The Australian construction industry's approach to embodied carbon assessment: a scoping study

Monique Fouche[1] and Robert Crawford[2]

[1,2] University of Melbourne, Melbourne, Australia

mfouche@student.unimelb.edu.au, rhcr@unimelb.edu.au

Abstract: The building sector is responsible for a significant proportion of a nation's greenhouse gas emissions. In an attempt to mitigate these emissions, industry and government have been mainly focussed on reducing operational emissions associated with buildings, leaving the embodied emissions largely ignored. As operational emissions continue to decrease, embodied emissions will start to play a larger role in the life cycle emissions of the built environment. Several tools and datasets have been created internationally and locally within Australia that seek to quantify these embodied carbon emissions. However due to lack of information, it is unclear first of all how the Australian construction industry is currently approaching embodied carbon analysis and secondly what tools and databases are being used for this analysis. A survey was executed as part of the Integrated Carbon Metrics (ICM) Project that aimed to not only addresses this lack of information but to also inform the ICM project tool outputs. These tool outputs will seek to address these often ignored embodied emissions and aim to quantify the carbon fabric of Australia's built environment.

Keywords: Embodied carbon; construction industry; Australia

1. Introduction

1.1 Background

Greenhouse gas (GHG) emissions from the building sector have more than doubled since 1970 to reach 9.18 $GtCO_2$eq in 2010 representing 19% of all global 2010 GHG emissions (IPCC, 2014). In Australia, 20% of all GHG come from the operation of commercial and residential buildings alone (Climate Works, 2013). These GHG emissions have been demonstrated to negatively contribute to the effects of climate change (IPCC, 2014) with growing emphasis placed on the need to implement mitigation strategies. These mitigation strategies have been largely focused on reducing these direct (operational) emissions, however the indirect (embodied) emissions from materials and manufacturing, transport, maintenance and disposal has been estimated to make up another 11% of national emissions (Schinabeck and Wiedmann 2014). With growing international pressure to decrease national GHG, coupled with the fact

that Australia is one of the highest GHG emitters in the world on a per capita basis (Garnaut, 2008; 2011), there is a need to address both the direct and indirect GHG emissions from buildings if Australia is to achieve their commitment of reducing GHG to 26-28% below 2005 levels by 2030.

A new project, launched in 2014, under the Cooperative Research Centre for Low Carbon Living (CRCLCL), sets out to correct this exclusion and help quantify the carbon fabric of Australia's built environment by including these largely ignored indirect emissions. The project, called the Integrated Carbon Metrics (ICM) aims create a multi-scale life cycle approach to assessing, mapping and tracking carbon outcomes of the built environment. The creation of a comprehensive embodied carbon (EC) database is a fundamental aspect of this research. This database will then be used within the ICM Tool, which will map Australian carbon flows and identify carbon hot spots. The Precinct Information Modelling (PIM) carbon extension tool will complement the ICM tool by providing a 3D visualisation aspect for the calculation of EC at a precinct level. In order to ensure tools get created that are not only internationally relevant but also relevant to the Australian construction industry, it was deemed necessary to launch a scoping study, as part of the project, to gain an understating of how the Australian construction industry currently approach EC analysis.

Even though previous research exists that looks at industry's perceptive of EC, they have been largely UK and American focused, such as Ariyarante and Moncaster (2014) and De Wolf and Ochsendorf (2014). There is currently a limited amount of research about EC within the Australian context and a severe lack of understanding as to how the Australian construction industry currently approach EC analyses (if at all) and what tools and datasets gets used for this analyses. The aim of this research was to conduct a scoping study that could provide this necessary insight. From the amount of companies currently providing this service; to the tools used for this service and to further identify any potential areas for tool improvement along with any perceived strengths and weaknesses of current tools. The survey result, which would be built upon in the next phase of the project, will be used to inform the ICM project and tool outputs. This research and survey focusses solely on carbon emissions related to the built environment. The survey is aimed to gain insight from industry and does not intend to provide insight from other project stakeholders, such as clients. Industry was selected as they are most often the project member utilising EC assessment tools within the project phase, not the homeowner, client or building occupant.

The following section will provide a brief overview of EC and include detail about current assessment methods and relevant standards. This will be followed by a mention of the similar surveys used as informants for this research' survey along with survey method, design and sampling. This paper will then conclude in a discussion of the survey results and highlight any limitations associated with its findings.

1.2 Embodied carbon

A building will emit carbon during a number of separate phases over its lifetime. These 'phases', as defined within BS EN 15978:2011, are broadly split up into the following four phases: product stage; construction process stage; use stage and end of life stage. Industry and government have been mainly focused on reducing the carbon emissions from the use phase, leaving the other phases largely ignored. However even before a building is occupied, between 30% to 70% of its lifetime carbon emissions have already been accounted for (ASBP, 2014). With the continuing decrease in OC, EC represents an increasingly significant component of the GHG emissions attributable to the built environment

(Crawford *et al.*, 2010; Dixit *et al.*, 2012; de Wolf and Ochsendorf, 2014). The increasing awareness has resulted in the following developments related to embodied carbon:

1.2.1 Methods of embodied carbon assessment

Life Cycle Assessment (LCA) is widely acknowledged as providing an appropriate framework for assessing carbon emissions throughout the whole building life cycle (Menzies et al., 2007; Zuo et al., 2012). LCA is a method for evaluating the environmental impacts of products holistically, including direct and supply chain impacts (Lenzen et al., 2004). There are four fundamental steps for conducting an LCA namely: goal; inventory analysis; impact assessment and interpretation (Crawford *et al.*, 2010). However each step requires a certain level of subjectivity. From defining the system boundary (to what extent each life cycle phase is included in the calculation) to interpretation of results (Treloar, 1998). This subjectivity can result in differing and often incomparable EC results for the same building element. Another aspect affecting the EC results is the inventory which in influenced by a wide range of factors, from age of data; geographic location and degree of completeness (Crawford *et al.*, 2010)

This LCA process is often seen as complex and time and resource heavy. There has been an increase in the amount of available tools and software to aid calculation. From commercially available tools, such as, SimaPro (Netherlands); GaBi (Germany); Boustead (UK) and eTool (Australia) to in-house developed data and tools, such as Arup's Project Embodied Carbon & Energy (PECD) dataset that consists of Arup projects with data extracted from Revit models. Each tool employs inventories that include the EC coefficients of building products and materials. The origin of these datasets ranges from ICE (UK); Ecoinvent (Switzerland) or AusLCI (Australia), to name but a few. Most of these datasets provide data from cradle to gate (resource extraction to factory gate). Several researchers have analysed and compared these available tools and concluded their advantages and disadvantages (Ariyarante and Moncaster, 2014 and De Wolf and Ochsendorf, 2014). The outcome of these comparisons often reflect some of the same characteristics that plague LCA as mentioned earlier, from inconsistent calculation methodologies and system boundaries resulting in a range of reported EC figures dependent on what tool is used. In addition to this, several upstream phases are left out of the calculation due to only relying on cradle to gate data (instead of cradle to cradle, i.e. resource extraction to re-use) , resulting in a degree of incompleteness which has been shown to be 50% or more (Crawford, 2008).

1.2.2 Standards and legislation

Even though there is no mandatory legislation requesting the assessment of EC, there is growing evidence that the international community is embracing the challenge of decreasing the embodied emissions associated with buildings. From the emergence of voluntary actions, where local city councils, such as Borough of Guildford in the UK, requests, as part of their planning requirements, the use of low embodied energy materials (Guildford Borough Council, 2011). To more mandatory actions, such as the Netherlands requiring the reporting of building material GHG emissions as part of their Dutch Building Decree. Some of Australia's local governments have followed suit and have set their own targets, such as City of Melbourne's Zero net emissions by 2020 with a strategy in place to create a carbon neutral city (City of Melbourne, 2014).

To help counteract the inconsistent methodologies and incomparable datasets, as mentioned earlier, that plagues EC analyses, there has been a move to standardise the calculation procedure. From the UK's PAS2050 (2008) Specification for the assessment of the life cycle GHG emissions of goods and

services (Developed by the British Standards Institute, BSI) to the internationally recognized ISO 14040:2006 ISO 14040:2006 Environmental management – Life Cycle assessment: Principles and framework and ISO 14044:2006 'Environmental Management – Life Cycle assessment: Requirements and guideline. However these standards are not mandatory yet and overall consensus on the correct approach has yet to be achieved.

1.2.3 Embodied carbon and industry

There is a limited amount of information available as to how the construction industry currently approach EC analyses. Surveys have been conducted, mostly in the UK or USA, and have largely been focused on challenges and barriers towards EC analyses uptake (UKGBC, 2014) or opinions on EC (ASBP, 2014). One study did explore four specific LCA tools through interviews with six industry experts, however the tools identity were not provided and specific tool recommendations were not included. Table 1 provides a brief breakdown of the relevant surveys consulted for this research. Even though these surveys do provide some insight into industry's current attitude towards EC and highlights some of the issues affecting EC analyses, no specific insight can be drawn as to what recommendations can be brought forward for new EC tools, which Arriyante (2014) has identified as an industry need. And due to lack of Australian based surveys, no clear insight is available as to how the Australian construction industry currently approach EC analyses and what tools and datasets are used within their organisations.

Table 1: Consulted surveys about embodied carbon assessment and industry

Author , year and location	Survey Method	Survey topic
UKGBC (2014) UK	Paper based survey with open-ended questions. Data was organised under four key themes identified from the feedback: Key messages; challenges; Next steps and Leadership.	UK industry's attitude towards EC. Key messages, challenges and next steps.
De Wolf et al (2014) UK and USA	Semi-structured interview with structural engineering and design firms	Critical review of what needs to be included in an EC database and how it needs to be presented.
Ariyarante and Moncaster (2014) UK	An initial scoping stage survey included collecting opinions from industry professionals on the methods used for EC assessment. This stage was then followed by 'expert' interviews, which were used to explore some of the identified EC tools and software.	Opinions on EC assessment. Exploration of four EC analysis tools.
ASBP (2014) UK	Interviews and consultations with industry professionals. Key themes and messages were identified and categorised.	Industry attitude and business case for EC; industry capacity and allowable solutions.

2. Survey

2.1 Survey design

The survey was designed based on method discussed by Vaus (2002) and Creswell (2007). The questions were based on some of the critical aspects raised in the surveys consulted in Table 1 and a review of current literature on the subject. The question types were a mixture between closed or forced-choice questions and open-ended questions. Space for respondents comments were also provided in the form of an optional comments box. The survey was built using the online survey software called Survey Monkey (Survey Monkey, 2011). This software generated a link to the survey which was then included in the email to the selected sample along with a brief introduction and explanation of the project and the survey instructions. Survey Monkey was also used for response collection. The survey was tested on a small sample to test the questions and usability of the online system. The test indicated that the time taken to complete the survey was acceptable and any additional feedback, such as rephrasing, was incorporated into the final survey. Survey was distributed via email and advertised on the CRCLCL website. The email included an invitation to participate in the survey (on a voluntary basis) with a brief description of the ICM project and the relevant URL link.

2.2 Survey population and sample

The population of the survey was construction industry professionals located within Australia. The sample identified were specifically professionals who work with building or building material related aspects. These professionals ranged from architects; engineers; LCA consultants; quantity surveyors and material manufacturers. The sample selection was identified via a web-based search. The selection criterion was based on the fact that the professionals had to be based in Australia. The intention of this study was to provide a base case that could be developed further and in more detail for the next phase of the project. This base case could be based on a small sample size that would provide a preliminary insight into the Australian construction practice with regards to embodied carbon. A total of a 100 questionnaires were distributed via email with 45 responses were collected over a two month period. The greatest percentage of responses came from LCA practitioners (27%); followed by sustainability consultants (20%), engineers (18%) and then contractors (11%). Most of the organisations represented, consisted of less than 10 people with 56% of the respondents mostly involved with residential projects and a further 24% stating they specialise in both residential and non-residential projects.

2.3 Survey analyses

The responses were collected via Survey Monkey, which automatically categorized the questions and counted the number of responses for each question. The percentage of each response in each category was calculated and translated into graph's, as illustrated in this report. Exploratory factor analysis was carried out on the open-ended questions, such as 'recommendations to new EC tools' (and questions such as the listing of strengths and weaknesses of current EC tools) to extract common codes and divide the items into the most common categories.

2.4 Survey results and discussion

2.4.1 Embodied carbon assessment provided as a service

The current focus on OC assessment is quite evident from the survey results with over 85% of the respondents providing this as an in-house service with only a small percentage outsourced, as illustrated in Figure 1 below. The next most prevalent service selected from the provided survey options was 'Energy/ Green ratings' (such as Green Star) with approximately 20% outsourced. Just over 60% of the organisations provided EC assessment services, but with a greater percentage outsourced. One respondent stated that "when requested on projects we complete these services; however the industry focus is on operational energy". Another respondent provided further insight by stating that these services are provided on a project specific basis with preliminary in-house assessments being undertaken regularly but outsourced for Green Star Projects. For those organisations that don't provide EC assessment as a service, the main reason given was lack of project budget (59%) followed by client disinterest (41%) lack of set standards (35%) and no clear cost/profit incentive (29%). However, when asked whether these organisations would consider providing EC assessment as part of their services in the future, 65% said they would.
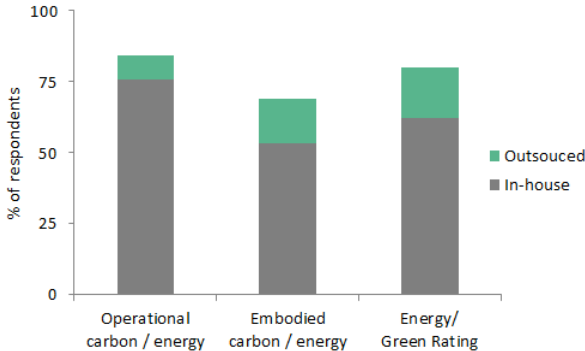

Figure 1: Services provided by percentage of respondents

What is evident from these results is that first of all there is significant interest from an industry perspective to provide EC assessment as a service. This can be seen from both the large percentage of industry professionals already providing this as a service and from the fact that for those organisations that don't, there is intention to include it as a service in the future. Secondly, that the in-house capability for EC assessment has not evolved as much as OC assessment, as is evident from the greater percentage outsourcing this service when compared to OC assessment.

2.4.2 Embodied carbon assessment: existing tools and databases

This section of the survey specifically focused on the organisations that provide EC assessment as part of their services. When asked what tool is used for this service, the most popular choice was the software tool SimaPro, as illustrated in Figure 2. SimaPro is a commercially available software tool, available for purchase, originating from the Netherlands. eTool, an Australian designed tool originating from Perth,

was only 4% behind SimaPro in terms of popularity. The 'Other' option tools, as illustrated in Figure 2 as the third most popular, included 2 respondents stating they use the 'Footprint Company', 1 respondent using Passivhaus PHPP, 1 respondent using LCADesing and another respondent stating AccuRate Sustainability. For the database used for EC assessment, both the Australian 'AusLCI' and databases within 'SimaPro' were stated as the most popular, closely followed by 'In-house'; 'eTool' and 'Ecoinvent' preferences.

Other:
Footprint Company
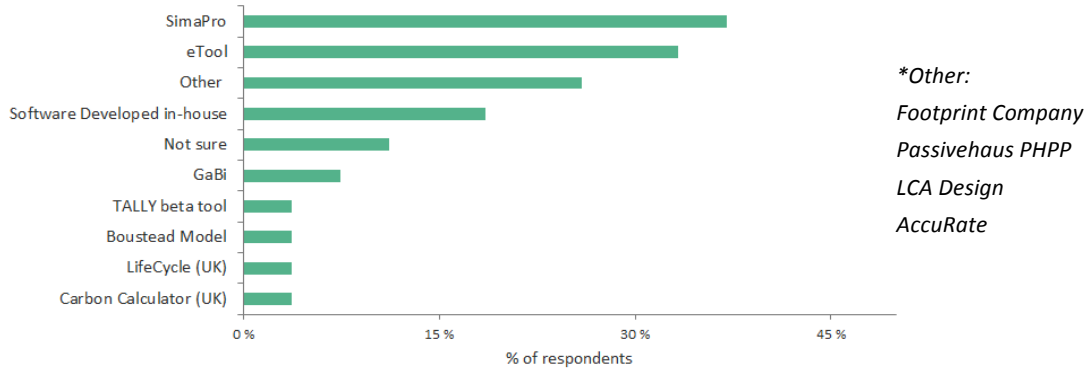*Passivehaus PHPP*
LCA Design
AccuRate

Figure 2: Tools used for embodied carbon assessment, by percentage of respondents

When asked to list the strengths and weakness of current EC assessment tools used by the organisation the following five themes became most evident (as detailed in Table 2 below) - data; method; usability; regulation and outcomes.

Table 2: Strengths and weaknesses of current EC assessment tools

Theme	Strengths	Weaknesses
Data	Ability to access multiple databases; Comparable metric	Lack of Australian data; lack of product specific data; Data source questionable
Method	Comprehensive and in-depth analysis; integrated with thermal performance	Inconsistent methodology; Not a holistic assessment
Usability	Affordable; Simple and online platform	Time consuming; requires expert knowledge and additional training; no Building Information Modelling (BIM) integration
Regulation	Compliant with existing ISO standards	Boundary and accuracy questionable
Outcomes	Multiple impact reporting; Ability to model recommendations; Nested templates; Ability to compare scenarios	Lack of benchmarks; Inability to compare building products ; No 3D integration; Life Cycle Cost Model

Tool users prefer having the option to access multiple databases through a simple, online tool that performs comprehensive analyses. Tools that are compliant with ISO standards are preferred along with

the option to include multiple impact reporting through nested templates that are able to compare scenarios. However, there is an overall concern about the lack of Australian data and the inconsistent methodology employed for this assessment. In addition to the data weaknesses, some of the tools are considered to be time consuming and requiring expert knowledge to use, presenting considerable barriers for their uptake. Desired outcomes include the availability of benchmarks; 3D visualisation and integration of life cycle costing into the analyses.

What is evident for these results is that even though internationally developed tools dominate the EC assessment tool preference options, there is overwhelming interest in Australian developed tools, such as eTool, with the fact that it is second most popular from an industry perspective. However based on the amount of weakness, there is still much room for improvement in current tools.

2.4.3 Embodied carbon assessment: new tool recommendations

When asked to indicate the top features desired in EC assessment tools, 'material cost' was deemed the most popular with 80% of respondents selecting this option, followed by 'data on recycled materials' (62%) and then 'source of materials' (57%). When asked to rank important features and functionality, 'Reliability of findings' and 'Ease of use' came out on top along with a need for a 'List of mitigation measures' and 'Comparison against a benchmark'.

The recommendations provided by the respondents for future EC assessment tools can be classified under the same themes as earlier, namely data; method; usability; regulation and outcomes (Table 3). Users want a tool that relies on sound data that is easy to update. A consistent and transparent methodology is needed that looks at EC holistically while adhering to Australian standards and practices. These findings suggest that either a new tool, or improvements to existing tools, are needed as none of the existing tools adequately address all of these user needs.

Table 3: Recommendations for embodied carbon assessment tools

Theme	Recommendations
Data	Sound data; Access to a broad range of databases; Easy to update; Data quality measures are in place.
Method	Transparent and consistent; Comprehensive; Whole footprint; Integration with existing tools.
Usability	Stream-line user interface that is simple to use with Building Information Modelling (BIM) compatibility.
Regulation	Adherence to Australian policies, standards and procedures.
Outcomes	Option for 'quick' analyses; Comparison against a benchmark and compatibility with Green Star.

3. Conclusion

This survey provided a brief insight into the construction industry's current approach to EC assessment, identifying which tools and services are the most prominent along with providing further insight into what features these users would want from new and improved EC assessment tools. What is most evident from the survey is that there is overwhelming interest from the Australian construction industry in either providing EC assessment or intending to provide EC assessment as a service in the future. Another conclusion to be drawn is that there is interest in locally developed tools but there are still several potential areas for improvements that need to be worked upon. As part of the ICM project, the ICM Tool and PIM Tool can help address these weaknesses and incorporate the suggested improvements so as to better support industry needs. There are still a few hurdles to overcome in order to evolve EC assessment uptake, such as lack of project budget, client disinterest, no clear cost incentive and lack of set standards. This 'lack of set standards' is further evidenced by the overall concern towards data, especially the lack of Australian data. Another ICM output would be a comprehensive database which will help address this data hurdle and help contribute to more reliable, holistic EC data.

This survey demonstrated that there is interest from the Australian construction industry to further develop Australian based EC research projects, such as the ICM project, and further identified the several potential areas where the ICM project outputs can help contribute to the current EC assessment method.

3.1 Limitations

There are several limitations to this study to be aware of when interpreting the results. The small sample size of 46 has implications on the limited amount of varied responses. However the study was aimed at providing a general overview of industry's current approach to EC so that future areas of research can be highlighted and investigated at a later stage. The non-response error was addressed through advertising the survey through multiple mediums (from email link, to twitter and on the CRC LCL website). Follow up emails were sent to the selected sample. Due to time constraints other techniques to minimize the non-response error was not employed, such as weighting or proxy respondents. Another limitation is that fact that the responses are dominated from professionals involved with LCA, thus potentially alluding to a higher percentage of industry organisations involved with EC assessment than in reality. However the results are still valid as the survey is primarily aimed at professionals involved with EC assessment (LCA practitioners, sustainability consultants and engineers), thus providing an adequate sample selection for this study. Another aspect affecting the results is reliability. The questions and results are subject to unreliability either due to bias of the researcher of the participant and depend on the motivation of the participant for completing the survey (whether it was to demonstrate and showcase their own tool or show genuine interest). In order to ensure reliability was achieved as much as feasibly possible, several techniques were used. Such as careful wording of questions so as not to pre-empt a desired answer; minimal use of 'do not know' responses and the use of multiple-item indicators (such as the Likert scale). Regarding the non-response rate, according to Vaus (2002) a 20% non-response rate can be expected. This survey incurred a 55% non-response rate. This could have been affected, as suggested by Vaus, by either survey length, content or method of administration. This survey results are also dependent on the researchers email list and the participants access to email.

3.2 Further research

A detailed study of existing EC assessment tools needs to be conducted in order to learn from current weaknesses and identify any recommendations for improvements to these tools. Further research into the prevalence of in-house EC assessment tools and datasets in order to determine the reasoning why commercially available software and data is not sufficient in these organisations is also needed. The development of an appropriate benchmark for EC of various building types, materials and components as well as the development of a consistent methodology is also required.

3.3 Acknowledgements

References

Ariyarante, C. I. and Moncaster, A. (2014) Stand alone calculation tools are not the answer to embodied carbon assessment, *Energy Procedia*, .(62), 150-159.

ASBP (2014) *Embodied Carbon IndustryTask Force Proposals*,The Alliance for sustainable building products London.

City of Melbourne (2014) *Zero net emissions update 2014*, Australia

Climate Works (2013) *Tracking progress towards a low carbon economy: National progress report* Australia

Crawford, R. H. (2008) Validation of a hybrid life-cycle inventory analysis method, *J Environ Manage*, 88(3), 496-506.

Crawford, R. H., Czerniakowski, I. and Fuller, R. J. (2010) A comprehensive framework for assessing the life cycle energy of building construction assemblies, *Architectural Science Review*, 53(3), 288-296.

Creswell, J. (2007) *Qualitative enquiry and research design* ed., Sage Publications California, USA.

de Wolf, C. and Ochsendorf, J. (2014) *Participating in an embodied carbon database*. Available from: ZweigWhite LLC <http://cenews.com/article/9730/participating-in-an-embodied-carbon-database> (accessed 11/03/2015).

Dixit, M. K., Fernández-Solís, J. L., Lavy, S. and Culp, C. H. (2012) Need for an embodied energy measurement protocol for buildings: A review paper, *Renewable and Sustainable Energy Reviews*, 16, 3730-3743.

Garnaut, R. (2008) The Garnaut review: Chapter 7 Australia's emissions in a global context.

IPCC (2014) *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge, United Kingdom and New York.

Lenzen, M., Suh, S., Treloard, G. J., Hondo, H., Horvath, A., Huppes, G., Jolliet, O., Klann, U., Krewitt, W., Moriguchi, Y., Munksgaard, J. and Norris, G. (2004) System boundary selection in life-cycle inventories using hybrid approaches *Environmental Science and Technology*, 38(3), 657-664.

Menzies, G. F., Banfill, P. F. G. and Turan, S. (2007) Life-cycle assessment and embodied energy: a review, *Proceedings of the ICE - Construction Materials*, 160(4), 135-143.

Schinabeck , J. and Wiedmann , T. (2014) *The long road to zero* Available from: The Fifth Estate <http://www.thefifthestate.com.au/spinifex/the-long-road-to-zero-embodied-carbon-in-the-built-environment/69464> (accessed 15/07/2015).

Treloar, G. J. (1998) *A comprehensive embodied energy analysis framework*, Faculty of Science and Technology, Deakin University, Australia.

Vaus, D. (2002) *Surveys in social research*, 5th ed., Allen & Unwin Australia

Zuo, J., Read, B., Pullen, S. and Shi, Q. (2012) Achieving carbon neutrality in commercial building developments – Perceptions of the construction industry, *Habitat International*, 36(2), 278-286.

There is a section break below, please do not delete it.

There is a section break above, please do not delete it.