C40 Clean Construction Accelerator

Technical Note

1. Why a C40 Accelerator on Clean Construction

1.1 The urgency to decarbonise the construction industry

By 2050 another 2.5 billion people are expected to live in urban areas. A billion new homes need to be built globally by 2025. This means construction of buildings and infrastructure equivalent to a city the size of Milan (1.5 million people) per week until 2050. The construction sector is responsible for over 23% of global GHG emissions, on top of consuming over 30% of global resources. Business as usual in the construction sector significantly contributes to a world on track for 3°C or more of over-heating.

Construction is one of the biggest contributors to the climate crisis globally, contributing more than 23% of the world's GHG emissions[1]. The production of concrete and steel, the two most commonly used construction materials, play a significant role with concrete alone representing 7 to 8% of global GHG emissions[2]. Construction materials and the building sector are also responsible for more than 30% of global resource consumption. Construction sites are responsible for significant air and noise pollution, linked to construction activities, the use of diesel machinery, lorry movements, and traffic congestion.

Yet construction is nowhere near to reduce speed. By 2050, another 2.5 billion people are expected to live in urban areas, with close to 90% of this increase taking place in Asia and Africa[3]. The need for buildings and infrastructure will intensify – by 2025 we will need to build 1 billion new homes. Globally, roughly 60% of buildings that will exist in 2050 are yet to be built. This means constructing a city the size of Stockholm or Milan (1.5 million people) per week until 2050, or a city the size of Singapore or New York every month until 2050.

The 2018 IPCC special report on the impacts of global warming showed that the world had a total 420 GtCO2 left to release if we are to limit warming to 1.5C (with a 67% probability). Since then, 160 GtCO2 have already been emitted, leaving us with a remaining total of 340 GtCO2. Figure 1 below shows the rate of reduction that must be achieved if we are to stay under a global warming of 1.5C. The IPCC report released in 2021 has not illustrated improvement in this area. Due to the severe accelerated reduction needed, reduction must happen across all sectors at once.

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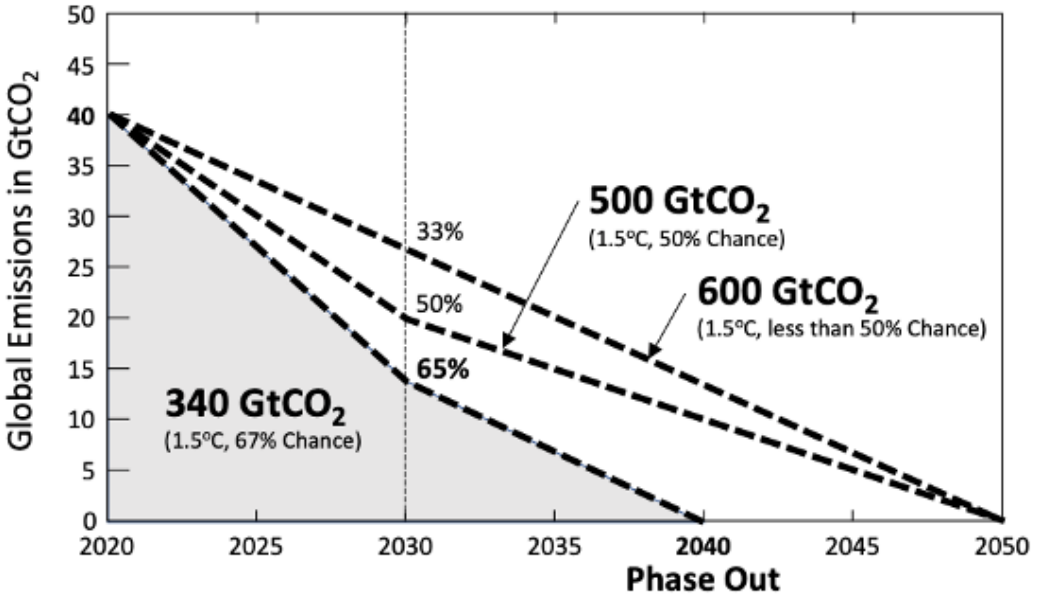
[1] Huang et al. (2017). Carbon emission of global construction sector. Renewable and Sustainable Energy Reviews. 81. 10.1016/j.rser.2017.06.001.

[2] Lehne, Johanna and Preston, Felix, 2018. *Making Concrete Change: Innovation in Low-carbon Cement and Concrete*. Chatham House.

[3] UN DESA, 2018

Figure 1 – IPCC reduction pathways to remain under a 1.5 degree of global warming

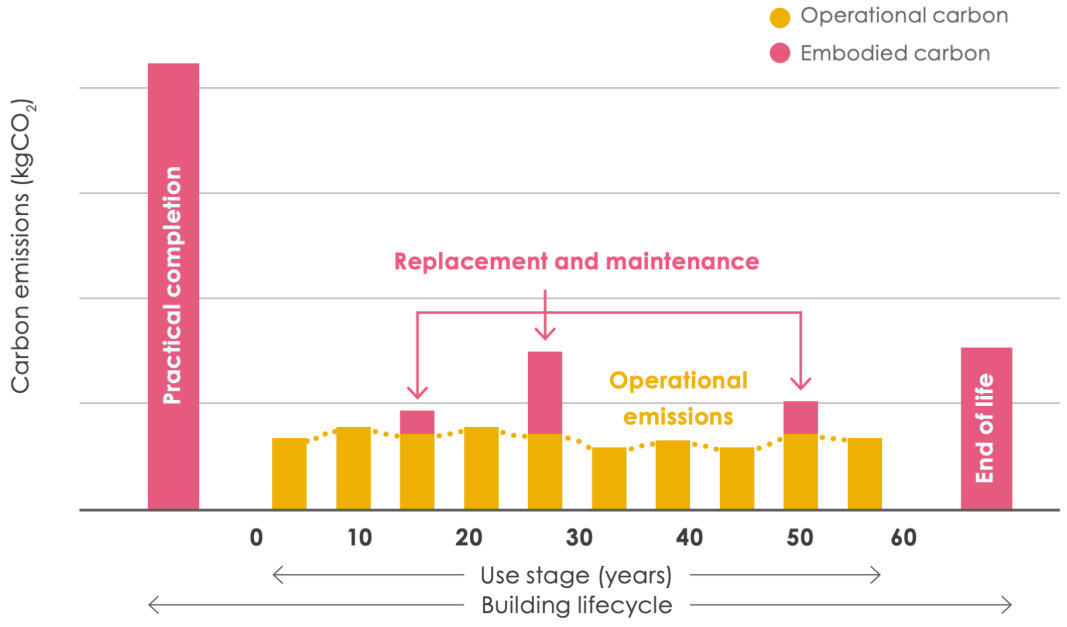


Source: Architecture 2030

Assumptions: 80 GtCO2 of the remaining budget have been used from January 2018 to January 2020

When assessing a building's impact over an average life span (60 – 80 years[4]), total cumulative operational emissions have historically been larger than embodied emissions. However, due to the increasing operational efficiency of buildings and our short 10-year window of action to remain in the 1.5 degree warming scenario, our focus must now shift to embodied emissions. Figure 2 below illustrates where along the life span of a building operational and embodied emissions are emitted.

Figure 2 - Operational and embodied emissions: a building's whole-life emissions



Source: London Energy Transition Initiative (LETI) Embodied Carbon Primer

[4] UCL Engineering, 2019. *Refurbishment & Demolition of Housing Lifespans & Decisions: Factsheets*. *UCL*

For this reason, an Accelerator targeting 50% reduction in embodied emissions by 2030 is necessary to meet the Paris Agreement.

1.2 The role of cities in accelerating the transition to a sustainable construction system

Cities have a major role to play in the transition to a sustainable construction system. Most construction over the next few decades will happen in cities[5]. Emissions from building and infrastructure construction are expected to form the single largest category of consumption - based emissions for C40 cities between 2017 and 2050 producing 21% of consumption emissions. Cities are responsible for these emissions, however they are currently not captured in most city's inventories, which has slowed action on this topic. As this period is critical for reducing greenhouse gas (GHG) emissions in line with keeping global temperature rise to within 1.5C above pre-industrial averages, serious action is needed from cities in this area.

Cities have a variety of levers at their disposal to influence the construction industry. Cities have varying degrees of power over the construction happening in their city. The built environment touches on almost every aspect of city life. While some cities will be able to leverage building and planning codes, others can tackle the impact of construction when addressing housing, air quality, waste, and jobs for example.

Transitioning to a sustainable construction system is key to achieving cities' green and just transition ambitions.
Transitioning to a sustainable construction system not only provides much needed emissions reductions, it is also a key component of a city's green recovery and the transition to a zero carbon city. With cities planning their recoveries from the COVID-19 pandemic, it is essential that the major environmental, social and economic influences of construction are harnessed to support green and just recovery strategies and a global green new deal that puts inclusive climate action at the centre of all urban decision-making.

This includes delivering a green and just transition and improving social equity. For example, creating decent work and quality green jobs by investing in local, sustainable business communities and expanding existing solutions and by educating and reskilling workers. This would safeguard residents' livelihoods and social and human rights.

[5] UN Department of Economic and Social Affairs, 2021. *68% of the world population projected to live in urban areas by 2050, says UN*, UN.

The move to increase retrofitting can reduce embodied carbon and spur job creation, as can the transition to circular material supply chains. Encouraging local sourcing of materials and short supply chains would benefit the local economy by growing local markets, know-how and skill sets using innovative and low carbon designs, materials and processes driving a better, inclusive, and just use of space.

1.3 The urgency to act now

National governments consider infrastructure and construction as one of the main engines of the economic recovery from the COVID-19 crisis, supported by increased public funding and stimulus packages. For instance, the United States of America's Senate approved in August 2021 a $1 trillion Infrastructure Bill to improve and modernize the country's aging infrastructure[6]. China has positioned 'new infrastructure' construction as a key policy pillar of its post-pandemic economic recovery, investing heavily in the country's own infrastructure, not just to build new roads, railway lines and sewage systems but also to make the equipment necessary for those projects[7]. The UK Government is investing £5bn to accelerate infrastructure projects in its economic recovery plan[8].

While the intention is to create jobs, pushing business-as-usual construction would prove damaging[9]. By overlooking and disregarding clean construction principles and materials impacts, urban air pollution will intensify due to construction sites, significant embodied emissions will be released and locked in the atmosphere, exacerbating the climate crisis, more resources will be extracted, contributing to the ecosystems and biodiversity crisis; and cities' resilience to future pandemic and climate shocks will be undermined. Increased construction over the next decade runs the risk of locking in huge amounts of GHG emissions unless cities make a switch to clean construction.

Building Back Better should be understood literally, as tackling the negative impacts of the construction sector on the people and the planet. The opportunity for change has never been so timely and cities have a narrow window of opportunity to embed Clean Construction considerations into their green and just recovery plans.

1.4 Objectives of the Clean Construction Accelerator

Over the past few years the key role of construction has garnered more attention within climate circles. However, action at scale still needs to be taken.

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[6] New York Times, (2021). *Senate Passes $1 Trillion Infrastructure Bill Handing Biden a Bipartisan Win*. New York Times.
[7] Keith Bradsher, (2020). *China Tries its Favorite Economic Cure: More Construction*. New York Times.
[8] Prime Minister's Office, 10 Downing Street, (2020). *'Build build build': Prime Minister announces New Deal for Britain*. Gov.uk.
[9] Richard Luscobe, (2020). *Florida accused of push for 'roads to nowhere' under cover of pandemic*. The Guardian.

The Clean Construction Accelerator has three objectives to support the need for global action:

- Aggregating the demand of global cities to increase their impact and instil confidence in the market to collectively reach a net zero emission build environment.
- Raising awareness within the construction system and the wider public. Construction impacts are often hidden and only felt indirectly. The Accelerator drives broader recognition of a component of city life that is often ignored in the climate context.
- Setting the global standard for what construction looks like in a city in a net zero carbon world.

2. What is the C40 Clean Construction Accelerator

The C40 Clean Construction Accelerator includes a suite of commitments for cities to meet their share of responsibilities in reaching the collective goals of the Accelerator and meet the Paris Agreement. By taking these commitments, cities can develop net zero emission, resource-efficient, resilient and healthy buildings and infrastructure of the future. Cities can enact policies and regulations where they have the powers to as well as bring together and inspire stakeholders to take complementary action.

2.1 The Clean Construction Accelerator commitments

As stated above, the commitments are the actions that cities commit to taking to meet the Accelerator goals. The commitments address the impact of construction in cities, which includes environmental factors such as embodied emissions, resource use and resilience of major renovation and new construction, as well as socio-economic factors including a just transition to green, decent and healthy jobs.

Cities have varying degrees of power over the building and infrastructure construction that happens within their boundaries, however we expect all cities to be able to take action on each commitment. The Accelerator's commitments are as follows:

1. **Prioritise the better use, repurposing, and retrofit of existing building stock and infrastructure** across the city to ensure their optimal use before new construction projects are considered.
2. **Lead by example with municipal procurement** by:
    - requiring life cycle assessments (LCAs) and the diversion of construction and demolition waste from disposal for all municipal projects.
    - Use municipal purchasing power to procure or demand zero emission construction machinery in municipal projects from 2025, where available.

    - Reward resource efficient and circular design, use of low carbon materials, and low to zero waste construction sites for all new projects and major retrofit.
3. **Demand transparency and accountability**, starting with requiring LCAs in planning permissions and embedding them into planning policies, processes and building codes within a year of endorsing this accelerator or in the next revision of planning policies and codes. Require the public disclosure of this data to facilitate greater transparency and foster accountability to develop robust baselines, standards, certifications and policies.
4. **Work with businesses, industry, public institutions, residents, workers, social partners and other organizations to establish a joint roadmap and set interim targets towards the collective 2030 targets** adhering to circular economy principles within two years of endorsing this accelerator, and incorporate them into our Climate Action Plan. The roadmap will provide an implementation pathway to the Clean Construction Accelerator actions and to reaching its goals inclusively and equitably.
5. **Approve at least one net zero emission (operational and embodied) flagship project by 2025.**
6. **Assess the impact our choice of materials and construction design will have on our cities' overall resilience to climate impacts** (i.e., increasing urban heat island, impermeable surface increasing the risk of flooding, etc.)
7. **Work with and advocate for regional, national and supranational government** to take action on sources outside the boundaries of our control.
8. **Publicly report every year** on the progress our cities are making towards these goals.

2.2 The Accelerator goals

The Accelerator goals are collective for the entire value chain. They apply city-wide to both buildings and infrastructure projects. Cities themselves do not have direct control over all construction occurring within their boundaries. However, by signing up to the Accelerator, cities are committing to use the powers they do have to move towards these goals, and to convene the industry and other relevant stakeholders in the city to collaborate on the citywide goals.

By taking the commitments above, cities are meeting their share of responsibilities to meet the collective goals of the Accelerator, which are the following:

- Reduce embodied emissions by at least 50% for all new buildings and major retrofits by 2030.
- Reduce embodied emissions by at least 50% of all infrastructure projects by 2030.

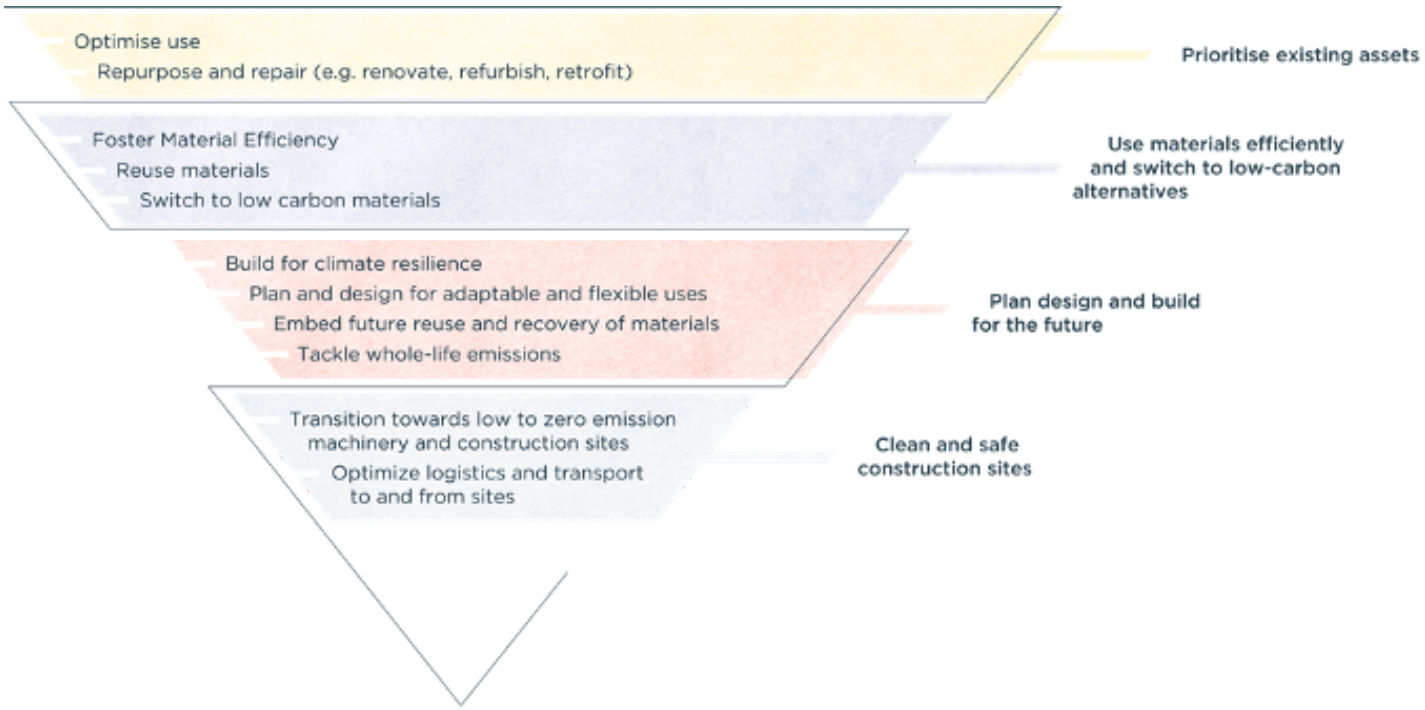
- Require zero emission construction sites city-wide by 2030, where technology is available.

3. How to meet the commitments of the Clean Construction Accelerator

3.1 Follow the Clean Construction Hierarchy

The construction hierarchy is a framework that can be used to ensure the most impactful strategies are used at each step of a project or policy development process. Use the Construction Hierarchy to guide thinking on the implementation of each of the city commitments in this Accelerator.
The construction hierarchy is laid out below in Figure 3.

Figure 3 - The Clean Construction Hierarchy[10]



3.1.1 Clean Construction Hierarchy Step 1: Optimise existing buildings and assets

The first step of the hierarchy is about valorising the structures that already exist in the city. Ensuring buildings and assets are used at their optimum capacity as well as repurposing and repairing existing structures brings environmental benefits and can maintain the social integrity and cultural face of the city.
Vacant, underused structures and stranded assets can be optimised, changed in the way they are used, repurposed and repaired. These approaches avoid demolition and new construction where it is not necessary and should be

[10] Developed by C40, with support from Buro Happold

prioritised before considering new construction. This approach mitigates embodied emissions in two ways, it ensures the materials that are currently in place continue to be used and are not waste through landfilling or low level reuse, and it reduces the amount of new materials that are required to be produced.

This initial priority is especially relevant where building use changes rapidly, including due to the effects of the COVID-19 pandemic. Retrofit and repair can also cut operational costs and reduce crime and security concerns exacerbated by vacant and underused areas.

3.1.2 Clean Construction Hierarchy Step 2: Use materials efficiently and switch to low-carbon alternatives

Once a new structure has been deemed necessary, material choices, both in terms of design and composition, play an important role in the overall emissions impact. Traditional construction has been found to use far more materials than are structurally necessary, for example, one study of apartment buildings in the UK found that structural steel was only used at 50% of its loading capacity[11] . Material efficiency strategies avoid this overdesign, ensuring only the right amount of material for the right purpose in a project.

Material switching to a lower carbon material is also a strategy. This does not have to mean switching to novel technologies or more expensive options. This can include reused materials, or materials that include a certain percentage of recycled content. Many of the most commonly used materials such as concrete have readily available low carbon options that do not come at a cost premium. For example, one study found that simply switching materials in a conventional design out for the low carbon alternatives on the market resulted in a 24-46% embodied carbon reduction at a cost premium of less than 1%[12].

3.1.3 Clean Construction Hierarchy Step 3: Plan, design, and build for the future

Extreme weather events are already illustrating that the built environment as it is constructed now is not designed to withstand the growing global extreme weather pressures. Planning for the future means new designs need to be built for resilience to ensure they can function for the entirety of their lifespans and not need to be replaced too early.

Planning for the future also means considering the whole life carbon impact of a project at its inception. Current construction and demolition practices also consume and waste vast quantities of resources. To reduce the resource impact cities should promote, reward or require designs that are flexible, adaptable, reversible and modular. Reducing excessive consumption of virgin materials and

[11] Moynihan, M. C. & Allwood, J. M., 2014. Utilization of structural steel in buildings. Proceedings of the Royal Society A, 470 (2168).

[12] RMI, 2021. *Reducing Embodied Carbon in Buildings*. RMI.

embracing circular approaches to reducing and reusing waste are critical to cutting embodied emissions.

3.1.4 Clean Construction Hierarchy Step 4: Clean and safe sites

Construction sites are major sources of air and noise pollution in cities. Unlike much of the emission, resource use, and waste impact felt in other steps of the construction hierarchy, the impacts of construction sites can be felt on the ground by residents and workers in the city themselves.

Air and noise pollution from construction sites comes from Non Road Mobile Machinery (NRMM) on site as well as from the delivery trips back and forth from the site. Low emission NRMM are available but implementation has lagged behind passenger vehicles (More information in section 3.3). Deliveries and other trips to and from construction sites are also usually poorly coordinated leading to many half empty trips increasing congestion, air, and noise pollution in the city. [13] Taking steps in this area not only directly protects city residents but also ensures a more efficient and greener construction industry with decent and quality green jobs.

3.2 Actions to meet the Clean Construction Accelerator commitments

The Accelerator commitments touch on every aspect of construction in cities. The actions are varied but all stem from the construction hierarchy, the theory of action underpinning all clean construction actions. The commitments further support the Accelerator goals and adjacent climate and societal benefits. They do not have to be completed in any particular order.

3.2.1 Commitment one: Prioritise existing buildings and infrastructure

Commitment one reads as follows:

> *Prioritise the better use, repurposing, and retrofit of existing building stock and infrastructure across the city to ensure their optimal use before new construction projects are considered.*

Commitment one falls very closely in line with Step 1 of the construction hierarchy. It is important to first consider existing buildings and infrastructure available before demolition and/or new construction are considered. This allows the existing materials to remain in use and avoids new emissions and resource use from new construction. If necessary, existing assets should be renovated and retrofitted to be brought back into use.

The following are examples of actions that can be taken to meet commitment one:

[13] Bellona, 2021. *Efficient transportation to and from construction sites can reduce CO2 emissions by 50%.* Bellona.

- **Identify vacant, unused, and underused structures in the city.** Monitor occupancy rates and survey relevant user groups both in municipal and private buildings to identify levels of usage and the reasons why assets are underused. Conversion post-COVID of underused office space to other purposes can make this especially relevant. The building itself may not be the problem. For example, inadequate transport, street lighting or sanitation infrastructure can be contributing factors to underuse.

- **Adopt tax measures on vacant buildings, for instance on vacant homes and office spaces.** Many cities have seen an increase in wealthy investors buying up homes and offices leaving them empty for extended periods of time. This increases the pressure on low and middle income residents as the supply of homes in the city decreases. Applying a tax to these vacant properties provides an incentive to reintroduce them into the market, increasing the availability of spaces and slowing the construction of additional housing and offices.

- **Take steps to bring underused and vacant municipal assets into better use.** Short-term leases of municipal assets for example can help to revitalise neighbourhoods or disused lands. The temporary provision of space can be a lifeline for communities in times of crisis; some cities have used schools and other temporarily closed facilities to provide food to vulnerable communities during the COVID-19 pandemic, for instance. Leasing or repurposing assets can also raise funds and provide a means of tackling housing shortages.

3.2.2 Commitment two: Lead by example with municipal procurement

Commitment two reads as follows:

Lead by example with municipal procurement by:

- *requiring life cycle assessments (LCAs) and the diversion of construction and demolition waste from disposal for all municipal projects.*
- *Use municipal purchasing power to procure or demand zero emission construction machinery in municipal projects from 2025, where available.*
- *Reward resource efficient and circular design, use of low carbon materials, and low to zero waste construction sites for all new projects and major retrofit.*

Commitment two is a call for cities to use their procurement power, lead by example and require or request best practice action in tenders. Even where some technologies are not widely available, requesting these to be considered in procurement documents is a call to action for industry and can indicate the direction of travel to industry.

To ensure a just and inclusive transition, municipal procurement should be oriented at a just transition and safeguard for the protection of rights.

The following are examples of actions that can be taken to meet commitment two:

- **Establish Global Warming Potential (GWP) ceilings for common construction materials**. Start by collecting relevant local data via Environmental Product Declarations (EPDs) about the emissions impact of commonly used construction materials. This can be done by requiring their submission in ongoing projects. Use this data to set a city-wide ceiling on the GWP that will be accepted for the materials in project bids and material purchases for future municipal projects. Gradually lower this ceiling for the materials over time.

- **Require LCAs and set a maximum waste generation and/or minimum waste diversion percentage for municipal construction sites.** Include requirements in tenders and audit performance on site.

- **Give weight to the inclusion of circular designs, low carbon materials, low waste provisions and zero emission construction machinery when assessing project proposals.** Adapt the scoring of municipal projects to consider environmental priorities. More information on the vehicles that meet this commitment to demand zero emission machinery where available can be found in Section 3.3.

3.2.3 Commitment three: Demand transparency

Commitment three reads as follows:

> *Demand transparency and accountability, starting with requiring LCAs in planning permissions and embedding them into planning policies, processes and building codes within a year of endorsing this Accelerator or in the next revision of planning policies and codes. Require the public disclosure of this data to facilitate greater transparency and foster accountability to develop robust baselines, standards, certifications and policies.*

Embodied carbon is a relatively new topic meaning accurate data at scale can be hard to come by. Embedding requirements to conduct LCAs into planning policies accomplishes two goals. First, it requires project teams to consider the impact of the choices that are being made in the design stage. Secondly, it can provide invaluable insights into the state of the industry allowing more relevant policies to be created

The following are examples of actions that can be taken to meet commitment three:

- **Integrate LCA requirements into planning requirements.** Start by requiring reporting, eventually establishing a ceiling for impact. In some cities LCAs can be seen as expensive or complex as they are a newer tool in the construction industry. In these cases start by requiring LCA reporting in areas of policy that impact larger projects with the resources to procure the assessments. This can include zoning changes that are often requested by larger projects, or introducing the LCA requirements first for projects seeking planning permission above a certain square meter threshold. Once LCAs are more readily available, integrate them into the broader planning requirements.

- **Establish a centralised data repository for LCA results** working towards public access. Collaborate with industry leaders to create a database that is useful to both policy development and industry innovation. Determine which data points will be relevant to share industry wide.

3.2.4 Commitment four: Create a joint roadmap

Commitment four reads as follows:

> *Work with businesses, industry, public institutions, residents, workers, social partners and other organizations to establish a joint roadmap and set interim targets towards the collective 2030 goals adhering to circular economy principles within two years of endorsing this accelerator, and incorporate it into our Climate Action Plan. The roadmap will provide an implementation pathway to the Clean Construction Accelerator actions and to reaching its goals inclusively and equitably.*

Cities will not be able to reach the ambitious goals laid out in the Clean Construction Accelerator on their own. However, cities can set the vision and use their convening power to create a coalition of necessary stakeholders with whom they can develop joint roadmap and implementation strategies. This collaboration will ensure that cities are on track to meet their embodied emission reduction goals in an equitable and just way beyond the reach of their direct powers.

By engaging key stakeholders in the creation of a joint roadmap cities will ensure the aspirational vision of the Clean Construction Accelerator is achievable and inclusive and will facilitate its adoption. A coalition of stakeholders will enable the local context and culture to be recognised and valued, unlocking a strong understanding of the interests of each group and safeguarding an equitable and just transition.

The following are examples of action that can be taken to meet commitment four:

- **Engage the full range of construction stakeholders and all relevant city departments to participate in the roadmap creation**. If a Climate Action Plan has already been published, cities should include the clean

construction roadmap as an addendum. Over the course of the two years after endorsing the Accelerator, cities can either directly integrate clean construction strategies into their Climate Action Plans or add clean construction as an addendum to be included formally in the next update of the city's climate action plan.

- **Engage key stakeholders into a just transition dialogue** to ensure decent work and quality green jobs are created, for instance by investing in local, sustainable business communities and expanding existing solutions; and by educating and reskilling workers.

3.2.5 Commitment five: Approve a net zero operational and embodied flagship project

Commitment five reads as follows:

> *Approve at least one net zero emission (operational and embodied) flagship project by 2025.*

Pilot projects serve as a source of inspiration for cities and industry. They also serve as a test run for new processes and technologies in the city and connections in industry. Many new buildings in cities are now proudly net zero in operation, pushing new developments to consider their embodied impact as well as their operational impact is a key next step to mainstream whole life thinking.

The following are examples of actions that can be taken to meet commitment five:

- **Participate in a design competition and require net zero operational and embodied carbon solutions.** Competitions such as Reinventing Cities see cities offer up disused or underused sites in the city for long term lease or for sale. Design teams compete to win the opportunity to develop the site with the most innovative projects which meet the environmental and social needs of the city. Cities set the design requirements for sites providing a great opportunity to set ambitious targets for embodied carbon and to receive a range of creative solutions.

- **Require net zero operational and embodied solutions for a municipal flagship project.** Municipal procurement is one of the most powerful tools cities can employ to shape the market. If there is a project upcoming in the city, the development of a community center, park, library, school or otherwise these are all great opportunities to develop a totally whole life net zero project by entering these requirements into the tendering documents.

- **Require large flagship projects in the city to be net zero in operational and embodied**. Cities often host some of the world's largest corporations and their headquarters. Increasingly global corporations are keen to be seen as environmentally conscious and design buildings which are both

healthy and operationally efficient. Cities can enter into discussions with these large developments and request or require they consider their embodied carbon impact.

3.2.6 Commitment six: Include resilience in clean construction plans

Commitment six reads as follows:

> *Assess the impact our choice of materials and construction design will have on our cities' overall resilience to climate impacts (i.e., increasing urban heat island, impermeable surface increasing the risk of flooding, etc.).*

Materials do not only have major impacts in terms of emission mitigation, they also play a role in the way a city can adapt to climate impacts. Cities will have differing adaptation needs, and it is important to consider these when developing legislation which will impact material choice. Two relevant impacts when discussing the choice of materials in the built environment are the urban heat island effect, and flooding.

The Urban Heat Island (UHI) effect, caused when heat is absorbed and then slowly released by hard surfaces, is already an issue for many cities and is predicted to push urban temperatures even higher. For example, analysis suggests that energy demand for cooling could triple between 2010 and 2050. One way to combat this is by choosing 'cool' materials or nature-based solutions on roadways, roofs or large parking areas. Cool materials can increase surface reflectivity (though it is important to avoid glare problems) therefore reducing the amount of heat absorbed by the material. Nature based solutions such as green roofs provide a localised cooling effect through evapotranspiration.

Climate change is leading to an increased frequency of intense rainfall. Most modern building materials are impermeable surfaces, which is exacerbating flood risk by reducing the natural drainage of the land. Here again, nature-based solutions such as sustainable urban drainage systems which include rain gardens and permeable materials (for pavements, roads) can reduce the risk of flooding. See the Urban Nature Accelerator for more information about nature based adaptation solutions.

Steps that can be taken to meet commitment six include:

- **Map current and expected climate risks and environmental and social vulnerability.** Complete an official assessment of the current and expected climate risks and their social impacts in the city. This assessment will inform decisions about adaptation actions to be implemented in the relevant areas and work to address social needs and a just transition that serves the most vulnerable populations, creates quality jobs and safeguards people's livelihoods.

- **Ensure adaptation needs are considered in building codes where relevant.** Following the climate risk and vulnerability assessment ensure the relevant policies for the city's adaptation needs are built into the built environment codes (e.g. using cool roofs to avoid buildings overheating, requiring permeable pavement in areas at high risk of flooding)

- **Integrate adaptation needs into all projects and legislation related to clean construction action**. Assess all new clean construction actions, particularly those related to material choices, for their impact on the adaptation needs of the city. For example, ensure the necessary material properties (e.g permeability) are also able to be met when setting global warming potential (GWP) limits for materials.

3.2.7 Commitment Seven: Advocate for regional, national, and supranational action

Commitment seven reads as follows:

> *Work with and advocate for regional, national and supranational government to take action on sources outside the boundaries of our control.*

National governments see infrastructure and construction as one of the main engines of the economic recovery, supported by increased public funding and stimulus packages. Decisions on projects taken in the next five years will lay the direction of travel for decades to come due to the inter-generational timescales at which buildings and infrastructure are financed, designed, developed. Cities do not have direct control over all construction that happens in their cities. Therefore to meet the construction goals it is necessary to engage regional, national, and supranational governments that impact construction in the city.

The following actions can be taken to meet this commitment:

- **Engage regional partners to discuss with relevant governments.** Engaging regional, national, or supranational governments outside of the city is often easier when speaking from a collective. Engage other cities with the same goals to increase the political weight of the asks.

- **Utilise international platforms offered by third party organisations and events.** Certain international organizations and events can offer the right public platform to share city action and advocate for broader government engagement.

3.2.8 Commitment eight: Report to C40 every year

Commitment eight reads as follows:

Publicly report every year on the progress our cities are making towards these goals.

C40 asks signatory cities to report on their progress annually. C40 has developed a reporting template and will work directly with cities to report progress on the Accelerator. The process is qualitative and includes:

- A qualitative assessment of the overall progress towards meeting the Accelerator commitments;
- A description of ambitious policies or programs that will be implemented in the near term.

Wherever possible, C40 will utilise existing information and data and minimise information requested from cities. Most quantitative data will be obtained from existing reporting platforms such as CDP wherever possible.

The objectives of the Accelerator reporting are:

- Provide credibility and accountability around the Accelerator and the city commitments
- Provide information and data to support C40 and cities to set global agendas by demonstrating and communicating city achievements and leadership
- Gather information to support cities in achieving the commitments
- Identify areas of support and fundraise for developing support programmes for cities

The action that can be taken to meet this commitment:

- **Complete the reporting process led by C40 on an annual basis for all Accelerators.**

4. How to meet the goals of the Clean Construction Accelerator

4.1 Measure the embodied emissions in cities

Goals one and two read as follows:

- *Reduce embodied emissions by at least 50% for all new buildings and major retrofits by 2030*
- *Reduce embodied emissions by at least 50% of all infrastructure projects by 2030*

Cities cannot make significant progress towards a sustainable construction industry which supports a green and just transition without detailed measurements on the embodied emissions emitted in their city. Many key steps such as prioritising the use of existing buildings, reusing construction materials, and increasing material efficiency do not require embodied carbon calculations to be put in place. However, collecting and understanding embodied carbon

emission data will be key to both showcasing progress and developing more sophisticated reduction initiatives in the near future.

4.1.1 Establishing a baseline

To establish embodied emission targets and report on achievements, cities need to determine the appropriate baselines for projects (new, retrofits, and infrastructure) to measure against. At this moment, there is no generalised guidance on how to establish a baseline and currently most cities do not have this data.

Establishing a baseline for buildings can be done in different ways, depending on the city resources, yet would include the following:

- Selecting a number of types of buildings and infrastructure representative of urban fabric
- Collecting the embodied emissions results per m^2 of each of the selected through LCAs – ideally in the design phase and using the same material database and scope
- Determining the average kgCO2/m2 of each building type
- Use the averages as your baseline to set reduction targets and embodied emissions limits

Cities with more resources can choose to set different targets for different building typologies to allow for more targeted policies.

Some existing baselines can be used as a guide. For example, the table below shows the London Environmental Transition Initiative's (LETI) 'Embodied Carbon Primer" suggested targets for embodied emissions from 2020 to 2030 for domestic and non-domestic new buildings[14]. These are especially relevant to the UK context but can serve as a sense check for other regions. The targets are presented with and without the inclusion of carbon sequestration. The targets also assume high levels of retrofitting, material reuse and recycling.

Table 1 – LETI's targets for embodied emissions reductions

	Current Benchmark	2020		2030	
		With Sequestration	w/o Sequestration	With Sequestration	w/o Sequestration
Domestic	800 $kgCO_2e/m^2$	500 $kgCO_2e/m^2$	400 $kgCO_2e/m^2$	300 $kgCO_2e/m^2$	200 $kgCO_2e/m^2$

[14] LETI uses building life cycle stages A1 – A5 for the substructure, superstructure, MEP, Façade and internal finishes as their scope but this is not the only relevant scope for calculating embodied emissions.

Non-Domestic	1000 $kgCO_2e/m^2$	600 $kgCO_2e/m^2$	500 $kgCO_2e/m^2$	350 $kgCO_2e/m^2$	250 $kgCO_2e/m^2$

For infrastructure, baselines can be determined by liaising with infrastructure providers and assessing the design, materials and construction processes of previous projects. Some project types such as road and utility works are often standardised within a city, making comparisons with older "business as usual" projects easier. Other more complex, often larger projects, such as transport stations or processing plants will be less standardised and require benchmarks on a case-by-case basis[15].

In some cases, cities may wish to establish material baselines, maximum embodied emission values for a particular construction material usually expressed as $kgCO_2e/kg$ of material. These maximum values can be useful in addition to or when it is not (yet) possible to complete project LCAs, however, these should not be the only approach to reducing embodied emissions. In the construction hierarchy, as explained under question 1 above, reducing the need for new construction and reducing the quantity of materials used in a project should be considered first before looking to lower the embodied carbon of the materials used.

4.1.2 Gather data through Life Cycle Assessments

To capture the embodied emission reduction taking place in the city, the city should aim to collect LCA data from as many projects as possible. This can be done by integrating embodied emission reporting into planning applications, following a similar path to energy efficiency data collection. When asking for LCAs cities should be mindful of the scope they are requesting. Ideally, all projects should cover the whole life cycle for all their assets. However, most product-specific EPDs only account for stage A as this is the stage the manufacturer has the most control over. As whole life cycle data is not yet widely available for most products, there will be a transitional period where either generic data (non-product specific material data) will be used to calculate the whole life cycle or LCAs are calculated only for stage A.

A 50% reduction in embodied emissions for a new building in 2030 means that the embodied emissions recorded for the new building or major retrofit is 50% lower per m^2 than the agreed upon building baseline.

A 50% reduction in embodied emissions for a new piece of infrastructure in 2030 means that the embodied emissions recorded for the project is 50% lower compared to the agreed upon baseline for the infrastructure typology.

[15] Construction Climate Challenge (2019) *Carbon Infrastructure Transformation Tool Project. Construction Climate Challenge*

Figure 4 illustrates the minimum, advanced, and comprehensive scopes for LCAs. The minimum reporting, shown in red in Figure 4, should be covered by all cities. When carbon sequestering materials are used, the total embodied emissions with and without the sequestered amount should be provided.

Figure 4 – Recommended scope of LCAs – Adapted from RICS Whole Life Carbon Assessment of the Built Environment (Table 13), For detailed material categories please reference RICS Method of Measurement (pg 27)

	Product Stage		Construction Stage			Use Stage							End of Life Stage				
	A					B							C				D
Category	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
1. Demolition prior to construction																	
2. Facilitating works																	
3. Substructure																	
4. Superstructure																	
5. Finishes																	
6. Fitting, furnishings, & equipment																	
7. Building Services / MEP																	
8. Prefabricated Buildings and Building Units																	
9. Work to Existing Buildings																	
10. External Works																	
Total																	

Key: Red: Minimum, Orange: Advanced, Yellow: Comprehensive scope, Grey: Not Applicable

4.1.3 Establish an LCA reporting scope

Figure 4 illustrates the range of scopes that cities can ask industry to assess and report on. While some projects may go above and beyond the asks, the chosen scope is what the city will use as their baseline for calculations so all projects should strive to meet at least that determined level of detail. **Not all element categories will be relevant to all retrofit, new build or infrastructure projects.** Each project should be assessed in its scope to determine which element categories will be most relevant to track.

The element categories are described in Appendix 2.

4.1.4 Use of tool or software system to measure embodied emissions

A range of tools is available to measure embodied emissions of buildings and infrastructure. All tools have different regional strengths. One tool in one city might not be the right fit for another city. Tools will continue to evolve and improve over the years as the target percentage and deadline approaches.
The tool does not matter as much as the method used by the tool, which should follow the appropriate international standards such as EN15804 for construction products, EN 15978 for buildings, ISO 21930, as well as ISO 14040 and ISO 14044. Cities should aim to keep the tools used as consistently as possible to allow for the most comparable embodied emission results.
Cities should request planning applicants to conduct LCA complying with the above standards and account for their selected scope. EPDs should be used in place of generic data where possible.

4.2 Action on the Zero Emission Machinery Goal

Goal three reads as follows:

> *Require zero emission construction sites city-wide by 2030, where technology is available*.

Where available, zero emission construction machinery should be preferred in municipal projects by 2025 and city wide by 2030. For many years NRMM have lagged behind other forms of transportation in the green transition. Recently there has been a surge in activity to develop different types of electric construction vehicles. To push the use of these vehicles it is important that cities request they be used where possible.

Vehicles travelling to and from site are not included in the scope of zero emission construction vehicles in this target. However, transport vehicles are strongly encouraged to be included in the transition to zero emission technology, as outlined in C40 Green and Healthy streets Accelerator. This will also contribute to the aims of the C40 Clean Air Accelerator.

Actions that can be taken to support this goal include:

- **Incentivize the use of low-to-zero emission NRMM via Low Emission Zones and other construction site requirements.** Setting emission requirements that become more stringent over time for a certain area of the city, similar to the low emission zones established for transport vehicles, can help phase in zero emission NRMM. The area- approach also allows for the targeted introduction of these sites allowing for the city to focus on areas where the need for air quality improvement is the largest, or where proportionally more construction will be happening over the coming years.

- **Support construction machinery retrofit programmes.** A rapid transition from one type of vehicle to another does not mean relatively new fossil fuel

vehicles must be replaced far before the end of their useful life. Retrofitting existing vehicles is a local solution which allows for the existing vehicles to be used.

- **Use municipal procurement power to request best practice action in tenders.** Even where technologies are not widely available, tenders can be structured so that offering cutting edge technologies in this area is rewarded in tender competitions.

4.2.1 What type of machinery counts as zero emission construction machinery?

In line with C40 Green and Healthy streets Accelerator, zero emission construction machinery must be zero emission at tailpipe. While the Accelerator is intentionally technology neutral, currently the only technologies on the market that are zero emissions at tailpipe are hydrogen fuel cell or battery electric vehicles.

C40 Green and Healthy streets Accelerator explains why biofuels do not meet the criteria for zero emission at tailpipe:

In terms of air pollution, the combustion of biofuels in vehicles generates emissions of various air pollutants. This includes particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NOx), hydrocarbons and VOCs. Hydrocarbons, VOCs and NOx are precursors for the formation of smog and ground level ozone[16]. Higher ethanol blends (E85) lead to comparable, or slightly lower, levels of PM, NOx and CO emissions than petrol, but still have five to 10 times higher acetaldehyde emissions[17], a probable human carcinogen[18]. Biodiesel has generally lower exhaust emissions of PM, CO, hydrocarbons and VOCs but higher NOx emissions than fossil fuel diesel. Despite having lower PM emissions, biodiesel exhaust emissions could potentially be more harmful to human health because of a higher proportion of ultra-fine particles compared to diesel exhaust. The human health impacts from biofuels is an area of ongoing study and debate[19].

Where possible, zero emission NRMM should be supplied by renewable energy on site, through the grid or through the equivalent purchase of renewable energy. There are several ways to source renewable energy, such as direct consumption from on-site or offsite installations, a green energy product accessed via the grid, Power Purchase Agreements (PPAs) or unbundled energy attribute certificates (also known as renewable energy certificates). The contractor that operates the NRMM should source renewable energy in a way that is compliant with the

[16] Sustainability of Liquid Biofuels, Royal Academy of Engineering, July 2017
[17] Sustainability of Liquid Biofuels, Royal Academy of Engineering, July 2017
[18] Based on EPA cancer assessments:
https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=290

[19] Sustainability of Liquid Biofuels, Royal Academy of Engineering, July 2017

Greenhouse Gas Protocol Corporate Accounting and Reporting Standard for scope 1 and scope 2 emissions[20]. All cities who undertake the shift to zero emission NRMM would do it according to their transition to a renewable energy supply.

Because the consumption of renewable energy is usually considered not to emit any GHG emissions from an accounting perspective, renewable energy should be a preferred option for cities signing this Accelerator – not only to operate NRMM but also through the whole life cycle of the building (e.g. in the extraction and manufacturing of materials). This approach does not take into account GHG emissions that might occur during the manufacturing, installation and end of life treatment of a renewable energy project (e.g. GHG emissions relating to steel use in a wind turbine). However, research shows that life cycle emissions of renewable technologies are much lower than for fossil fuel power plants (even when retrofitted with Carbon Capture and Storage technologies)[21][22].

[20] World Resource Institute, WBCSD (2020) *Scope 2 Guidance*. Green House Gas Protocol
[21] Pehl, M., Arvesen, A., Humpenöder, F. et al. Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling. *Nat Energy* 2, 939–945 (2017).
[22] *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 Chan*

Appendix 1 - Definition of Terms

Carbon sequestering materials

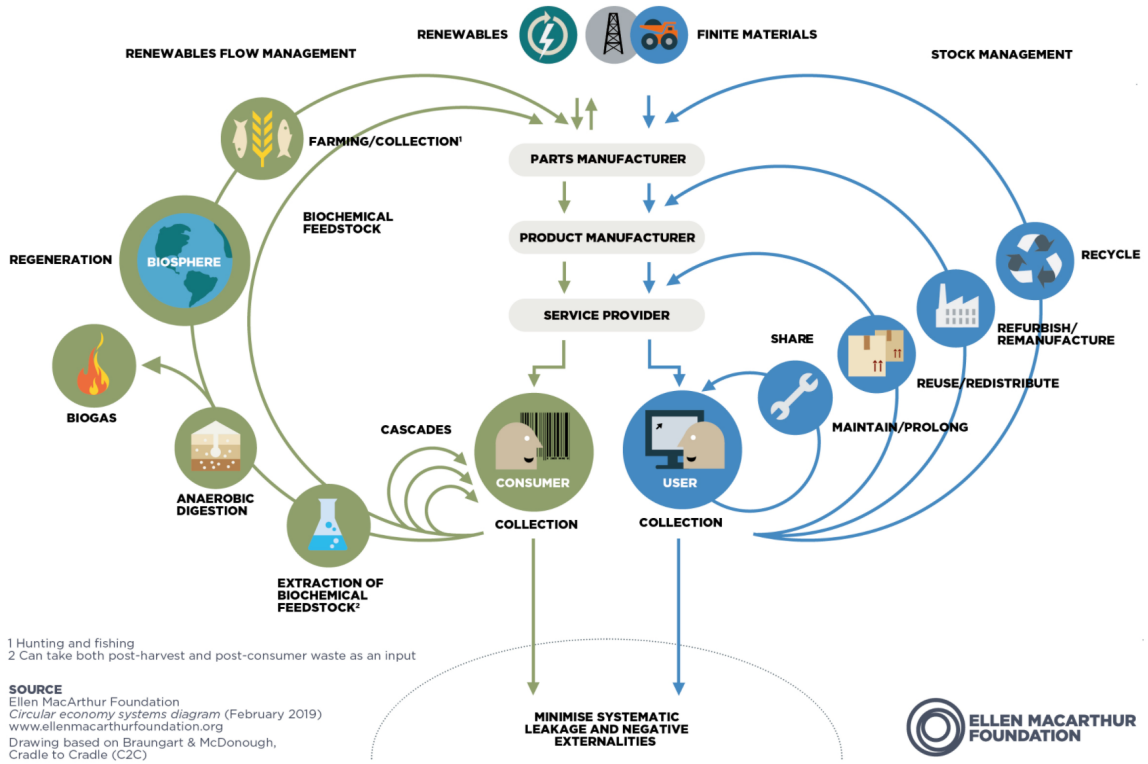
Building materials that sequester substantial amounts of carbon are usually bio-based materials, e.g. materials made from natural sources: trees, grasses, mycelium etc. Carbon sequestering materials include timber, cork, bamboo, strawbale, hempcrete and cellulose. In addition to these, some new innovative materials are being developed which sequester carbon back into limestone to form aggregate. If a product is carbon sequestering, it will be indicated on their EPD.

Circular economy

The Ellen MacArthur Foundation (EMF), a leading think tank on the subject, defines the circular economy as being "based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.' It involves "a new way to design, make, and use things within planetary boundaries."

The Waste and Resources Action Programme (WRAP) defines a circular economy as an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life. By definition the circular economy runs on renewable energy and regenerates natural systems. Figure A1.1 below is the EMF "butterfly" diagram, showing how biological and technical materials are circulated.

Figure A1.1 – Ellen MacArthur Foundation's Butterfly Diagram



Clean construction

Clean Construction is the overarching term used to describe C40's initiative addressing the embodied emissions of the urban built environment and the adoption of zero emission construction sites.

C40's definition states that Clean construction values our existing stock, prioritizes retrofits, and ensures new buildings and infrastructure embed circular economy principles in their design, material and construction choices. Clean construction help deliver a green and just recovery from the COVID-19 crisis and improve social equity. Clean Construction can create good, green jobs by investing in local sustainable business communities and expanding already existing solutions; and by educating and reskilling workers.

Construction and demolition waste

Refers to any waste generated in the activities of companies belonging to the construction sector and included in category 17 of the European List of Wastes. The category 17 provides the codes for several individual materials that can be collected separately from a construction or demolition site. See the EU Construction and Demolition Waste Management Protocol.

Consumption based emissions

Consumption-based GHG emissions are emissions associated with the goods and services consumed in the city.

Emissions are usually accounted for according to the Greenhouse Gas Protocol. This accounts for scope 1 and 2 emissions within the city's geographical boundaries.

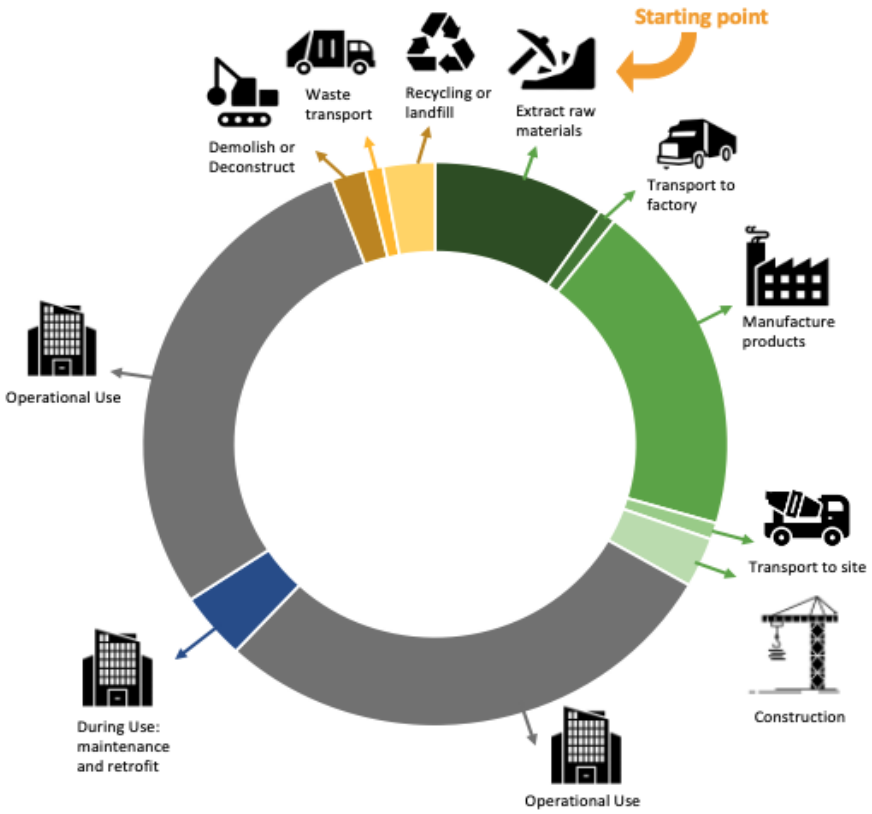
- Scope 1 emissions are emissions that are directly emitted within the city's geographical boundaries, this would include the emissions from vehicles or crop burning.
- Scope 2 emissions are the emissions emitted due to the energy consumed within the city's boundary.
- Scope 3 emissions are the result of the production of all other resources – for example clothes, food, building materials – that are consumed within the city boundaries.

Urban consumption is a key driver of global GHG emissions. Cities can have a significant impact on greenhouse gas emissions beyond their geographic borders by influencing global supply chains. C40 member cities alone represent 10% of global GHG emissions when accounting for consumption-based emissions. Cities are already leading on addressing climate breakdown by setting science-based targets in their resilient and inclusive climate action plan aligned with the 1.5˚C ambition of the Paris Agreement and taking meaningful action to reduce local emissions from buildings, energy, transport and waste. However, it is crucial that emissions from consumption are measured when considering how to reduce a city's full impact on climate change. Urban action on consumption can significantly reduce emissions from the key consumption categories: buildings and infrastructure; food, clothing and textiles; private transport; aviation; and electronics and household appliances. Cutting consumption-based emissions will deliver wider benefits for a city and its residents. Individuals, businesses and city governments all stand to gain if changes are delivered in the right way. For more see The future of urban consumption in a 1.5°C world.

Embodied emissions

In the built environment embodied emissions refer to the emissions related to the extraction of raw materials, their manufacturing, assembly during construction, any maintenance or replacements, the disassembly and demolition, and any associated transport, waste and end of life impacts. These have been represented as the coloured blocks in Figure A1.2 below.

Figure A1.2 Illustration of the whole life carbon impacts of a construction project



Embodied emissions do not include the emissions generated by the operation of the building, represented in grey blocks. Embodied emissions are measured in kgCO2e, usually presented as kgCO2e/m2 for buildings.
The term embodied carbon is often used and is interchangeable when referring to kgCO2e.

Environmental Product Declaration (EPD)

An Environmental Product Declaration quantifies the environmental impact of a product over its life cycle. Most often EPDs cover stages A1 – A3, as defined by EN15978, also known as cradle to gate. It follows a set of procedures that compile the inputs and outputs of materials and energy, and the associated environmental impacts of the product.

Inclusive, resilient and thriving climate action

“A thriving city is a socially just and ecologically safe city” C40 Thriving Cities Initiative

Delivering on the goals of the Paris Agreement presents a unique opportunity to follow a low-carbon and climate-resilient development path that can create a

more inclusive urban society, with new protections for the groups that have been historically marginalised by the fossil fuel economy.

- Inclusivity in climate action planning is where efforts are made to ensure:
- engagement of a wide range of communities and stakeholders (inclusivity of the process)
- fairness and accessibility in design and delivery (inclusivity of the policy)
- wider benefits of action as equitably distributed as possible (inclusivity of the impact)

Applied to the construction industry, inclusivity requires analysis of construction projects to combat and avoid systemic inequalities and racial discriminations. One of the ways of achieving this is through an equity analysis for a project which should consider:

- for who is it built and who will be the immediate end user
- who benefits from it and who is affected by it
- where is it built
- by who is it built
- what is the history of the urban planning policies of the area and its role in cementing lasting racial inequalities

The green transition should also be just. The workforce of the high-impact construction industries such as cement and steel must be encouraged and supported in reskilling, upskilling and training to provide them with solid green construction jobs opportunities. The same applies to informal construction workers, recognising when they use sustainable methods and sustaining those whilst providing them with adequate social protection.

Infrastructure project

Infrastructure projects are understood as the construction of assets that perform essential city functions such as transport, water, waste, energy and flood defences. This includes but is not limited to:

- Transport infrastructure
- train and tram lines, stations and depots;
- cycle lanes, roads, pavements, car parks;
- bridges, tunnels;
- airports
- Water supply, sanitation, drainage, treatment plants
- Gas and energy supply / grid
- Telecommunications
- Public lighting
- Flood protection systems, including sea walls

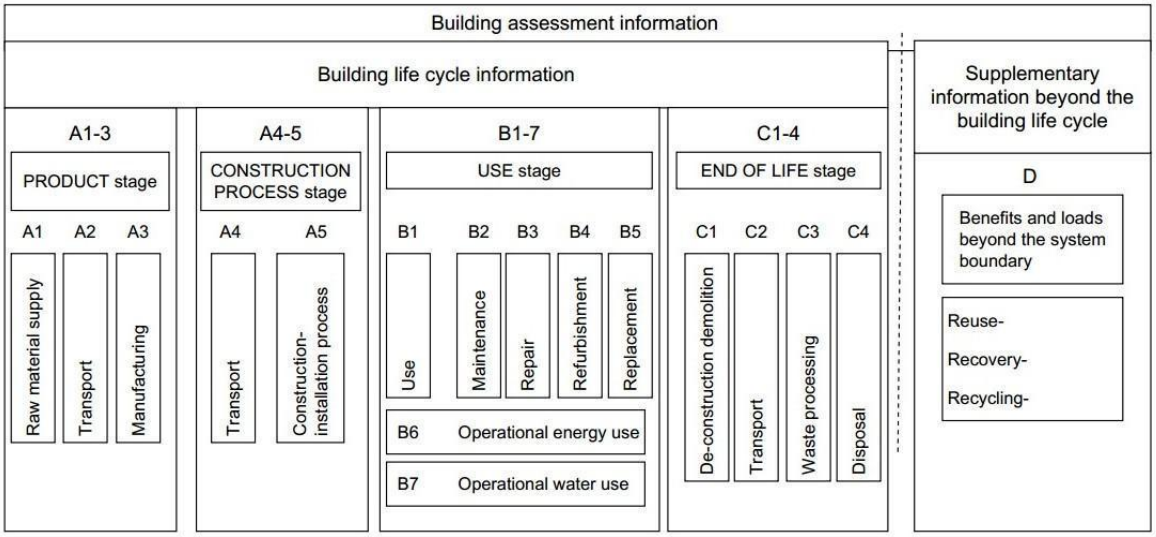
Life Cycle Assessment (LCA)

A Life Cycle Assessment quantifies the environmental impact of a product, material, building or infrastructure over its life cycle. It follows a set of procedures

that compile the inputs and outputs of materials and energy, and the associated environmental impacts as defined by ISO 14040: 2006.

The European standard EN15978 and the international standard ISO 21930 define the different life cycle stages of a building, as illustrated in Figure A1.3. The stages also apply to infrastructure. A whole-life assessment includes all the stages, whilst the assessment of the embodied emissions includes all stages except B6 and B7, as those are for operational energy and water use. Data used to complete LCAs are either taken from product-specific EPDs or generic data sets which are averages for a material in a specific region. Product-specific EPDs come from manufacturers who only have control over stage A. For this reason, most LCAs only cover stage A.

Figure A1.3: The life cycle stages of a building as per EN15978 and ISO 21930



Low carbon materials

Types of materials with low embodied emissions include:

- Materials from renewable bio-based sources, such as timber, bamboo, cork, straw, hemp, earth and natural fibre;
- Innovative materials manufactured with low process and energy emissions
- Reused materials
- Materials with high recycled content.

The location, type and use of the building or infrastructure project largely determine which low carbon materials to choose. The best solution is the material with the lowest emissions that meets the project's structural needs (durability, flexibility, seismic-proof, etc) and is ethically and locally sourced.

Major retrofit

There are a variety of interpretations of the terms retrofits, renovations, and refurbishments. Some definitions for example rely on the total cost of the renovation as a portion of the market value of the structure, or the number of occupants that must relocate while works are taking place. In the context of this Accelerator, the main goal is to capture any significant material flows. For this reason, any retrofit, renovation, or refurbishment that requires planning approval is considered a major retrofit.

Materials and resource efficiency

The Waste and Resource Action Programme (WRAP) defines a resource-efficient built environment as "a built environment that makes best use of materials, water and energy over the lifecycle of built assets to minimise embodied and operational impacts."

According to UNEP , "Material Efficiency means using less materials to provide the same level of well-being. It is measured by the amount of service obtained per unit of material use. Materials include biomass, cement, fossil fuels, metals, non-metallic minerals, plastics, wood, among others."

Resource Efficiency encompasses material efficiency, but is a broader term which includes materials, water, energy and land. A resource efficient economy will include optimized systems of production and consumption from a natural resource perspective. The term encompasses strategies of dematerialization (savings, reduction of material and energy use) and re-materialization (reuse, remanufacturing and recycling) in a systems-wide approach to a circular economy.

Nature based solutions

Nature based Solutions (NbS) are defined by the international union for the conservation of nature IUCN as "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" . See the Urban Nature Accelerator for more information.

Net zero carbon

To be net zero carbon over its whole life cycle, both the operational and embodied emissions of a building or an infrastructure piece need to be considered net zero.

In line with C40's Net Zero Carbon Buildings Accelerator, a building or infrastructure asset is considered net zero for operational emissions when the amount of carbon dioxide emissions released on an annual basis is zero or negative. Using the WorldGBC definition, a net zero carbon building is highly

energy efficient and fully powered from on-site and/or off-site renewable energy sources and by offsets .

C40 defines net zero embodied emissions building or infrastructure asset as:

- highly resource efficient,
- designed to be adaptable and disassembled at the end of their life, in accordance with circular economy principles
- and with embodied emissions minimized to the greatest extent possible. The WorldGBC definition states that all remaining embodied emissions reduced with offset should only be done as a last resort to achieve net zero across the life cycle .

If a construction project involves the demolition of a pre-existing structure, the embodied emissions associated with any demolished materials that are not recycled or reused must be added to the project's embodied emission total. In this way, the end-of-life emissions of pre-existing structures are taken into consideration.

Operational emissions

Operational emissions are the emissions associated with the energy used to operate the building or in the operation of infrastructure. It includes how we power, heat and cool our built assets. C40's Net Zero Carbon Buildings Accelerator addresses the operational phase of buildings, aiming to have all new buildings operate at net zero operational carbon by 2030, and all buildings by 2050. The Clean Construction Accelerator complements it by specifically addressing the embodied emissions of buildings and infrastructure.

Renewable energy

Renewable energy is generated from sources of energy that can naturally replenish themselves such as wind, solar, water, geothermal energy and biomass. Hydrogen (and its various uses under different forms) is considered renewable if it produced from renewable energy sources (such as wind or solar powered water electrolysis).

Roadmap

A roadmap is the project timeline of the Commitment and will have key milestones as the cornerstone of the document. The milestones of the roadmap are intended to align with the actions planned by cities to deliver the Commitment.

Upfront emissions

The WorldGBC defines upfront emissions as the emissions caused in the materials production and construction phases (A1-5) (see Figure A1.3). These emissions have

already been released into the atmosphere before the building is occupied or the infrastructure begins operation.
Upfront emissions only deal with the production and construction phases and are therefore only a portion of the total embodied emissions of a building or infrastructure asset.

Waste diversion

Waste diversion is the process of avoiding waste being sent to disposal in landfills and incinerators, with materials being put to more beneficial uses such as: composting, recycling, anaerobic digestion, filling, etc. Post-treatment residues, such as, bottom ash or landfilled compost, that need to be disposed of at the end of the treatment should not be considered as diverted. Waste that is shipped outside of the jurisdiction and for which the municipality has no certainty of its destination or treatment should not be considered as diverted. See Advancing Towards Zero Waste Accelerator for more information.

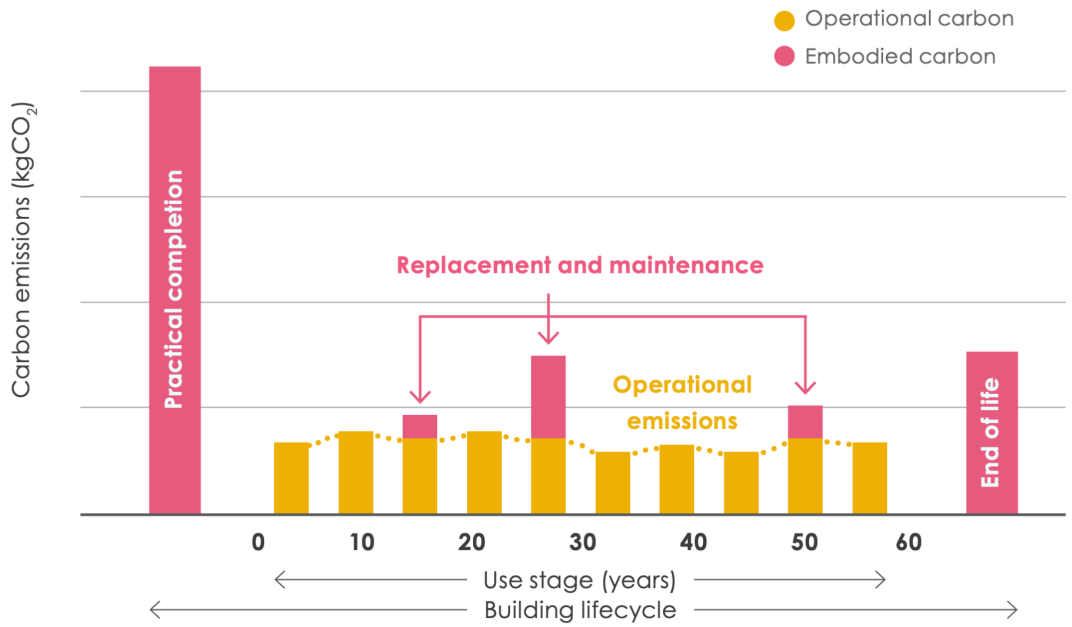
Whole life cycle emissions

To properly evaluate the environmental impact of a building or an infrastructure project, its impact must be viewed holistically, by considering the whole life cycle emissions.

Whole life cycle emissions refer to all the emissions emitted throughout the life cycle of a building or piece of infrastructure. This starts with the extraction of the raw materials, their manufacturing into construction products, the construction process, maintenance, repairs, the operation of the building, deconstruction, demolition and the impacts of construction and demolition waste, as well as all the transport needed along the way. The emissions categories are schematically represented in Figure A1.2.

The whole life cycle emission footprint of a building can be separated into two groups: the operational emissions and the embodied emissions. Operational emissions currently have the biggest footprint, yet as we make our buildings more energy-efficient, the share of embodied emissions will grow in proportion. The embodied emission categories are practically defined in the European standard EN 15978 and the international standard ISO 21930.

Figure A1.4: Operational and embodied emissions: a building's whole-life emissions



Source: London Energy Transition Initiative (LETI) Embodied Carbon Primer

Zero emission construction machinery

Zero emission construction machinery are non-road mobile machines (NRMM) with zero tailpipe emissions.

NRMM refers to any mobile machine that is not intended for carrying passengers or goods on the road. We expect policies to mainly target NRMM of net power between 37kW and 560 kW though it is good practice to apply the same targets to all machine types.

Examples of NRMM include but are not limited to:

- Chainsaws
- Mobile cranes
- Excavators
- Pumps
- Bulldozers
- Generators
- Fork lifts

Currently, the only technologies on the market that are zero GHG emission at tailpipe are battery-electric vehicles (BEVs) and hydrogen fuel cell (HFC) vehicles. Although lifecycle emissions from both BEVs and HFC depend on how the electricity and hydrogen are generated, they offer the potential for a dramatic reduction in lifecycle emissions as electricity generation is decarbonised.

Zero emission construction sites

Zero emission construction sites are construction sites where only zero emission NRMM, heating equipment, and generators are used.

It is strongly recommended to include transport vehicles to and from sites in this definition. This would be facilitated by, as well as support, the C40 Green and Healthy streets Accelerator target to ensure a major area of a signatory city is zero emission by 2030.

The goals of this commitment contributes to those outlined in the C40 Clean Air Accelerator, where cities have committed to setting ambitious reduction targets for air pollutants and implementing new substantive policies and programmes to address the top causes of air pollution in their cities.

Appendix 2 – The categories in the recommended scope of LCAs

The element categories are taken from the Royal Institution of Chartered Surveyors (RICS), a further detailed explanation of the accounting can be found here in *RICS Method of Measurement,)*.

Demolition prior to construction: New projects are usually considered to commence on a clear, flat, developed site for purposes of consistency. This means that if there was an existing structure on site, it is not considered in the total. We encourage cities to record and include the end of life impacts of the demolished material in the total for the new build asset. In this way then end of life impacts (stage C and D) for these materials are captured and there is a strong incentive to reuse and recycle these materials.

Facilitating works: Facilitating works encompass works that need to be undertaken on a certain site before it can be built upon. This includes specialist ground works like soil stabilisation, the removal of hazardous material, the addition of temporary support to adjacent structures etc.

Substructure: The substructure is the part of the structure that is underground. This includes foundations, lower floors like basements, parking lots, and basement retaining walls.

Superstructure: This is the part of the building that is above ground, for a building this would be the frame, upper floors, roof, stairs and ramps, external walls, windows, external doors, internal walls and internal doors.

Finishes: This includes all finishes for walls, floors and ceilings such as paints, varnishes, plaster etc.

Fittings, furnishings, equipment: Sometimes also called furniture, fixtures, and equipment, this category covers all furniture, fixtures and equipment that are not an integrated part of the superstructure. Examples would be washing machines, fume cupboards, drink stations etc. These must be considered during the construction phase to allow for the design of the appropriate power, air supply, water supply, and drainage.

Building services/ MEP: MEP stands for mechanical, electrical, and plumbing. This includes all the ducts, wiring, plumbing and associated controls of water installations, heat sources, space conditioning, ventilation, electrics, waste disposal etc.

Prefabricated buildings and building units: This category include entire buildings and individual modular room units that are almost entirely constructed

offsite. This category accounts for the total impact of these units to avoid the need to deconstruct their impact into the constituent elemental parts. For example, when constructing a hotel, the foundations and the frame will be accounted for in their respective categories, however the rooms might arrive as pre-fabricated pods. In this case most of the total embodied emissions for internal partitions will be in the prefabricated units total and not in the individual element category.

Work to existing buildings: During the construction of a project there may be works that need to be completed on existing structures. This can include façade retention, restoration, and cleaning among others.

External works: This includes all works on roads, paths, fences, external drainage, external services, vegetation management in and around the site. Similar to facilitation works, this category includes works to prepare the building site, excluding all removal of hazardous material which falls under facilitation works.