# Net Zero in Context: Climate Change & Buildings

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As buildings account for a significant amount of global energy consumption and greenhouse gas emissions, understanding the confluence of buildings and climate objectives has never been more crucial. In this article Inhabit's **Jason Gaekwad, Technical Director | Building Physics + Sustainability**, looks at the nuances of "Net Zero", its significance in the building sector, and how we can harness its potential to transform our built environment in the quest to combat climate change.

## The challenge at hand – Climate Change

Scientists have long warned that the amount of carbon dioxide in the atmosphere should remain below 450 parts per million, to avoid potentially catastrophic climate change. In 2016, 175 countries signed the Paris Agreement on climate change, a global framework for action on climate change. The agreement aims to limit global warming to well below 2°C by having countries voluntarily reduce emissions of carbon dioxide and other greenhouse gases. Australia is a signatory to the agreement, and as part of this commitment, must submit emissions reduction commitments to the United Nations Framework Convention on Climate Change every 5 years.

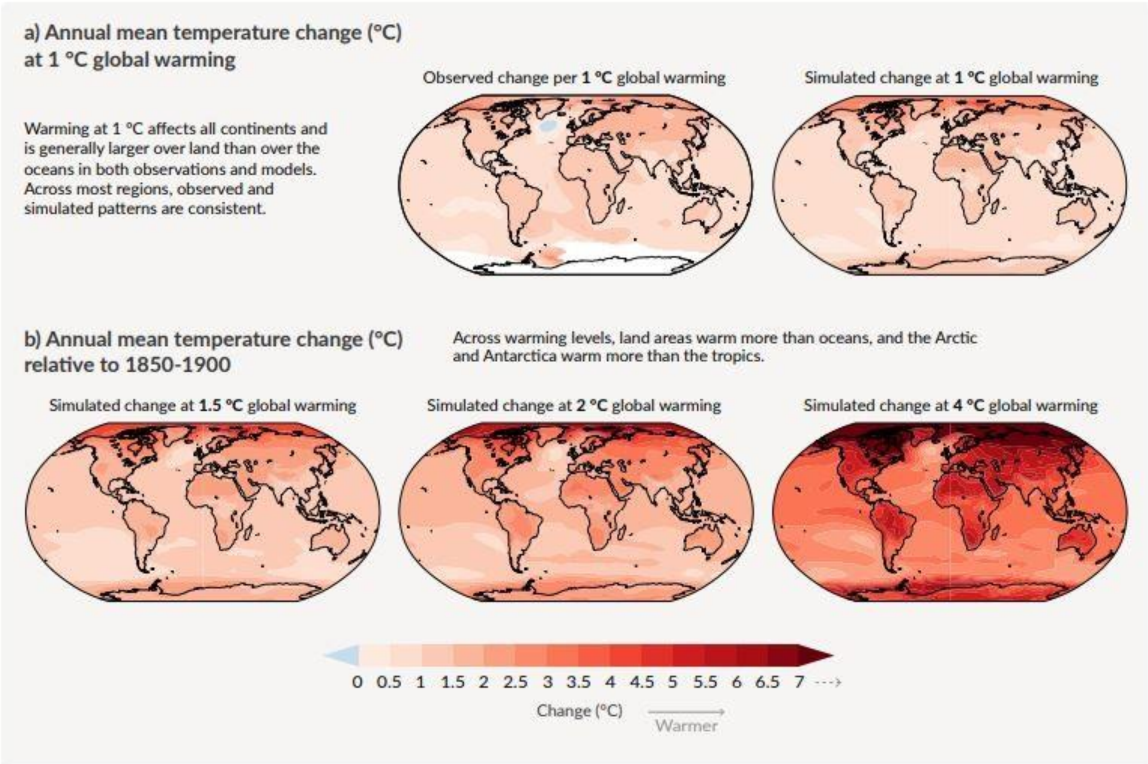



**Image: Figure SPM.5 from IPCC Climate Change 2021: The Physical Science Basis AR6 WGI Report Summary For Policymakers.**

In August 2021, the Intergovernmental Panel on Climate Change (IPCC) released its sixth assessment report (AR6) [i1] which details the scientific basis of the current and potential future states of the climate. The future scenarios considered put the 'best estimate' increase in average temperature at 1.5°C in between now and 2040, with estimates of longer term (up to 2100) increase ranging from 1.4°C to 4.4°C. This report adds a level of urgency, now that we know major climate change impacts are irreversible.

Prior to the release of the AR6 report, the IPCC maintained a series of reports detailing the state of the climate and likely future climate scenarios. In 2018, a report (SR15) by the IPCC warned of punishing environmental impacts if emissions are not curtailed sufficiently to prevent even 1.5°C of warming. Climate warming will result in extreme weather events, rising sea levels, and food and water scarcity, according to the report. It highlighted the need to limit warming to no more than 1.5°C; many ocean ecosystems, including the majority of the world's warm water coral reefs, are likely to disappear if warming exceeds this level [[ii]2].

Limiting warming to below 1.5°C imposes significant challenges globally; according to the SR15 reports, if Net Zero emissions is achieved by 2048 there is only a 50% chance that warming will stay below 1.5°C. Achieving net zero by 2038 improves this chance to two thirds, but global emissions must fall by up to 75% (relative to 2017 levels) by 2030. Further, for every year of failed action the window to reach net zero is reduced by two years.

## Buildings as a contributor

Globally, buildings are responsible for around 40% of carbon emissions [3[iii]]. This figure can be conveniently attributed to operational emissions (≈30%) and embodied emissions (≈10%). For clarity:

- Operational emissions are associated with operating a building and typically include emissions from heating and cooling, lighting, ventilation, appliances and plug loads, domestic hot water, etc. Generally, in Australia, grid electricity and natural gas are the main sources of operational greenhouse gas (GHG) emissions.
- Embodied emissions are associated with the construction of a building and all its input materials and processes. Various methods are used to assess embodied emissions; however, the whole life cycle of a material should generally be considered, from primary extraction of raw materials through manufacturing, transport, construction or installation, use, and end-of-life. Various methods of approaching embodied emissions and system boundaries are discussed further in this article.

**Photo by Ayush Jain on Unsplash.**

From a global perspective this narrative indicates that emissions associated with both existing and new building stock can make a significant difference to achieving global climate targets. The goal of reducing building-related emissions is in varying stages of action (or inaction) globally. Although both operational and embodied factors are the essence of what is driving the international 'Net Zero' concept today, the trend of electricity networks towards including more renewable energy sources puts a focus on embodied emissions.

The carbon footprint of Australian buildings is a slightly more tenuous figure, variously estimated at around a fifth [4[iv]] or a quarter [5[v]] of national carbon emissions. Even more tenuous is the relative contribution of operational and embodied emissions. The Australian Sustainable Built Environment Council [6[vi]] appears to estimate operational contributions at around 25% of Australia's total GHG emissions, further stating that buildings are responsible for about half of the country's electricity consumption. Yu et al [7[vii]] estimate that construction activities in Australia contribute to 18% of Australia's total GHG emissions. Electricity use was found to be the highest contributor, followed by embodied emissions from the material supply chain.

Although specific figures are elusive, the data agree that both operational and embodied emissions are significant contributors to global and Australian GHG emissions. There is a clear case for widespread reduction of both operational and embodied emissions.

## More than carbon

It is important to note that, while this article is focused on carbon emissions, building and construction is detrimental to the environment in a number of ways. A convenient list, forming part of the latest LEED Green Building audit tool, lists the following impact categories due to building material lifecycles:

- Global warming potential
- Depletion of the stratospheric ozone layer
- Acidification of land and water sources
- Eutrophication (undesirable nutrient enrichment of water bodies)
- Formation of tropospheric ozone
- Depletion of non-renewable/fossil fuel energy sources

The above list is generally associated with upstream lifecycle impacts associated with transport and manufacturing but provides a simple description of the large impacts the construction industry can have. Furthermore, there are deeper and more complex environmental impacts, such as habitat destruction and loss of biodiversity, as well as social and economic effects. Although carbon is important, and potentially the most pressing global issue, there are a range of impacts that need to be minimised and managed.

## Net Zero, Carbon Neutral, Embodied, & Upfront Carbon

**Common Terminology**

In the context of building operational and embodied emissions 'Net Zero' typically refers to 'zero' operational carbon emissions only, with the term 'Carbon Neutral' referring to zero operational and embodied emissions. It is noted that definitions can widely vary between rating and reporting systems.

The pathway to minimising operational carbon is generally quite clear in industry, with a focus on drastically reducing energy use, maximising on-site renewable energy generation, changing fuel sources (e.g. switching to a renewable energy provider), and (if necessary), purchase of carbon offsets. The pathway to minimising embodied carbon is often less well understood.

**Achieving Carbon Neutrality – Embodied Carbon**

The term ‘embodied carbon’ encompasses all carbon emissions associated with the creation, existence, and end-of-life of a building, except day-to-day operational carbon emissions. This includes all the energy (and associated carbon emissions) associated with the planning, construction, maintenance, refurbishment, and end-of-life of a building. This way of thinking highlights the importance of the amount of materials and products used in a building, and the history (and future) of each particular material and product used on site. For example, does a particular material use a large amount of fossil fuels in its manufacture (such as Portland cement)? Was a particular product transported inefficiently, or over a long distance, using fossil fuel based transport methods? Can a particular material have a high recycled content (such as steel), or be recycled itself?

The Life Cycle Analysis concept of ‘system boundaries’ becomes quite important here. Often ‘cradle to gate’ data is discussed, which includes primary extraction (‘cradle’), manufacture and packaging, right to the ‘gate’ as the material or product exits the factory. However, this style of thinking doesn’t take transport, the construction process, or end-of-life into account. Cradle-to-grave, or cradle-to-cradle thinking is more holistic, accounting for emissions associated with disposal or (hopefully) reuse/recycling. However reliable data, especially for downstream effects, can be difficult to come by. Figure 1 displays the many stages and boundaries applicable in Life Cycle Analysis for embodied carbon. These techniques, which have been available for over 50 years, are critical is assessing and minimising embodied impacts. (Facing image: Figure 1 from WorldGBC (2019). Bringing Embodied Carbon Upfront.)

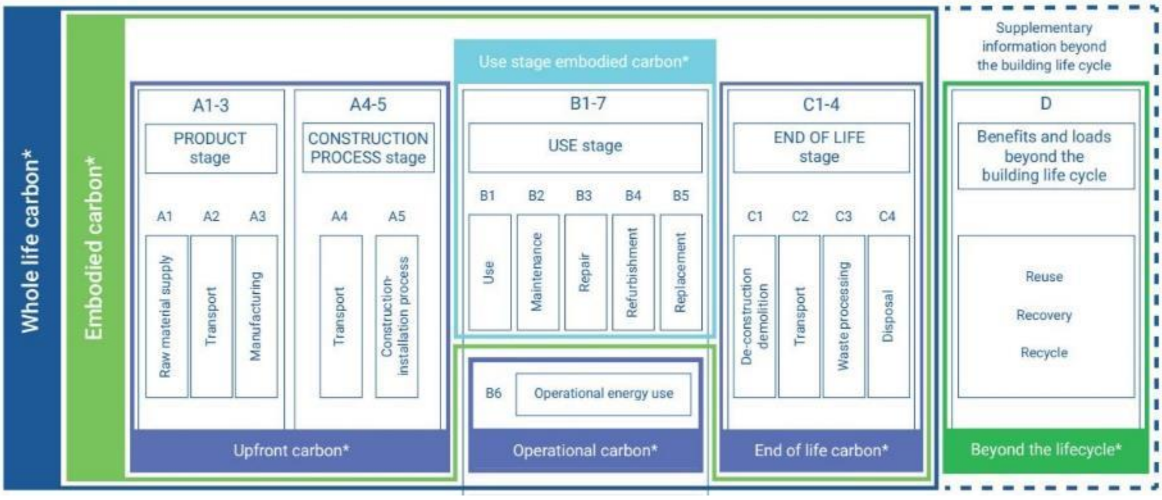



**Figure 1: The various stages of the life cycle and definition of common terms, according to the commonly adopted standard EN 15978**

**Upfront or Embodied Carbon**

The discussion around embodied carbon in buildings often switches between two terms, ‘embodied carbon’ and ‘upfront carbon’. Embodied carbon, as discussed previously, encompasses all carbon emissions associated with the production, transport, construction, use, and end-of-life of a material. Upfront carbon encompasses only the emissions from production to construction (A1-A5). A convenient way of thinking about it is that upfront carbon is all the carbon that has already been emitted once the project is completed.

The general discussion around product material and carbon emissions in Australia has largely switched from embodied carbon to upfront carbon. Green Star, a common Green Building audit tool used in Australia, considers upfront carbon, and NABERS, the operational reporting tool used in Australia, is considering upfront carbon as an option for its embodied emissions initiative.

Whilst this article generally addresses embodied carbon, the ideas are also applied to upfront carbon. There are some strategy specific differences between the two however (e.g. engineered timber has very low upfront carbon but moderate embodied carbon). Considering the urgency of our climate crisis, I encourage detailed consideration of upfront carbon, without compromising the future with high use or end-of-life carbon emissions.

**Why embodied carbon?**

It is worth noting that, whilst operational carbon currently dominates the carbon emissions from the property and construction industries, embodied carbon is predicted to dominate in the future (refer Figure 2). This is due to the (hopeful) conversion of energy networks from fossil fuel dependent to renewable sources. However, this doesn't mean that development of low operational carbon and energy buildings is no longer desirable. Low energy buildings provide a multitude of benefits to building owners and occupants including low operational costs, climate and grid resilience, occupant comfort, lower absenteeism, increased productivity, etc.

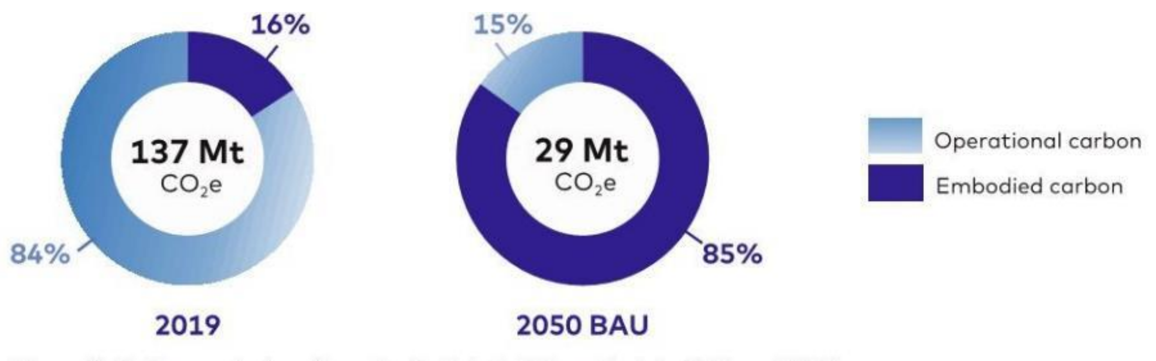



**Figure 2: Future estimates for carbon emissions from Australian building stock show embodied carbon dominating emissions. Sourced from GBCA and thinkstep-anz. (2021). Embodied Carbon and Embodied Energy in Australia's Buildings.**

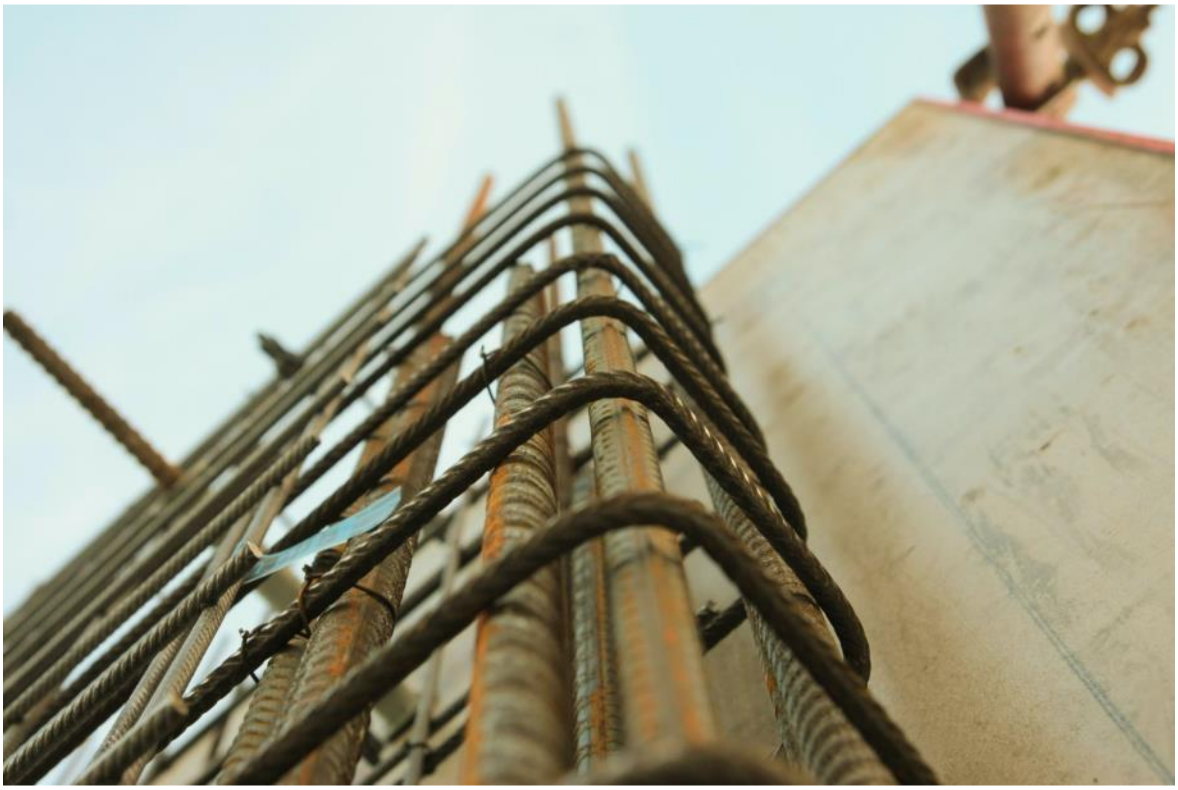
## Reducing Embodied Carbon in Buildings

This section provides an overview of pathways to reduce embodied carbon in building projects. It touches on major parts of the low-carbon journey in an effort to raise some key ideas without detailing every element in the carbon neutral playbook.

**Challenges for Embodied Carbon**

Embodied carbon emissions can be quite difficult to consider, as availability of life cycle impact data from building products is often limited. However, the awareness of suppliers is slowly developing, with research bodies also assisting with creation of geographically specific datasets. These datasets attempt to capture the impact of any particular product across the whole life cycle and supply chain of the constituent raw materials.

It is worth noting that there is significant room for error in both the development of and application of various life cycle impact datasets. This is largely due to the broad scope, complexity, and non-specific nature of the data. There is advantage in using generic data sets for comparison and benchmarking, with application of geography and project specific materials, products, and designs developing throughout the design and construction phases of a project.



**Geographic factors add complexity to the embodied carbon design and assessment process. Photo by Michael Bader on Unsplash.**

In the early stages of a project there can be challenges in determining benchmarks from which to reduce embodied carbon, and proposed materiality (material + volume or mass) of the design. Project specific definitions and targets are required at an early stage, often produced through research and investigation of case studies. Furthermore, optimisation of major assemblies or components of the design, such as optimising the typical structural system used in a building rather than assessing the structure of a whole building, can assist in providing design direction when levels of uncertainty are still high.

**Strategies to reduce embodied carbon**

Project Roles

Strategies to reduce embodied carbon can be implemented by a variety of project stakeholders, however as usual the building developer/owner plays a pivotal role in keeping the vision alive and implemented throughout the project lifecycle. Other key stakeholders include the carbon engineer (a somewhat new role proposed below), wider design team, and contractor. These key stakeholders need to be aligned to deliver on carbon reduction strategies for the project, as a defined KPI on the project outside of town planning or other legislated requirements.

Having clear embodied and operational carbon goals for the project is critical to achieving results. These goals can be based on case studies or absolute values calculated for certain building types. A mixed approach is recommended to provide a range of certainty for the embodied carbon goal. Relative goals are attractive (e.g. 20% less than some reference construction) however by nature they encourage incremental thinking and not the radical change that we require. Absolute goals (refer figure below) are quite the opposite and can be intimidating and difficult to apply. The UK based LETI targets in the image below indicate that we need to reduce upfront carbon by 50% to

75% by 2030. Using both of these methods is the best way to develop a target for a project. Including these goals in the construction contract is also key, as is requiring the main contractor to undertake actions such as sourcing appropriate product data and reducing construction waste diverted to landfill.

**Upfront Embodied Carbon, A1-5** (exc. sequestration)

| | Band | Office | Residential (6+ storeys) | Education | Retail |
|---|---|---|---|---|---|
| | A++ | <100 | <100 | <100 | <100 |
| | A+ | <225 | <200 | <200 | <200 |
| LETI 2030 Design Target | A | <350 | <300 | <300 | <300 |
| | B | <475 | <400 | <400 | <425 |
| LETI 2020 Design Target | C | <600 | <500 | <500 | <550 |
| | D | <775 | <675 | <625 | <700 |
| | E | <950 | <850 | <750 | <850 |
| | F | <1100 | <1000 | <875 | <1000 |
| | G | <1300 | <1200 | <1100 | <1200 |

**Life Cycle Embodied Carbon, A1-5, B1-5, C1-4**

| | Band | Office | Residential (6+ storeys) | Education | Retail |
|---|---|---|---|---|---|
| | A++ | <150 | <150 | <125 | <125 |
| | A+ | <345 | <300 | <260 | <250 |
| | A | <530 | <450 | <400 | <380 |
| RIBA 2030 Build Target | B | <750 | <625 | <540 | <535 |
| | C | <970 | <800 | <675 | <690 |
| | D | <1180 | <1000 | <835 | <870 |
| | E | <1400 | <1200 | <1000 | <1050 |
| | F | <1625 | <1400 | <1175 | <1250 |
| | G | <1900 | <1600 | <1350 | <1450 |

**Figure 3: An example of absolute embodied carbon targets https://www.leti.uk. Typical present-day buildings are somewhere between Band C and Band E. Embodied carbon needs to reduce by a factor of 2 to 4 to achieve the 2030 design and build targets (i.e. a 50% to 75% reduction).**

The Carbon Engineer role on the project is important in assisting with project definition, goals, and assurance. Early in the project lifecycle, the focus of this role is exploratory, conducting research, sourcing data for benchmarking, ideating, and evaluating various options that align with the project goals. As the project progresses, the role becomes more conventional: conducting calculations (e.g. Life Cycle Analysis), providing assurance, and co-ordinating with the rest of the project team. The Carbon Engineer also acts as a custodian of the project carbon data set, potentially handing over this responsibility to the contractor team. Finally, it is up to the Carbon Engineer to conduct final verification of the as-built condition and, with the owner, distribute this data as a case study for others to take and build upon.

Project Definition & Design

Consideration of embodied emissions and the complex systems in which our projects sit changes the way we think about design and construction. Fundamentally, we must change the way we meet our needs. Refurbishment becomes much more appealing than new build, with both economic and environmental pillars to the business case. Ways of making a building stay useful for longer, such as flexible spaces, become key in design and operation. We also now view an older building as a resource, if not for the space it can provide, than the materials it's comprised of. These decisions make the biggest difference in embodied carbon, and we need to see more of this happening.

Down the track, if we do decide to build or refurbish, our opportunities to reduce embodied carbon become restricted. The biggest changes we can make are major material substitutions (e.g. from reinforced concrete to engineered timber) and clear ability to disassemble and reuse building materials (commonly called 'design for end-of-life' or alternatively termed 'design for next life'). It is worth noting that timber has potential to be a true carbon neutral material, but this is heavily dependent on the extraction and processing methods used, as well as transport distances. It isn't the magic solution for low carbon buildings that it is often touted to be, but it can be a big step in the right direction, especially for reducing upfront carbon emissions.

Minor reductions in embodied carbon can be seen through a push for efficiency in materials, low-tech solutions, and minor material substitutions. An example of these changes would be omitting certain finishes (i.e. raw finishes) and using 'low carbon' concrete (i.e. concrete with a reduced Portland cement ratio). Whilst these choices can make a big difference to the building design, they are relatively minor in their ability to reduce the embodied carbon of a building. My estimate on the collective impact of these minor measures is a maximum reduction in embodied carbon by circa 20%.

**Bringing It All Together**

The first thing the stakeholders need to do is think about what the project needs to achieve, what resources the site features, and how the team can work with the site resources to help achieve the project goals. This is the stage where we have the most influence on reducing embodied carbon.

If we decide to design/build something we need to think about materiality (typically structural materiality) and end-of-life methods to encourage reuse and discourage diversion to landfill. Once we've made these major design decisions, our effectiveness is limited to activities which give us small reductions in carbon but may still have challenges in design implementation. For example, 'low carbon' concrete mixes may have longer curing times. Using such products may lengthen project programme for only a minor to moderate reduction in embodied carbon.

Achieving all of this requires open-mindedness, research, and exploration at an early stage. Targets then need to be set and taken through, with assurance increasing throughout the project lifecycle as the design becomes more certain and more data becomes available. A 'Carbon Engineer' role within the project team greatly assists with this.

## Case Studies

Inhabit has acted as the Carbon Engineer on several projects, a few of which are presented here. Much of our recent work has been focused on early-stage design and optioneering to reduce upfront carbon. The project team can have a huge impact on minimising upfront carbon at this project stage, however there is also a large amount of uncertainty in the design and data availability. To this end, we have developed a custom concept design tool for carbon optioneering which allows Inhabit to steer the design and provide data-driven advice at an early stage.

The figures below plot the upfront carbon intensity (emissions per square metre) of a number of recent projects Inhabit has undertaken. These figures demonstrate a baseline figure, followed by changes in material, and then major design changes to reduce carbon intensity. The carbon intensity is plotted LETI targets curve, which provides a yearly target intensity from the years 2015 to 2050, with the aim of achieving global climate goals. In this way, a project can be tracked against its performance on the global stage – with some projects well ahead of their time, and some projects lagging behind. The individual projects are discussed below.

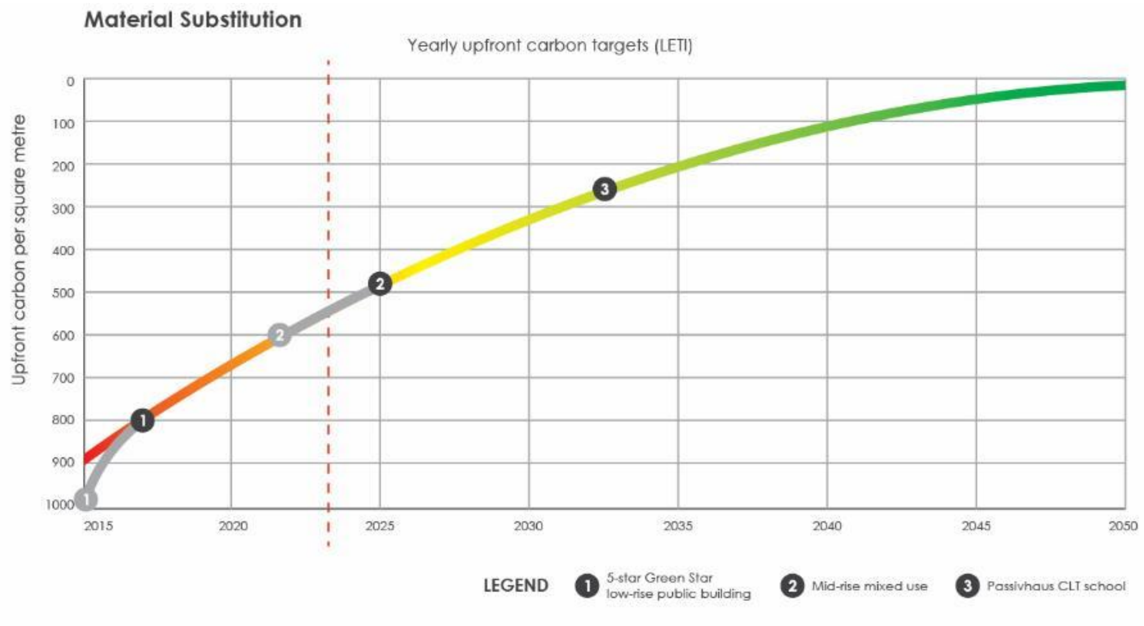
**The 5-star Green Star public building** started as a high emissions intensity design due to a requirement for large volumes of in-situ and precast concrete. Material substitution alone achieved the 20% reduction from baseline required by the latest Green Star Buildings tool. The emissions intensity of the building is still high, at LETI emissions Band E. However, the building achieved its Green Star requirement. This project demonstrates that materials substitution should be a clear and common design decision on projects, with few drawbacks and clear implications for reduction in carbon intensity. The figures also demonstrate the weakness of a relative target for carbon emissions intensity, with the Green Star relative target being met, but absolute intensity figures remaining high.

**The mid-rise mixed-use building** had a relatively low baseline emissions intensity due to its urban infill location and associated limitations on façade area, slab depth, and basement extent. This resulted in an overall reduction of material (largely structural and glazed façade material), putting the baseline design roughly at the LETI target for the early 2020s. Material substitution alone lifts the performance to the late 2020s, putting the project a little ahead of its time for upfront carbon emissions intensity. Major design changes are required to achieve major gains to a 2030 target. These design changes include use of novel non-cement concrete, structural timber, renewable and/or recycled aluminium and glass, reuse of existing materials, etc.

**The Passivhaus cross-laminated timber (CLT) school** is the result of the Carbon Engineering design process. The design involved both material substitution and major design changes to reduce upfront carbon, as well as significantly decrease operational carbon through certification to the Passivhaus standard. Designing to achieve Passivhaus, such as reducing surface to volume ratio, also results in an efficient design for material quantity and therefore emissions intensity. I believe case studies like this make a very strong argument for the use of high quality as-built standards like the Passivhaus Standard in concert with a Carbon Engineering design approach.

The result of this design approach is a school that is around 10 years ahead of its time, according to the LETI targets. It provides excellent outcomes for occupants, the asset owner, and the environment, as well as driving broader economic and social benefits. It is noted that biogenic emissions were included as part of this calculation, reducing upfront carbon associated with timber products.


Baseline
Yearly upfront carbon targets (LETI)
Upfront carbon per square metre
0
100
200
300
400
500
600
700
800
900
1000
2015
2020
2025
2030
2035
2040
2045
2050
LEGEND
1 5-star Green Star low-rise public building
2 Mid-rise mixed use
3 Passivhaus CLT school


Material Substitution
Yearly upfront carbon targets (LETI)
Upfront carbon per square metre
0
100
200
300
400
500
600
700
800
900
1000
2015
2020
2025
2030
2035
2040
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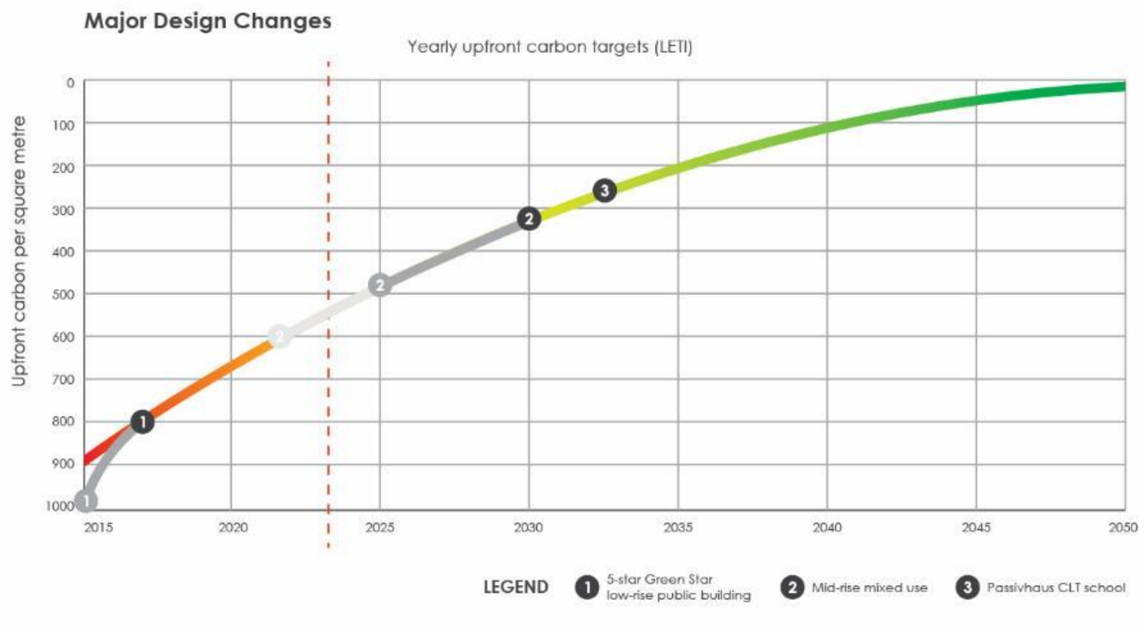


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i https://www.ipcc.ch/report/ar6/wg1/

ii https://www.ipcc.ch/sr15/

iii https://architecture2030.org/why-the-built-environment/

iv https://www.sciencedirect.com/science/article/pii/S1877705817316879

v https://www.asbec.asn.au/wordpress//wp-content/uploads/2016/05/160509-ASBEC-Low-Carbon-High-Performance-Summary-Report.pdf

vi https://www.asbec.asn.au/wordpress//wp-content/uploads/2016/05/160509-ASBEC-Low-Carbon-High-Performance-Summary-Report.pdf

vii https://www.sciencedirect.com/science/article/pii/S1877705817316879