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"Life Cycle Assessment in Green Star" Discussion Paper

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Green Building Council of Australia

Thank you for the opportunity to make this submission on "Life Cycle Assessment in Green Star" Discussion Paper .

Quasar Management Services Pty Ltd has been providing consulting assistance to a number of industry associations and other organisations that are vitally concerned with marrying ecolabelling and cradle-to-grave LCAs. At various times we have provided assistance to:

- Cement Concrete and Aggregates Australia
- Think Brick Australia
- Concrete Masonry Association of Australia
- Australian Windows Association
- Building Products innovation Council.

This submission is made on behalf of Quasar, and not the organisations listed above; although it is very likely that some (many?) of the comments made herein are similar to the position taken by some of these organisations. In particular, it is similar to (but not identical to) the submission by CCAA, which we helped to prepare.

Quasar is keen to cooperate with the Green Building Council of Australia to achieve "cradle-to-grave assessments" via LCA methodology covering both embodied and operational impacts. These must analyse the change in environmental impacts on whole building over the whole of their life caused by the change of building materials from stated benchmarks.

Quasar recommends that Green Star support the principles and methodology of the "Whole-of-structure, whole-of-life, benchmarked LCA" cradle-to-grave method, which has been developed in cooperation with National Standards and other organisations; and soon to be available as public review draft NS 12000.2.

I remain willing to assist GBCA in achieving this outcome.

Rod Johnston
B Tech, M Eng Sc, MICD, CP Eng, NPER, MIE Aust, RPEQ
Principal – Quasar Management Services Pty Ltd

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GBCA Question:
Is it appropriate for the GBCA to undertake this project or would any other organisation be better placed to do it. If yes, which organisation?

Quasar Response:
Yes – Given that GBCA is a respected organisation involved in the assessment of the environmental impact of building materials, it is appropriate to undertake this project.

However, GBCA should be aware of the development of a similar method by National Standards, in consultation with other stakeholders including industry associations.

In particular, an appropriate method of "cradle-to-grave" LCA for evaluating the environmental impact of building products and systems is set out in the soon-to-be-published public-review-draft NS 12000.2 *The Establishment, Recognition And Authorisation Of Type III Environmental Labels And Declarations For Building Products And Materials Part 2: Declaration Of Environmental Attributes Of Building Products Using A Whole-of-Structure, Whole-of-Life Comparative Benchmark Method.*

Quasar recommends that GBCA adopts the principles and benchmarks set out in this public-review-draft standard (and its source material) as the basis of this project.

> Note:
> The draft standard deliberately uses the term "structure" , because (with the definition of suitable benchmarks) the method is capable of use with a comprehensive range of structures; e.g. houses, apartments, multi-storey buildings, warehouse/industrial buildings, landscaping, earth-retaining structures, roads, bridges, civil engineering projects etc. However, in the context of this submission to the GBCA, the word "building" is used; and is taken to be limited to houses, apartments, multi-storey buildings, warehouse/industrial buildings, for which draft NS 12000.2 defines benchmarks.

GBCA Question:
Is the Australian market ready for LCA as a tool for assessing the environmental impact of materials?

Quasar Response:
Yes – The building industry is currently subjected to a range of uncoordinated and conflicting regulations and self-imposed environmental requirements that lead to confusion and poor design.

For example, the National Construction Code (building regulations) imposes requirements for reducing operational greenhouse gas emissions, but do not deal with embodied considerations. On the other hand, EPD assessors deal with cradle-to-gate issues, but ignore effects on the operational impacts. Some are weighted to give a single index; while others are not.

As a matter of urgency, the building industry (and, in particular, the building products industry) needs a single genuinely level playing field, whereby both "benefit" and "significance" can be quantified; i.e. assess whether a particular material or system (a) reduces environmental impact and (b) whether the change is significant when compared to the total cradle-to-grave (embodied plus operational) effect of the whole benchmark buildings over the whole of their lives.

GBCA Question:
If no, in how many years time do you think the market would be ready?

Quasar Response:
NA – As a matter of urgency, the building industry (and, in particular, the building products industry) needs a single genuinely level playing field for assessing the environmental impact of building products and systems in the pre-design product and system selection stage.

GBCA Question:
What do you see as the main barriers to implementing LCA as an assessment methodology for materials in Green Star?

Quasar Response:
The main barriers to implementing LCA for materials are:

- Fear of the unknown – Competing building products manufacturers fear that any change must necessarily disadvantage them. While this is not true, the perception remains.
- Most LCA practitioners and advocates do not understand that LCA methodology can be easily developed to provide for the equitable "pre-design product selection" of building products and systems; PROVIDED:
    - i. A set of common benchmark buildings and climates are defined and consistently adopted (a matrix of 4 x 4 is recommended); and
    - ii. The output of the LCA (for embodied plus operational impact) is expressed as "% change" in impact from that of the benchmark buildings in the benchmark climates.

GBCA Question:
If the GBCA decided to introduce the methodology described in this paper, how much notice would you recommend the GBCA give to the market?

Quasar Response:
6 months – Provided GBCA adopts a methodology similar to that described in draft National Standards NS 12000.2, it can be introduced very quickly.

However, the development of yet another competing and conflicting method (which probably would not provide a truly level playing field) would most likely to attract a lot of resistance from manufacturers and would extend the time for eventual adoption by several years.

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GBCA Question:
Objectives -The Green Building Council of Australia invites feedback from stakeholders on the objectives of the project.

Quasar Response:
Quasar agrees with, and enthusiastically embraces, the stated objectives; but qualified as follows:

> Quasar proposes the adoption of a "cradle-to-grave" LCA method for evaluating the environmental impact of building products and systems using a "Whole-of-Structure, Whole-of-Life Comparative Benchmark Method". This is consistent with ISO 14025; but because impacts are reported as percentage change in the performances of the whole structure, it is unnecessary to differentiate between products on the basis of Product Category Rules. Therefore those parts of ISO 14025 that deal with Product Category Rules should be interpreted in the context of the proposed method.

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GBCA Question:
The list of inclusions may be expanded in the future, is it appropriate to start with a limited scope of assessment in order to simplify the LCA?

Quasar Response:
No – The LCA used to compare building products should consider together all components that interact to affect the performance of whole buildings.

> For example, while the cradle-to-gate impact of ceilings may have little to do with the cradle-to-gate impact of masonry walls, they both affect the operational performance of the building as a whole (via thermal resistance and thermal mass); and thus they both contribute to the total impact of the building. Therefore they both define the context of a percentage change in impact, and thus define the "significance" of the impact.

It is incorrect to assume that this approach makes individual assessments more difficult. To the contrary, it is only necessary to determine the impact of the benchmark buildings once. After that, analysing the effect of changing one component only involves recalculating for that component.

> For example, the initial benchmark calculations are done for a standardised building incorporating all components (e.g. including masonry, ceilings etc). After that, analysing the effect of changing (say) the masonry only involves recalculating incremental change in embodied and operational impacts on the same building, but with only the new masonry component substituted.

GBCA Question:
Please provide feedback on the list of inclusions and exclusions.

Quasar Response:
All commonly constructed parts of the building structure necessary of compliance with the National Construction Code (BCA) should be included in the Benchmark Building. All other items would be excluded.

- columns
- beams
- slabs
- exterior walls, including curtain walls
- windows, including framing and glazing
- core structure
- interior load bearing walls
- roofs
- foundations; and
- cabling, pipes, conduit and related fittings used in the provision of water and waste water services, electric and data services, ventilation and air conditioning.
- elements associated with the construction process (including those related to components included within the scope as listed above). For example mortar, formwork, etc.
- paints, adhesives, grouts and sealants

- ceiling systems
- non-load bearing internal walls and partitions
- shading structures and other elements that form part of the exterior skin of the building
- flooring, furniture, joinery, raised floors and other elements of the interior fitout
- hand rails, balustrades, stairs, and other interior hardware; and

Although services, HVAC and lighting are excluded from this list, Quasar believes that a separate method of evaluating the combination of their operational performance and embodied impacts should be devised.

GBCA Question:
Are there additional materials should be addressed by the inclusions and exclusions?

Quasar Response:
All building materials and components may be easily assessed using the method proposed by Quasar.

The Benchmark building covers the basic components necessary for a functional building and National Construction Code (BCA) compliance. However, all other building components may be assessed against the Benchmark, by comparing their incremental impact to the total impact of the basic building.

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GBCA Question:
Is the use of a 'cradle to constructed, sealed and serviced' building approach appropriate?

Quasar Response:
No – Quasar rejects any limitation of the boundary conditions to anything less than "Cradle-to-grave including operational impacts". Further, the impacts must also include the impact of using the particular product or system on the total impact of the whole building. i.e. a "whole-of-structure, whole-of-life" LCA.

GBCA Question:
Is it practical to make qualified assumptions about the origin and the distances that material must be transported in a Green Star design submission, i.e. at a tender stage when some the specific materials are unknown?

Quasar Response:
Yes. The benchmarks should be averages based on generic products used in generic buildings for each of the climate zones.

The four BCA climate zones (1, 2, 5 and 6) suggested for analysis broadly correspond to geographic regions. Specific products being rated should include an allowance from the place of manufacture to the "major" market four BCA climate zones (1, 2, 5 and 6).

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GBCA Question:
Is 1m^2 of GFA an appropriate unit?

Quasar Response:
Yes and No.

For assessing the impact of particular products within any standard building, “per 1m^2 of GFA” is reasonable as an equitable base for reporting impacts.

However, “per 1m^2 of GFA” fails to adequately convey the sense of scale or significance of the impact.
Draft NS 12000.2, refines this unit further, by requiring the reported values to be expressed as “% change in impact [from the corresponding value for the benchmark building]”. i.e. This it is then independent of the units of measurement; and can be used to compare the impacts of any building component to any other component.

Quasar will accept the expression of impacts as “per 1m^2 of GFA”; provided it is required that assessments also report “% change in impact [from the corresponding value for the benchmark building]”.

GBCA Question:
Are there constraints to using this unit?

Quasar Response:
“per 1m^2 of GFA” fails to adequately convey the sense of scale or significance of the impact.

GBCA Question:
If there are constraints or reservations about the proposed functional unit, what are the alternatives?

Quasar Response:
Quasar will accept the expression of impacts as “per 1m^2 of GFA”; provided it is required that assessments also report “% change in impact [from the corresponding value for the benchmark building]”.

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GBCA Question:
Is it appropriate to limit the number of environmental impact categories to six?

Quasar Response:
Yes, but there is a case developed below that it could (should ?) be further reduced.

GBCA Question:
If more categories are to be included, which categories do you recommend be included? What method should be applied to determining the impact categories the LCA will take into account?

Quasar Response:
No other categories should be added.

GBCA Question:
If fewer categories are to be included which categories do you recommend be removed?-

Quasar Response:
However, there is also a reasonable argument that, of these, only Climate Change needs be covered. See the reasoning below:

1. Climate Change
   This is likely to be the major impact on the environment, when one considers the operational impacts in combination with the cradle-to-gate impacts. It should be reported; but perhaps it is the only impact that should be reported. Notwithstanding, the inclusion of Climate Change should be done in such a way that it is consistent with the requirements of the National Construction Code (BCA), which provides the overriding requirement in respect of operational green-house gas emission.

2. Land transformation
   Land Transformation impacts are the responsibility of state and local government, and depend on the location of the manufacturing process. For example, a large mine in the middle of nowhere may be preferable to a small factory in suburbia. Alternatively, the suburban local government may consider it desirable to make land available to industry to relocate close to population centres. These are the responsibilities of governments, advised by town planners – not building product EPD assessors.

3. Ecotoxity to land and water use
   Caps on Ecotoxicity are the responsibility of government advised by environmental scientists – not building product EPD assessors.

4. Mineral and fossil fuel depletion
   The Commonwealth and State governments are trying their hardest to deplete out mineral resources – i.e. exporting them overseas. Policies for controlling the rate of resource depletion are the are the responsibility of government – not building product EPD assessors.

5. Water depletion
   The importance of water depletion depends on location. It is much more critical in Central Australia than in the tropical north. Policies for controlling water use are the are the responsibility of government – not building product EPD assessors.

6. Human toxicity
   Caps on Human Toxicity are the responsibility of government, advised by health professionals – not building product EPD assessors.

The role of EPD assessors should to provide tools that reflect government policies on each of the six listed categories; but not to subvert government policies.

The most effective way for the GBCA to facilitate the reduction of negative environmental impacts related to buildings, is to provide a framework for EPDs that reflect and build on government policy, as stated in the National Construction Code (BCA) and other health and environment regulations.

GBCA Question:
If six impact categories are appropriate, are the six categories above the most appropriate?

Quasar Response:
Yes - Notwithstanding the points above, the six impact categories listed in the Discussion Paper are the most appropriate.

GBCA Question:
Is it appropriate to refer to the AusLCI impact categories?

Quasar Response:
Not necessarily, but it may be a pragmatically sensible strategy.

GBCA Question:
Is there an alternative which should be used? Why?

Quasar Response:
Concentrate on Climate Change.
This is likely to be the major impact on the environment, when one considers the operational impacts in combination with the cradle-to-gate impacts. It is the only impact that should be reported.

Notwithstanding, the inclusion of Climate Change should be done in such a way that it is consistent with the requirements of the National Construction Code (BCA), which provides the overriding requirement in respect of operational green-house gas emission.

The role of EPD assessors should to provide tools that reflect government policies on each of the six listed categories; but not to subvert government policies.

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GBCA Question:
Is it appropriate to reference the BC LCI weightings?

Quasar Response:
If the argument above (that only Climate Change need be assessed) is accepted, then weighting is not required and this question is not relevant.

If the argument above (that only Climate Change need be assessed) is NOT accepted, then the BC LCI weightings would be preferable. However, as stated above, this should be a policy determination by government – not by EPD assessors.

GBCA Question:
If not, what should be used instead?

Quasar Response:
Weightings imposed by government would be more appropriate, since they would then reflect government policy. The most appropriate body to develop such weightings would be the Australian Building Codes Board.

GBCA Question:
Is it appropriate to have separate credits for each of the environmental categories or should the total score be weighed together and assessed in one credit?

Quasar Response:
“Separate credits” for each environmental category is a much more preferable scheme, since it enables the building product to be assessed on its merits when judged against various differing government policy criteria.

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GBCA Question:
Is it practical to establish a standard practice reference case for low-rise, mid-rise and high-rise buildings of different classes? If not, what other methods could be used to establish a reference case?

Quasar Response:
Quasar strongly supports the principle of defining and reporting against the performance of benchmark buildings.

This is similar to the approach developed for draft NS 12000.2 *The Establishment, Recognition And Authorisation Of Type Iii Environmental Labels And Declarations For Building Products And Materials Part 2: Declaration Of Environmental Attributes Of Building Products Using A Whole-of-Structure, Whole-of-Life Comparative Benchmark Method*.

This method currently defines the four benchmark buildings in four BCA climate zones:

Single-storey Detached Dwelling	1 storey
Sole-Occupancy Unit Building	3 storeys
High-rise Office Building	14 storeys
Low-rise Warehouse Building	1 storey

Assessments are carried out for four “Representative Locations” corresponding to the tabulated corresponding Climate Zones, as defined in the National Construction Code (BCA).

Representative Location	Climate Zone Represented	Additional Climate Zones Represented
Darwin	1	
Brisbane	2	
Sydney	5	
Richmond (Victoria)	6	3, 4, 7, 8

Please refer to Appendices 1 and 2 of this submission for a full description of this method and the benchmark buildings.

GBCA Question:
Should the reference case distinguish between new building on a green field site, refurbishment of existing buildings and fitouts?

Quasar Response:
No – The purpose of the LCAs is to distinguish the impacts of various building products or systems, in the context of their most common use. While it is clear that particular building products and systems will have greater or lesser impact in different applications (e.g. whole buildings or fit-outs), the percentage change in impact can be demonstrated to be relatively constant.

GBCA Question:
How can an equitable system be developed which acknowledges the advantages of the options from an environmental impact perspective?

Quasar Response:
Please refer to Appendices 1 and 2 of this submission for a full description of this method.

GBCA Question:

If the reference case is constructed in a similar manner to that described above, would you be able to provide your interpretation of how this may operate in practice?

Quasar Response:

The "Whole-of-Structure, Whole-of-Life, Benchmarked LCA" cradle-to-grave method for Environmental Product Declarations for pre-design selection of building products and systems, which is similar, but slightly different from the GBCA proposed model, is based on the following principles, and would be interpreted as follows.

1. LCA of Proposed Buildings
   This method is not a substitute for proper building analysis using LCA methods, once the preliminary design and product selection for any particular building has been carried out.

2. Level Playing Field
   This method provides a "level playing field" for the representation of the sustainability attributes of building systems and products that make up the external building envelope; and their potential contribution to overall building sustainability.

3. "Beneficial" and "Significant"
   Environmental Product Declarations indicate quantitatively whether building systems or products are both "beneficial" and "significant", in the context of the whole building throughout its whole life.

4. Application
   Environmental Product Declarations should be applicable to particular building products, generic building products and building systems.

5. Embrace both Embodied and Operational
   Environmental Product Declarations should address all phases of the building product cycle, including raw materials, manufacture, transport, construction, operational effect and reuse; i.e. both embodied and operational characteristics.

6. Draft NS 12000
   Draft National Standard NS 12000,2 is currently being prepared to address all phases of the Australian building product cycle, including raw materials, manufacture, transport, construction, operational effect and reuse; i.e. both embodied and operational characteristics.

7. Occupancy Profiles
   Benchmarking is against common forms of construction, (e.g. deemed-to-satisfy requirements of the National Construction Code (BCA) 2011). By referencing the National Construction Code (BCA), draft NS 12000.2 provides suitable benchmark occupancy and use profiles complying with the Building Regulations.

8. Results to be Expressed as Percentage Impact
   To minimise the effect of building shape, size, orientation and the like, impacts are expressed as the change in the total sustainability of the standard buildings, when incorporating the subject product or system, expressed as a percentage of the total sustainability of the standard buildings, when incorporating the benchmark products and systems.

9. Application
   The method may be used for particular building products, generic building products, and building systems used in the structure and envelopes of buildings.

10. "Whole-of-building, Whole-of-life, Cradle-to-grave"
    Environmental Product Declarations for the components of the structure and building envelopes should be determined using "Whole-of-building, Whole-of-life, Cradle-to-grave, Benchmarked Life Cycle Assessments" that include all phases of the building product cycle, including raw materials, manufacture, transport, construction, operational effect and reuse. In other words, the both embodied characteristics and operational characteristics are included in the considerations.

11. Australian Building Products
The method currently references the BPIC-ICIP data for Australian building products.

12. Overseas Building Products
It is recommended that the method include a requirement that building products manufactured overseas be analysed by a method consistent with the BPIC-ICIP Protocol.

13. Transport
The method should include a requirement that all building products, whether manufactured in Australia or overseas, include allowance for the impact of transport that is consistent with the BPIC-ICIP Protocol.

14. Operational Climate Change mpact Analysis
The method requires the operational impact to be calculated using simulation packages that account for the building envelope thermal resistance, thermal mass, surface solar absorptance, surface emissivity, glazing conductance, glazing solar heat gain, ventilation, orientation, Australian use profiles and the like. It should also deem suitable certain simulation packages (e.g. AccuRATE [for residential applications] and Energy Plus [for commercial/industrial applications]).

15. Construction, Demolition and Maintenance
Because the environmental impacts of construction, demolition and maintenance are relatively small, compared to the total impact, it is considered reasonable to omit details of these stages from the method for the time being.

16. Design Life of Elements
The method should include a requirement that the manufacture, transport, construction and demolition impacts of building envelope elements with a design life shorter than the estimated building life be multiplied by a factor equal to the building design life divided by the element design life.

17. Recycling and Reuse
The method should include rules covering Recycling and Reuse of building envelope elements.

18. "**Positive** indicating good performance" and "**Negative** indicating poor performance"
The convention of expressing "**Positive** numbers indicating good performance" and "**Negative** numbers indicating poor performance", consistent with the normal perceptions of common people, should be formalised and explained.

19. 4 x 4 matrix
To ensure that there is sufficient data available to designers, while keeping the costs down, the method currently requires the presentation of the results of sixteen simulations for the effects of products (or systems) presented in a 4 x 4 matrix.

    - A standard house, apartment block, high-rise office and warehouse
    - In Climates Zones 1, 2, 5 and 6.

However, GBCA may wish to vary the number of standard buildings.

20. Orientation
Data analysed indicates that the building orientation has some (albeit small) influence on the calculated changes in building performance. This is to be expected, since it alters the effectiveness of thermal mass, and is the basis of passive design. However, because the method deals with percentage change and constant orientation [major openings facing north], the effect of orientation is considered small enough to be ignored.

21. Suitability of Benchmark
The selection of the benchmark may be reasonably arbitrary, provided it reflects a practical form of construction; although once selected and specified in the standard, it should not be changed. If the benchmark is too liberal, most practical construction will "look good". If the benchmark is too conservative, most practical construction will "look bad". However, irrespective of whether the benchmark is liberal or conservative, the relativities between the various target systems and products will remain the

same. In other words, the selection of the benchmark does not affect the apparent comparison of one system or product to another.

The form of construction selected as the benchmark is that complying with National Construction Code BCA Volume One and BCA Volume Two Deemed-to-Satisfy provisions.

Data indicates that the benchmark house in the benchmark locations provides reasonable predictability of the improvements in the other three house types in the same climate zone. It indicates that changes applied to the benchmark construction (expressed either as % change in operational energy]) provide a reasonable prediction of corresponding changes in energy use in the target buildings.

Four BCA Climates Zones (1, 2, 5 and 6) are specified in the method. The relative performance of building components in BCA Climate Zones 3, 4, 7 and 8, have been shown to be reasonably consistent with the predictions made using the benchmark building in Climate Zone 6.

22. <u>Summary</u>
The method provides a reasonable tool for predicting the environmental impact of various building systems and products. Whilst the predictability is not perfect, any reasonable prediction of the contribution of both embodied and operational effects is preferable to a system that does not deal with operational impacts at all.

GBCA Question:
Can LCA methodology in the Green Star Materials category operate without a reference case? If so, how do you see this working?

Quasar Response:
No – Use Benchmark Construction.

GBCA Question:
Is it practical to conduct two iterations of the LCA with different inputs for the project?

Quasar Response:
Yes – One iteration provides the impact of the Benchmark Building, and the second iteration provides the change in impact with the subject material substituted.

However, it is important to note that the first iteration (i.e. the benchmark calculations for a standardised building) need only be carried out once; and used repeatedly as the base for future iterations involving various building product and systems to be analysed.

GBCA Question:
How much additional time would it take to do the second iteration of the LCA having completed the first one? Is it 25% more, 50% more, 100% more etc?

Quasar Response:
Because the first iteration, to determine benchmark performance on a standardised building, is only carried out once; there is no significant increase in time required to use the method as described above.

GBCA Question:
Does the intended content of Table 1 include enough data to determine the input parameters for the standard practice case LCA? If not, what is missing?

Quasar Response:
No – Please refer to Appendix 2 of this submission.

GBCA Question:
What would be the best way to determine the rules for the input parameters in Table 1?

Quasar Response:
Please refer to Appendix 2 of this submission for an example of the proposed data.

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GBCA Question:
Is it appropriate to nominate ISO 14025 as the reporting mechanism?

Quasar Response:
ISO 14025 can set a broad framework, but the report should be in the following form described above.

GBCA Question:
Is there an alternative that is preferred or should be considered?

Quasar Response:
Yes. Data should be expressed as percentage change in a matrix that reflects climates and standard buildings. See the following comment.

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GBCA Question:
Is percentage reduction in impact an appropriate way to award points for improvement?

Quasar Response:
Yes - The following 4 x 4 matrix is an example of the format that is recommended.

2010 Generic mix				
Building Type Climate Zone	Single-storey Detached Dwelling	Sole-Occupancy Unit Building	High-rise Office Building	Low-rise Warehouse Building
1	**-1.6%**	**1.8%**	**0.4%**	**-0.6%**
2	**-1.8%**	**5.0%**	**0.6%**	**-0.4%**
5	**-3.0%**	**5.1%**	**0.8%**	**-0.7%**
6	**-6.1%**	**1.0%**	**0.9%**	**-1.5%**

GBCA Question:
Is it appropriate to have separate credits for each of the environmental categories or should the total score be weighed together and assessed in one credit?

Quasar Response:
Separate is preferred. However, there can be some weighting assigned; although regulation accounts for the major nasty effects.

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GBCA Question:
Should the Aus LCI Building Product inventory dataset be used in a LCA methodology within Green Star rating tools?

Quasar Response:
Yes - But GBCA should verify that the Aus LCI data is both correct and comprehensive. If it is not (as is most likely), GBCA should develop generic Australian data to populate the benchmark assessments.

GBCA Question:
Should a European LCI be used?

Quasar Response:
Yes, but only when Australian data is not available. In this case, it may need to be modified using expert judgement to approach reasonable estimates of what Australian data would be if it was available.

GBCA Question:
Are penalties needed?

Quasar Response:
Yes – A policy need s to be developed.

GBCA Question:
What data sources would be acceptable for a credible LCA to be conducted.

Quasar Response:
Default to Aus LCI, then to European LCI. Report any major deviations and modify using expert judgement to approach reasonable estimates of what Australian data would be if it was available

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GBCA Question:
Is it appropriate to exclude fitouts based on the lack of an agreed functional unit for fitout items?

Quasar Response:
No. Units are not important if percentage change is reported. Refer to details of the method.

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GBCA Question:
Will the proposed LCA methodology accommodate existing LCA systems and tools?

Quasar Response:
The method used in draft NS 12000.2 has been developed using a Microsoft Excel Workbook, published LCI data and the operational CO_2 emissions from AccuRATE and Energy Plus. It is anticipated that software will be developed to integrate these separate calculations.

GBCA Question:
What constitutes an LCA practitioner, what qualifications should be required, and should the system ALCAS are developing be referenced?

Quasar Response:

For Type III Environmental Product Declarations, independent certification should be carried out by:

a) A Third-Party Certification Body accredited by JAS-ANZ (Joint Accreditation Scheme – Australia and New Zealand), meeting the requirements of:
   - BCA Volume 1 Part A2.2(a)(iv)
   - BCA Volume 2 Part 1.2.2(a)(iv); or

b) A suitably qualified and experienced chartered professional engineer or other appropriately qualified person, meeting the requirements of:
   - BCA Volume 1 Parts A2.2(a)(iii) and A2.2(b)(i)
   - BCA Volume 2 Parts 1.2.2(a)(iii) and 1.2.2(b)(i); or

c) Industry Association that represents the manufacturers of the products or systems covered by the Environmental Product Declaration, provided the Environmental Product Declaration is verified by a person or organisation complying with the requirements of paragraphs a) or b) .

GBCA Question:
How much would you estimate it would cost to complete the assessment outlined in this paper?

Quasar Response:
The cost will depend to a very large extent on the volume of work being undertaken. The most time is in establishing the benchmark case. After that there is relatively little effort involved.

GBCA Question:
And how does that cost compare to the cost of demonstrating compliance with the current Materials Category in Green Star?

Quasar Response:
Once the Benchmark Case is established, the cost of using the method would be similar to the current Material Category in Green Star.

GBCA Question:
Is the requirement to adhere to international standards necessary?

Quasar Response:
No - Although Australia should consider the broad principles developed elsewhere. European LCI cradle-to-gate data is very misleading, since it gives no idea on impact over the whole of life when the operational impact is taken into consideration. In fact, Australia could lead the world into developing a method which gives a truly level playing field. This may represent some future international advantage.

GBCA Question:
Which are the relevant standards that Green Star related LCAs should adhere to?

Quasar Response:
ISO 14025 is a good starting point, but we should be prepared to deviate in order to achieve a level playing field.

GBCA Question:
Is the requirement to use recognised software necessary?

Quasar Response:
No. We should encourage innovation in software development. However, the software must comply with the ABCB Protocol.

GBCA Question:
Should the GBCA recognise particular softwares?

Quasar Response:
No – GBCA should be flexible.

GBCA Question:
Which software should be recognised, and why?

Quasar Response:
For the operational energy calculations, software should comply with the ABCB Protocol.

GBCA Question:
The requirements of the Energy category within Green Star rating tools, stipulate that any energy simulation software used are BESTEST compliant. Does equivalent software exist for LCA?

Quasar Response:
GBCA will need to establish this.

GBCA Question:
Is the requirement for peer review necessary?

Quasar Response:
No - Not if the practitioner meets the qualifications suggested above.

GBCA Question:
What other requirements are necessary to ensure best practice LCA modelling?

Quasar Response:
Periodic audit of reports by a government agency such as JAS-ANZ.

Appendix 1

Whole-Of-Building, Whole-Of-Life, Cradle-To-Grave, Benchmarked LCA" Environmental Product Declarations for Pre-Design Selection of Building Systems and Products

Introduction

The provision of environmentally sustainable solutions, which are credible and designer-friendly, represents one of the most significant challenges facing building product-suppliers. To date, building regulators have concentrated on the in-service performance of buildings, making provision for both Deemed-to-Satisfy Solutions and Alternative Solutions (based on computer simulation and the published verification methods). This is a soundly–based decision, given that, in many cases, in-service energy performance far outweighs the other energy expenditure associated with building products.

There is now a strong push to consider the environmental effect of winning the raw materials, manufacture, transport, construction and demolition of building products. Ecolabelling organisations now produce "cradle-to-gate" ecolabels dealing with these aspects. However, "cradle-to-gate" ecolabels will fail to provide data on the in-service performance for each system or product, under a range of applications and climates. If used in pre-design system selection, these ecolabels (which appear at first sight to be environmentally friendly) will lead to poor decision-making the selection of inappropriate systems and products.

An alternative method, "Whole-Of-Building, Whole-Of-Life, Cradle-To-Grave, Benchmarked LCA" Environmental Product Declarations has been proposed for pre-design building system and product selection. This report deals with the suitability of that method.

Purpose of Report

The purpose of this report is to establish the suitability of "whole-of-building, whole-of-life, cradle-to-grave, benchmarked LCAs" as a suitable tool for "pre-design building system and product selection". The method discussed in this paper is not a substitute for the proper design of buildings by LCA methods. Rather, it concerns the honest representation of the sustainability attributes of building systems and products, such that their potential contribution to overall building sustainability can be easily recognised and evaluated.

Example demonstrating problem with "cradle-to-gate" ecolabels

The nature of the problem can be demonstrated in practical terms by the following example, which compares "cradle-to-gate" ecolabels to "whole-of-building, whole-of-life, cradle to grave, benchmarked LCA" environmental product declarations for three competing concrete blocks.[1]

[1] For convenience, this analysis has only considered carbon equivalent emitted, BUT could consider a weighted index of all sustainability criteria – the results would be similar.

"Cradle to Gate" Ecolabels

Hollow concrete block type	Carbon emitted kg CO2-e/kg	Carbon emitted kg CO2-e/m² wall	Ecolabel
2010 Dense mix (Manufacturer A)[2]	0.111	23	Good
2010 Generic mix[3]	0.118	25	Bad
200B Light mix (Manufacturer B)[4]	0.510	60	Ugly

"Whole-of-building, whole-of-life, cradle-to-grave, benchmarked LCA" Environmental Product Declarations

200B Light mix (Manufacturer B)				
Building Type BCA Climate Zone	Single-storey Detached Dwelling	Sole-Occupancy Unit Building	High-rise Office Building	Low-rise Warehouse Building
1	2.1%	2.2%	0.5%	-0.5%
2	8.7%	4.9%	1.1%	2.2%
5	8.7%	5.1%	1.2%	2.1%
6	1.4%	4.6%	1.5%	-0.2%

2010 Dense mix (Manufacturer A)				
Building Type Climate Zone	Single-storey Detached Dwelling	Sole-Occupancy Unit Building	High-rise Office Building	Low-rise Warehouse Building
1	-1.6%	1.8%	0.4%	-0.6%
2	-1.7%	5.1%	0.6%	-0.3%
5	-2.8%	5.2%	0.8%	-0.7%
6	-6.0%	1.1%	0.9%	-1.4%

2010 Generic mix				
Building Type Climate Zone	Single-storey Detached Dwelling	Sole-Occupancy Unit Building	High-rise Office Building	Low-rise Warehouse Building
1	-1.6%	1.8%	0.4%	-0.6%
2	-1.8%	5.0%	0.6%	-0.4%
5	-3.0%	5.1%	0.8%	-0.7%
6	-6.1%	1.0%	0.9%	-1.5%

"Cradle-to-gate" Ecolabels make 200B Light mix (Manufacturer B) appear to be the worst, but in fact, it leads to the greatest reduction in greenhouse emissions.

- "Cradle to Gate" Ecolabels can be misleading
- "Cradle to Grave" Benchmarked LCA indicates both relative "benefit" and "significance".

Brief Description of the Method

The following section provides a brief description of the "Whole-Of-Building, Whole-Of-Life, Cradle-To-Grave, Benchmarked LCA" Environmental Product Declarations for "Pre-Design Selection of Building Systems and Products".

[2] Hypothetical block, typical of the industry.

[3] Data provided to the BPIC-ICIP project by the CMAA

[4] Commissioned research for one particular manufacturer.

To be useful for the pre-design selection of building products and building systems, Environmental Product Declarations should indicate quantitatively whether the substitution of a particular building product or system for common construction is both “beneficial” and “significant”. The following criteria have been adopted.

1. Environmental Product Declarations shall be capable of use for:
   - particular building products,
   - generic building products, and
   - building systems.
2. Environmental Product Declarations shall be determined using "whole-of-building - whole-of-life" Life Cycle Assessments that include all phases of the building product cycle, including raw materials, manufacture, transport, construction, operational effect and reuse. In other words, the both embodied characteristics and operational characteristics are included.
3. Environmental Product Declarations shall quantify (for any particular product, generic product or generic system) both:
   - the nature of the effect i.e. whether its use is beneficial [or detrimental] to sustainability; and
   - the significance of the benefit [or detriment], in the context of the whole building throughout its whole life.
4. In order to demonstrate both “benefit” and “significance”, Environmental Product Declarations shall be benchmarked against common forms of construction. Given that all buildings in Australia should comply with the BCA[5] the most common deemed-to-satisfy requirements of the Building Code of Australia 2011[6] have been selected.
5. To ensure that the cost of preparing such Environmental Product Declarations is limited to sixteen for the product (or system) and sixteen for the benchmark. These are for:
   - A standard house, apartment block, high-rise office and warehouse[7]
   - In Climates Zones 1, 2, 5 and 6.
6. Environmental Product Declarations shall report the information in a format that minimises the effect of building shape, size, orientation[8] and the like. To achieve this, the percentage <u>change</u> in the total sustainability of the standard buildings, when incorporating the subject product or system, shall be expressed as a <u>percentage of the total sustainability</u> of the standard buildings, when incorporating the benchmark products and systems.
7. Suitability of Benchmark - Environmental Product Declarations shall report the information such that changes in the benchmark construction reflect corresponding changes in the target construction.

[5] Building Code of Australia, published in two parts. BCA Volume Two covers Class 1 buildings (houses, duplexes, villa units, row houses etc) and Class 10a buildings (garages and sheds). BCA Volume One covers all other buildings.

[6] Initially, the “most common deemed-to-satisfy” forms of construction have been made based on experience. However, this can be refined to consider also Australian Bureau of Statistics data if appropriate.

[7] The four standard buildings reflect the most common forms of construction, but also to permit other less-common components to be also tested. For example, there is provision for skylights, even though these may not be very common.

[8] This report shows that building orientation has some (albeit small) effect in changing the percentages. This is to be expected, since it alters the effectiveness of thermal mass. However, because the report deals with percentage change and provided a constant orientation is used [say major openings facing north], the effect of orientation is considered small enough to be ignored.

8. Relevance - The Environmental Product Declarations described herein are relevant for components of building envelopes, which affect to some degree the embodied and/or operational sustainability of a building. This includes (but is not limited to) the following components and their competitor products:
    - Concrete in frames, floors, roofs etc
    - Steel in frames, roofs etc
    - Masonry
    - Timber in frames, cladding and lining
    - Plasterboard
    - Windows, doors, glazing
    - Ventilators
    - Insulation
    - All roofing systems and their components
    - All cladding systems and their components
    - All lining systems and their components.

    The Environmental Product Declarations described herein are relevant, not only to the major components (e.g. bricks), but also to minor components (e.g. cement in mortar). (See further comment below)

9. Interpreting "Benefit" and "Detriment" - The Environmental Product Declarations described herein report the degree of "Benefit" and "Detriment" when compared to the common forms of construction. This can account for all parts of the building cycle, both embodied and operational. Provided suitable simulation tools are used (e.g. AccuRATE), the Environmental Product Declarations will account for thermal mass, ventilation and Australian user profiles. This will minimise much of the "green-wash" surrounding the marketing of building components that have low embodied impact, but also often-unreported detrimental effects on the operational sustainability. i.e. These products look good on the basis of "cradle-to-gate" data, but are not beneficial at all when "cradle-to-grave" is considered.

10. Interpreting "Significance" - As noted above, the Environmental Product Declarations described herein are relevant, not only to the major components (e.g. bricks), but also to minor components (e.g. cement in mortar). However, Environmental Product Declarations for minor components will often yield the conclusion that, changing from one type of minor component to another type of minor component has little significance. In a market plagued by "green wash", this is important information to be communicated. It should logically lead a designer/specifier to conclude that there is no <u>significant</u> benefit to be gained by over-specifying the sustainability of many minor components. This will have three important effects:
    1. It will ensure that building costs are not escalated by chasing illusory non-existent sustainability gains originating in some minor products.
    2. It will put an end to much of the "green-wash" surrounding the marketing of many minor components.
    3. It will allow designers to identify the components that do have a real significant effect on sustainability, and to concentrate efforts on those products.

11. An extract from a typical report is shown below, to demonstrate the format of the principal information. This data should be accompanied by notes, which interpret and explain the data.

Percentage Change in Environmental Impact				
BCA Climate Zone	Single-storey Detached Dwelling	Sole-Occupancy Unit Building	High-rise Office Building	Low-rise Warehouse Building
1	**+ 1.2%**	**- 1.0%**	**- 0.1%**	**+1.5%**
2	**+ 3.4%**	**- 0.5%**	**+1.3%**	**+ 4.9%**
5	**+ 0.3%**	**- 0.7%**	**+1.4%**	**+ 5.4%**
6	**+ 0.3%**	**+ 0.1%**	**+1.9%**	**+ 4.3%**

Notes

1. The environmental impact covered by this table are greenhouse gas emissions (% change in t CO_2-e).
2. **Positive** numbers indicate good performance – i.e. A typical building with the "subject building system" emits less greenhouse gas over the building life, than the same building with benchmark construction.
3. **Negative** numbers indicate poor performance – i.e. A typical building with the "subject building system" emit more greenhouse gas over the building life, than the same building with "benchmark construction".
4. The magnitude of the numbers express the degree of impact associated with the "subject building system"; expressed as a percentage of the impact associated with "benchmark construction".
5. Data for BCA Climate Zone 6 is most likely to be relevant in BCA Climate Zones 3, 4, 7 and 8.

Appendix 2
Proposed Text for a Draft Standard - Benchmark Construction for Environmental Product Declarations for Building Products using the "Whole-of-structure, Whole-of-life, Benchmarked, LCA" Cradle-to-Grave Method"

1. **Scope**
   This standard specifies the form and properties of four standard buildings (house, sole-occupancy units, high-rise office building and warehouse building), to be adopted as the benchmark when preparing Environmental Product Declarations, in accordance with NS 12000.1, for ranking the "cradle-to-grave" performance of competing building products and systems, accounting for their embodied and in-service performance.

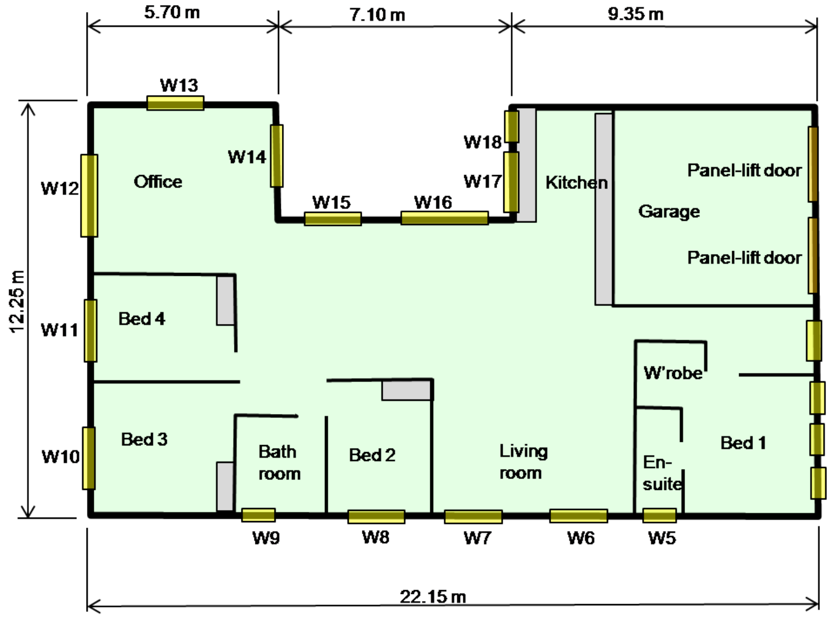
2. **Benchmark Construction Definition**
   Benchmark Construction consists of the buildings, materials and properties defined in this Standard.

3. **Benchmark Buildings**
   The standard buildings used to define Benchmark Construction shall be as defined in:
   - Figure 1 Single-storey Detached Dwelling
   - Figure 2 Sole-Occupancy Unit Building
   - Figure 3 High-rise Office Building
   - Figure 4 Low-rise Warehouse Building

4. **Benchmark Material Properties**
   The building definition and material properties used to define the Benchmark Construction shall comply with Table 1.

5. **Benchmark Quantities**
   The quantities used to define the Benchmark Construction shall comply with Table 2.

6. **Benchmark Unit Impacts**
   The unit environmental impacts used to define Benchmark Construction shall comply with Table 3.

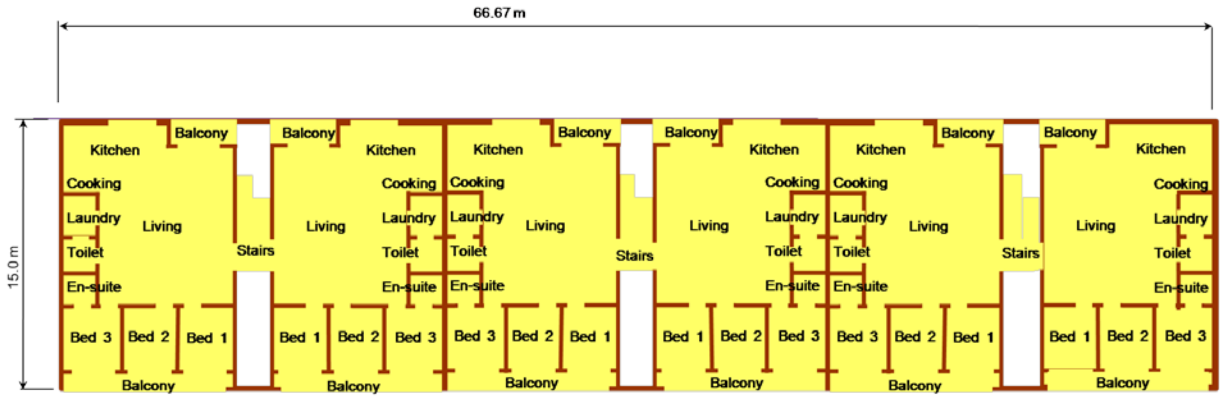


House

Window Schedule		
No	Height	Width
1	2110	1745
2	1800	610
3	1800	730
4	1800	610
5	1200	910
6	1800	1810
7	1800	1810
8	1200	1810
9	1200	1210
10	1200	1810
11	1200	1810
12	1200	2410
13	1800	1810
14	1800	1810
15	1800	1810
16	2100	2725
17	1200	1510
18	2100	890

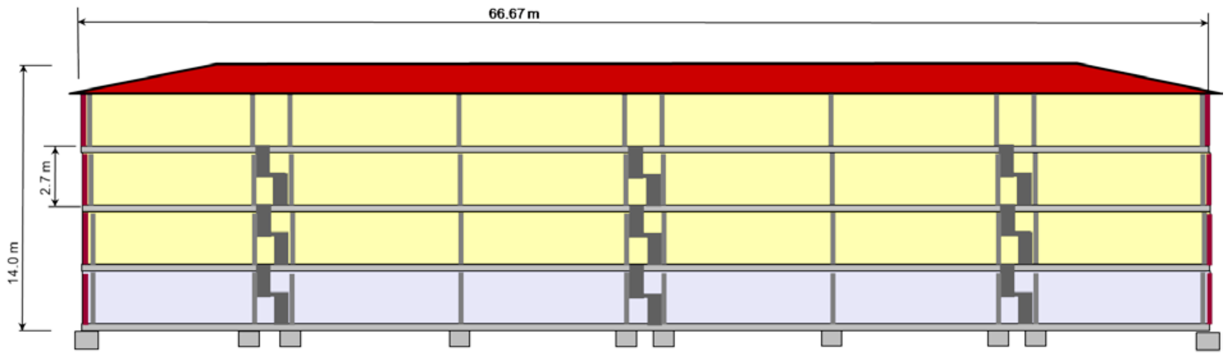
Single storey house

Figure 1 - Single-storey Detached Dwelling



Three floors, each of six Sole Occupancy Units (total 18), over a ground floor parking area

Class 2 Apartment Building



Three floors, each of six Sole Occupancy Units (total 18), over a ground floor parking area

Apartment Building

Figure 2 - Sole-Occupancy Unit Building

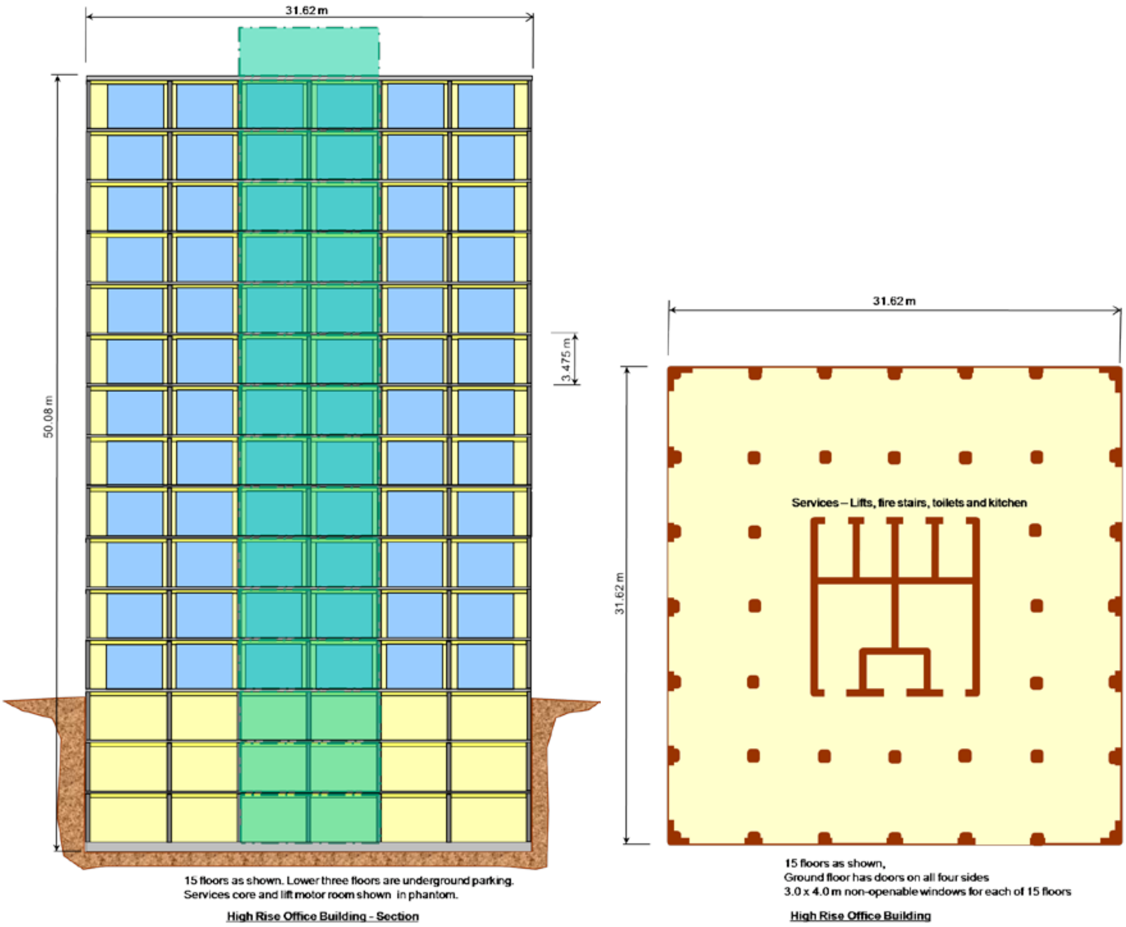


Figure 3 - High-rise Office Building

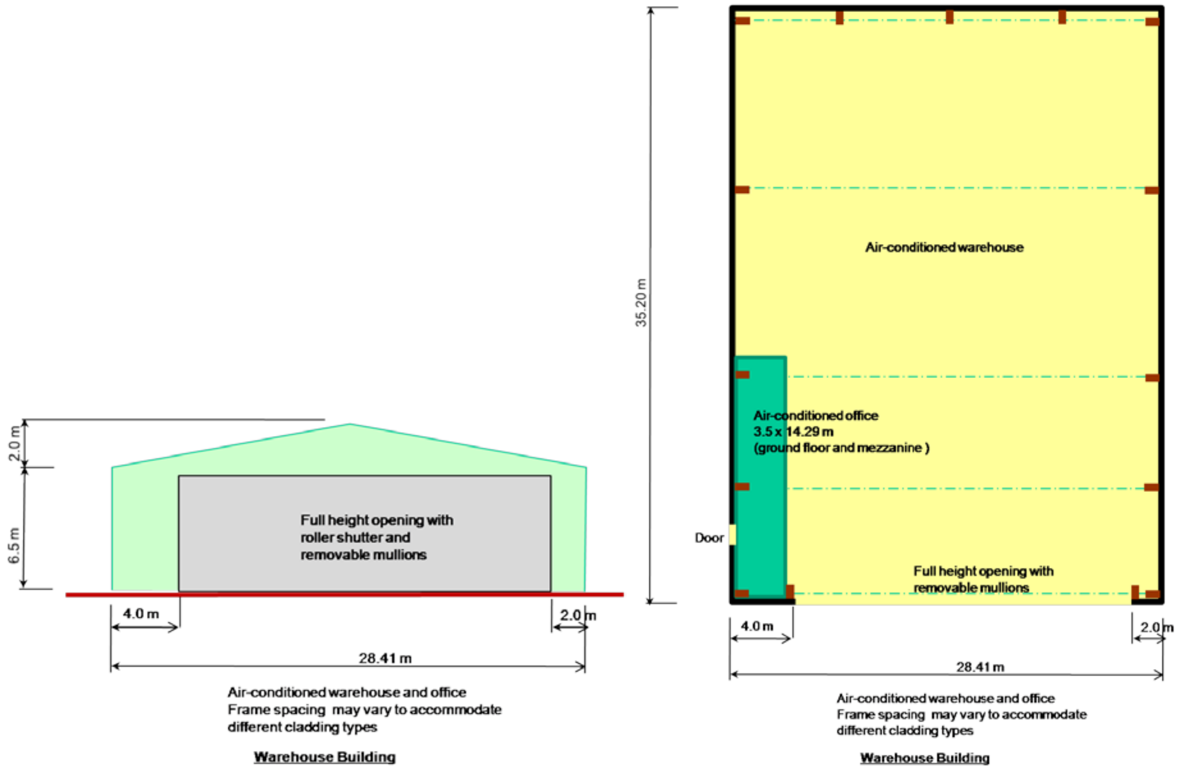


Figure 4 - Low-rise Warehouse Building Table 1 - Benchmark Construction - Building Definition and Material Properties

Building Type		**Single-storey Detached Dwelling**	**Sole-Occupancy Unit Building**	**High-rise Office Building**	**Low-rise Warehouse Building**
Building Classification		**1**	**2**	**5**	**7b**
Simulations		The simulations shall be carried out for whole house. The total energy and carbon shall be taken as the values of the house analysed.	The simulations shall be carried out for one unit in the middle storey. The total energy and carbon shall be taken as 18 times that of the unit analysed.	The simulations shall be carried out for one storey at mid-height. The total energy and carbon shall be taken as 15 times that of the storey analysed.	The simulations shall be carried out for whole building. The total energy and carbon shall be taken as the values of the building analysed.
Orientation		Dominant openings to north	Dominant openings to north	Any principal cardinal point - there are no dominant openings	Dominant openings to north
Plan dimensions					
Average north & south length (floors, excluding eaves)	m	22.15	66.67	31.62	28.410
Average east & west width (floors, excluding eaves)	m	12.25	15.00	31.62	35.200
Thickness of external walls	m	0.26	0.26	0.30	0.20
Heights					
Number of stories		1	4	15	1
Concrete slab-on-ground total thickness	m	0.100	0.150	0.175	0.150
Concrete suspended slab total thickness	m	0.000	0.175	0.175	0.000
Average floor to ceiling height	m	2.44	2.70	3.00	6.50
Average ceiling to top of floor above	m	0.00	0.00	0.30	0.00
Average storey height (floor to floor, incl suspended floors)	m	2.44	2.70	3.30	6.50
Total storey height	m	2.44	10.80	49.50	6.50
Subfloor height	m	0.40	0.40	0.40	0.15
Roof height	m	2.29	2.80	0.175	2.00
Total height	m	5.13	14.00	50.08	8.65
Areas					
Total floor perimeter (including parking, stairs & balconies/verandas)	m	75.60	199.33	138.49	127.22
Total footprint area (including parking, stairs & balconies/verandas)	m^2	271.3	1,000.0	1,000.0	1,000.0
Total floor area (including parking, stairs & balconies/verandas)	m^2	271.3	4,000.0	15,000.0	1,000.0
Total internal parking area, stairs & balconies/verandas	m^2	55.8	1,486.0	6,192.9	0.0

Total habitable floor area (external dimensions)	m^2	215.6	2,514.0	8,807.1	1,000.0
Total habitable room area (internal dimensions)	m^2	198.0	957.8	962.4	974.7
Number of rooms	No	7	90	176	1
Roof and Ceiling					
		BCA Volume Two Table 3.12.1.1a requires a total of thermal resistance of 5.1 m^2.K/W for a solar absorptance more than 0.6.	BCA Volume One Parts J0.1 & J0.2 requires verification using JV3 (reference building), and do not provide a DTS solution. The roof insulation is applicable to the non-conditioned stairwells. The simulations shall be carried out for one unit in the middle storey, with concrete slab + R1 batts + plasterboard above & below.	BCA Volume One Table J1.3a requires a total of thermal resistance of 3.2 m^2.K/W for heat DOWN for solar absorptance more than 0.5.	BCA Volume One Parts J0.1 & J0.2 requires verification using JV3 (reference building), and do not provide a DTS solution for Class 7, 8 or 9b buildings. Therefore the DTS has been derived on the basis of what is reasonable and common.
Total roof area (excluding eaves area)	m^2	271.3	1000.0	1000.0	1000.0
Eaves	m	0.45	0.45	0.00	0.00
Roof overall length	m	22.60	67.12	31.62	28.41
Roof overall width	m	12.70	15.45	31.62	35.20
Roof area (including eaves)	m^2	287.0	1036.9	1000.0	1000.0
Roof lights					
Roof light proportion of roof area	%	0.74%	0.00%	0.00%	2.00%
Roof light area	m^2	2.0	0.0	0.0	20.0
Roof light shaft index	-	1.00	1.00	1.00	1.00
Roof light Solar Heat Gain Coefficient	-	0.83	0.83	0.83	0.83
Roof light Total Thermal Transmittance	W/m^2.K	8.50	8.50	8.50	8.50
Clad Roof Areas					
Total clad roof area (excluding eaves & roof light areas)	m^2	269.3	1000.0	1000.0	980.0
Roof Type	-	Tiles	Tiles	175 mm concrete	Steel sheet
Total thermal resistance (up and down) of roof	m^2.K/W	5.10	5.10	3.20	3.20
Total thermal resistance (up and down) of roof of conditioned space	m^2.K/W	5.10	1.40	3.20	3.20
Total thermal resistance of floor of conditioned space- UP and DOWN	m^2.K/W		1.40		
Solar absorptance	-	0.75	0.75	0.45	0.55
Emissivity	-	0.90	0.90	0.90	0.90

External Walls

Total gross area of walls (including cladding & glazing)	m^2	184.5	2,152.8	6,855.3	826.9

External Doors

Total door area / total floor area		4.38%	2.90%	2.00%	14.74%
Total door area	m^2	11.89	29.02	20.00	147.40
North-facing External Door area	m^2	0.00	7.25	5.00	0.00
East-facing External Door area	m^2	11.89	7.25	5.00	0.00
South-facing External Door area	m^2	0.00	7.25	5.00	145.67
West-facing External Door area	m^2	0.0	7.3	5.0	1.73
External Door External air film thermal resistance	m^2.K/W	0.04	0.04	0.04	0.04
External Door thermal resistance	m^2.K/W	0.06	0.06	0.06	0.06
External Door Internal air film thermal resistance	m^2.K/W	0.12	0.12	0.12	0.12
External Door Other components thermal resistance	m^2.K/W	0.00	0.00	0.00	0.00
External Door Total thermal resistance	m^2.K/W	0.22	0.22	0.22	0.22
External Door Solar absorptance	-	0.70	0.70	0.70	0.70
External Door Emissivity	-	0.90	0.90	0.90	0.90

External Glazing

Total glazing area / total wall area		24%	20.1%	63%	2%
Total glazing area	m^2	45.0	432.0	4,320.0	16.5
North-facing glazing area	m^2	19.3	172.8	1,080.0	4.1
East-facing glazing area	m^2	7.2	0.0	1,080.0	4.1
South-facing glazing area	m^2	11.2	259.2	1,080.0	4.1
West-facing glazing area	m^2	7.2	0.0	1,080.0	4.1
Shading overhang	m	0.45	0.45	0.00	0.00
Shading height	m	2.24	2.7	3.3	6.5
Shading overhang / shading height	-	0.20	0.2	0.0	0.0
Shading lintel	m	0.0	0.0	0.3	0.0
Solar Exposure Factor (Method 1)	-	0.37	0.37	0.52	0.52
Glazing Total Thermal Transmittance	W/m^2.K	7.90	7.90	7.90	7.90
Glazing Solar Heat Gain Coefficient	-	0.81	0.81	0.36	0.81
North-facing glazing Total Thermal Transmittance	-	152.8	1,365	8,532	33
North-facing glazing Solar Heat Gain	-	5.80	51.79	202.18	1.74
East-facing glazing Total Thermal Transmittance	-	56.85	0.00	8,532.02	32.66
East-facing glazing Solar Heat Gain	-	5.89	0.00	501.55	4.32

South-facing glazing Total Thermal Transmittance	-	88.8	2,048	8,532	33
South-facing glazing Solar Heat Gain	-	5.0	115	338	3
West-facing glazing Total Thermal Transmittance	-	56.8	0	8,532	33
West-facing glazing Solar Heat Gain	-	5.8	0	513	4
Conductance Constant	-	2.4	2.4	2.4	2.4
Aggregate Conductance limit	-	651	9,600	36,000	2,400
Aggregate Conductance	-	355	3,413	34,128	131
Solar Heat Gain Constant	-	0.09	0.09	0.09	0.09
Aggregate Solar Heat Gain limit	-	24	360	1350	90
Aggregate Solar Heat Gain	-	23	167	1,555	13

External Wall Cladding

		BCA Volume Two Table 3.12.1.3a requires a total thermal resistance of 2.8 m^2.K/W. A reduction of 0.55 m^2.K/W is made for brick veneer walls in houses, because bulk insulation is permitted to be fitted between studs, leading to thermal bridging.	BCA Volume One Parts J0.1 & J0.2 requires verification using JV3 (reference building), and do not provide a DTS solution. The values adopted are based on BCA Volume One Table J1.5a(a), which requires a total thermal resistance of 3.3 m^2.K/W in Climate Zones 5 and 6 and 2.8 m^2.K/W in Climate Zones 5 and 6; less a reduction of 0.5 m^2.K/W for 220 kg/m^2 surface density.	BCA Volume One Table J1.5a(a) requires a total thermal resistance of 3.3 m^2.K/W in Climate Zones 5 and 6 and 2.8 m^2.K/W in Climate Zones 5 and 6; less a reduction of 0.5 m^2.K/W for 220 kg/m^2 surface density.	BCA Volume Two requires verification using JV3 (reference building), because Part J1.1 excludes Class 7, 8 and 9b buildings from the DTS solutions. Therefore the benchmark has been based on Table J1.5a(b) for Class 3, 5, 6 or 9a buildings with furring channels.
Total clad wall area (excluding subfloor and roof)	m^2	137.1	1,718.1	2,532.0	803.9
North Wall Area	m^2	40.2	574.6	578.2	179.5
East Wall Area	m^2	22.2	129.3	578.2	222.4
South Wall Area	m^2	40.2	574.6	578.2	179.5
West Wall Area	m^2	22.2	129.3	578.2	222.4
Wall Type	-	Masonry Veneer (110 brick + cavity + insulation + 10mm plasterboard)	Cavity Masonry (110 brick + cavity + insulation + 90 block+ 12 render)	Precast Concrete (150 precast + 22 cavity insulation + 10 plasterboard)	Precast Concrete 150 hollowcore + insulation in cavity formed by furring channels + 10 plasterboard
External air film thermal resistance	m^2.K/W	0.04	0.04	0.04	0.04
External cladding thermal resistance	m^2.K/W	0.09	0.09	0.10	0.14
Insulation thermal resistance	m^2.K/W	1.77	Zones 1 & 2 2.32	Zones 1 & 2 2.31	1.04
	m^2.K/W		Zones 5 & 6 1.82	Zones 5 & 6 1.81	

Cavity thermal resistance	m^2.K/W	0.17	0.17	0.17	0.00
Internal lining thermal resistance	m^2.K/W	0.06	0.06	0.06	0.06
Internal air film thermal resistance	m^2.K/W	0.12	0.12	0.12	0.12
Total thermal resistance	m^2.K/W	2.25	Zones 1 & 2 2.80	Zones 1 & 2 2.80	1.40
	m^2.K/W		Zones 5 & 6 2.30	Zones 5 & 6 1.30	
Solar absorptance	-	0.70	0.70	0.70	0.70
Emissivity	-	0.90	0.90	0.90	0.90
Surface mass	kg/m^2	196	351	369	252
Specific heat	J/kg.K	960	960	960	960
Thermal capacitance	kJ/m^2.K	188	336	354	242
Floors					
Total area of floors	m^2	271.3	4,000.0	15,000.0	1,000.0
Concrete Slab-on-Ground Area	m^2	271.3	1,000.0	1,000.0	1,000.0
Concrete Slab-on-Ground Type	-	100 mm Concrete SOG	150 mm Concrete SOG	200 mm Concrete SOG	200 mm Concrete SOG
Concrete Slab-on-Ground Surface mass	kg/m^2	240	360	420	360
Concrete Slab-on-Ground Specific heat	J/kg.K	960	960	960	960
Concrete Slab-on-Ground Thermal capacitance	kJ/m^2.K	230	346	403	346
Enclosed Suspended Floor Area (habitable to non-habitable)	m^2	0.0	1000.0	1000.0	
Enclosed Suspended Floor Type	-		175 mm Suspended Concrete	200 mm Suspended Concrete	
Enclosed Suspended Floor Internal air film thermal resistance - UP	m^2.K/W		0.11	0.11	
Enclosed Suspended Floor floor thermal resistance - UP	m^2.K/W		0.10	0.10	
Enclosed Suspended Floor Insulation thermal resistance - UP	m^2.K/W		0.47	0.00	
Enclosed Suspended Floor Cavity thermal resistance - UP	m^2.K/W		0.15	0.15	
Enclosed Suspended Floor Lining thermal resistance - UP	m^2.K/W		0.06	0.06	
Enclosed Suspended Floor External air film thermal resistance - UP	m^2.K/W		0.11	0.11	
Enclosed Suspended Floor Internal air film thermal resistance - DOWN	m^2.K/W		0.16	0.16	
Enclosed Suspended Floor floor thermal resistance – DOWN	m^2.K/W		0.10	0.10	
Enclosed Suspended Floor Insulation thermal resistance – DOWN	m^2.K/W		0.00	0.00	

Enclosed Suspended Floor Cavity thermal resistance – DOWN	$m^2.K/W$		0.22	0.22	
Enclosed Suspended Floor Lining thermal resistance – DOWN	$m^2.K/W$		0.06	0.06	
Enclosed Suspended Floor External air film thermal resistance – DOWN	$m^2.K/W$		0.16	0.16	
Enclosed Suspended Floor Surface mass	kg/m^2		360	420	
Enclosed Suspended Floor Specific heat	J/kg.K		960	960	
Enclosed Suspended Floor Thermal capacitance	$kJ/m^2.K$		346	403	

Internal Walls

Total internal walls / total perimeter area		75%	75%	50%	4.50%
Internal Walls Total gross area (including cladding & glazing)	m^2	138.3	1,614.6	3,427.7	37.2
Internal Walls	m^2	138.3	1,614.6	3,427.7	37.2
Internal Walls Type	-	10mm plasterboard + timber stud	Concrete masonry	10mm plasterboard + steel stud	10mm plasterboard + steel stud
Internal Walls Surface mass	kg/m^2	27	198	27	27
Internal Walls Specific heat	J/kg.K	2080	960	2080	2080
Internal Walls Thermal capacitance	$kJ/m^2.K$	56	190	56	56

Internal Ceilings or Mezzanine Floors

Total Internal Ceilings or Mezzanine Floors / total floor area		0%	0%	0%	2%
Internal Ceilings or Mezzanine Floors Total gross area (including cladding & glazing)	m^2	0.0	0.0	0.0	22.5
Internal Ceilings or Mezzanine Floors	m^2	0.0	0.0	0.0	22.5
Internal Ceilings or Mezzanine Floors Type	-	Timber	Timber	Timber	Timber
Internal Ceilings or Mezzanine Floors Surface mass	kg/m^2	24	24	24	24
Internal Ceilings or Mezzanine Floors Specific heat	J/kg.K	2080	2080	2080	2080
Internal Ceilings or Mezzanine Floors Thermal capacitance	$kJ/m^2.K$	50	50	50	50

Table 2 - Benchmark Construction - Quantities

Concrete					
Concrete on ground, N20	tonnes	132.6	793.5	2,283.8	1,274.9
Suspended concrete, N25	tonnes	0.0	2,240.7	0.0	0.0
Suspended concrete, N32	tonnes	0.0	0.0	14,351.8	0.0
Suspended concrete, N40	tonnes	0.0	0.0	2,904.5	427.0
Bedding sand	tonnes	25.0	93.0	93.0	93.0
Timber formwork on ground	tonnes	0.16	1.53	1.92	1.16
Timber suspended formwork	tonnes	0.00	34.32	258.71	0.00
Permanent steel formwork	tonnes	0.00	8.02	7.88	0.00
Permanent steel edge form	tonnes	0.00	0.99	3.28	0.00
Vapour barrier	tonnes	0.082	0.295	0.330	0.330
Steel in concrete on ground, N20	tonnes	2.5	15.2	43.9	24.5
Steel in suspended concrete, N25	tonnes	0.0	223.6	0.0	0.0
Steel in suspended concrete, N32	tonnes	0.0	0.0	1,432.1	0.0
Steel in concrete walls, N40	tonnes	0.0	0.0	70.7	10.4
Structural Steelwork					
Fabricated miscellaneous sections	tonnes	0.20	0.78	5.82	0.00
Fabricated Universal Beams	tonnes	0.00	0.00	0.00	11.74
Light Gauge Cold Formed Sections	tonnes	0.00	0.00	0.00	4.10
Timber					
Roof Trusses	tonnes	5.13	17.04	0.00	0.00
External Walls - Studs, noggings & plates	tonnes	0.65	0.00	0.00	0.00
Internal Walls - Studs, noggings & plates	tonnes	1.18	0.00	0.00	0.00
Roof Battens	tonnes	1.19	3.91	0.00	0.00
Roof					
Concrete tiles	tonnes	0.00	0.00	0.00	0.00
Sheet steel roof	tonnes	1.66	5.86	0.00	5.78
Timber battens	tonnes	5.8	20.4	20.1	20.1
Roof Plumbing					
Steel eaves gutter	tonnes	0.12	0.27	0.21	0.21
Steel ridge flashing	tonnes	0.05	0.12	0.10	0.10
Steel fascia	tonnes	0.36	0.83	0.64	0.65
Steel downpipe	tonnes	0.04	0.50	2.25	0.30

Masonry					
Clay bricks	tonnes	21.08	264.22	0.00	0.00
Concrete masonry units	tonnes	0.00	448.47	0.00	0.00
Mortar - Grey GP cement	tonnes	0.99	22.65	0.00	0.00
Mortar - Lime	tonnes	0.37	8.46	0.00	0.00
Mortar - Sand	tonnes	7.96	182.11	0.00	0.00
Cladding, Carpentry & Joinery					
Fibre cement	tonnes	0.17	0.40	0.00	0.00
Ceiling & Wall Lining					
10mm plasterboard	tonnes	5.21	0.00	0.00	0.00
13mm plasterboard	tonnes	10.50	54.91	205.92	13.74
Insulation					
Roof/Ceiling Insulation glass wool ceiling batts	tonnes	0.38	1.41	1.41	1.38
Wall Insulation glass wool wall batts	tonnes	0.19	2.42	3.57	0.00
Vehicular Doors					
Steel doors and mechanisms	tonnes	0.09	0.21	0.18	1.28
External Timber Doors					
External timber doors and mechanisms	tonnes	0.05	0.16	0.00	0.06
Windows, Doors & Glazing					
Aluminium Framed Glass Doors & Windows (5 mm clear float glass)	m^2	45.0	0.0	0.0	0.0
Aluminium Framed Glass Doors & Windows (8 mm clear float glass)	m^2	0.0	432.0	0.0	16.6
Fixed Glass Windows (10 mm heat absorbing float glass)	m^2	0.0	0.0	4,320.1	0.0

[9] **Table 3 - Benchmark Unit Impacts**

	Climate change	Land alienation	Marine toxicity	Freshwater toxicity	Terrestrial toxicity	Water depletion	Ozone depletion	Acidification
	t CO_2-e / t	ha/t				m^3/t	t CFK11/t	t SO_2/t
Concrete on ground, N20	0.112							
Suspended concrete, N25	0.121							
Suspended concrete, N32	0.129							
Suspended concrete, N40	0.136							
Bedding sand	0.005							
Timber formwork on ground	0.460							
Timber suspended formwork	0.810							
Permanent steel formwork	1.780							
PVC vapour barrier	2.500							
Fabricated light steelwork	1.780							
Fabricated heavy steelwork	1.780							
Timber roof trusses	0.460							
Timber wall framing	0.460							
Timber battens	0.460							
Concrete roof tiles	0.100							
Sheet roof sheeting	1.800							
Steel gutters flashing RWDPs	1.800							
Clay bricks	0.204							
Concrete masonry units	0.118							
Grey GP cement	0.830							
Lime	0.740							
Sand	0.100							
Fibre cement	2.110							
10mm plasterboard	0.380							
13mm plasterboard	0.380							
10mm wet plasterboard	0.500							
Glass wool ceiling batts	1.764							
Glass wool wall batts	1.764							
Steel doors and mechanisms	1.800							
External timber doors	0.460							
Aluminium framed glass doors & windows (5 mm clear float glass) t CO_2-e / m^2	0.201							
Aluminium framed glass doors & windows (8 mm clear float glass) t CO_2-e / m^2	0.204							
Fixed glass (10 mm heat absorbing float glass) t CO_2-e / m^2	0.015							

[9] DRAFTING NOTE
The values for Table 3 should be provided by BPIC. Preliminary approximate data has been used to date.