 https://doi.org/10.1051/e3sconf/202234904005

Challenges to quantify the life cycle carbon footprint of buildings in Chile

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Abstract. This study identifies key challenges to measure the carbon footprint (CF) over the whole life cycle of buildings in Chile, although its findings are also applicable to other countries. This paper presents four of the said challenges that emerge from the analysis of certification programs, design guides, databases, CF/LCA calculators, standards, and Measurement, Reporting and Verification (MRV) programs worldwide. The four challenges are: (i) a sustainable governance for the carbon footprint system which ensures CF quality, enables regular updates of the data, and has guaranteed funding, (ii) adoption of the system by industry, (iii) standardization of reporting, and (iv) standardization of measurements over the full life cycle. An MRV appears as the best option to coordinate multiple actors and data needs; however, it requires a sustainable governance model as well as widespread adoption. Such an MRV would need a common reporting system. However, comparability may be compromised due to a lack of consensus on which standard to follow in the industry and on definitions for basic building measurements, such as area. The reporting system must be based on a standardized tool, i.e., a CF calculator for buildings. Many of these exist; however, they differ in a fundamental aspect: whether they are used to guide low carbon design or to certify carbon emissions by buildings. Finally, the calculator will need an agreed upon methodology. Although several standards exist, one must be chosen, updated and deployed. Some countries may be more advanced than others on these challenges, but none have solved them completely. A concerted effort would be best to reduce the CF of the construction sector globally.

Keywords: carbon footprint, building, standards, MRV.

1 Introduction

In 2018, the use of energy and materials for buildings led to over 21% of the global greenhouse gas (GHG) emissions. This is higher than the whole transport industry, which contributed 14.2% [1]. Therefore, it is vital to manage the GHG coming from the full life cycle (construction, operation, and end of life) of buildings to reach the Paris Agreement targets.

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However, management of the carbon footprint in the buildings sector is complex. A building is a complex product, comprising thousands of materials and construction products (such as doors, windows, steel bars, etc.). It has a life span of over 50 years and is handled by a great number of actors: architects, builders, occupants, administrators, and others. Also, the carbon footprint of a building will be interesting to different groups: builders, regulators, buyers, administrators and even the international community (e.g., the Paris Agreement).

To handle this complexity and provide valuable information to this varied groups, at least three components are necessary: (i) systems for Measurement, Reporting and Verification (MRV), (ii) carbon footprint calculators for buildings and construction materials and (iii) standardized methodologies for data collection. The implementation of any of these components require collaboration from different groups and an inclusive decision-making process to promote its adoption.

This is why the Ministry of Urbanism and Housing of Chile requested a national and international state of the art for these three components up to December 2019. The state of the art analyses more than 20 certification systems, methodologies, and databases, as well as over 30 carbon footprint and life cycle assessment calculators for the construction sector (in general, the “elements”). This information is systematized in a matrix [2] showing which life cycle stages [3] are in the scope of each analysed element. The state of the art is complemented with a qualitative analysis of the current state of the industry in Chile, used to identify current gaps and potential challenges to the implementation of the three components.

Based upon that information, this contribution highlights four key gaps to successfully implement each of the three components in Chile. Uses are considered at the product (e.g., cement, steel), industry (e.g., associations, constructing companies) and public sector levels (e.g., ministries and government agencies).

For the complete underlying data and analysis of the state of the art, please refer to the set of reports [4, 5, 6, 7]. For action points to guide decision making, please refer to the Summary for Decision Makers [7] (all the reports are in Spanish only).

2 Results and discussion

2.1 Sustainable governance

A Measurement, Reporting and Verification (MRV) system facilitates the calculation of the carbon footprint in a sector, an industry, or even a country. It does so by integrating information and providing standardized reporting in a format such that it serves the needs of one or more users, as is depicted in Figure 1.

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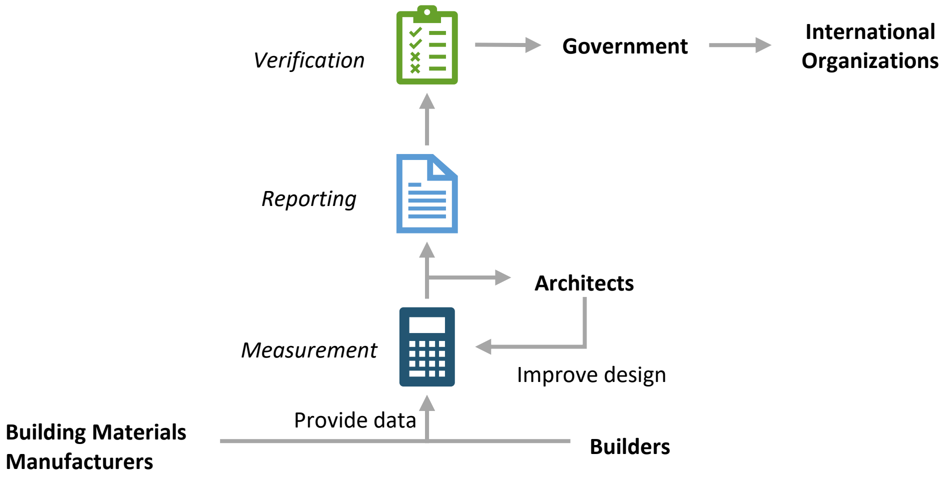

Figure 1. Basic structure of an MRV of the building sector. Actors (in bold) make actions within the MRV systems.

Embedded in an MRV is a robust methodology, a data measurement, reporting and verification system, and a tool to facilitate the calculation in the industry. In other words, there must be at least an agreed upon methodology and a calculator to automate and keep the integrity of the results. Verification keeps the quality of the information and its reliability.

A life-cycle carbon footprint calculator could provide timely and reliable information to sectors to implement public policies, to the building industry to design low-carbon buildings, and to building materials producers to reduce the impact of their products on climate change.

It would also reduce uncertainty about the price of the carbon footprint, as the process would be standardized both in its methodology and timeline. This would, in turn, open a sizeable market for the expansion of technical expertise in the country.

The building carbon footprint reports, made with the calculator, are expertly verified and in this way other actors, such as the government, can obtain aggregated industry data to inform the country progress on the carbon neutral pathway to the international community.

Key challenges to an MRV are:

1. Who controls the system? Any system, no matter how good, may be corrupted. Who is a trustworthy actor that will keep the rules clear and decide upon controversies?
2. Who finances the system? Server maintenance, calculator upgrades, verification systems, promotion, and personnel to keep all running require resources. An MRV needs a stable source of income to continue working and not become another example of a good project that ran out of finance in the middle term.
3. Who keeps quality? In general, carbon footprint standards have requirements for verifiers. The problem here is the lack of capable verifiers available in the Chilean market.

2.2 Incentivizing industry

There are approximately 20 MRV systems in Chile, but there are still some challenges for the implementation and later adoption of an MRV for the carbon footprint over the full life cycle of buildings.

A common incentive for calculating the carbon footprint of buildings is gaining points towards a voluntary certification, i.e., the international LEED and BREEAM and the local

CES or CVS certifications.[†] In Chile, regulations could also drive industry, such as the carbon tax to vehicles and large emitters or the requirement to report emissions by the Register for Pollutant Release and Transfers (RETC). However, these are not yet a driving force for change. Finally, new technologies could motivate builders to calculate and report their footprints, such as the Abaco calculator, that aids the choice of suppliers in public sector construction tenders based on several criteria, including the carbon footprint.

Even though there are some elements that indicate a trend in the industry, there is still the need for more incentives to generate an appropriate momentum to respond to the great challenge of carbon neutrality. Industrial Associations will have a vital role to play in fostering the transformation of the sector through their reach, capacity building and negotiation within the industry and with other sectors.

2.3 Choosing a goal for the CF calculator

There is a critical decision to make on how to use the results of the carbon footprint calculator. Most of the calculators reviewed (over 30) for this study fall into one of two categories, unidentified previously in the literature:

- Guide building *design* for low carbon intensity or
- Certify the environmental *performance* of a building.

These distinct uses impact the *data collection procedure,* because each use requires data of different quality and provenance, as shown in Table 1.

Table 1. Comparison of the two categories of carbon footprint calculators.

	Guide sustainable design	Certify sustainable performance
Type of results	Directional	Actual
Uncertainty	High uncertainty	Lower uncertainty
Primary data sources	BIM models, material estimates	Construction site, Actual operation
Secondary data sources	Generic databases	Region- and technology-specific databases
Examples	One Click LCA, Tally, Ábaco Chile	Arc, Greenhouse Gas Protocol, Sima Pro, Open LCA

Secondary data are useful to guide the design, but to prove performance and communicate it, standards normally require high quality data that reflects as best as possible the real impacts of the product (in this case, a building or an apartment). Such quality of data is even more relevant when thinking that regulators, consumers and other actors will use to make decisions. For a product as complex and long lived as a building, it may be necessary not just to report on the embodied carbon, but also on the operational emissions (i.e., energy consumption) that may require data input over the years.

These factors impact the costs and complexity of the carbon footprint calculator, as well as the users that may input information and the time this information should be available.

The calculator is only a part of a larger MRV system that will coordinate all actors. In consequence, the goal for the calculator should be made considering the goals for the MRV

[†] LEED: Leadership in Energy and Environmental Design. BREEAM: Building Research Establishment Environmental Assessment Method. CVS: Certificación de Vivienda Sustentable (Sustainable Housing Certification). CES: Certificación de Edificio Sustentable (Sustainable Building Certification).

system. In it, different users (manufacturers, constructors, ministries, consumers) will require varied data (quality, methodology, scope) to fulfil their needs. In spite of this variety, results should be comparable and traceable, while protecting data privacy.

Currently in the Chilean construction sector, the majority of MRV systems are focused on the building quality (e.g., thermal standards, energy use), with a few including environmental impact (i.e., climate change, carbon footprint). Still, the latter are mainly focused on the energy use *during* the operation and would need to be adapted to consider all activities that emit GHG over the entire life cycle, including the use of materials (embodied carbon).

2.4 Making results comparable

Internationally, there are multiple methodologies for calculating the carbon footprint of buildings and building materials, from which the most popular are the ISO 21930 and EN 15978 standards. These standards include product category rules (PCR), which clarify the methodology to be used for the calculation of the carbon footprint. In addition to the building standards, Chile has also adopted ISO 14067 for the calculation of product and service carbon footprints, which could also be used to guide the CF of buildings over their life cycle (after all, a building is a very complex product).

These international standards were updated since 2017 to include specific instructions for carbon consideration. However, in Chile, NCh 3423 (the local version of ISO 21930) has not been updated to the date of close of this study. The update would bring relevant methodology to the local industry (see Table 2).

Table 2. State of the art of standards for data collection, Chilean situation and gap identified.

	Products	Buildings	Country
State of the Art	ISO 14067 – product CF ISO 21930 – EPD & PCR for construction materials	ISO 21931 and EN 15978 - Assessment of buildings performance	IPCC methodology for National GHG Inventory
National Situation	Both adopted in Chile	Not adopted in Chile	Adopted by Chile
Gap	Update to new version of ISO 21930:2017	Adopt ISO 21931-1:2010 (a newer version is under development)	Construction sector aggregated under “manufacturing”

Furthermore, to generate a system that coordinates so many actors, the stakeholders need to agree on reporting formats and key definitions to carbon footprint production.

To facilitate uptake by industry, it would be best to choose a single indicator that is congruent with traditional Architecture, Engineering and Construction (AEC) industry measurement units, such as carbon intensity per square meter (kg CO_2eq/m^2) [8, 9]. However, it has been reported previously (see **Table 3**) that even quintessential definitions such as area are in fact not standardized across the industry, or even between projects. To massively increase the use of this indicator, it becomes imperative that all actors agree on the definition of "total floor area" expressed in m^2 or any other agreed upon quantity for comparison.

Therefore, to foster comparison and usability of carbon intensity, it is paramount to create standards for the taxonomy used in the building sector.

Table 3. Different AEC names for floor area [9].

Gross internal floor area (GIFA)
Units for functional equivalent
Total gross floor area
The total net gross floor area (GFA)
The total floor area
The ground area
Site area, (m^2)
Reference area, (m^2)
Net Internal floor area (NIA) (m^2)
Net internal floor area (NIA)
Land area (m^2)
GSA (m^2)
Gross internal area (GIA)
Gross floor area (GFA) (m^2)
Gross Building Area (ft)
Floor area, (m^2)

Finally, comparability hinges upon quality assurance. To achieve the level of quality needed for these data to be used to track the national carbon neutrality goal, the country will also need to build capacity in surrounding industries: particularly in carbon footprint verification for construction and in the analysis and management of large databases that would have to be available to multiple stakeholders on an ongoing basis.

2.5 Current state of the Chilean building industry to calculate the carbon footprint

Chile has a good foundation to foster the carbon footprint calculation for the building life cycle. The country has adopted the base standards (e.g., ISO 21930), has initial experience in the use of product category rules to generate environmental product declarations (e.g., steel EPD), and has budding databases with primary and secondary data, official emission factors, and impact models to calculate the carbon footprint.

The country also has information systems that facilitate reporting and, potentially, verification of carbon footprints. One example is the Register for the Emission and Transfer of Pollutants (RETC) which contains a corporate carbon footprint calculator (HuellaChile).

On the other hand, there are many challenges and gaps to implement a management system for the carbon footprint of buildings in Chile:

- There are many actors involved in the different stages of the building life cycle, and they lack proper communication channels.
- There is no adopted standard for industry definitions to help the construction of informatic systems to support carbon footprint calculations.
- Digitization of the sector is only the beginning, which is particularly relevant at the design stage, using widely accepted software and tools (e.g., BIM) that could be integrated to informatic systems already in use.
- Very little local data for the life cycle of building materials and systems to collect precise data during the building stage.
- No standard for reporting, which necessarily entails standardizing the functional units for the different types of buildings.
- Adoption of these new technologies during the design and construction phases by different actors in the industry.
- Capacity to ensure calculation and verification quality.

• A robust economic and management model that allows to constantly update and improve the MRV system and the calculator.

3 Conclusion

In order to build an MRV system to calculate the carbon footprint of buildings in Chile, three key components are required: (i) systems for Measurement, Reporting and Verification (MRV), (ii) carbon footprint calculators for buildings and construction materials and (iii) standardized methodologies for data collection.

Chile has adopted methodologies to calculate the carbon footprint in the full life cycle of buildings. However, their implementation is difficult due to the lack of naming conventions, and to the little penetration of digitization in the industry.

The country has experience and data systems that can ease the generation of an MRV for the carbon footprint in the full life cycle of buildings, but these systems must be adjusted so they are consistent, comparable and encompass all the life cycle. In addition, there must be collaboration among the industry actors to take up these systems and to make decisions that reduce the carbon footprint of the building.

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