Student Symposium on

Life Cycle Management and Industrial Ecology

Symposium Proceedings

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Massey University,

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Editors

Professor Sarah McLaren and Dr. Ranvir Singh

New Zealand Life Cycle Management Centre

Massey University, Palmerston North

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Welcome

The New Zealand Life Cycle Management Centre and Life Cycle Association of New Zealand (LCANZ) are delighted to host the 2017 Student Symposium on Life Cycle Management and Industrial Ecology.

The Student Symposium provides an opportunity to showcase the work of postgraduate students who have chosen to conduct research in this area. The number and range of presentations is indicative of the maturity of this research field both in New Zealand and overseas. As more students continue to graduate with qualifications in Life Cycle Assessment and environmental footprinting, as well as Life Cycle Management more generally, we look forward to seeing life cycle thinking becoming increasingly integrated into future management practices amongst companies and government agencies in New Zealand.

We extend a warm welcome to Dr Anthony Halog from the University of Queensland who is joining us as a Keynote Speaker for the Symposium. His field of research encompasses Life Cycle Sustainability Assessment, Industrial Ecology, Corporate Environmental Management, and Greening Supply Chains. Together we hope to use this event to identify opportunities to catalyse uptake of LCM and Industrial Ecology, and increased cooperation between Australian and New Zealand academics and students.

We are particularly grateful to Massey University for supporting Dr Halog's trip to New Zealand, and to thinkstep for sponsoring the Prize for Best Paper at this event.

Sarah McLaren
Director
New Zealand Life Cycle Management Centre

Barbara Nebel
President
Life Cycle Association of New Zealand

PROGRAMME

Location: Room QB6, Massey University, Albany Campus, Auckland

9:10 am	Welcome and introductions
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10:15 am	Update on ISO Carbon Footprinting Standards (Dr. Barbara Nebel)
10:30 am	Morning tea
10:50 am	Session 1:
	Life Cycle Considerations In the New Zealand Energy System – An Alternative Look At the Solar Debate (Kiti Suomalainen)
	Addressing Limitations In Current New Product Development Eco-Tools: a Case Study of Domestic Hot Water Products (Mike Horrell)
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	Assessing Eutrophication in New Zealand (Dr. Sandra Payen)
	The Blue Water Footprint of New Zealand's Electricity Mix (Andy McCall)
	Driving a Life Cycle Based Environmental Improvement Strategy in Auckland Council Leisure Centres (Nathan Palairet)
12:50 pm	Lunch
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	Consequential LCA modelling of office building refurbishment in New Zealand (Agneta Ghose)
	Influence of Indoor Air Emissions on the Human Health Results in Life Cycle Assessment of PET Acoustic Panels (Adam Schofield)
	Incorporation of Life Cycle Uncertainty Assessment Into the Structural Design of an Office Building (Mehdi Robati)
	Big Data Analytics In Life Cycle Assessment (Thomas Betten)
2:50 pm	Session 4: Workshops
	Workshop 1: Water footprinting (Facilitator: Dr Ranvir Singh)
	Workshop 2: Impact assessment and site-specificity (Facilitator: Dr Stewart Ledgard)
	Workshop 3: Life cycle-based decision-support in the design process (Facilitator: Prof Sarah McLaren)
3.30 pm	Afternoon tea
4:00 pm	Session 4 (continued): Report back to main group on outcomes
4.30 pm	Current state of LCA and footprinting techniques in New Zealand – and future directions (facilitated discussion)
5:00 pm	Finish

Life Cycle Considerations in the New Zealand Energy System – An Alternative Look at the Solar Debate

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Abstract

New Zealand has seen rapid growth in solar power in the last three years, most of which has occurred in the residential sector [1]. Much of the debate has narrowed on mainly two issues, namely the impact on CO_2 emissions and the impact of cost recovery of lines charges related to the current pricing mechanism and the introduction of the so called solar tax, imposed by some lines companies. However, there are broader aspects that need to be brought in to the debate, including value based judgements. Investigating both the consequential (or marginal) and the attributional (long-term) environmental and social impacts of solar power in New Zealand forces us to evaluate our weighting of several complex impacts commonly considered in LCA impact assessment methods.

New Zealand has a hydro-based electricity system, where natural gas is used to balance the natural cycles of hydro availability. An increase in solar power may marginally displace natural gas, or even coal, but in the long term we can assume it will displace the average electricity mix – both options are explored. Power production from these resources supports employment in New Zealand, while potentially contributing to greenhouse gas emissions (in the case of natural gas and coal), and potentially having some local impacts, such as impacts of human and ecosystem health.

For an analytical assessment, we need to compare these impacts against the life cycle impacts of solar panels imported from China, produced with energy from a greenhouse gas intensive electricity system, with potential impacts on local ecosystems and human health, while creating jobs in production in China, but also some e.g. in the installation and maintenance in New Zealand, while producing virtually no GHG during its use-phase in New Zealand.

This talk is about using an LCA based approach to assess these complex and seemingly incomparable impacts that we need to quantify in order to have a rational debate on solar power in New Zealand. How do we weigh local environmental impacts in New Zealand vs. those in China? How do we value job creation here vs. there? How do weigh a local environmental impact against a global one? LCA provides us with a scientific approach to create a baseline for this debate. We consider a simple baseline approach comparing electrical energy produced by solar power and that from the New Zealand electricity mix to “set the scene” for a more versatile debate on the impacts of solar power in New Zealand.

For the New Zealand electricity mix, we use recent results from Sacayon Madrigal (2015) [2], for representing the Chinese electricity mix and production of PV panels, we use data compiled from the NEEDS project [3]. Gaps and eventual misrepresentations will be discussed. We compare several impact assessment methods in order to discuss different impact categories within then, and present our insights.

References

[1] Electricity Authority, Electricity Market Information (EA-EMI), Installed distributed generation, http://www.emi.ea.govt.nz/Reports/Dashboard?reportName=5YPBXT&categoryName=Retail&reportDisplayContext=Dashboard (website accessed 12 February 2017).

[2] Sacayon Madrigal, E.E. (2015). *Assessment of the Life Cycle-Based Environmental Impacts of New Zealand Electricity*, Master’s Thesis, Massey University, Palmerston North, New Zealand.

[3] http://www.needs-project.org/

Addressing Limitations In Current New Product Development Eco-Tools: a Case Study of Domestic Hot Water Products

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Abstract

Pressures from environmentally conscious consumers have led to producers exploring opportunities to develop products and systems that can offer environmentally superior alternatives. However, integrating methods such as quantitative Life Cycle Assessment (LCA) and qualitative eco-tools into New Product Development (NPD) practices has so far been reported to have limited success. LCA can be costly and time consuming and requires upfront detailed design information; this makes it unsuitable for early design. Qualitative tools (such as those based on checklists) require extensive experience and knowledge to be implemented properly.

This study addresses these types of limitations in New Product Development (NPD) practices by identifying potential eco indicators for a shower product that could be used to enhance existing qualitative eco-tools. Previous studies have shown that the use phase has the greatest environmental impacts in the life cycle of a shower product, and therefore is the focus for this study. A custom recording device was constructed to collect data using a flow meter, temperature probe and real time clock. These devices were installed in five households in the Auckland region and used to monitor shower use for several months. The experiment was conducted as a full factorial study with changing treatments over the duration of the experiment to test the factors 'Spray Technology' and 'User Feedback' in order to determine how the response variables (Energy, Water and Duration) change when these factors are varied. Spray Technology included Convention and Collision Sprays. 'User Feedback' tested the response to different types of information provided to the user: cost of the shower in cents, and scales which displayed energy and water use as low, medium and high indicator lights.

For 'Spray Technology', the results indicated a statistically significant decrease in energy use when using a conventional shower spray versus a luxury spray. This is attributed to a similar change in water use between sprays but also represents energy losses related to the spray technology dynamics. 'User Feedback' results indicate that providing information on the cost of the shower is more effective at reducing duration than using the indicator lights but – surprisingly - there is no significant corresponding decrease in energy or water use. One possible explanation for this apparent contradiction is that users may be rushing to shower when cost is displayed, and thus feel the need to have a hotter shower at a higher flow rate. However, the indicator lights are more effective at reducing energy and water use by influencing users to turn down the temperature and reduce the water flow (as opposed to reducing the shower duration).

The study has provided insight into how future shower designs could influence the use phase in order to reduce life cycle-based environmental impacts. It also provides an example of an approach for testing environmental metrics for NPD in the form of independent variables that can be tested against relevant response variables. When combined with insights from the research on rebound effects, this information could be used to enhance environmental policy associated with household carbon emissions.

A Novel Methodological Approach for the Implementation of Sustainable Development Goals Centred on a Planetary Boundaries-Based LCA

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Abstract

Life Cycle Assessment (LCA) is a tool that assesses the potential environmental impacts of products and processes from a life cycle perspective and contributes to improving products' eco-efficiency. The improved eco-efficiency creates a perception that the product having the minimal environmental impacts is "green" or "sustainable", however, this perception may become questionable when considered in terms of alternative patterns of global consumption and production [1]. Therefore, scholars have started integrating carrying capacity references to develop absolute sustainability assessment frameworks overcoming this limitation. The attempt to integrate the Planetary Boundaries (PBs) framework into LCA impact assessment methods is one of them [1, 2]. Meanwhile, in September 2015, the United Nations launched the Sustainable Development Goals (SDGs): a set of goals covering a broad range of sustainable development issues. Although consensus has emerged within the scientific and political communities that the environmental boundaries for Earth system processes need to be incorporated when operationalizing SDGs [3], until recently, no theoretical frameworks have been developed (or published) on how to integrate the idea of PBs with the SDGs. Hence, we present a five-fold approach by linking SDGs with the PBs in an LCA framework: (i) modify the areas of protection of a conventional LCA based on the SDGs, (ii) explore the links between the PBs and SDGs, (iii) estimate country-specific limits, (iv) allocate the national limits within the economic sectors, (v) assess the sectors' current sustainability performances using an LCA, and benchmark the sectoral performances against the estimated sectoral limits. In this study, an application of the approach is presented to investigate whether the sustainability performances of the chosen economic sector(s) in New Zealand is (are) aligned (or not) with the SDGs. The proposed novel methodology would be useful to estimate impact reduction targets if the sectors have transgressed their limits and if not, distance to limits ratios can be suggested. Overall, the study guides the New Zealand decision- and policy-makers to effectively operationalize SDGs within the ecological limits of the Earth system and to contribute towards a global agenda: achieving sustainable development by 2030.

References

[1] Rockström, J., Steffen, W., Noone, K. et al. (2009). "Planetary boundaries: exploring the safe operating space for humanity," *Ecology & Society*, Vol. 14 (2), No. 32.

[2] Bjørn, A., Hauschild, M.Z. (2015). "Introducing carrying capacity based normalization in LCA: framework and development of references at midpoint level". *International Journal of Life Cycle Assessment*. Vol. 20, pp. 1005-1018.

[3] Kim, R.E., Bosselmann, K., (2015). "Operationalizing Sustainable Development: Ecological Integrity as a Grundnorm of International Law," *Review of European Community & International Environmental Law*, Vol. 24, No. 2, pp. 194-208.

The Water Footprint of New Zealand's Electricity Mix

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Abstract

Water scarcity is becoming an increasingly significant problem for large parts of the world; this problem is only likely to worsen with the effects of climate change and an expanding world population. Volumetric water footprints are being used to provide a measure of the water consumption and associated environmental impacts arising in the life cycle of products, processes and activities – including electricity generation. Although numerous studies have examined the water use associated with electricity generation, a consumptive volumetric water footprint until now had not been calculated for the bulk (85%) of New Zealand's electricity mix. In this research, the volumetric water footprint is calculated for 85% of New Zealand's geothermal and thermal electricity generators, and compared with an existing volumetric water footprint for New Zealand's hydropower generators [1]. Data were obtained directly from power plant operators.

The results of the study indicate that hydropower is the single largest consumer of freshwater because of evaporation of water from storage facilities, namely dams. Hydropower has a volumetric water footprint of 19.74 litres per kilowatt hour (L/kWh). Geothermal electricity is the second largest consumer of freshwater after hydropower with a result of 3.93 L/kWh. Thermal electricity is the lowest consumer of freshwater with a result of 1.51 L/kWh, which includes the volumetric water footprint of the gas and coal fuels used in these types of plants. The results were combined to produce an average blue water volumetric water footprint for New Zealand's electricity generation of 8.4 L/kWh. The results were contextualised using two additional methods: The Water Scarcity Index (WSI) [2] and the Sustainability of the Blue Water Footprint (impact assessment) (SBWF) [3]. The data sources for these methods were obtained via regional councils, NIWA and the author's own GIS manipulations to provide suitable data inputs. The two methods correlate well with one another generally; they both calculate the water consumption of the study power plants to be negligible relative to water availability in the respective water catchments of the power plants. Both methods rank the Tekapo hydropower plant as the most significant consumer of water relative to water availability in the same catchment. Although, the WSI then selects the Matahina, Benmore, Aviemore, Ohau, Manapouri, Ohakuri and Waitaki hydropower plants as being the next most significant plants. The SBWF ranks the Matahina hydropower plant second highest, followed by the kawerau and Nga Awa Purua geothermal plants, followed by the Benmore, Aviemore and Ohau hydro plants. The remainder of the study plants rank very low in both methods.

The WSI and SBWF results for the study water catchments indicate that only the Waitaki River catchment is experiencing water stress, with a WSI of 0.06. All the other catchments in the study are at or below the minimum 0.01 value for the WSI indicating there is no water stress in these catchments. The SBWF method indicates that the blue water volumetric footprint of the Rangataiki/Tarawera catchment is completely unsustainable as over 100% of the available blue water has been consumed. The WSI however, does not indicate water stress in the Rangataiki/Tarawera catchment. For the other catchments, the results are negligible per the SBWF, indicating that the vast majority of the available blue water is unused and hence is still available for use within the catchment by other users. The importance of using local data rather than global estimates has been highlighted during this research process, as has the difficulty inherent in meeting the data requirements for overseas-based methods when applied to New Zealand.

References

[1] Herath, Deurer, M., Horne, D., Singh, R., & Clothier, B. (2011). The water footprint of hydroelectricity: a methodological comparison from a case study in New Zealand. *Journal of Cleaner Production, 19*(14), 1582-1589. doi:10.1016/j.jclepro.2011.05.007

[2] Pfister, S., Koehler, A., & Hellweg, S. (2009). Assessing the environmental impacts of freshwater consumption in LCA. *Environ Sci Technol, 43*(11), 4098-4104.

[3] Hoekstra, A. Y., Mekonnen, M. M., Chapagain, A., & Aldaya, M. M. (2011). *The Water Footprint Assessment Manual - Setting the Global Standard*: Earthscan.

Driving a Life Cycle Based Environmental Improvement Strategy in Auckland Council Leisure Centres

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Abstract

In the scientific literature, there have not been any reported Life Cycle Assessment (LCA) studies done on public swimming pools. Auckland Council owns and operates 22 aquatic centres, and together they are the most significant energy user in their property portfolio. To inform an environmental improvement strategy, LCA case studies on two representative Auckland Council facilities were conducted; a large site and a medium-sized site. The activities with the most significant environmental impacts were identified for improvement, and these potential improvements were quantified through scenario modelling.

The LCA studies used the ReCiPe 1.08 Impact Assessment methodology, looking at 19 midpoint environmental indicators with a Hierarchical cultural perspective. The results showed that energy usage was the most significant contributor to the environmental impacts, with natural gas used to heat water comprising the largest proportion of that. The use of the boiler contributed between 61% and 77% of the total Climate Change (excluding biogenic carbon), depending on the season and facility modelled. Electricity used for pumps and ventilation systems was also significant. This environmental impact makeup showed that a simplified life cycle approach focussing on energy, wastewater and the most-used chemicals would be suitable for further development to inform Council's environmental improvement strategy.

The LCA results informed the development of two software tools for Council to use. One tool was designed as a real-time, customer-facing environmental tracker that informs members of the public of the environmental performance trends of the facility, with the aim of influencing their personal behaviour. The second tool was a simplified LCA tool for Council managers to easily track their environmental performance month-to-month, assisting them to meet environmental improvement targets. Feedback was gathered from Council managers throughout the process of design and development to ensure alignment with their goals.

Consequential LCA Modelling of Office Building Refurbishment in New Zealand

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Abstract

Large building refurbishments are likely to become more common to improve the energy consumption in New Zealand's existing building sector, and therefore it is relevant to assess the environmental impacts associated with these activities. In particular, there may be interdependencies between key elements such as resource availability, energy use, recycling potential and final disposal options. This study applied consequential LCA methodology to identify the environmental impacts arising from use of key construction materials in a large refurbishment aimed at transforming a building's operational energy consumption. A prototypical refurbished model of an office building located in Auckland, New Zealand was used as a case study. The refurbishment included major changes to the building envelope with additional insulation, modified wall-window ratio, installation of low-e double glazed windows, solar shading as well as technical replacement of the lighting and HVAC system. Scenarios related to the best practice construction methods related to waste material recovery and supply of materials from alternative production were compared to conventional construction practices in New Zealand which was used as a reference scenario.

According to the main results, increasing the rates of recovery and recycling of construction waste can significantly improve the overall environmental performance of a building refurbishment. The supply of materials from alternative production sites can also improve the environmental performance; however, this benefit is limited compared to waste recovery at site. Therefore it is recommended to combine both recommended strategies to minimize the total environmental impact. Regarding the modelling, the identification of resource constraints using New Zealand-specific market information emphasized the importance to accurately identify the marginal suppliers of materials and energy, and in particular the marginal electricity supply in each location. A sensitivity analysis was performed using past and forecasted market information for the identification of marginal suppliers of electricity and key construction elements to reduce uncertainty related to modelling and to increase the quality of the study.

The results were also compared to an existing study which applied the attributional modelling approach to estimate the cumulative environmental impacts of the building refurbishment and its subsequent operation over a period of 25 years [1]. The cumulative results of the consequential LCA study were 25-40 percent higher compared to the attributional LCA results. These differences were related mainly to the differences in inventory modelling with respect to the use of marginal data in consequential modelling compared to average data used in attributional modelling. The cumulative impact of the building was sensitive to the share of fossil fuel in energy used to operate the building and to produce the construction materials required for refurbishment. As the share of fossil fuel played a dominant role in marginal energy used to produce grid electricity in New Zealand, the impact calculated using the consequential method showed higher impacts.

In conclusion, this study investigated the environmental impacts of large scale building refurbishment and the best practice measures that could potentially reduce the overall impacts of this type of refurbishment using consequential LCA. The findings enforce the need to adopt practical solutions to increase material recoverability at site e.g. planning for both waste minimization and material recovery. In addition, the study also highlights the influence of modelling assumptions with respect to constraints in resource availability and the choice of marginal suppliers based on local and global market information.

References

[1] Ghose, A., Mclaren, S., Dave, D., & Phipps, R. (2017). Environmental assessment of deep energy refurbishment for energy efficiency: case study of an office building in New Zealand. doi: 10.1016/j.buildenv.2017.03.012

Influence of Indoor Air Emissions on the Human Health Results in Life Cycle Assessment of PET Acoustic Panels

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Abstract

The impacts on human health due to emissions of chemical substances to indoor air are well known and well publicised [1]. However, standard Life Cycle Impact Assessment models generally do not include any characterisation factors that are specific to indoor (as opposed to outdoor) air emissions [2]. As a result, current Life Cycle Assessments (LCAs) may be underestimating the human health impacts associated with these emissions.

This study determined the life cycle-based human health impacts of a PET interior acoustic panel manufactured by Autex Industries, including the impacts from indoor air emissions during the use stage using the USETox 2.0 model [3]. A sensitivity analysis was also done to determine how important indoor air emissions were on the overall impacts on human health.

LCA studies and methods the human health impacts of indoor emissions are assumed to be the same as outdoor emissions, or ignored completely. This is due to the complexities around modelling indoor emissions and the added uncertainties on the exact relationship between pollutants and human health due to political factors. The political interaction is true for any impacts on human toxicity in general, not just indoor human health, as most scientific models tend to become politically charged and subject to much debate outside the scientific realm. Several LCA studies that focused on human toxicity from indoor emissions from the past 7 years were reviewed as to their treatment of indoor air emissions and how the different uncertainties were assessed.

The USETox model was selected after a review of the major methodologies available that included human health impact models available in different methodologies, such as ReCiPe, CML 2002 & TRACI. The USETox 2.0 model was chosen as it included characterisation factors for indoor air and had good scientific rigour behind the methodology [4]. Other emissions that also contributed to the human health area of protection were calculated using the ReCiPe endpoint characterisation factors for human health, as recommended by ILCD [4,5].

The study showed that the relative importance of the use stage when modelled with higher levels of indoor VOC emissions, and using indoor-specific human health characterisation factors, means that these indoor emissions should be separately modelled in LCAs and EPDs of Interior Acoustic products. This would ensure that the indoor air emissions from products are both transparent and provided in context with all other human health impacts. At the same time, more information should be collected on the composition of the VOCs being emitted during the use phase, and on the amount and composition of emissions during installation and cleaning to gain a better understanding of the overall human health impacts associated with acoustic products.

References

[1] World Health Organisation Regional Office for Europe (2010). "Introduction", WHO *guidelines for indoor air quality: selected pollutants*, WHO Regional Office for Europe, Copenhagen, pp. 1-13.

[2] G. Finnveden, M. Z. Hauschild, T. Ekvall, J. Guinée, R. Heijungs, S. Hellweg, A. Koehler, D. Pennington, and S. Suh, (2009). "Recent developments in Life Cycle Assessment.," *Journal of Environmental Management.*, vol. 91, no. 1, pp. 1–21

[3] P. Fantke, M. Huijbregts, M. Margni, M. Hauschild, O. Jolliet, T. McKone, R. Resenbaum, and D. van de Meent, (2015). *USEtox 2.0 User Manual (v2),* Lyngby.

[4] European Commission, (2011). "Human Toxicity", *International Reference Life Cycle Data System (ILCD) Handbook: Recommendations for Life Cycle Impact Assessment in the European context*. European Commision Joint Research Centre, Luxemburg, pp 25-32 .

[5] M. Goedkoop, R. Heijungs, M. Huijbregts, A. De Schryver, J. Struijs, and R. Van Zelm, (2013). *ReCiPe 2008: A life cycle impact assessment method*, Amersfoort.

Incorporation of Lifecycle Embodied CO2-e Assessment into the Structural Design of an Office Building in Australia

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Abstract

Sustainable building design has become a multidisciplinary research investigation. From a structural design perspective, there is concern how to develop a decision-making process in order to reduce their negative impact on the natural environment. Understanding the main strategies, parameters and tools associated with sustainable building design requires knowledge of contextual factors.

Several sustainability reporting tools (inventory databases and online tools) have been published to assess the potential environmental impact associated with the selection of the structural systems and materials. These reporting tools review different phases of the project and provide guidelines for the design. Besides the advantages, these building sustainability reporting tools have been criticised for lack consideration of the whole of lifecycle of a building [1]. Other concerns about sustainability reporting tools have been raised due to using different methodologies to calculate embodied CO_2-e that results variation in embodied energy data [2]. Different tools employ different system boundaries [3-6], methods of embodied energy computation [4, 7, 8], geographic location of the study [3, 7], types of energy used (primary and delivered) [3, 9], quality and source of data [4, 10, 11]. Therefore, this study aims to quantify the significance of the variations in methodologies on the ecological impact (embodied CO2-e) of the buildings. The embodied CO2-e is known as a major greenhouse gas (GHG) into the atmosphere [12], and there is strong evidence that the build-up of GHGs is the primary cause of the global warming that has occurred in recent decades [12].

This study assesses the lifecycle impacts of different structural materials and construction forms used in a typical 15 storey office building in Australia as proposed by National Standards Development Organisation [13]. A risk analysis approach is used to quantify uncertainties associated with the calculation of CO_2-e. The current study employs Monte Carlo simulation techniques to quantify the variability associated with environmental impact (CO_2-e) for each construction material and structural system. The lifetime of the proposed benchmark building is taken as 50 years. The results of the study illustrate that the reliability of the CO_{2-}e estimate is reasonable for some materials but not for others. The variability in the embodied carbon for an in-situ concrete slab can be as much as 50% to 60%. Instead of relying on a single value for calculating the environmental impact of building materials, the cumulative Monte Carlo distribution curve reveals a range of embodied CO_2-e for construction materials through the lifecycle of the building. Additionally, the results of this study help to establish the baseline for the proposed benchmark office building.

References

[1] R. Y. J. Siew, M. C. A. Balatbat, D. G. Carmichael, A review of building/infrastructure sustainability reporting tools (SRTs), Smart and Sustainable Built Environment, 2 (2) (2013) 106-139.

[2] M. Robati, T.J. McCarthy, G. Kokogiannakis, Incorporating environmental evaluation and thermal properties of concrete mix designs, Construction and Building Materials, 128 (2016) 422-435.

[3] M.K. Dixit, J.L. Fernández-Solís, S. Lavy, C.H. Culp, Need for an embodied energy measurement protocol for buildings: A review paper, Renewable and Sustainable Energy Reviews, 16 (6) (2012) 3730-3743.

[4] M. Lenzen, Errors in conventional and Input-Output—based Life—Cycle inventories, Journal of Industrial Ecology, 4 (4) (2000) 127-148.

[5] G.P. Hammond, C.I. Jones, Embodied carbon: The concealed impact of residential construction, in: Global Warming, Springer, 2010, pp. 367-384.

[6] J. Reap, F. Roman, S. Duncan, B. Bras, A survey of unresolved problems in life cycle assessment, The International Journal of Life Cycle Assessment, 13 (5) (2008) 374.

[7] M. Optis, P. Wild, Inadequate documentation in published life cycle energy reports on buildings, The International Journal of Life Cycle Assessment, 15 (7) (2010) 644-651.

[8] P. Joseph, S. Tretsiakova-McNally, Sustainable non-metallic building materials, Sustainability, 2 (2) (2010) 400-427.

[9] M.K. Dixit, J.L. Fernández-Solís, S. Lavy, C.H. Culp, Identification of parameters for embodied energy measurement: A literature review, Energy and Buildings, 42 (8) (2010) 1238-1247.

[10] E.C. Peereboom, R. Kleijn, S. Lemkowitz, S. Lundie, Influence of Inventory Data Sets on Life-Cycle Assessment Results: A Case Study on PVC, Journal of Industrial Ecology, 2 (3) (1998) 109-130.

[11] G.F. Menzies, S. Turan, P.F. Banfill, Life-cycle assessment and embodied energy: a review, Proceedings of the Institution of Civil Engineers-Construction Materials, 160 (4) (2007) 135-144.

[12] P. Ciais, C. Sabine, G. Bala, L. Bopp, V. Brovkin, J. Canadell, A. Chhabra, R. DeFries, J. Galloway, M. Heimann, Carbon and other biogeochemical cycles, in: Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, 2014, pp. 465-570.

[13] NS11401.1, Labelling and declaration of environmental attributes of building products- Type III environmental declarations, in: Part 1: Whole of structure, whole of life, benchmark method, National Standards Development Organisation Limited, 2014.

Big Data Analytics in Life Cycle Assessment

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Abstract

Data availability is constantly rising across all sectors (e.g. public data, social media and business data) with methods and tools in the field of Big Data Analytics making major progress (e.g. in user-friendliness). Despite the great anticipated potential of Big Data Analytics, this development is not yet triggering any significant improvements within the conduction of LCA. Therefore, the study assesses possible applications of Big Data Analytics within the field of LCA.

The identification of possible Big Data applications was carried out in three steps. First appropriate methods and tools of Big Data Analytics were identified based on the CRISP-DM methodology. Second the LCA methodology according to ILCD handbook and ISO 14040 standard was assessed for possibilities to implement the identified Big Data Analytics methods and tools in LCA by systematic examination of each process step. In the third step the relevance and efficiency of the derived applications were rated.

Diverse applications of Big Data Analytics within LCA were identified. The applications include methods and tools from all fields of Big Data Analytics and can be applied within every stage of the LCA methodology. Examples for applications include the use of classification and regression analysis to support the decision-making along the whole LCA process as well as the prediction of data gaps or future values while regression analysis predicts numeric values instead of classes. Potential use cases were performed and include the regionalisation of LCA results by predicting algorithms and the outlier detection to improve LCI data.

Supported by the fact that conducting Big Data Analytics recently became feasible for users without computer science background, through a variety of easy-to-use software, this study shows the extensive potential of Big Data Analytics within Life Cycle Assessment. Especially simple applications can already create a big advantage within LCA. But in order to integrate Big Data Analytics on a large scale in LCA and LCA software for the future, a systematic and holistic approach will be necessary.