellulose fibre (loose fill): R=1.0	m^3	76.4	• Assumed the same as above (only different thickness)
Cellulose fibre (loose fill): R=1.5	m^3	76.4	• Assumed the same as above (only different thickness)
Cellulose fibre (loose fill): R=2.0	m^3	76.4	• Assumed the same as above (only different thickness)
Cellulose fibre (loose fill): R=2.5	m^3	76.4	• Assumed the same as above (only different thickness)
Cellulose fibre (loose fill): R=3.0	m^3	76.4	• Assumed the same as above (only different thickness)
Cellulose fibre (loose fill): R=3.5	m^3	76.4	• Assumed the same as above (only different thickness)
Cellulose fibre (loose fill): R=4.0	m^3	76.4	• Assumed the same as above (only different thickness)
Glass fibre batt (k=0.057 density = 7 kg/m^3)	m^3	22.3	• Adopt European data from Ecoinvent (2004, glass wool mat, at plant/kg/CH)
Glass fibre batt (k=0.044 density = 12 kg/m^3)	m^3	38.3	• Adopt European data from Ecoinvent (2004, glass wool mat, at plant/kg/CH)
Glass fibre batt: R=1.0	m^3	38.3	• Assumed the same as above (only different thickness)

Glass fibre batt: R=1.5	m^3	38.3	• Assumed the same as above (only different thickness)
Glass fibre batt: R=2.0	m^3	38.3	• Assumed the same as above (only different thickness)
Glass fibre batt: R=2.5	m^3	38.3	• Assumed the same as above (only different thickness)
Glass fibre batt: R=3.0	m^3	38.3	• Assumed the same as above (only different thickness)
Glass fibre batt: R=3.5	m^3	38.3	• Assumed the same as above (only different thickness)
Glass fibre batt: R=4.0	m^3	38.3	• Assumed same as above (only different thickness)
Polyethylene foam (k=0.04)	m^3	84.7	• Data taken from Australian LCI DB in SimaPro (2007, LDPE, Low density polyethylene/AU/U) • Density is 24 kg/m^3 from AccuRate (default value)
Polyester or polyester blanket (k=0.063, density:8 kg/m^3)	m^3	93.3	• Adopt European data from IDEMAT (2001,Polyester fabric) • Density is 8kg/m^3 from AccuRate (default value)
Polyester or polyester blanket (k=0.045, density:16 kg/m^3)	m^3	186.6	• Adopt European data from IDEMAT (2001,Polyester fabric) • Density is 16kg/m^3 from AccuRate (default value)
Polyester or polyester/wool blanket: R1.0)	m^3	186.6	• Assumed the same as polyester or polyester blanket (k=0.045, density 16kg/m^3) (only different thickness)
Polyester or polyester/wool blanket: R1.5)	m^3	186.6	• Assumed same as polyester or polyester blanket (k=0.045, density 16kg/m^3) (only different thickness)
Polyester or polyester/wool blanket: R2.0)	m^3	186.6	• Assumed the same as polyester or polyester blanket (k=0.045, density 16kg/m^3) (only different thickness)
Polyester or polyester/wool blanket: R2.5)	m^3	186.6	• Assumed the same as polyester or polyester blanket (k=0.045, density 16kg/m^3) (only different thickness)
Polyester or polyester/wool blanket: R3.0)	m^3	186.6	• Assumed the same as polyester or polyester blanket (k=0.045, density 16kg/m^3) (only different thickness)
Polyester or polyester/wool blanket: R3.5)	m^3	186.6	• Assumed the same as polyester or polyester blanket (k=0.045, density 16kg/m^3) (only different thickness)
Polyester or polyester/wool blanket: R4.0)	m^3	186.6	• Assumed the same as polyester or polyester blanket (k=0.045, density 16kg/m^3) (only different thickness)
Polystyrene expanded(k=0.039)	m^3	58.7	• Adopt European data from Ecoinvent (2007, polystyrene, expandable, at plant/kg/RER) • Process includes production and thermoforming of EPS • Density is 16kg/m^3 from AccuRate (default value)
Polystyrene expanded R1.0	m^3	58.7	• Assumed the same as polystyrene expanded (k=0.039) (only different thickness)
Polystyrene expanded R1.5	m^3	58.7	• Assumed the same as polystyrene expanded (k=0.039) (only different thickness)
Polystyrene expanded R2.0	m^3	58.7	• Assumed the same as polystyrene expanded (k=0.039) (only different thickness)
Polystyrene expanded R2.5	m^3	58.7	• Assumed the same as polystyrene expanded (k=0.039) (only different thickness)
Polystyrene expanded R3.0	m^3	58.7	• Assumed the same as polystyrene expanded

			(k=0.039) (only different thickness)
Polystyrene expanded R3.5	m^3	58.7	- Assumed the same as polystyrene expanded (k=0.039) (only different thickness)
Polystyrene expanded R4.0	m^3	58.7	- Assumed the same as polystyrene expanded (k=0.039) (only different thickness)
Polystyrene extruded (k=0.028)	m^3	140.5	- Adopt European data from Ecoinvent (2007, polystyrene, extruded (XPS), at plant/kg/RER) - Process includes the production of extruded polystyrene (melting of polystyrene pearls in the extruder, the discharge through a slot die, as well as the cooling with water) - Density is 32kg/$m^3$from AccuRate (default value)
Polystyrene extruded R1.0	m^3	140.5	- Assumed the same as polystyrene extruded (k=0.028) (only different thickness)
Polystyrene extruded R1.5	m^3	140.5	- Assumed the same as polystyrene extruded (k=0.028) (only different thickness)
Polystyrene extruded R2.0	m^3	140.5	- Assumed the same as polystyrene extruded (k=0.028) (only different thickness)
Polystyrene extruded R2.5	m^3	140.5	- Assumed the same as polystyrene extruded (k=0.028) (only different thickness)
Polystyrene extruded R3.0	m^3	140.5	- Assumed the same as polystyrene extruded (k=0.028) (only different thickness)
Polystyrene extruded R3.5	m^3	140.5	- Assumed the same as polystyrene extruded (k=0.028) (only different thickness)
Polystyrene extruded R4.0	m^3	140.5	- Assumed the same as polystyrene extruded (k=0.028) (only different thickness)
Polyurethane rigid foamed aged (k=0.028)	m^3	86.3	- Adopt European data from Ecoinvent (2003, polyurethane, rigid foam, at plant/kg/RER) - Process includes the transports of the monomers as well as the production (energy, air emissions) of the PUR foam - Density is 24kg/m^3 from AccuRate (default value)
Polyurethane rigid foamed aged R1.0	m^3	86.3	- Assumed the same as polyurethane rigid foamed aged (k=0.028) (only different thickness)
Polyurethane rigid foamed aged R1.5	m^3	86.3	- Assumed the same as polyurethane rigid foamed aged (k=0.028) (only different thickness)
Polyurethane rigid foamed aged R2.0	m^3	86.3	- Assumed the same as polyurethane rigid foamed aged (k=0.028) (only different thickness)
Polyurethane rigid foamed aged R2.5	m^3	86.3	- Assumed the same as polyurethane rigid foamed aged (k=0.028) (only different thickness)
Polyurethane rigid foamed aged R3.0	m^3	86.3	- Assumed the same as polyurethane rigid foamed aged (k=0.028) (only different thickness)
Polyurethane rigid foamed aged R3.5	m^3	86.3	- Assumed the same as polyurethane rigid foamed aged (k=0.028) (only different thickness)
Polyurethane rigid foamed aged R4.0	m^3	86.3	- Assumed the same as polyurethane rigid foamed aged (k=0.028) (only different thickness)
Rockwool loose fill (k=0.04)	m^3	101.6	- Adopt European data from Ecoinvent (2003, rock wool, packed, at plant/kg/CH) - Process includes mechanical packing and the administration of the rock wool factory. - Density is 64kg/m^3 from AccuRate (default value)
Rockwool batt (k=0.033)	m^3	48.8	- Adopt European data from Ecoinvent (2004,

			rock wool, at plant/kg/CH) - Process includes melting, fiber forming & collecting, hardening & curing furnace, and internal processes (workshop, etc.). Transport of raw materials and energy carrier for furnace are also included (Not included are administration, packing and infrastructure) - Density is 32kg/m^3 from AccuRate (default value)
Rockwool batt R1.0	m^3	48.8	- Assumed the same as rockwool batt (k=0.033) (only different thickness)
Rockwool batt R1.5	m^3	48.8	- Assumed the same as rockwool batt (k=0.033) (only different thickness)
Rockwool batt R2.0	m^3	48.8	- Assumed the same as rockwool batt (k=0.033) (only different thickness)
Rockwool batt R2.5	m^3	48.8	- Assumed the same as rockwool batt (k=0.033) (only different thickness)
Rockwool batt R3.0	m^3	48.8	- Assumed the same as rockwool batt (k=0.033) (only different thickness)
Rockwool batt R3.5	m^3	48.8	- Assumed the same as rockwool batt (k=0.033) (only different thickness)
Rockwool batt R4.0	m^3	48.8	- Assumed the same as rockwool batt (k=0.033) (only different thickness)
Wool loose fill (k=0.08)	m^3	602.6	- Adopt European data from Ecoinvent (2007, wool, sheep, at farm/kg/US) - Process includes sheep husbandry on pasture land. Machine infrastructure and a shed for machine sheltering and shearing is included. Inputs of fertilisers, feedstuffs, pesticides and irrigation as well as transports to the farm are considered. The direct emissions on the field are also included. - Assumed transport within 1000km - Density is 12kg/m^3 from AccuRate (default value)
Wool/polyester batt 80/20 (k=0.059 density= 8 kg/m^3)	m^3	334.6	- Adopt wool from US data in Ecoinvent (2007, wool, sheep, at farm/kg/US) and polyester from European data from IDEMAT (1996, polyester fabric) - Density is 8kg/m^3 from AccuRate (default value)
Wool/polyester batt 80/20 (k=0.045 density= 16 kg/m^3)	m^3	669.2	- Assumed the same as wool/polyester batt 80/20 (k=0.059) - Density is 16 kg/m^3 from AccuRate (default value)
Wool/polyester batt 80/20 R1.0	m^3	669.2	- Assumed the same as wool/polyester batt 80/20 (k=0.045, density 16 kg/m^3)
Wool/polyester batt 80/20 R1.5	m^3	669.2	- Assumed the same as wool/polyester batt 80/20 (k=0.045, density 16 kg/m^3)
Wool/polyester batt 80/20 R2.0	m^3	669.2	- Assumed the same as wool/polyester batt 80/20 (k=0.045, density 16 kg/m^3)
Wool/polyester batt 80/20 R2.5	m^3	669.2	- Assumed the same as wool/polyester batt 80/20 (k=0.045, density 16 kg/m^3)
Wool/polyester batt 80/20 R3.0	m^3	669.2	- Assumed the same as wool/polyester batt 80/20 (k=0.045, density 16 kg/m^3)
Wool/polyester batt 80/20 R3.5	m^3	669.2	- Assumed the same as wool/polyester batt 80/20 (k=0.045, density 16 kg/m^3)
Wool/polyester batt 80/20 R4.0	m^3	669.2	- Assumed the same as wool/polyester batt 80/20 (k=0.045, density 16 kg/m^3)

Note: for detailed sources and assumptions used to obtain the ECO_2 for each building material/product, please refer to Seo (2010).

APPENDIX B – METHODOLOGIES FOR ESTIMATING MISSING INFORMATION

Table 3 lists the major components which are not specified or not fully specified in the existing AccuRate user input. Among the listed components, the current ECO_2 module implementation considered the following ‘missing’ components: foundation (stump, pad footing, strip footing, edge beam, internal beams); framing (floor, wall and roof framing); internal doors (external doors have already been included in the existing AccuRate input and automatically included in the ECO_2 calculation. Users should not enter external door information in the ECO_2 module again); windows (existing AccuRate window information is limited and some special treatments may be required as described in Appendix B.7) and staircase.

In order to minimise user input efforts, automatic estimation of the material quantities and ECO_2 emissions for these components are implemented with default assumptions. At the same time, various user modifications are allowed for better representation of these components. This section details the assumptions and implementation of these ‘missing’ components.

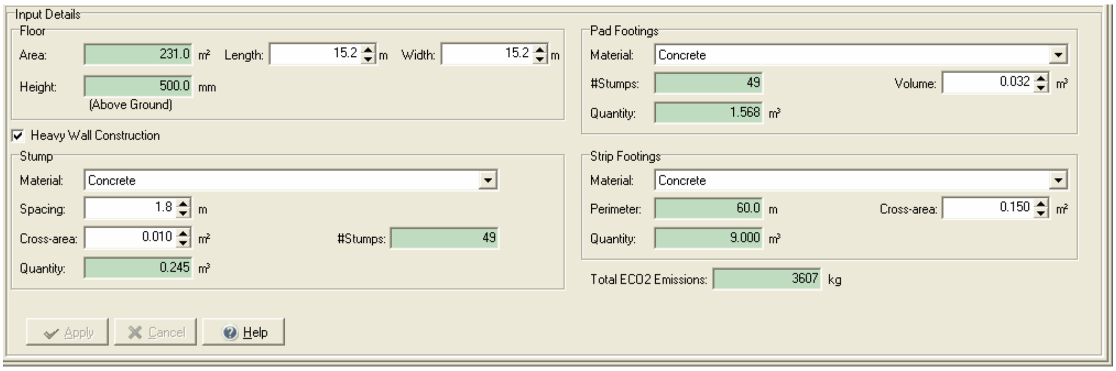
Table 3 Major components missing in existing AccuRate user input

Component	**Considered in the Embodied CO_2 Module (Yes/No)**	**Quantity calculation (Algorithm/Cumulative)**
Foundation		
Stump	Yes	Algorithm
Pad footing	Yes	Algorithm
Strip footing	Yes	Algorithm
Edge beams	Yes	Algorithm
Internal beams	Yes	Algorithm
Framing		
Floor	Yes	Algorithm
Wall	Yes	Algorithm
Roof	Yes	Algorithm
Door	Yes	Algorithm
Window	Yes	Algorithm
Staircase	Yes	Algorithm
Fire place	No	
Plumbing	No	
Electrical	No	
Painting	No	
Cabinets	No	
Appliances	No	
Shower screen	No	
Bath tub	No	
Interior trim		
Columns	No	
Mouldings	No	
Fireplace Mantles	No	
HVAC	No	
Nails/Screws	No	

Appendix B.1 Foundation - Subfloor

In the current ECO_2 module implementation, the subfloor stumps, pad footing and strip footing information are estimated based on the subfloor area of the house.

As shown in Figure 7, the subfloor area of the house is automatically calculated based on the floor element information and assumed to be square as default. Users are allowed to change the length and/or width of the floor to approximately represent non-square floor geometry. The assumptions and calculations of stumps, pad footing and strip footing are dependent on whether the external wall construction is heavy weight or light weight.



Input Details

Floor
Area: 231.0 m² Length: 15.2 m Width: 15.2 m
Height: 500.0 mm (Above Ground)

☑ Heavy Wall Construction

Stump
Material: Concrete
Spacing: 1.8 m
Cross-area: 0.010 m² #Stumps: 49
Quantity: 0.245 m³

Pad Footings
Material: Concrete
#Stumps: 49 Volume: 0.032 m³
Quantity: 1.568 m³

Strip Footings
Material: Concrete
Perimeter: 60.0 m Cross-area: 0.150 m²
Quantity: 9.000 m³

Total ECO2 Emissions: 3607 kg

Figure 7 Subfloor foundation details in the Embodied CO_2 module input page

B1.1 Heavyweight External Wall Construction

For brick veneer, cavity brick or other heavyweight external wall constructions, it is assumed that stumps and concrete strip footing are required. The number of stumps is estimated by Eq. (1) (rounded to the nearest integer):

$$NumStumps = \left(\frac{Floor\,length}{StumpSpacing} - 1\right)\left(\frac{Floor\,width}{StumpSpacing} - 1\right) \tag{1}$$

where the default stump spacing is assumed to be 1.8 m and is user adjustable as shown in Figure 7.

The stump material can be selected among timber (default), concrete and brick and the total stump volume is estimated using Eq. (2).

$$V_{Stumps_i} = CrossSectionArea \times Subfloor\ Height \times NumStumps \tag{2}$$

Table 4 lists the assumed stump cross section area for different stump materials.

Table 4 Stump cross section area

Material	Cross Sectional Area (m²)
timber	0.01
concrete	0.01
brick	0.106

The material commonly used for pad footing is concrete (as default). The volume of a pad footing is assumed to be 0.032 m^3 (400 x 400 x 200 mm thick) (as default) and is user adjustable. The total volume of pad footings can be estimated using Eq. (3):

$$V_{PadFooting} = PadFootingVolume \times NumStumps \tag{3}$$

The material commonly used in strip footing is concrete (as default). The cross sectional area assumed to be 0.15 m^2 (500 x 300 mm) and is user adjustable. The total volume of strip footings can be estimated using Eq. (4):

$$V_{StripFootings_i} = Perimeter_{house} \times CrossSectionArea_{StripFooting} \tag{4}$$

where $Perimeter_{House}$ is the house subfloor perimeter.

B1.2 Lightweight External Wall Construction

For weatherboard or other lightweight external wall constructions, it is assumed that stumps and pad footings are required. The number of stumps is estimated by Eq. (5) (rounded to the nearest integer):

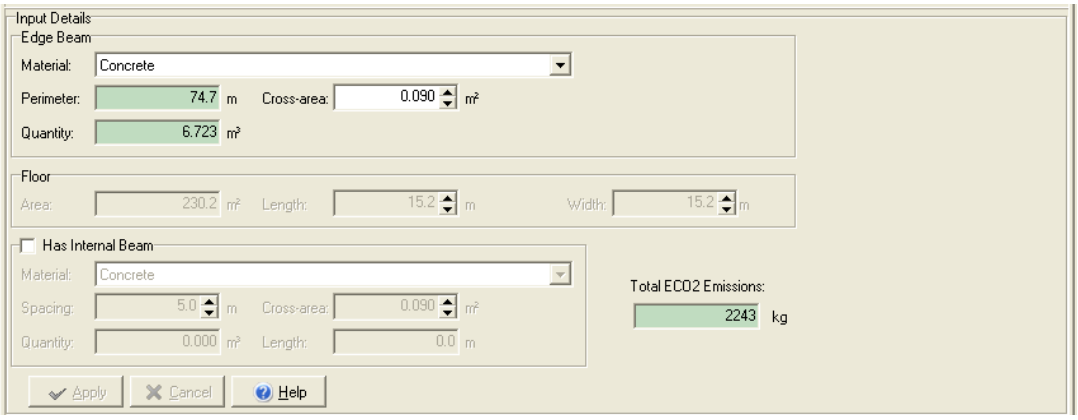
$$NumStumps_{lightweight} = \left(\frac{Floor\ length}{StumpSpacing}+1\right)\left(\frac{Floor\ width}{StumpSpacing}+1\right) \tag{5}$$

where the default stump spacing is assumed to be 1.8 m and is user adjustable.

The stump material can be selected among timber (default), concrete and brick and the total stump volume is estimated using Eq. (2). The material commonly used for pad footing is concrete (as default). The volume of pad footings of light weight constructions is again estimated using Eq. (3). For light weight construction, there is no strip footing.

Appendix B.2 Foundation – Slab-on-ground

In the existing AccuRate input, the slab floor area and slab thickness are available. However, there is no information for edge beams and internal beams. Figure 8 shows the slab-on-ground input details in the ECO_2 module. The volume of the edge beams is estimated by Eq. (6).



Input Details

Edge Beam

Material: Concrete

Perimeter: 74.7 m

Cross-area: 0.090 m²

Quantity: 6.723 m³

Floor

Area: 230.2 m²

Length: 15.2 m

Width: 15.2 m

☐ Has Internal Beam

Material: Concrete

Spacing: 5.0 m

Cross-area: 0.090 m²

Quantity: 0.000 m³

Length: 0.0 m

Total ECO2 Emissions: 2243 kg

Figure 8 Slab-on-ground foundation details in the Embodied CO_2 module input page

$$V_{EdgeBeams} = Perimeter_{house} \times CrossSectionArea_{EdgeBeam} \qquad (6)$$

where $Perimeter_{House}$ is the house slab perimeter and $CrossSectionArea_{EdgeBeam}$ is the edge beam cross section area (default 0.3 x 0.3 = 0.09 m^2).

Internal beams are not required in most cases (as default). If the site classification requires internal beams, users can check the ‘Has Internal Beam’ checkbox (as shown in Figure 8) and the volume of the internal beam is estimated by Eq. (7):

$$V_{InternalBeam} = CrossSectionalArea_{InternalBeam} \times InternalBeamLength \qquad (7)$$

Where $InternalBeamLength$ is the total internal beam length calculated as:

$$InternalBeamLength = \left(\frac{length}{InternalBeamSpacing} - 1\right) \times \left(FloorWidth\right)$$

$$+\left(\frac{width}{InternalBeamSpacing} - 1\right) \times \left(FloorLength\right) \qquad (8)$$

The $InternalBeamSpacing$ and the cross sectional area default to 5 m and 0.3 x 0.3 = 0.09 m² respectively which are both user adjustable.

Appendix B.3 Roof Framing

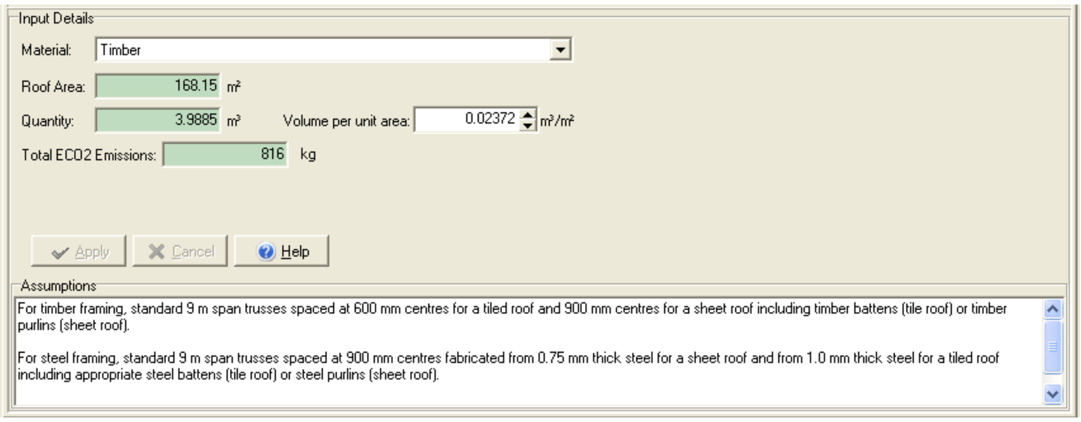
The volume of roof frame materials is estimated by Eq. (9)

$$V_{RoofFrame} = RoofArea \times VolumePerUnitArea_{RoofFrame} \tag{9}$$

Where $RoofArea$ is the total roof area including the eave area which is calculated from the existing AccuRate input.

The default roof frame volume per unit area of roof is a given value in m^3 per unit area (m^3/m^2) as listed in

Table 5. In the case of timber framing these values assume a standard 9 m span truss spaced at 600 mm centres for a tiled roof and 900 mm centres for a sheet roof including timber battens (tile roof) or timber purlins (sheet roof). In the case of steel framing these values assume a standard 9 m span truss spaced at 900 mm centres fabricated from 0.75 mm thick steel for a sheet roof and from 1.0 mm thick steel for a tiled roof including appropriate steel battens (tile roof) or steel purlins (sheet roof). As shown in Figure 9, the roof frame volume per unit roof area is user adjustable.



Material: Timber

Roof Area: 168.15 m²

Quantity: 3.9885 m³

Volume per unit area: 0.02372 m³/m²

Total ECO2 Emissions: 816 kg

For timber framing, standard 9 m span trusses spaced at 600 mm centres for a tiled roof and 900 mm centres for a sheet roof including timber battens (tile roof) or timber purlins (sheet roof).

For steel framing, standard 9 m span trusses spaced at 900 mm centres fabricated from 0.75 mm thick steel for a sheet roof and from 1.0 mm thick steel for a tiled roof including appropriate steel battens (tile roof) or steel purlins (sheet roof).

Figure 9 Roof frame details in the Embodied CO_2 module input

Table 5 Default roof frame volume per unit area of roof

Roof framing material	**Roofing type**	**Roof Frame Volume per Unit Area (m^3/m^2)**
Timber (assume softwood 506kg/m^3) (Default)	Tile (Default)	0.02372
	Sheet	0.01976
Steel	Tile (Default)	0.00141
	Sheet	0.00115

Appendix B.4 Floor Framing

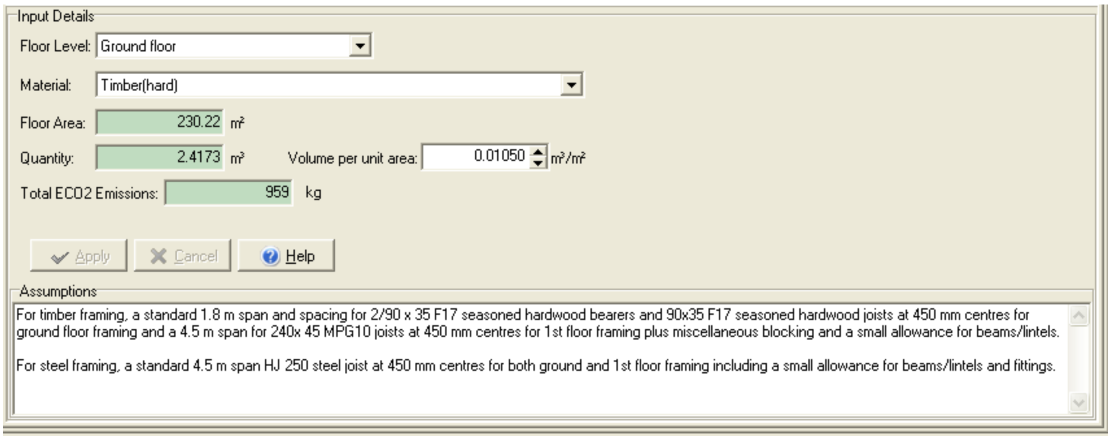
Floor framing should be calculated for suspended floors. The volume of floor framing materials is estimated by Eq. (10):

$$V_{FloorFrame} = \sum_{level_j} \left(FloorArea_{level_j} \times VolumePerUnitArea_{FloorFrame} \right) \qquad (10)$$

Where $FloorArea_{level_i}$ is the total floor area at level$_j$ which is automatically calculated from the existing AccuRate input.

The default floor frame volume per unit floor area is a given value in m^3 per unit area (m^3/m^2) as shown in Table 6. In the case of timber framing these values assume a standard 1.8 m span and spacing for 2/90 x 35 F17 seasoned hardwood bearers and 90x35 F17 seasoned hardwood joists at 450 mm centres for ground floor framing and a 4.5 m span for 240 x 45 MPG10 joists at 450 mm centres for 1st floor framing plus miscellaneous blocking and a small allowance for beams/lintels. In the case of steel framing these values assume a standard 4.5 m span HJ 250 steel joist at 450 mm centres for both ground and 1st floor framing including a small allowance for beams/lintels and fittings.

As shown in Figure 10, the floor frame volume per unit floor area is user adjustable.



Input Details

Floor Level: Ground floor

Material: Timber(hard)

Floor Area: 230.22 m²

Quantity: 2.4173 m³

Volume per unit area: 0.01050 m³/m²

Total ECO2 Emissions: 959 kg

Assumptions

For timber framing, a standard 1.8 m span and spacing for 2/90 x 35 F17 seasoned hardwood bearers and 90x35 F17 seasoned hardwood joists at 450 mm centres for ground floor framing and a 4.5 m span for 240x 45 MPG10 joists at 450 mm centres for 1st floor framing plus miscellaneous blocking and a small allowance for beams/lintels.

For steel framing, a standard 4.5 m span HJ 250 steel joist at 450 mm centres for both ground and 1st floor framing including a small allowance for beams/lintels and fittings.

Figure 10 Floor frame details in the Embodied CO$_2$ module input

Table 6 Default floor frame volume per unit area of floor

Floor framing material	**Floor level**	**Volume per unit area (m^3/m^2)**
Timber	Ground	0.0105
	1st or above	0.02372
Steel	Ground	0.00096
	1st or above	0.00096

Appendix B.5 Wall Framing

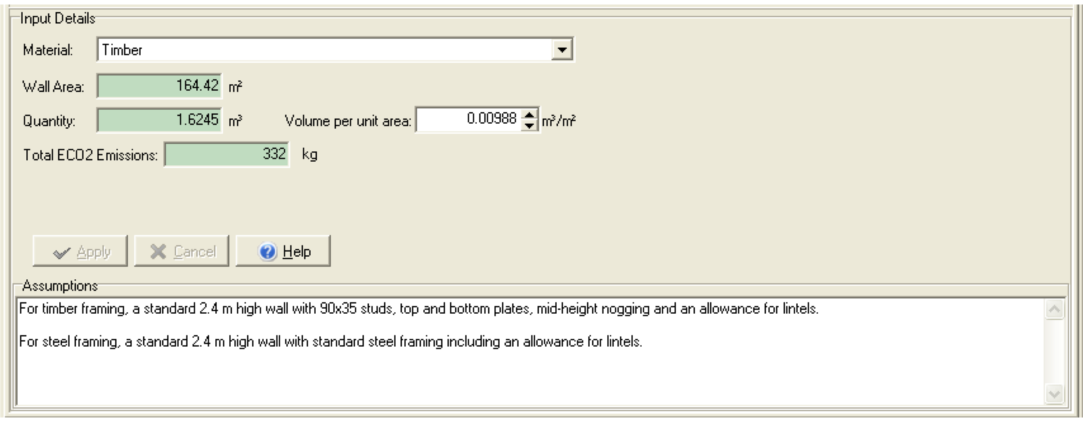
The volume of wall frame materials is estimated by Eq. (11)

$$V_{WallFrame_i} \quad = \quad WallArea \times VolumePerUnitArea_{WalFrame_i} \qquad (11)$$

where $WallArea$ is the total house wall area which is automatically calculated from existing AccuRate input. It is assumed that cavity double brick, single brick and concrete walls do not have wall frames.

The default wall frame volume per unit wall area is a given value in m^3 per unit area (m^3/m^2) as shown in Table 7. In the case of timber framing these values assume a standard 2.4 m high wall with 90x35 studs, top and bottom plates, mid-height nogging and an allowance for lintels. In the case of steel framing these values assume a standard 2.4 m high wall with standard steel framing including an allowance for lintels.

As shown in Figure 11, the wall frame volume per unit floor area is user adjustable.



Material: Timber

Wall Area: 164.42 m^2

Quantity: 1.6245 m^3

Volume per unit area: 0.00988 m^3/m^2

Total ECO2 Emissions: 332 kg

For timber framing, a standard 2.4 m high wall with 90x35 studs, top and bottom plates, mid-height nogging and an allowance for lintels.

For steel framing, a standard 2.4 m high wall with standard steel framing including an allowance for lintels.

Figure 11 Wall frame details in the Embodied CO_2 module input

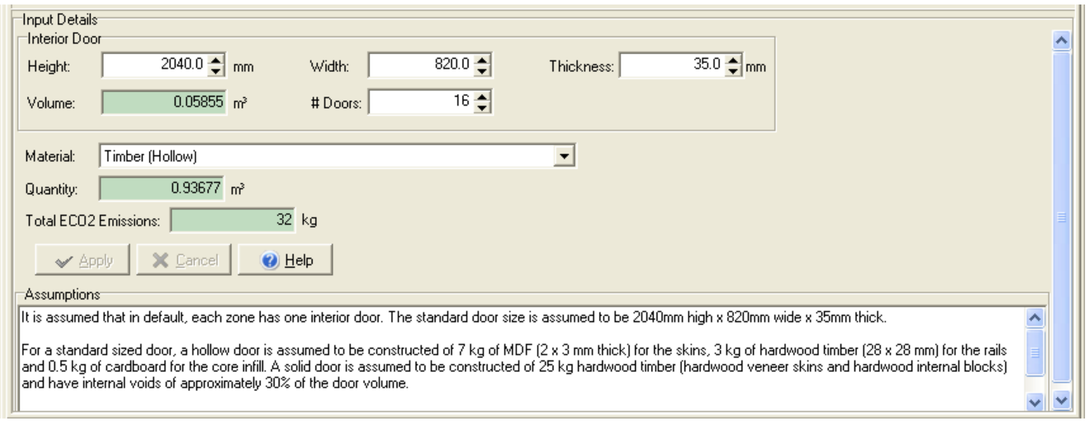
Table 7 Default wall frame volume per unit area of wall

Material	**Volume per unit area (m^3/m^2)**
Timber	0.00988
Steel	0.00051

Appendix B.6 Interior Doors

In the existing AccuRate user input, only external door information is available and internal door is not explicitly described. It is assumed that in default, each zone has one interior door. The standard door size is assumed to be 2040mm high x 820mm wide x 35mm thick. The users can adjust the number of interior doors and their dimensions as shown in Figure 12.

For a standard sized door, a hollow door is assumed to be constructed of 7 kg of MDF (2 x 3 mm thick) for the skins, 3 kg of hardwood timber (28 x 28 mm) for the rails and 0.5 kg of cardboard for the core infill. A solid door is assumed to be constructed of 25 kg hardwood timber (hardwood veneer skins and hardwood internal blocks) and have internal voids of approximately 30% of the door volume. For non-standard sized interior doors, the materials used are assumed to be proportional to the door volume.



Height: 2040.0 mm
Width: 820.0
Thickness: 35.0 mm
Volume: 0.05855 m³
Doors: 16
Material: Timber (Hollow)
Quantity: 0.93677 m³
Total ECO2 Emissions: 32 kg

It is assumed that in default, each zone has one interior door. The standard door size is assumed to be 2040mm high x 820mm wide x 35mm thick.

For a standard sized door, a hollow door is assumed to be constructed of 7 kg of MDF (2 x 3 mm thick) for the skins, 3 kg of hardwood timber (28 x 28 mm) for the rails and 0.5 kg of cardboard for the core infill. A solid door is assumed to be constructed of 25 kg hardwood timber (hardwood veneer skins and hardwood internal blocks) and have internal voids of approximately 30% of the door volume.

Figure 12 Internal door details in the Embodied CO_2 module input

Appendix B.7 Staircase

Figure 13 and Figure 14 show the schematic views of the rise and the going of a stair and a step respectively. It is assumed that the default thickness of the Riser and the Going is 20 mm. Assuming the upper floor thickness of 0.25m, the total rise of the stair is

$$TotalRise = Max.Ceiling\ Height\ Above\ Floor + 0.25 \tag{12}$$

Assuming the going of a step is twice the height of the rise of a step and the nosing is 0.2 that of the height of the rise of a step, the total run which is the horizontal distance in metres (m) between the edge of the upper floor and the end of the bottom step can be calculated as

$$TotalRun = 2.2 \times TotalRise \tag{13}$$

Assume a default stringer height of 285mm and a thickness of 25 mm for each side of the stair. Length of the stringer is estimated as:

$$Length_{Stringer} = \sqrt{TotalRise^2 + TotalRun^2} \tag{14}$$

The volume of the Riser, the Going and the Stringers can then be estimated by Eqs. (15), (16) and (17).

$$Vol_{Riser} = TotalRise \times RiserThickness \times Width_{staircase} \tag{15}$$

$$Vol_{Going} = TotalRun \times GoingThickness \times Width_{staircase} \tag{16}$$

$$Vol_{Stringer} = 2 \times Length_{Stringer} \times StringerThickness \times Height_{Stringer} \tag{17}$$

Figure 15 shows the staircase detail input page. Users can adjust where the staircase is (if the ceiling height is different in the zone), the material (Timber or MDF), the stair width, the stringer height, the thickness of the riser, the going and the stringer.

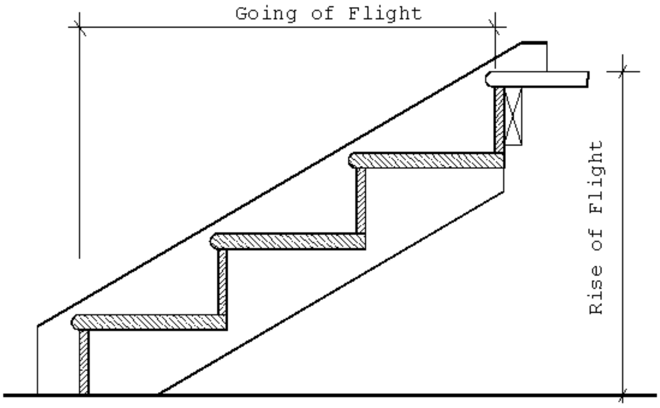


Figure 13 Rise and Going of a flight of stairs

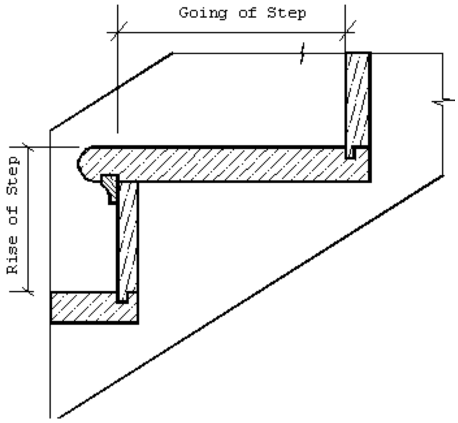
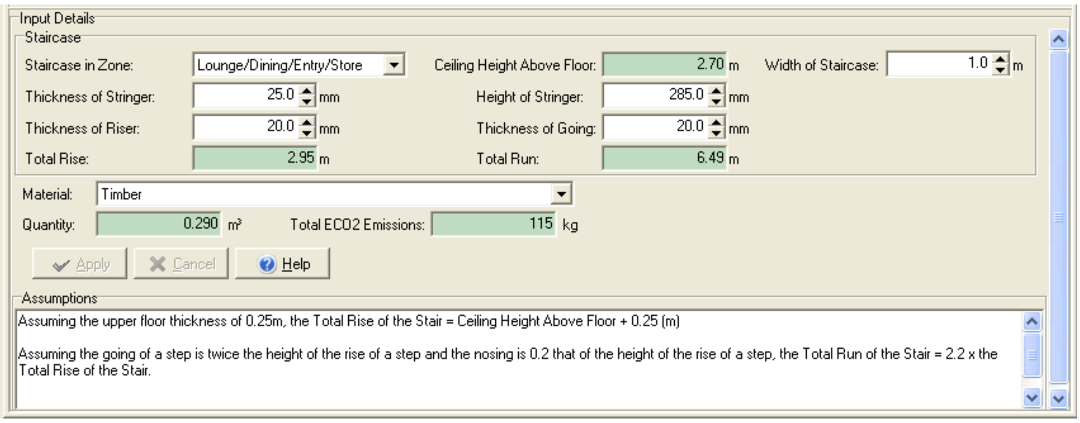


Figure 14 Rise and Going of a step



Input Details

Staircase

Staircase in Zone: Lounge/Dining/Entry/Store
Ceiling Height Above Floor: 2.70 m
Width of Staircase: 1.0 m
Thickness of Stringer: 25.0 mm
Height of Stringer: 285.0 mm
Thickness of Riser: 20.0 mm
Thickness of Going: 20.0 mm
Total Rise: 2.95 m
Total Run: 6.49 m

Material: Timber
Quantity: 0.290 m³
Total ECO2 Emissions: 115 kg

Assumptions

Assuming the upper floor thickness of 0.25m, the Total Rise of the Stair = Ceiling Height Above Floor + 0.25 (m)

Assuming the going of a step is twice the height of the rise of a step and the nosing is 0.2 that of the height of the rise of a step, the Total Run of the Stair = 2.2 x the Total Rise of the Stair.

Figure 15 Staircase details in the Embodied CO_2 module input page

Appendix B.8 ECO_2 from Windows

Estimation of ECO_2 emissions from windows is based on Howard *et al* (2007), however, with the following material ECO_2 emission factors:

Materials	**ECO2 Factor (kg CO2-e/kg)**
Aluminium	13.4
Timber - Western red Cedar	0.404
Timber- Generic Eucalypt	0.586
Timber - Pinus radiata	0.404
PVC	2.41
Glass	0.55
Paint	2.06

In Howard *et al* (2007), 51 window systems were chosen as representative of the window systems used in the Australian housing industry. These 51 window systems include 14 glazing doors and 37 wall windows with different fenestration type, different window frame and size as shown in Table 8.

It is noted that windows in Table 8 may not accurately represent specific windows encountered in practice. Considering the limited window information available in the existing AccuRate user input, the window ECO_2-e calculation in the ECO_2 module is based on a lookup table as shown in Table 9 which is rearranged from Table 8.

In the existing AccuRate input, some information of window systems such as glazing types and window frames are not available or not fully available. The window frame information may be partially extracted from the window naming conventions used in AccuRate, i.e., the last non-blank character of the first 20 characters of the window name is used as the code to identify the dominant window frame material as following:

"A" and "B"	Aluminium frame
"W"	Timber frame
"I"	Aluminium Skinned frame

As shown in Figure 17, in the Window detail input, the window frame has been defaulted based on the above window naming conventions. However, the users are allowed to modify the window frame via a dropdown list of Aluminium, Timber, uPVC and Aluminium Skinned.

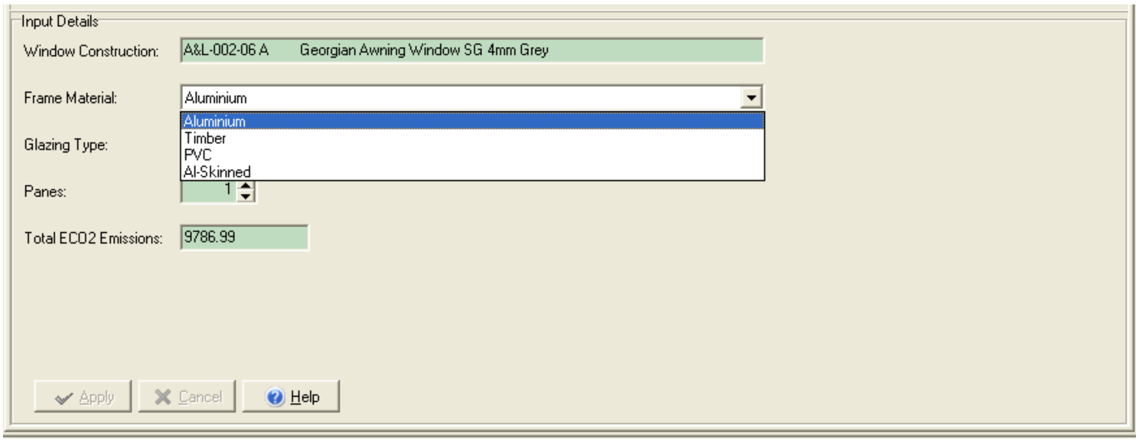
With the frame material, the following criteria are used to match the window system and the corresponding ECO_2 emissions factor from the lookup table - Table 9:

1. the frame type of the window system must be matched; and then

2. chose the window system which has the most match for pane number, fenestration type and glazing type with the diminishing priority from pane number, fenestration type to glazing type.

The ECO_2 emission for one window is then calculated by the product of the window area and the ECO_2 emissions factor (in kg/m^2) in Table 9.

Due to the limitation of the available window system information in AccuRate, the above method for estimating the ECO_2 emission from window systems is an approximate approach and may not represent specific window system in practice. Further improvement is required in the future for window system ECO_2 emission calculation.



Input Details

Window Construction: A&L-002-06 A Georgian Awning Window SG 4mm Grey

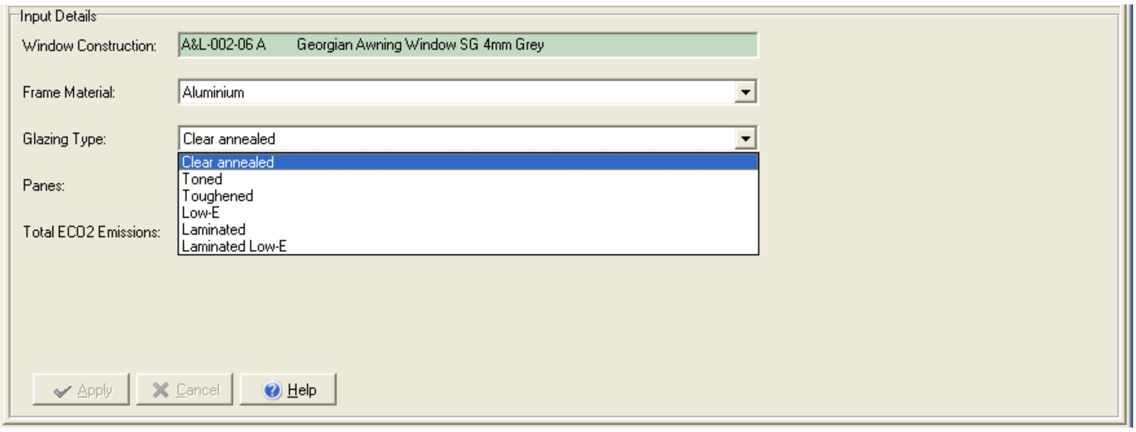
Frame Material: Aluminium

Glazing Type:

Panes: 1

Total ECO2 Emissions: 9786.99

Figure 16 Window frame details in the Embodied CO_2 module input page



Input Details

Window Construction: A&L-002-06 A Georgian Awning Window SG 4mm Grey

Frame Material: Aluminium

Glazing Type: Clear annealed

Panes:

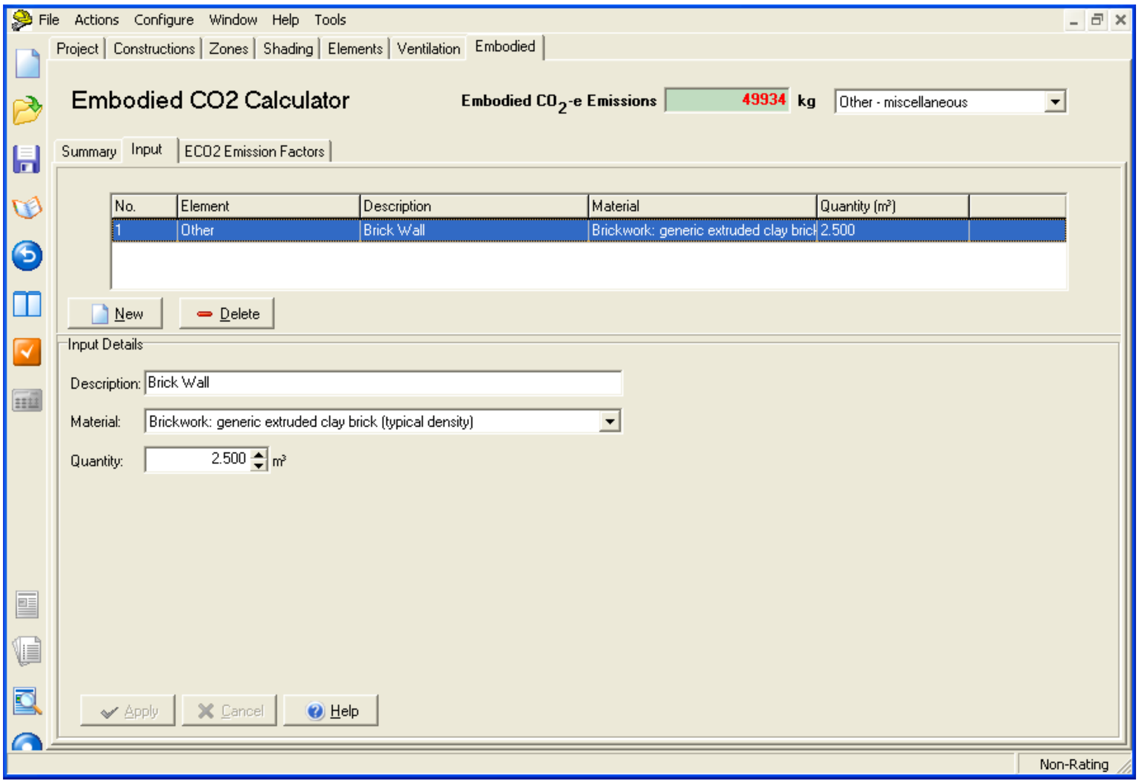
Total ECO2 Emissions:

Figure 17 Glazing type details in the Embodied CO_2 module input page

Appendix B.9 Other Components

To cater for miscellaneous items which are not handled in the ECO$_2$ module, a separate category ‘Others - miscellaneous’ is included to allow the user to explicitly enter the quantity of the material of interest as shown in

Figure 18.



Embodied CO2 Calculator

Embodied CO$_2$-e Emissions: 49934 kg

Other - miscellaneous

No.	Element	Description	Material	Quantity (m³)
1	Other	Brick Wall	Brickwork: generic extruded clay bricl	2.500

Input Details

Description: Brick Wall

Material: Brickwork: generic extruded clay brick (typical density)

Quantity: 2.500 m³

Figure 18 ‘Other – miscellaneous’ details in the ECO$_2$ module input page

Table 8 Window ECO2 based on Howard *et al* (2007)

	Door / Window	Fenestration type	Height (mm)	Width (mm)	Panes	Framing	Glass 1 type	Glass 1 thickness (mm)	Gap between panes (mm)	Gas Fill	Glass 2 type	Glass 2 thickness (mm)	ECO2 (kg/m^2)
1	Door	Double Casement (French)	2100	1800	1	Aluminium	Toughened	5	0	0	0	0	167.13
2	Door	Double Casement (French)	2100	1800	2	Aluminium	Toughened	5	12	0	Toughened	5	201.64
3	Door	Double Casement (French)	2100	1800	1	Timber	Toughened	5	0	0	0	0	59.39
4	Door	Double Casement (French)	2100	1800	1	Al-Skinned	Toughened	5	0	0	0	0	76.40
5	Door	Double Casement (French)	2100	1800	1	PVC	Toughened	5	0	0	0	0	81.37
6	Door	Double Casement (French)	2100	1800	2	PVC	Toughened	5	12	0	Toughened	5	110.33
7	Door	Sliding Patio (Ranchslider)	2100	2700	1	Aluminium	Toughened	5	0	0	0	0	152.33
8	Door	Sliding Patio (Ranchslider)	2100	2700	2	Aluminium	Toughened	5	12	0	Toughened	5	183.57
9	Door	Sliding Patio (Ranchslider)	2100	2700	1	Timber	Toughened	5	0	0	0	0	61.10
10	Door	Sliding Patio (Ranchslider)	2100	2700	1	Al-Skinned	Toughened	5	0	0	0	0	59.58
11	Door	BiFold	2100	3600	1	Aluminium	Toughened	5	0	0	0	0	160.27
12	Door	BiFold	2100	3600	2	Aluminium	Toughened	5	12	0	Toughened	5	187.99
13	Door	BiFold	2100	3600	1	Timber	Toughened	5	0	0	0	0	62.53
14	Door	BiFold	2100	3600	1	Al-Skinned	Toughened	5	0	0	0	0	61.39
15	Window	Horizontal Slider	1200	1800	1	Aluminium	Laminated Low-E	6.7	0	0	0	0	163.99
16	Window	Horizontal Slider	1200	1800	2	Aluminium	Clear annealed	4	6	Argon	Clear annealed	4	196.77
17	Window	Horizontal Slider	1200	1800	1	Aluminium	Clear annealed	4	0	0	0	0	160.84
18	Window	Horizontal Slider	1200	1800	1	Aluminium	Toned	5	0	0	0	0	162.01
19	Window	Horizontal Slider	1200	1800	1	Aluminium	Laminated	6.38	0	0	0	0	163.62
20	Window	Horizontal Slider	1200	1800	2	Aluminium	Clear annealed	4	12	0	Clear annealed	4	205.03
21	Window	Awning, toilet	900	600	1	Aluminium	Clear annealed	4	0	0	0	0	227.34
22	Window	Awning, toilet	900	600	1	Aluminium	Toned	5	0	0	0	0	228.25
23	Window	Awning, toilet	900	600	2	Aluminium	Clear annealed	4	12	0	Clear annealed	4	304.26
24	Window	Awning, toilet	900	600	1	Timber	Clear annealed	4	0	0	0	0	43.11
25	Window	Awning, toilet	900	600	2	Timber	Clear annealed	4	6	0	Clear annealed	4	153.62
26	Window	Awning, toilet	900	600	1	Timber	Toned	5	0	0	0	0	43.59
27	Window	Awning, toilet	900	600	2	Timber	Clear annealed	4	6	0	Clear annealed	4	82.49
28	Window	Awning, toilet	900	600	1	Al-Skinned	Clear annealed	4	0	0	0	0	40.95
29	Window	Awning, toilet	900	600	2	Al-Skinned	Clear annealed	4	12	0	Clear annealed	4	94.04
30	Window	Awning, toilet	900	600	2	PVC	Clear annealed	4	12		Clear annealed	4	149.52
31	Window	Casement	1200	1200	1	Timber	Clear annealed	4	0	0	0	0	53.88
32	Window	Casement	1200	1200	1	Timber	Toned	5	0	0	0	0	54.72
33	Window	Casement	1200	1200	1	Timber	Laminated	6.38	0	0	0	0	55.88
34	Window	Casement	1200	1200	2	Timber	Clear annealed	4	6	0	Clear annealed	4	83.57
35	Window	Casement	1200	1200	1	Al-Skinned	Clear annealed	4	0	0	0	0	52.30
36	Window	Casement	1200	1200	1	Al-Skinned	Toned	5	0	0	0	0	53.14
37	Window	Casement	1200	1200	1	Al-Skinned	Laminated	6.38	0	0	0	0	54.30
38	Window	Casement	1200	1200	2	Al-Skinned	Clear annealed	4	12	0	Clear annealed	4	91.14
39	Window	Double Hung	1200	900	1	Aluminium	Clear annealed	4	0	0	0	0	196.55
40	Window	Double Hung	1200	900	1	Aluminium	Toned	5	0	0	0	0	197.59
41	Window	Double Hung	1200	900	1	Aluminium	Laminated	6.38	0	0	0	0	199.03
42	Window	Double Hung	1200	900	2	Aluminium	Clear annealed	4	12	0	Clear annealed	4	254.94
43	Window	Double Hung	1200	900	1	Timber	Clear annealed	4	0	0	0	0	50.49
44	Window	Double Hung	1200	900	1	Timber	Toned	5	0	0	0	0	51.20
45	Window	Double Hung	1200	900	1	Timber	Laminated	6.38	0	0	0	0	52.19
46	Window	Double Hung	1200	900	2	Timber	Clear annealed	4	6	0	Clear annealed	4	82.63
47	Window	Double Hung	1200	900	1	Al-Skinned	Clear annealed	4	0	0	0	0	49.18
48	Window	Double Hung	1200	900	1	Al-Skinned	Toned	5	0	0	0	0	49.90
49	Window	Double Hung	1200	900	1	Al-Skinned	Laminated	6.38	0	0	0	0	50.89
50	Window	Double Hung	1200	900	2	Al-Skinned	Clear annealed	4	12	0	Clear annealed	4	91.63
51	Window	Double Hung	1200	900	2	PVC	Clear annealed	4	12	0	Clear annealed	4	132.76

Table 9 Window ECO2 lookup table

Framing	Fenestration type	Glass 1 type	Panes	ECO_2/m^2
Al-Skinned	Awning	Clear annealed	1	40.95
Al-Skinned	Awning	Clear annealed	2	94.04
Al-Skinned	Casement	Clear annealed	1	52.30
Al-Skinned	Casement	Clear annealed	2	91.14
Al-Skinned	Casement	Laminated	1	54.30
Al-Skinned	Casement	Toned	1	53.14
Al-Skinned	Casement	Toughened	1	76.40
Al-Skinned	Other	Toughened	1	61.39
Al-Skinned	Single or Double Hung	Clear annealed	1	49.18
Al-Skinned	Single or Double Hung	Clear annealed	2	91.63
Al-Skinned	Single or Double Hung	Laminated	1	50.89
Al-Skinned	Single or Double Hung	Toned	1	49.90
Al-Skinned	Sliding	Toughened	1	59.58
Aluminium	Awning	Clear annealed	1	227.34
Aluminium	Awning	Clear annealed	2	304.26
Aluminium	Awning	Toned	1	228.25
Aluminium	Casement	Toughened	1	167.13
Aluminium	Casement	Toughened	2	201.64
Aluminium	Other	Toughened	1	160.27
Aluminium	Other	Toughened	2	187.99
Aluminium	Single or Double Hung	Clear annealed	1	196.55
Aluminium	Single or Double Hung	Clear annealed	2	254.94
Aluminium	Single or Double Hung	Laminated	1	199.03
Aluminium	Single or Double Hung	Toned	1	197.59
Aluminium	Sliding	Clear annealed	1	160.84
Aluminium	Sliding	Clear annealed	2	205.03
Aluminium	Sliding	Laminated	1	163.62
Aluminium	Sliding	Laminated Low-E	1	163.99
Aluminium	Sliding	Toned	1	162.01
Aluminium	Sliding	Toughened	1	152.33
Aluminium	Sliding	Toughened	2	183.57
PVC	Awning	Clear annealed	2	149.52
PVC	Casement	Toughened	1	81.37
PVC	Casement	Toughened	2	110.33
PVC	Single or Double Hung	Clear annealed	2	132.76
Timber	Awning	Clear annealed	1	43.11
Timber	Awning	Clear annealed	2	118.05
Timber	Awning	Toned	1	43.59
Timber	Casement	Clear annealed	1	53.88
Timber	Casement	Clear annealed	2	83.57
Timber	Casement	Laminated	1	55.88
Timber	Casement	Toned	1	54.72
Timber	Casement	Toughened	1	59.39
Timber	Other	Toughened	1	62.53
Timber	Single or Double Hung	Clear annealed	1	50.49
Timber	Single or Double Hung	Clear annealed	2	82.63
Timber	Single or Double Hung	Laminated	1	52.19
Timber	Single or Double Hung	Toned	1	51.20
Timber	Sliding	Toughened	1	61.10

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