The Potential of Mass Timber Building for Future-proof Cities

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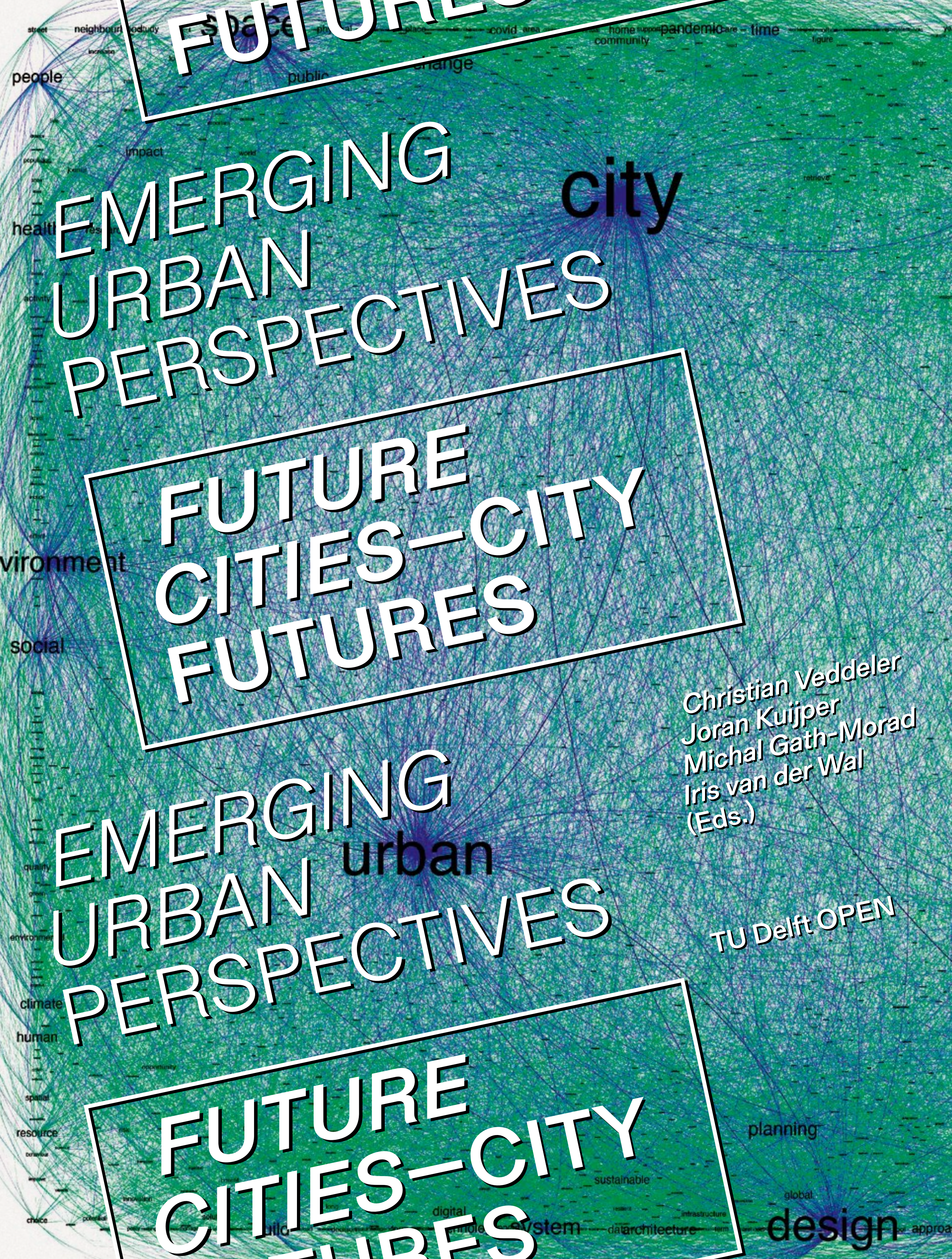
Publication date
2023

Document Version
Final published version

Published in
Future Cities - City Futures

Citation (APA)
van der Lugt, P. (2023). The Potential of Mass Timber Building for Future-proof Cities. In C. Veddeler, J. Kuijper, M. Gath Morad, & I. van der Wal (Eds.), *Future Cities - City Futures: Emerging Urban Perspectives* (pp. 318-331). TU Delft OPEN Publishing.



EMERGING URBAN PERSPECTIVES

FUTURE CITIES—CITY FUTURES

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TU Delft OPEN Publishing, Delft University of Technology, The Netherlands

COLOPHON

Future Cities—City Futures
Emerging Urban Perspectives

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KEYWORDS
City; Future; Urban; Design; Building; Architecture; Environment.

PUBLISHED BY
TU Delft OPEN Publishing, Delft University of Technology, The Netherlands

ISBN 978-94-6366-642-8
DOI https://doi.org/10.34641/mg.55

Electronic version of this book is available at https://books.open.tudelft.nl/

PROOFREADING
Simon Milligan

BOOK BLOCK DESIGN/TYPESETTING
Joran Kuijper

SPECIAL THANKS TO
Roberto Cavallo, Delft University of Technology, Faculty of Architecture and the Built Environment, Department of Architecture; Werner Sübai, Gerhard Feldmeyer, and Joachim Faust, Helmut Hentrich Foundation; Lola Ben-Alon, Columbia University, Graduate School of Architecture, Planning and Preservation (GSAPP), New York City

Cover graph by Michal Gath-Morad, edited by Christian Veddeler and Joran Kuijper

FUTURES

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ABSTRACT

The latest generation of timber products enable complete multi storey neighbourhoods to be built from sustainably sourced softwood.

This chapter explores how a large-scale transition to timber building in urban environments could contribute to solving the three major global crises we are currently facing with climate, natural resources, and health. If key external determinants are used to set the right preconditions, by 2030, the combined forestry and construction sectors in Europe could mitigate 23 per cent of greenhouse gas emissions and provide sufficient timber to sustainably meet housing demand in Europe while contributing significantly to the well-being of urban citizens.

KEYWORDS

mass timber; biobased building; climate; circularity; health and well-being.

Chapter 24—The Potential of Mass Timber Building for Future-Proof Cities

Pablo van der Lugt

The pivotal role that cities play in relation to the mental and physical health and well-being of their inhabitants has become extremely clear from the COVID-19 pandemic. Meanwhile, cities also play a crucial role in meeting global climate and circularity goals.

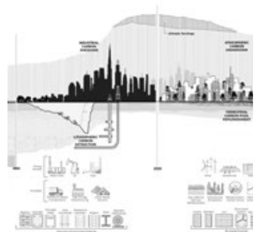

Figure 1 ▸ p. 328

FUTURE CITIES: A HEALTH, CLIMATE AND RESOURCE CHALLENGE

Because of increased urbanization, about 68 per cent of the global population will live in cities by 2050 (UN DESA, 2018), which emphasizes the need to develop diversely planned, multifunctional, and nature-inclusive cities. Building with regenerative, biobased materials, particularly mass timber, could help to shape our future cities in a healthy, climate-proof, and circular manner.

HOW BIOBASED MATERIALS COULD HELP SHAPE FUTURE CITIES

In the Middle Ages, renewable materials such as timber, reed, and straw were the predominant building materials. During the Industrial Revolution, these were largely substituted by minerals and metals due to their high level of industrialization and consistent and superior performance. However, they are responsible for a considerable proportion of the global carbon footprint, currently accounting for about 11 per cent of total global greenhouse gas emissions (GABC, 2019).

Consequently, increased urban development will become a threat to sustainable resource management and climate ambitions when largely executed in non-renewable, abiotic materials such as concrete, brick, and steel. A viable alternative is provided by mass timber: large industrially engineered timber products made from strength-graded softwood, such as cross-laminated timber (CLT), glue-laminated timber (glulam), and laminated veneer lumber (LVL). Because of their very consistent and high performance, these can directly substitute abiotic materials in the bearing structure of buildings up to twenty storeys high.

Because of their low weight and good workability, mass timber construction systems are very suitable for prefabrication, including adding storeys on top of existing buildings. When executed well, this results in significantly fewer transport movements and very quick installation on site, with lower emissions and less disturbance to the surroundings.

Moreover, an increasing body of evidence shows that visible application of natural materials in the built environment has a positive impact on the health and well-being of the occupants (Suttie, 2019). This is very relevant to the mental health issues that have arisen from the lockdowns during the COVID crisis, particularly in high-density urban areas.

THE POTENTIAL IMPACT OF TIMBER BUILDING ON FUTURE CITIES

HEALTH AND WELL-BEING

Trees and other vegetation are known to have a positive impact on various social, physical, and mental aspects of well-being in the urban environment (Elmqvist et al., 2019). For example, urban vegetation and greenery can have a positive effect on social cohesion in neighbourhoods (De Vries et al., 2013), significantly lower the heat-island effect in cities (Steeneveld et al., 2011), and improve air quality by filtering pollutants from the air (Hartig et al., 2014). However, their positive effect on the health and well-being of the inhabitants, such as better concentration and lower stress levels (Hartig et al., 2014), may prove especially crucial. Currently, this is particularly relevant for high-density urban areas with a high incidence of physical and mental illnesses such as anxiety, depression, and stress as a result of the COVID crisis and the related lockdowns.

THE HEALTH EFFECT OF TIMBER BUILDINGS

It is generally known that exposed timber is a hygroscopic material that creates a comfortable indoor climate by absorbing or releasing moisture depending on the indoor humidity. Furthermore, several studies have shown that the visible use of timber in buildings fits very well with the principles of biophilic design.[1] This philosophy suggests that mankind has a natural tendency to connect to nature. When applied to the built environment, this approach can contribute to healthier buildings through visible natural elements and increased exposure to daylight and water (Grinde & Patil, 2009).

The visibility of timber and other biobased materials is suggested to lead to lower stress levels, increased mental and physical well-being, higher productivity, and lower absence levels. This offers clear advantages in office, educational, and health care environments. For example, it may lead to quicker recovery rates in health care situations (Fell, 2010). In the study 'School Without Stress' (Kelz et al., 2011), students in a timber-furnished classroom showed lower stress levels and heart rates (8,600 beats less per day) than the control classroom featuring plastered walls.

The same biophilic design rationale raises the expectation that visible timber in outdoor urban environments will have a similar positive impact; additional research is required to validate this hypothesis. Together with greening the city, this should help to achieve more nature-inclusive urban environments, which may well have a beneficial impact on the mental and physical health of their inhabitants.

CLIMATE

We are quickly spending the carbon budget we have if we are to stay within the 1.5°C cap of the Paris Agreement. In the Netherlands, for example, this budget will be spent by 2029 (DGBC, 2021). The building industry is a major factor, responsible for 39 per cent of global anthropogenic greenhouse gas emissions, of which about one-third is directly related to materials production (GABC, 2019).

Climate change can be mitigated through sustainable forest management and timber building through three levers.

Carbon stored in sustainably managed forests

Global forests play an important role in the carbon cycle: negatively through deforestation, particularly in tropical areas and mainly driven by land conversion for cattle pasture and large-scale agriculture; and positively through reforestation and afforestation, particularly in temperate regions. During growth, trees absorb CO_2 from the atmosphere and convert

Figure 2 ► p. 330

1
An excellent overview is provided by Suttie (2019)

2
The largest task for the building industry lies in fast-developing economies such as China, India, Africa, and South America. For example, by 2015, the building stock in China was already double the size of that in Europe, and it is expected to be five times higher by 2050: 562 Gt versus 107 Gt of raw materials. Of this quantity, more than half (323 Gt) still has to be built (Circle Economy, 2019).

it by photosynthesis to oxygen and glucose, from which the wood grows and forms cellulose and lignin. Oven-dry wood consists of about 50 per cent biogenic carbon. European forests are predominantly under sustainable management, and their total area is growing each year, which makes them a net CO_2 sink that reduces CO_2 emissions in the EU annually by about 10 per cent, which is 435 Mt CO_2/year (Nabuurs et al., 2015).

Carbon stored in timber buildings

When wood is used for biomass energy production, the biogenic carbon it stores is released by incineration as CO_2. However, when wood is turned into high-value construction products such as mass timber, the biogenic carbon remains stored in the built environment. The amount of carbon stored in a timber building, also known as construction-stored carbon (CSC), is relatively easy to calculate following European norm EN 16449 when the wood species and the quantity of timber used are known (Climate Cleanup, 2021). Through circular design practices and 'cascading' (see below), mass timber elements can be reused multiple times. This locks in the biogenic carbon for even longer across consecutive useful lives, potentially well beyond the hundred-year time limit defined by the Intergovernmental Panel on Climate Change (IPCC).

Carbon savings in timber buildings through substitution

When mass timber replaces carbon-intensive abiotic building materials such as concrete and steel, 2.2 tons of CO_2 emissions are avoided per ton of timber applied (Leskinen et al., 2013). Combined, the CSC and the CO_2 emissions avoided can lead to significant carbon savings in multistorey buildings. Thus, a large-scale transition to timber construction in cities worldwide could lead to very significant climate benefits. Churkina et al. (2020) estimated that in a radical 90 per cent timber construction scenario in 2050, the total benefit could total 111 Gt CO_2, which is a significant proportion of the 400 Gt CO_2 budget within the 1.5°C cap.

Additional carbon benefits through densification

Besides these three levers, the lightness of mass timber buildings, approximately five times lighter than concrete, provides various possibilities for densification, such as in topping up, refurbishment, and floating constructions, and increased flexibility, such as allowing open-building floor plans. This is important, because denser cities have a considerably smaller carbon footprint and higher productivity (IRP & UNEP, 2018).

RESOURCES

The increasing scarcity of natural resources worldwide (e.g., various metals are expected to be depleted within decades) together with the expected doubling in materials use by 2050 (from 92.1 Gt to 177 Gt in 2050, with 44 per cent related to the built environment[2]) means that transitioning to a more circular economy is crucial. However, only 9 per cent of resources are being recycled or downcycled, revealing an immense 'circularity gap' (Circle Economy, 2019). This will particularly affect urban areas, which are expected to grow by 60 per cent by 2050 (UNEP, 2013).

Although priority selection of circular strategies following the R-ladder (refuse, rethink & reduce, redesign, reuse, repair, recycle, and recover) is desirable for any material, mass timber has several distinct advantages.

First, mass timber buildings are very suitable for design-for-disassembly approaches, using dry, reversible connections in contrast to wet approaches such as casting concrete. Thus, mass timber elements such as CLT panels and glulam beams used in an indoor environment retain their technical quality and keep their value. If designed well, they can easily be reused in second or third or even fourth high-value lives. Only after that does it

make sense to chip the mass timber elements to produce panel products and finally incinerate the material for bio-energy production, or better, use it for biochar or biochemistry purposes. With this ‘cascading’ approach, biogenic carbon can theoretically be locked in for over a hundred years. In the meantime, sustainably managed forests will be able to produce a surplus of wood for producing new timber, thus making timber building ‘double circular’.

Churkina et al. (2020) made a projection of the global timber supply from forests and plantations to 2050. They concluded that unexploited harvest potential should provide enough wood to meet demand, even for a radical scenario of 90 per cent timber use in global cities by 2050.

Figure 4 ► p. 330

In Europe, annual growth in forests is 1,000 Mm^3, and harvesting accounts for 600 Mm^3. This means there is an additional annual capacity of 400 Mm^3 in the European forests (Nabuurs et al., 2021). Assuming 25 per cent additional harvesting of this capacity annually (100 Mm^3) and a conversion rate of 50 per cent from sawlog to timber, an additional two million apartment units of 25 m^3 timber could be constructed each year—enough to meet the annual European housing demand.

Figure 5 ► p. 331

DISCUSSION: KEY SUCCESS FACTORS FOR A MASS TIMBER URBAN TRANSITION

Although the potential of mass timber building to help solve the three global crises is very significant, there are several key external determinants that will influence the adoption rate of timber building concepts in future cities. The most important are briefly highlighted below.

BUSINESS CASE

The material costs of mass timber building are still considerably higher than traditional construction, by up to 10–20 per cent. This means that for many projects with a tight budget, the traditional route is often still chosen. A total costs of ownership approach provides a fairer comparison by weighing such other aspects of the building process as faster and cleaner construction, lighter foundations, and quicker return on investment against life cycle factors such as higher residual value, lower environmental, social and governance risks, and positive value development. If a carbon tax on building materials were introduced, or at least a voluntary carbon credit system that values carbon storage, this could shift the balance in favour of mass timber.

← Figure 3
The carbon stored in 1 m^3 of cross-laminated timber is almost ten times higher than the quantity emitted during production (Nina Rundsveen/ Moelven) (photograph by Tomorrow’s Timber, MaterialDistrict).

LEVEL OF INDUSTRIALIZATION AND DIGITALIZATION

Mass timber building systems are very suitable for industrialized, modular housing production. Through improved value chain integration and increased digitalization, construction time could be reduced by 20–50 per cent and eventually total investment costs for projects could be reduced by 10–20 per cent, further helping the business case (Barbosa et al., 2017; Bertram et al., 2019). This requires significant investment in new mass timber building system factories and further upscaling of mass timber plants.

POLICY AND LEGISLATIVE INCENTIVES

Climate and circularity targets are already actively stimulating the application of timber building in several areas of Europe, for example through financial, policy, and legislative incentives.

This is sometimes at the municipal level: for instance, the Metropolitan Region Amsterdam has committed to 20 per cent timber building by 2025. Regional and national levels are also active: for example, the French government has prescribed 50 per cent use of biobased materials by 2023. Increasing the adoption of such policies in other places will help the mass timber industry scale up and attract the investments it requires.

MISCONCEPTIONS AND LACK OF KNOWLEDGE

Many common and unjustified prejudices against mass timber building still

hamper its large-scale adoption, for example involving fire safety, the availability of timber, and durability. Furthermore, higher education support at universities and professional consulting in such fields as engineering, building physics, and costs are still underdeveloped in many countries. This can sometimes lead to wrong choices in construction, which raise costs and damage the reputation of mass timber.

CONCLUSION—BIOBASED CITIES, A PROMISING PERSPECTIVE

This chapter has shown that a large-scale transition to timber buildings in urban environments could provide a significant contribution to the three global crises we are currently facing.

The Climate Crisis—In a radical 90 per cent urban timber scenario, a total of 75 Gt CO_2 could be stored and 36 Gt CO_2 emissions avoided by 2050, apart from additional carbon stored in new forests planted to fuel this potential timber revolution.

The Resource Crisis—In the same scenario, additional production capacity and increased harvesting in global temperate forests should provide enough timber to meet the increased demand. This is particularly the case in Europe, with an annual additional forest capacity of 400 Mm³, potentially enough to meet the European housing demand.

The Health Crisis—Besides the broad consensus on the positive social and health effects of green urban environments, the benefits of applying biophilic design principles in indoor and outdoor built city environments are complementary. However, more research is needed to know the magnitude of the well-being benefits of visible timber.

Various urban regions have recognized the potential of mass timber building. For example, cities such as Amsterdam, Copenhagen, Trondheim, and Toronto have already presented large-scale plans for complete neighbourhood developments built with biobased materials.

Meanwhile, the forestry supply side should also be actively stimulated to achieve increased afforestation, reforestation, and improved forest management following 'climate smart forestry' principles (Nabuurs et al., 2018). If this is done well and a higher portion of the harvested wood is turned into mass timber to replace CO_2 intensive materials, the climate mitigation effects of the combined forestry and construction sectors in Europe could reduce European greenhouse gas emissions by up to 23 per cent by 2030.

This could even go further than forestry alone, if cattle lands used by the dairy and meat industry are converted to cropland for the production of biobased fibres such as hemp, flax, miscanthus, bamboo, and straw. These raw materials can be used for construction applications in panels, insulation, and suchlike with similar carbon storage and substitution effects.

Ultimately, large-scale implementation of mass timber building in urban environments will lead to significantly lower carbon emissions in the land-use and construction sectors while overcoming resource scarcity and creating a more pleasant, climate-resilient, nature-inclusive environment for urban citizens with substantial health and well-being effects.

Figure 7 ▸ p. 331

← Figure 6
The 80-meter-high Sara Cultural Center in Sweden (design White Arkitekter) features over 13,000 m³ of mass timber, resulting in a carbon benefit of over 22,000 tons CO_2 (~10,000 tons of stored CO_2 plus ~12,000 tons of avoided CO_2 emissions). At a CO_2 price of 125 euro/ton, this represents a climate value of 2.75 million euros (photograph by Patrick Degerman).

"Ultimately, large-scale implementation of mass timber building in urban environments will lead to significantly lower carbon emissions in the land-use and construction sectors ..."

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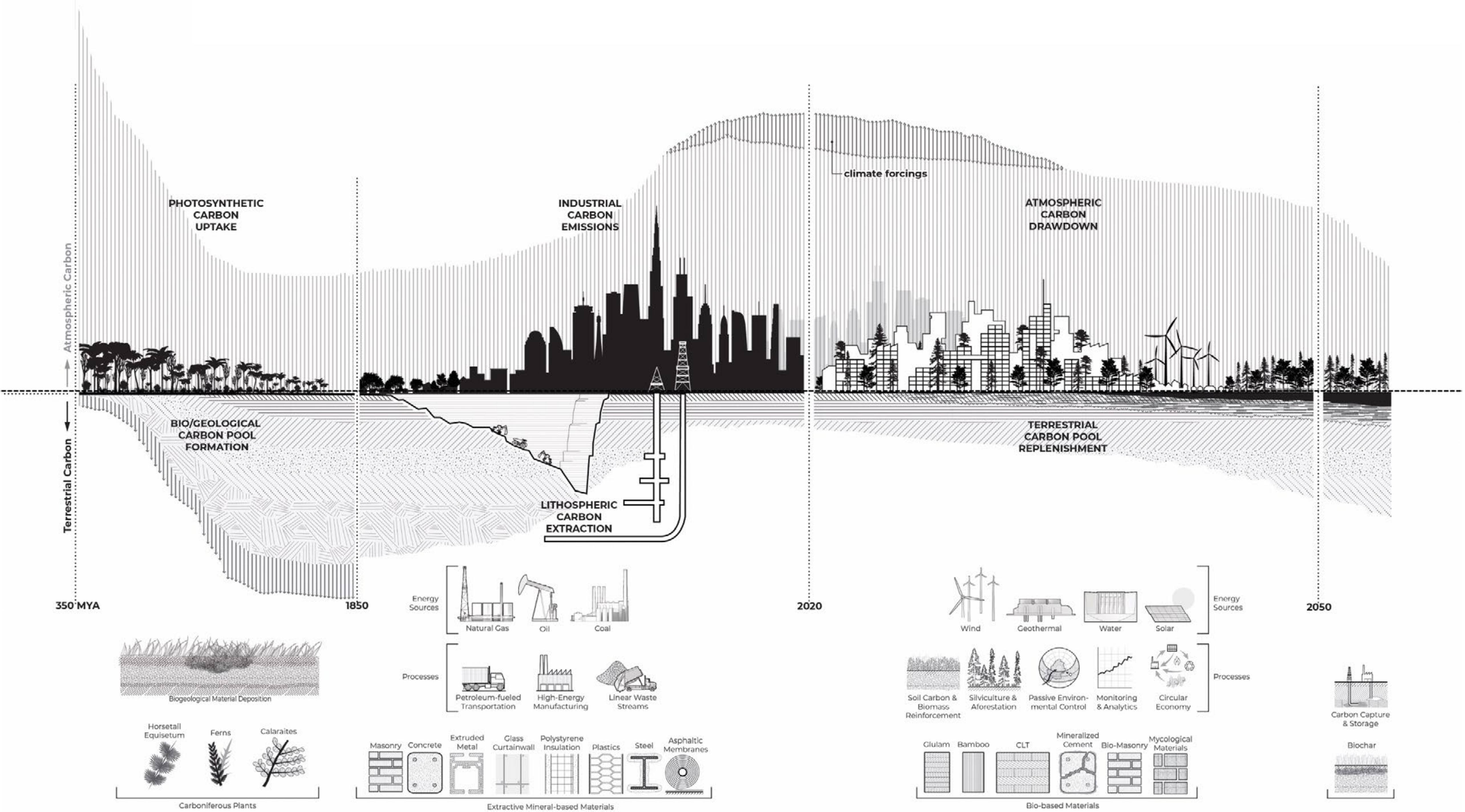

Figure 1
The imbalance between atmospheric carbon versus terrestrial carbon over time. Reforestation and mass timber building could help regain the global carbon balance (Kuittinen et al., 2022). Courtesy of John Wiley & Sons, Inc.

Figure 2
The Edge Olympic office building (design: Eric van Noord, de Architekten Cie.) is a successful redevelopment in Amsterdam (Well Platinum certified), where two storeys were added to the existing two-storey concrete building using a glulam post and beam construction (photograph by Ossip van Duivenbode).

Figure 4
Where possible building on water utilizes otherwise neglected surface area and is future-proof, even with rising sea levels. The floating office featuring amongst others the Global Centre on Adaptation (design: Powerhouse Company) in the harbour of Rotterdam is the largest floating office in the world (3,600 m²) (photograph by Marcel IJzerman).

Figure 5
WThis school in Rotterdam (design: SeArch) was built within a very low budget and designed for disassembly with timber modules. It is planned to be rebuilt in five years in another location (photograph by Ossip van Duivenbode for SeArch).

Figure 7
Modular mass timber housing factory (20,000 m²) in the Netherlands, set to produce 1,500 houses a year (photograph by Lister Buildings).