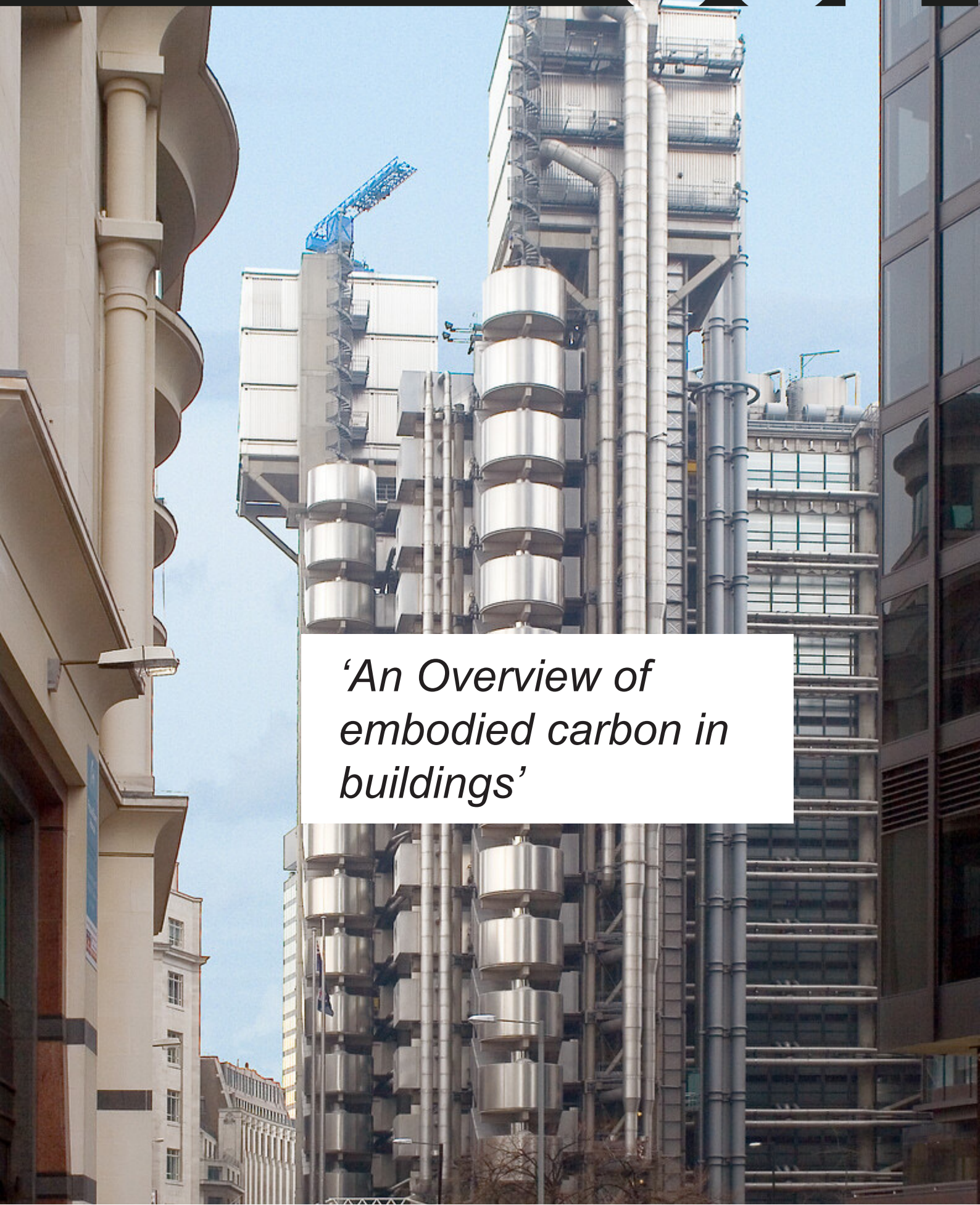
UCL INSTITUTE FOR SUSTAINABLE RESOURCES



'An Overview of embodied carbon in buildings'

Key Message

- To reach net zero, there must be a focus on the whole life carbon of buildings

- A change in our relation to building materials is required

- Designers and contractors need to have a broader understanding of the greener materials available

- We must also start developing and implementing long-term solutions to reduce embodied carbon

- If we at the very least understand how bad many of the construction materials are to the environment, conversations will lead to a discussion of change

Background and Context

Carbon Emissions from the built environment make up a large portion of global emissions. This is not only a result of the buildings' operational emissions – material production, transportation, and on-site construction make up a large amount of embodied carbon emissions.

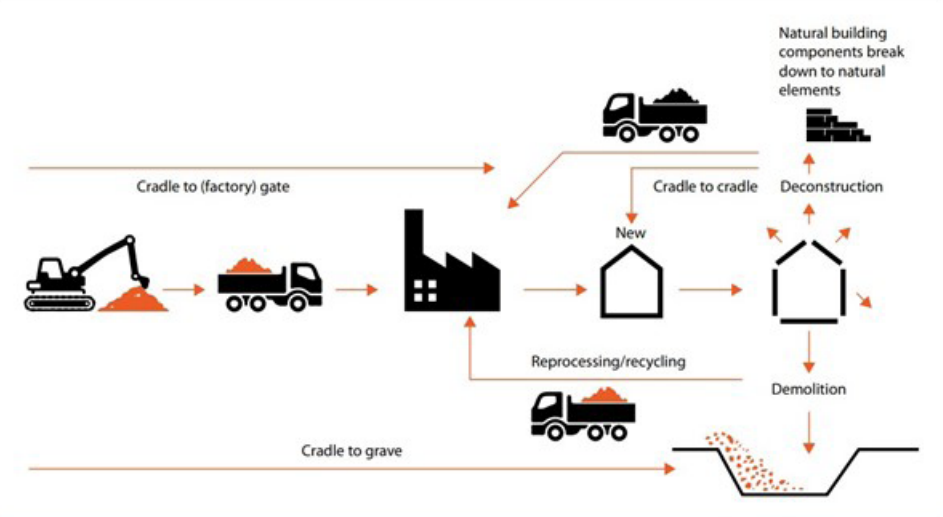


Diagram showing where carbon dioxide is produced in the supply chain "embodied Carbon Factsheet" UCL

"The buildings and construction sector accounted for 36% of final energy use and 39% of energy and process-related carbon dioxide (CO2) emissions in 2018, 11% of which resulted from manufacturing building materials and products such as steel, cement and glass" [1].

To reach net zero, there must be a focus on the whole life carbon of buildings. This can only be made possible through understanding how the built environment comes to fabrication and implementing a conscious change in our future buildings.

0.2 Key terms:

***'Embodied/up-front Carbon'** This includes the amount of carbon emission released during the production of building materials (including material extraction, transport to manufacturer, manufacturing) as well as transporting those materials to site and the practices used in construction.*

***'Operational Carbon'** Energy needed to keep the building running. This includes heating, cooling, ventilation, powered.*

***'Whole life Carbon'** A collective of embodied and operational carbon throughout a building's lifetime in addition to the emissions released from demolition and disposal.*

What is Required?

We need to turn our attention to how much energy building construction and material production emit.

In March of 2022, 'PartZ' proposed amendments to implement a mandatory assessment of whole life carbon of buildings as well as a cap on embodied carbon. The amendments will result a shift in how designers and contractors plan future construction, with huge decrease in carbon emissions. The campaign to introduce regulations is growing traction, with support from the Environmental Audit Committee (EAC), part-z proposes legal carbon limits to be introduced from 2027.

In recent years there has been a good movement in reducing operational carbon, however, to make a greater impact on total emissions we need to start tackling embodied carbon. PartZ plans to mandate "whole life carbon assessments and reporting of all projects of more than 1000m2...from 2023 for non-domestic buildings, and 2025 for domestic"[2].

A few firms have already started calculating the whole carbon of buildings either voluntarily or as per the client's request. In addition to this, Arup, a multinational design company, have pledged to do assessments of all their projects worldwide.[3] The compulsory assessments will dictate what areas to calculate so that clear statistics can be generated.

The assessments will allow a more accurate understanding of construction emissions and will help determine legal carbon limits which Part Z proposes to be introduced from 2027. This timeline has been informed through the influence of European countries who have started implementing management of construction emissions.

A change in our relation to building materials is required. This means designers and contractors need to have a broader understanding of the greener materials available. 'Green Building Calculator' developed by Brian Murphy is an open-source directory for people in the construction sector to understand how green their materials and services are. The 'BEAM Estimator' from Builders for Climate Action can also offer tools to help understand embodied carbon during of a drawing.

Applications like these are a great tool to help designers and contractor understand the energy emission behind materials and are useful in transitioning towards an age where whole life carbon assessments will be a requirement.

A list of other carbon calculators can be found here:Carbon Footprint Calculators

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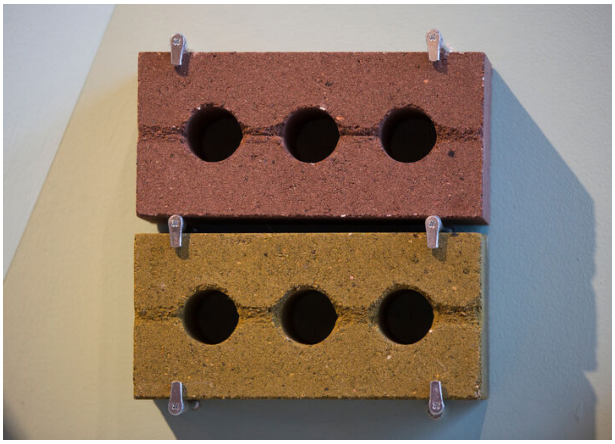
2 'Part Z', Part Z, accessed 9 September 2022, https://part-z.uk.

3 Though understanding the whole life carbon is a good start - we must also start developing and implementing long-term solutions to reduce it.

Low Carbon Products

Though understanding the whole life carbon is a good start - we must also start developing and implementing long-term solutions to reduce it.

Designers and inventors have been researching into ways we can reduce the carbon emission from the construction process. Materials and how they are produced has been one of the focusses, with many new products being introduced to tackle carbon emissions as well as issues surrounding construction waste.
K-Briq™, invented by Professor Gabriela Medero in Edinburgh's Heriot-Watt University. It is an unfired brick made from construction waste and emits a tenth the amount of carbon as a standard fired clay brick. The K-briqs weigh and behave like normal bricks but offer better thermal properties and have the bonus of coming in an assortment of colours.



K-briqs by Kenofeq
Image by Michael McGurk

CLT (Cross-Laminated Timber) is an engineered wood product which is a worthy opponent to steel. It is a fire-resistant wood product which lowers carbon through the carbon absorption of trees and replacing structural steel and concrete.

Layers of wood strips are glued together in changing orientation to make CLT much stronger than the standard wooden beam. The main reason CLT is a is a great low carbon product is because it can be used in large buildings which would normally require steel or concrete and thus promoting wood construction. CLT products are advancing all the time, achieving taller and more impressive structures with the tallest timber building now reaching 85m high.

The Smile by Alison Brooks Architects
Image by Alison Brooks

As the name suggests, ***Hempcrete*** is a concrete block alternative which utilises hemp shivs and a lime binder. It is lightweight, mould-resistant, insulative and best of all, Hemp absorbs 15 tonnes of CO_2 per hectare. It is becoming more and more popular, however, the production of hemp does have it's drawbacks – hemp crop can only be harvested at certain times of the year which can be difficult for producing enough supply.

Learning from Vernacular Architecture

The discovery of these materials and processes is a successful endeavour and should be applauded, though it should be noted that low carbon construction methods have been around for centuries and make up the most ancient forms ***Vernacular Architecture.*** They are built using traditional material sourced in the region and using the tools and skills available in the community. These methods of building began through primitive means of construction, however, over a long span of time and many iterations later became optimum to the context.

Vernacular architecture became less and less used as materials like steel and concrete, which are quicker and require less labour, became widespread.

As the focus moved to how buildings could be built bigger faster, vernacular architecture became overshadowed in many parts while western architecture became dominant

There have however been groups of architects who continue to learn from vernacular architecture often implementing them in radical ways like the Earthship style developed by Michael Reynolds. Their architectural style can be quite radical and go against the grain of common contemporary architecture.

Now, we can apply crafts from around the world, using them with locally sourced materials, giving birth to a new form of local architecture. The combination of easy to source products and low-tech fabrication means that a lot of this techniques are considerably low in embodied carbon.

View of the west side of the Brighton Earthship
Image by Mischa Hewitt

Vernacular Materials

One of the obstacles with historic methods of construction is that that do not always align with the post-industrialised culture of building. We now have mass produced standardised materials for all the contemporary building methods making it easier for contractor to plan, procure and order materials quicker. Till now mass production of sustainable materials has not been in focus.

HG Matthews is a company creating low-carbon building blocks taken from historical styles of construction uses chopped straw and clay and does not require firing. "Strocks can be used for internal load bearing walls typically up to 3 storeys" [4], not to mention they offer great insulation.

Natural Building Blocks made of clay and straw www.hgmatthews.com

Section showing different cob mixes used in wall Image by Sadek Ahmed

Le Cobbauge, Plymouth University. At Plymouth University, researchers have been experimenting with Cob style building techniques to offer greater load-bearing and thermal qualities. The project uses materials that have been locally sourced and processed with very little energy to produce the cob wall of the house. Once completed, the structure will be tested to assess how much the operational carbon emitted is, which the team at Cobbauge predict to be very low due to the insulative qualities of cob. The aim of this project is to prove Cob walls capability to meet regulation for building and establish as a viable building material.

The research team went through many iterations of mix ratios to determine the most suitable material composition. They can now offer this information to others desiring to build with cob so that they can determine what locally sourced materials are suitable. Test samples of Earth can also be sent to Plymouth University to determine the clay levels and suitability as a building material. With the completion of Cobbauge project, we could be seeing more engineered cob houses around the coast of England.

4 'Strocks - H.G Matthews Limited', accessed 9 September 2022, https://www.hgmatthews.com/lime-and-cob/natural-building-blocks/strocks/.

Vernacular Materials

At the Centre for Alternative Technology in Wales, they erected an auditorium from rammed earth. The Shepperd Lecture Theatre used soil found at a local quarry with the naturally existing clay providing the strength. The Auditorium earth walls measure at a height of 7.2m and “prevent the building from overheating and buffer the temperature at colder times of the day”[5].

Sheppard Lecture Theatre
Centre for Alternative Technology, Wales

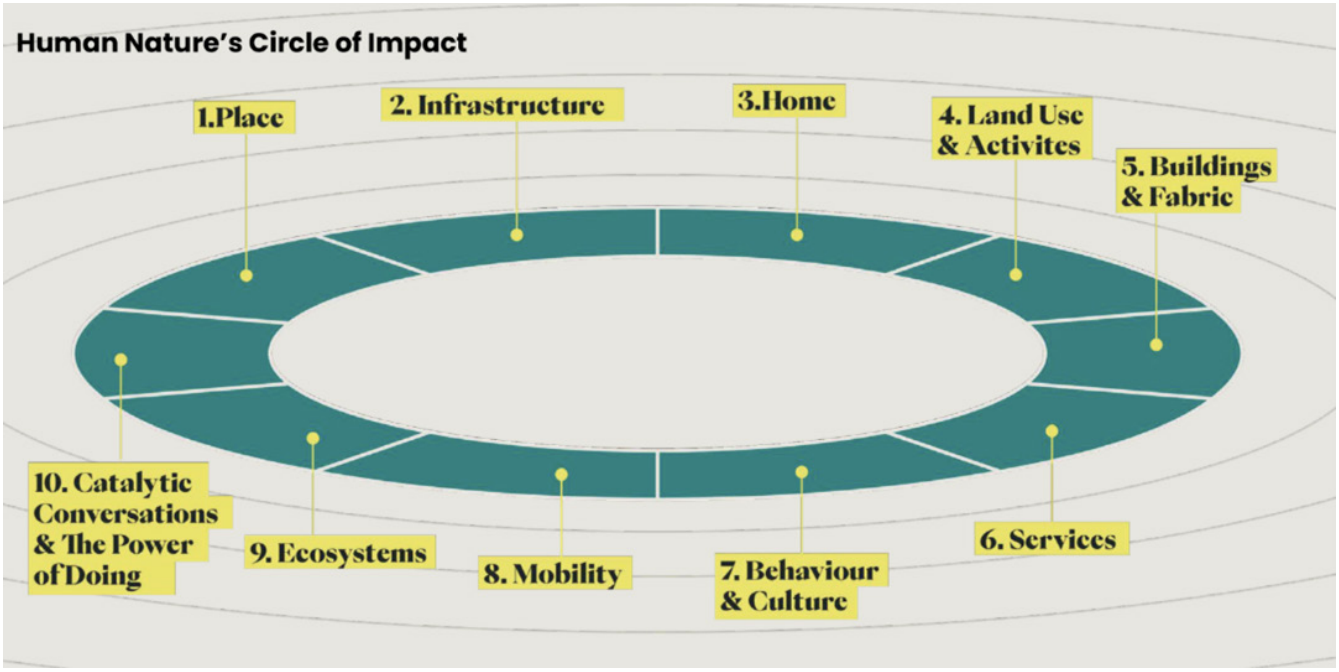
Other institutions who have enlisted sustainable materials include Nottingham University and their Gateway Building which used prefabricated strawbale sourced from local farmland. The building boasts a 13% saving in total carbon emissions and High Thermal conductivity. Naturally, using a material like straw would raise concerns about safety, however “straw is health-friendly, much more insulating on the long run, and fire resistant” and its biggest hurdle is ensuring the straw is moist free during construction.

1. Prefabricated Straw bales
2. Interior of Gateway building
Cred. Zander Olsen

5 ‘Home - Centre for Alternative Technology’, accessed 9 September 2022, https://cat.org.uk/.

Material Cultures

Material Cultures is a not-for-profit organization that is set out to educate and implement sustainable materials in the built environment. They are currently working on ongoing regeneration development, The Phoenix, in Lewes which will have a focus on the environmental impact of the design. The Development will be led by ***Human-Nature*** who have a note-worthy process of public engagement throughout the design development process. These methods, when done correctly, can bring about healthy ownership from the public and act as a passive way of educating people about sustainable building.



Human-Nature's "Circle of Impact" shows how information can be spread
www.humannature-places.com

Challenges and Opportunities

Standardisation - A lot of the time we find that natural materials (e.g. earth, straw) do not behave the same from place to place. This makes it difficult to regulate them for mass application, something that is a result of post industrialisation culture of construction. One of the ways, as shown by HG Matthews, is to produce standardised blocks of the material which have a small area of tolerance in variation.

Hempcrete is another material product which offers these qualities, making it easier for workers who are used to working with sheet/brick products and creates more inclination towards using these sustainable materials.

Health and Safety - Natural materials may sometime have a stereo type of not being as structurally sound as industrial material such as steel. However, as shown in the previous examples, products like cross-laminated timber and hempcrete being used replace steel and concrete and continuous research and testing is allow for them to be used in taller, larger structures.
There may also be preconceptions of some material like straw and timber being a fire hazard but as discussed previously, testing and research has been done to ensure that they are suitable for contemporary use. Even so, these materials should be understood, and the know-how of these materials should be taught correctly when being implemented, like any other material.

Wellbeing - These materials and method have great potentials for reducing embodied carbon and helping towards a net zero world. They also may create an environment which improves our wellbeing and connection to the surrounding. Earth buildings are known for filtering pollutants from the air and timber for it's positive effects to our wellbeing and performance. Research has shown that having timber elements in a work or study space greatly improves workers' brain activity and lower stress.(ref. How wood can help) So, using these low carbon materials would be having a benefit to us directly as well reducing the overall carbon emissions.

Finally, our relation to materials must change. Just as there is a growing focus on food and fashion production, we must open our eyes to how we source the materials for our buildings and how sustainable they are. If we at the very least understand how bad many of the construction materials are to the environment, conversations will lead to a discussion of change.
A change that helps us the health of the world using low carbon materials. A change that uses materials that benefit our health. Furthermore, a change which offers new job opportunities for builders wanting to work with sustainable materials.