DESIGN

Decarbonisation

IN DEPTH

RAMBØLL

EDITION NO. 7
MARCH 2024

Prologue

"Our relationship with carbon, greenhouse gases, and the whole agenda of decarbonisation, is a true story of 2 halves!"

On the one hand,

there have been many well-intended initiatives by committed individuals and organizations, not least the UN over the past 50 years or so, to reduce or cap such harmful and deleterious emissions into the atmosphere.

The following key milestones are noteworthy:

- 1979: First World Climate Conference
- 1987: Brundtland Report "Our Common Future" was published,
- 1990: First IPCC Assessment report,
- 1995: First UN Climate Change Conference,
- 2005: Kyoto Protocol entered into force,
- 2009: Copenhagen Accord,
- 2015: Paris Agreement adopted,

These, and a multitude of COPs (Conference of Parties), including:
COP26 in Glasgow (2021),
COP27 in Sharm Al Shaikh (2022),
COP28 in the UAE (2023),
and the recently published 6th IPCC Report (AR6 Synthesis Report: Climate Change 2023).

These provide valuable resources produced by highly committed and competent climate scientists and other committed individuals, corporations and governments from across the globe, on the dangers of inaction on the climate front, and on ways to control, minimize, and eradicate deleterious gases into the atmosphere, and to adopt practices which are more in tune with planetary boundaries and a congruent co-existence and co-creation with nature.

On the other hand,

the concentration of such gases in the atmosphere has relentlessly continued to go up, and exponentially too! Carbon dioxide (CO_2) concentration, measured in parts per million, in the atmosphere stands at 422 ppm in December 2023.

This has gone up by more than 70 since 1984; the same level of increase seen in the previous 200 years since the late 1700s!

Similar degenerative tendencies are observed in all environmental indicators, from loss of biodiversity and forests, to the acidification of our oceans. It is as if the good intentions and deeds of the very competent and capable scientists, activists and agencies have happened on a different planet to the one we live on, and in which these harmful gases are pumped into and piled up in its atmosphere.

The harmful mechanisms of the effects of fossil fuels in all our industries, and the resulting harm they do have now been known for over a century.

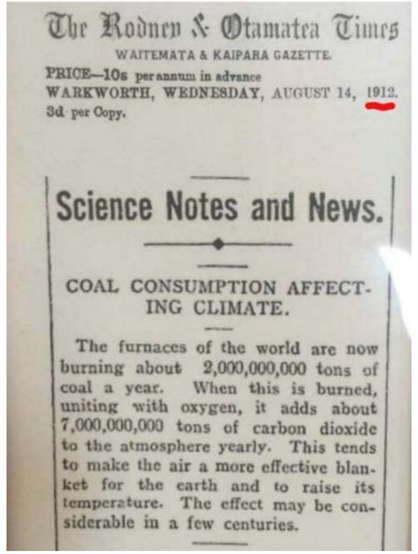
However, vested interests and cheap oil and coal, have persisted and until recently prevailed. This must change, and must do so in the very short window still available to keep the rise in average atmospheric temperatures above those prevailing in the late 18th century, to below 1.5 degrees, as committed in the Paris Agreement: COP21.

The paramount environmental indicator is the heating of the biosphere. Terms like global warming, climate change, global heating, and more recently, global boiling, have been coined to describe this phenomenon.

The rise in average temperatures compared to those prevailing at the onset of the industrial revolution, back in the 1780s, currently sits at around 1.1 degrees centigrade. There is near consensus amongst climate scientists that 1.5 degrees is the trigger point for unforeseen (unimaginable) consequences.

Key amongst all environmental drivers, like greenhouse gases, biodiversity, forest areas, etc, ought to be about controlling these temperature rises with a view to keeping them within the 1.5 degrees. Emission of excessive amount of Greenhouse Gases (GHGs) into the atmosphere is not the only contributor, but a key contributor, to rise in atmospheric temperatures.

This edition of Ramboll DESIGN addresses decarbonisation of the built environment, and makes hard and verifiable commitments to reducing them in Ramboll buildings. It also invites all industry partners to join us, and make similar or better commitments.



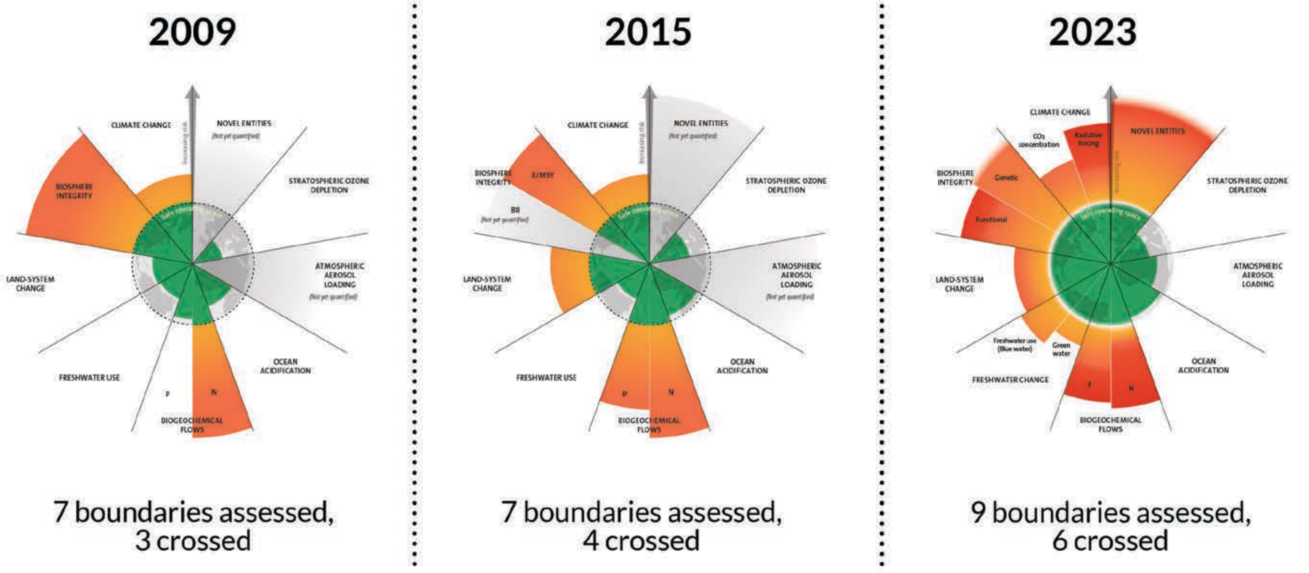
The Rodney & Otamatea Times
WAITEMATA & KAIPARA GAZETTE.
PRICE—10s per annum in advance
WARKWORTH, WEDNESDAY, AUGUST 14, 1912.
3d per Copy.

Science Notes and News.

COAL CONSUMPTION AFFECTING CLIMATE.

The furnaces of the world are now burning about 2,000,000,000 tons of coal a year. When this is burned, uniting with oxygen, it adds about 7,000,000,000 tons of carbon dioxide to the atmosphere yearly. This tends to make the air a more effective blanket for the earth and to raise its temperature. The effect may be considerable in a few centuries.

Newspaper cutting from 1912 New Zealand
Over a century ago, coal furnaces were recognized for emitting Carbon Dioxide (CO2), and there was an early understanding that this greenhouse gas contributed to global warming.



Planetary boundaries:
A regression in progress ...

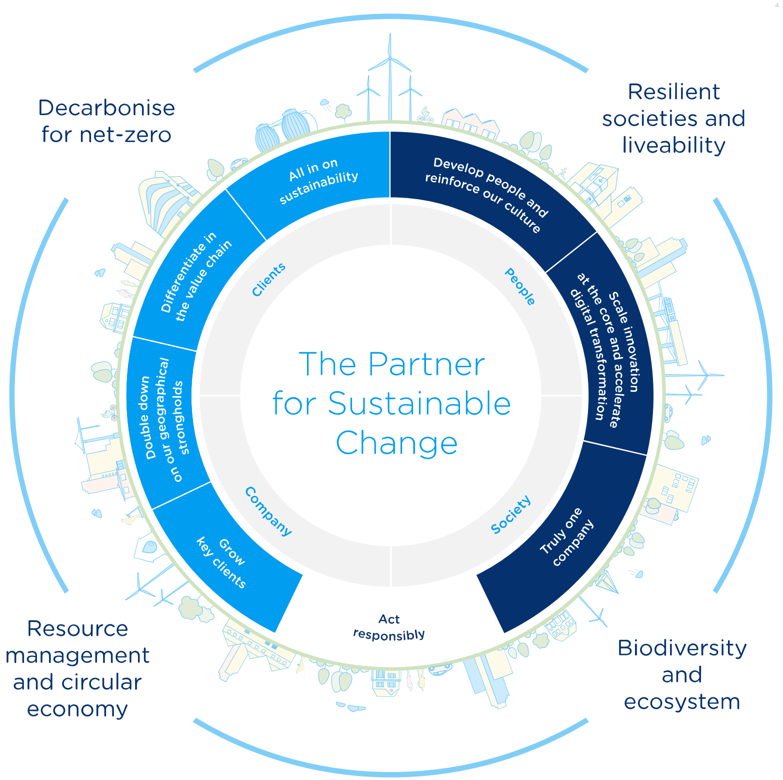
Ramboll's Global Strategy 2022 - 2025

Ramboll's global strategy for the strategy period 2022 to 2025, "The Partner for Sustainable Change", is built around four key themes, one of which is, 'Decarbonise for net-zero'.

The other three are aimed at, "Resilient societies and liveability", care for "Biodiversity and ecosystem", and on "Resource management and circular economy".

Key commitments in Ramboll's Decarbonisation strategy are:

- That decarbonisation must be pursued until a net-zero state is achieved. (Our commitment is not about "doing less harm", but about "halting the harm")
- That hard limits are to be set now on the limits on Embodied Carbon we allow in each and every one of our projects, (We are committing to a hard limit on embodied carbon of $150kg.m^2$ for the superstructure of the buildings we design. More on this later in this edition of DESIGN.)
- That a roadmap to zero carbon is set, so that it is achieved in a finite and definable timeframe. (We commit to reducing the embodied carbon in the building structures we design by 30% by 2025, and by 50% by 2030.)



4 strategic unifying themes in Ramboll
In our strategy for 2022 – 2025, we go all in on sustainability and deepen our commitment to a sustainable future.

"With our strategy, we commit our expertise and effort towards solving the world's toughest challenges within decarbonisation, resilience, circularity, and biodiversity"

Jens-Peter Saul
Ramboll CEO

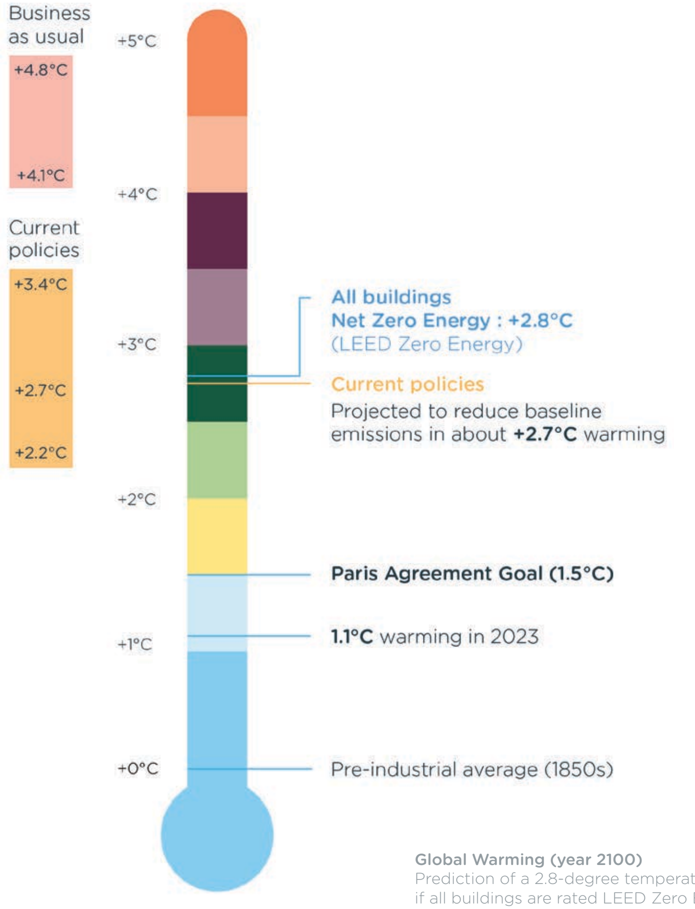
Decarbonisation in the Built Environment

The built environment is both the largest consumer of energy and the largest consumer of materials. Whilst this poses a huge challenge, arguably it is also our greatest opportunity to tackle Greenhouse Gas (GHG) emissions. The vast majority of the emissions associated with the built environment is associated with the energy required to produce the materials used in the industry, the energy required to power the processes of construction, as well as the operational energy demand, whether it be for heating, lighting or increasingly, cooling – by 2050, it is anticipated that we will use more energy for cooling than for heating.

Energy generation is still dominated by fossil fuels though some countries are rapidly decarbonising their grid. As such, one may assume that electrical gird decarbonisation will automatically lead to the decarbonisation of operational energy in buildings.

However, many buildings still use fossil fuels directly, and as more of our energy becomes electrical, there will be a huge spike in electrical demand that may be impossible to meet through renewables alone. Demand reduction in existing buildings and infrastructure is therefore critical.

Demand reduction, through improved building performance is also key to addressing fuel poverty, health and well being, especially as we must adapt to more uncertain weather patterns in the future.

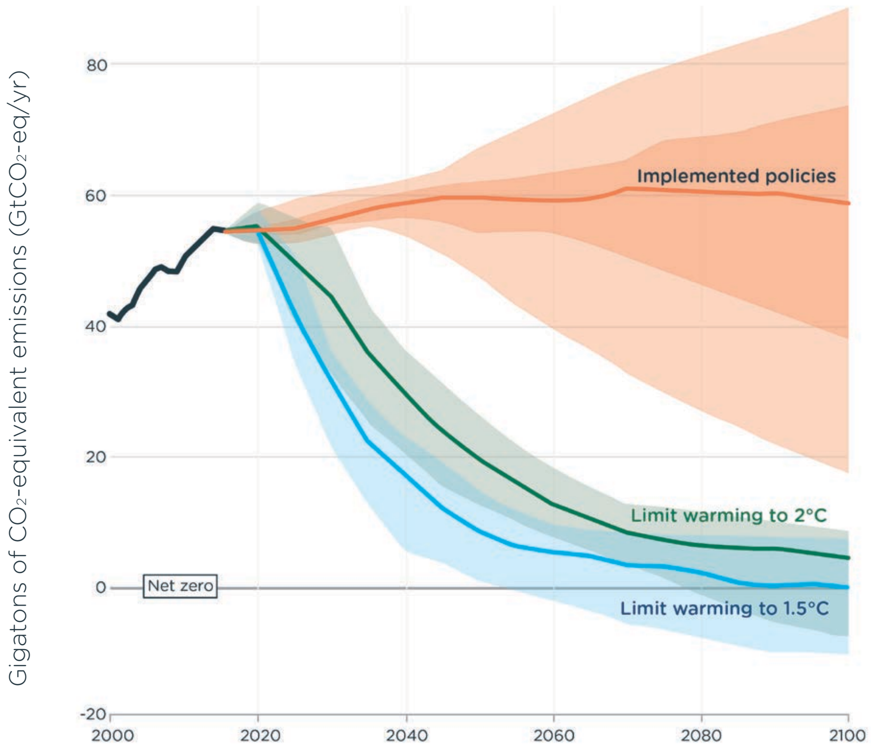


Global Warming (year 2100)
Prediction of a 2.8-degree temperature increase even if all buildings are rated LEED Zero Energy. Relying solely on decarbonisation initiatives within the built environment industry is insufficient to effectively mitigate global warming.

Adapted from Climate Action Tracker. The CAT Thermometer
Credit: Climate Analytics and NewClimate Institute

Pathway to 1.5°

Net global greenhouse gas (GHG) emissions



Global emissions pathways consistent with implemented policies and mitigation strategies

Source: AR6 Synthesis Report - Climate Change 2023, IPCC, Figure SPM.5

Key decarbonisation "shifts" required in the Built Environment industry:

Shift 1:
Retaining and Retrofitting existing buildings

Shift 2:
Decarbonisation of energy and all

Shift 3:
Design excellence, disruptive innovation, technology and regenerative design.

Shift 4:
Alternative materials, carbon-capture and carbon-sequestration

Shift 5:
Decarbonisation through Behavioural Change

Furthermore, we must also be cognisant of the significant inequality that faces the population, much of this must be addressed through improved infrastructure and buildings. This, coupled with population growth and urbanization, reinforces the fact that our remaining carbon budget must be targeted at where it can provide most value.

Decarbonisation through valuing Existing Buildings

"In Praise of Retrofit" : an homage to Edition 5

Ramboll DESIGN periodical, issued in June 2023 emphasizes the importance of addressing existing buildings' environmental impact, as 95% of the structures projected for 2030 are already built and often fall below modern environmental standards. The focus on greening existing structures through retrofits, refurbishments, and alterations, and developing the skills, teams, and knowledge in this area is necessary.

The edition argues that the demolish-and-rebuild development model has a similar environmental impact to deforestation, making it vital to explore alternatives. To make informed decisions about retaining existing structures, assessing the residual life of these buildings is crucial. While a "build nothing" scenario is impractical given societal development needs, a more achievable approach involves smart planning and technology utilization to reduce the demand for new construction. The combined effect of limiting embodied carbon and net positive operational carbon will allow us to work towards full decarbonisation in the built environment.

We must learn to stop replacing what we already have and place greater value on our existing assets, valuing the carbon investment they represent.

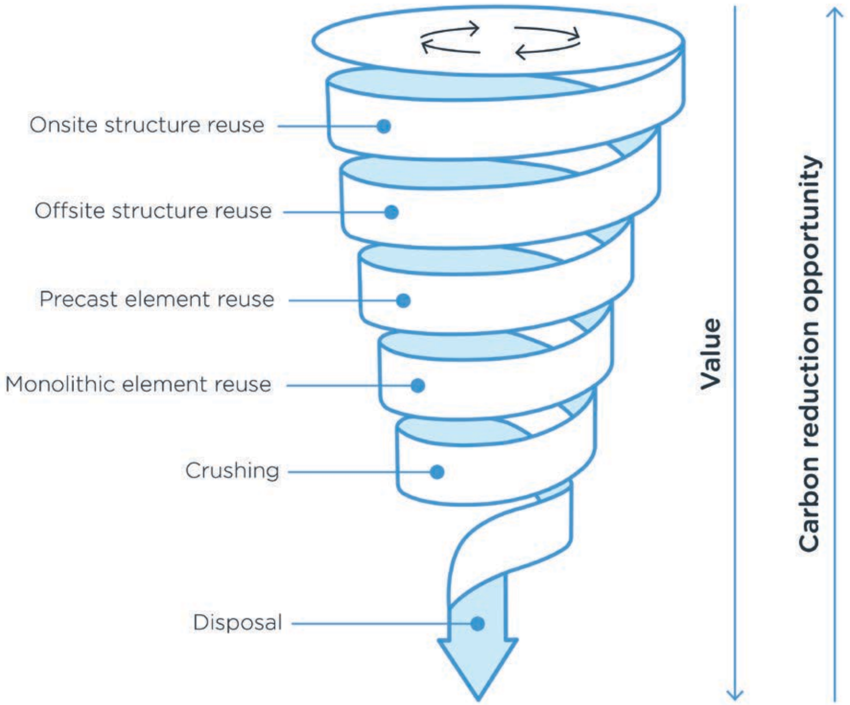
"Every existing building has the right to be heard."

Golden Mile Complex
Also known as Little Thailand, the building is slated for redevelopment. Designated as a conserved building by the Urban Redevelopment Authority, its physical structure is expected to be preserved.

Photo credit: Darren Soh

Understanding the 'carbon value' of existing buildings is key to its use as a broader decarbonisation lever in the built environment. Embracing an existing building hierarchy, which prioritises reuse, adaptation, and careful deconstruction over demolition, offers substantial carbon benefits.

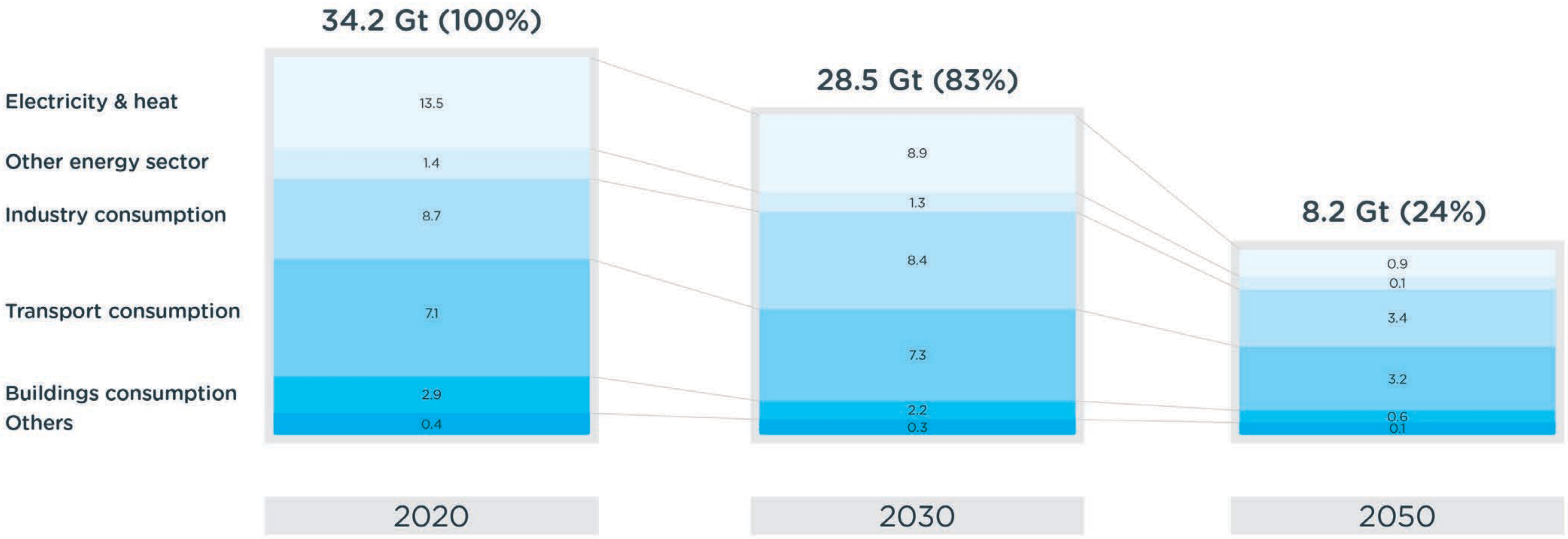
Reusing and adapting existing structures avoid carbon emissions by reducing the material demand of new buildings. In addition, it cuts down on waste generation and supports the principles of a circular economy. Whilst not all buildings will be suitable, every effort must be made to see our existing buildings not as a constraint, but a catalyst for creative design. We must take advantage of the history of a building to tell a story, or possibly reuse its elements in a new way. Existing buildings offer us many opportunities for the future, and if we are to meet our climate goals we must make full use of the life they still have to give.



"Longevity of the buildings we design is by default a decarbonisation strategy."

Decarbonisation of Energy and all...

"In our efforts to decarbonise the built environment industry, decarbonisation of energy is key."



The industry is highly energy-and electricity-intensive. Globally, over 80% of annual GHG emissions come from energy sources. The predominant component of operational carbon is the energy footprint. Embodied Carbon (EC) of most construction materials is essentially their energy footprint.

Concrete, which is an exception to this, has approximately 60% of its embodied carbon attributed to the sources of energy used to extract raw material, transportation, heating, and grinding clinkers in cement factories. Over 90 percent of EC of normal concrete is in the cement alone. The other 40% of EC of normal concrete comes from the carbon release due to the pulverisation of base clinkers, and from the actual hydration process leading to the hardening of cement/concrete.

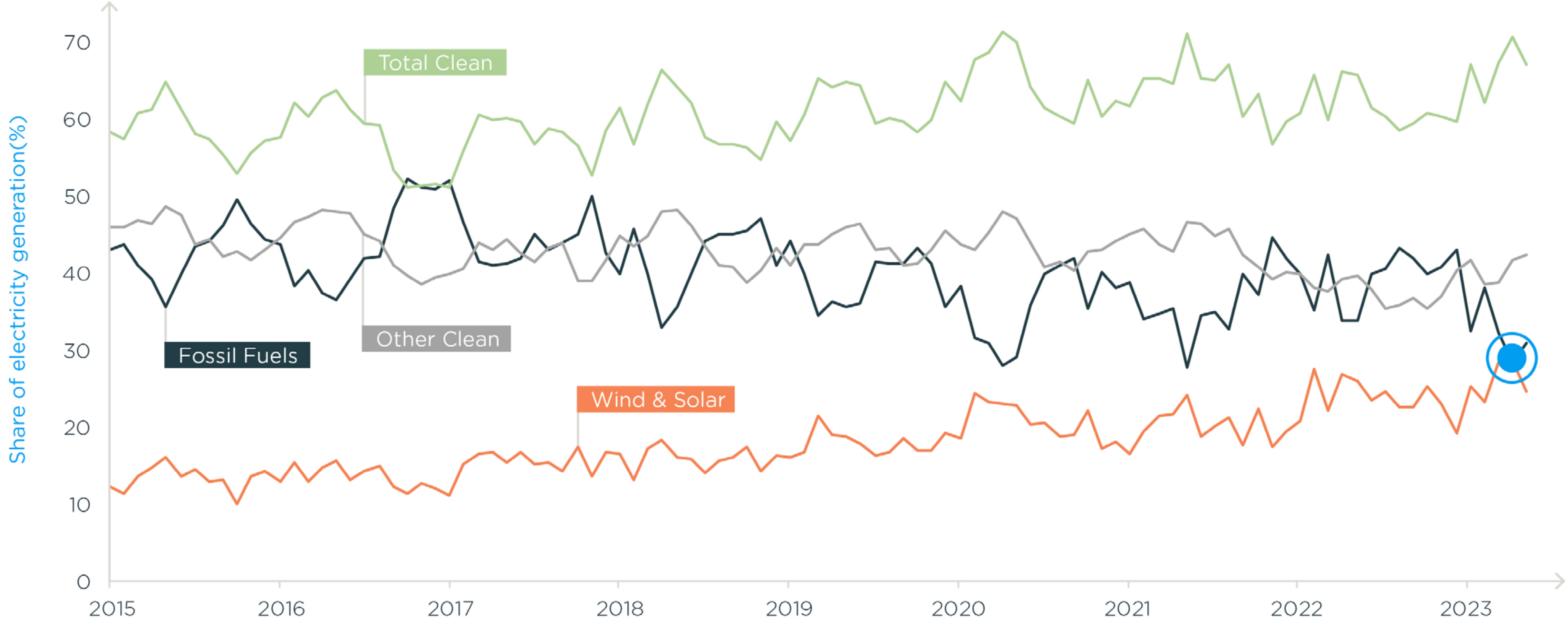
The energy sector must therefore lead in the decarbonisation of the industry. Projections for such reductions by the IEA are encouraging. It is projected that GHG emissions in the energy sector will drop by 17% by 2030. The reduction is projected to continue until 2050 when it will be reduced by 76% from the baseline figure of 34.2 Giga ton in 2020. With such large reductions, the built environment, our buildings and bridges, etc, will have a fraction of their current EC by 2050.

Percentage of carbon footprint in relation to year 2020

Source: Internatinal Energy Agency (IEA), World Energy Outlook 2021

Wind & Solar produced more EU electricity than Fossil Fuels in 2023

On this journey, the electricity production sector is making great strides. As recently as last year, the EU electricity production crossed an important milestone; the EU is now producing more of its electricity from renewable sources than from conventional fossil fuel sources. Conversely, it is now cheaper to produce electricity from a brand new wind/solar-powered power station than from a brand new coal-powered equivalent. Challenges with the current grids, and their adaptability to renewably sourced power remain persistent, but solutions are within reach.



Energy

Huge strides have been made in the energy performance of our buildings and as a result it is now possible to create buildings that are net zero in operational energy – meaning they have such low energy demand that this can be met through onsite and offsite renewable energy sources. Passivhaus levels of performance are also starting to become increasingly common, and it is clear that there are technical and commercially suitable solutions for new buildings. This does not mean the problem is solved; delivering these projects is still challenging and requires the necessary skills, knowledge, supply chains and most importantly, the drive to ensure they are a success.

There is now also a recognition of the sheer size of the refurbishment challenge – there are a vast number of existing buildings that require deep refurbishment. Many of these buildings have cherished heritage that must not be disturbed but most are simply rather stubborn and unyielding to modern construction; their successful and effective refurbishment requires the only source we have in abundance – human ingenuity.

One of the key challenges in the deep refurbishment of buildings, especially at a portfolio level, is understanding the best suite of options to implement.

There are a large number of different operational system options as well as fabric upgrades that can be undertaken – which is the most efficient and lowest risk?

Ramboll has been developing a tool to address this challenge. Zebrafish (as featured in Edition 6 published in September 2023) is a system that allows the rapid analysis of thousands of potential system upgrades to determine the most appropriate options for a client.

Other Clean: hydro, nuclear, bioenergy and other renewables
Fossil Fuels: Coal, gas and other fossil fuels
Total Clean: is the sum of Wind & Solar with Other Clean.

Source: Monthly Electricity Data, Ember

Decarbonisation through Design Excellence, Disruptive Innovation, Technology and Regenerative Design

The best approach to decarbonising buildings is to just use less material. This can be achieved through excellence in design.

High labour costs in the late twentieth century represented a departure from thousands of years of ambition to use less material in buildings. But now, using less is resurging, encouraging a return to craft in design and construction.

Modern engineering has accomplished incredible architectural monuments. But defying gravity comes with enormous carbon cost, which becomes increasingly corporately and socially unacceptable. A well-designed building is an elegant resolution between competing requirements. Engineering must be purposeful and a vital part of the genesis of the idea, rather than an exercise in post-rationalisation which disproportionately adds carbon to buildings.

Excellent design starts with challenging the design brief. Can the design be contextualised differently? Can it ask for less physical ambition without diminishing the experience? Can it better serve the client and also the environment? The challenge to clients and collaborators promotes time to reflect on whether the business-as-usual is still relevant. Design is rooted in empathy, so the communication and narrative that connects clients to engineers and designers are completely vital.

Design excellence then promotes creative thinking to establish better, and new ways to form buildings. Innovation is borne of big ideas that use less materials and therefore less carbon. Business-as-usual cannot credibly continue in a carbon-conscious world. Disruptive innovation is therefore vital if buildings and the construction industry are to remain credible.

Optimisation of building elements and systems to remove unnecessary material is vital for low-carbon outcomes. The reputation of engineers as cautious designers is not unfounded, and we promote the incremental gains that arrive with optimisation. This can be taken further by advanced optimisation and technology in the design process to produce lower-material designs that contain less carbon. Topological optimisation spatially arranges material where it is most needed, and the use of evolutionary solvers allows designers to test an exhaustive range of options and allow natural selection to perfect the design. For designers looking to adopt new but tried-and-tested techniques, biomimicry allows designers to take inspiration from nature to create a regenerative design paradigm.

Forming optimised and unusual shapes requires craft from contractors. Such techniques are evolving quickly, and advanced forms are becoming viable, facilitated by advanced and additive manufacturing; all serve to provide a practical delivery of advanced design thinking.

Advanced and Additive Manufacturing
Experiments on 3D printed concrete fin walls

SUTD Additive Manufacturing
A 3D-printed clay mold used to cast concrete in. Once the concrete is cured, the clay was washed off to reveal an elegant sculpted concrete structure

Decarbonisation in the built environment is about using design as a lever of innovation. Operational energy and carbon associated with existing buildings and infrastructure must be addressed, but the materials used to achieve this, as well as those required to meet ongoing development must not excessively draw down our carbon budget. Through brilliant design approaches, we can achieve the retention and refurbishment of our existing assets, continue development, whilst meeting our carbon goals, though it is not going to be easy.

Carbon Distribution

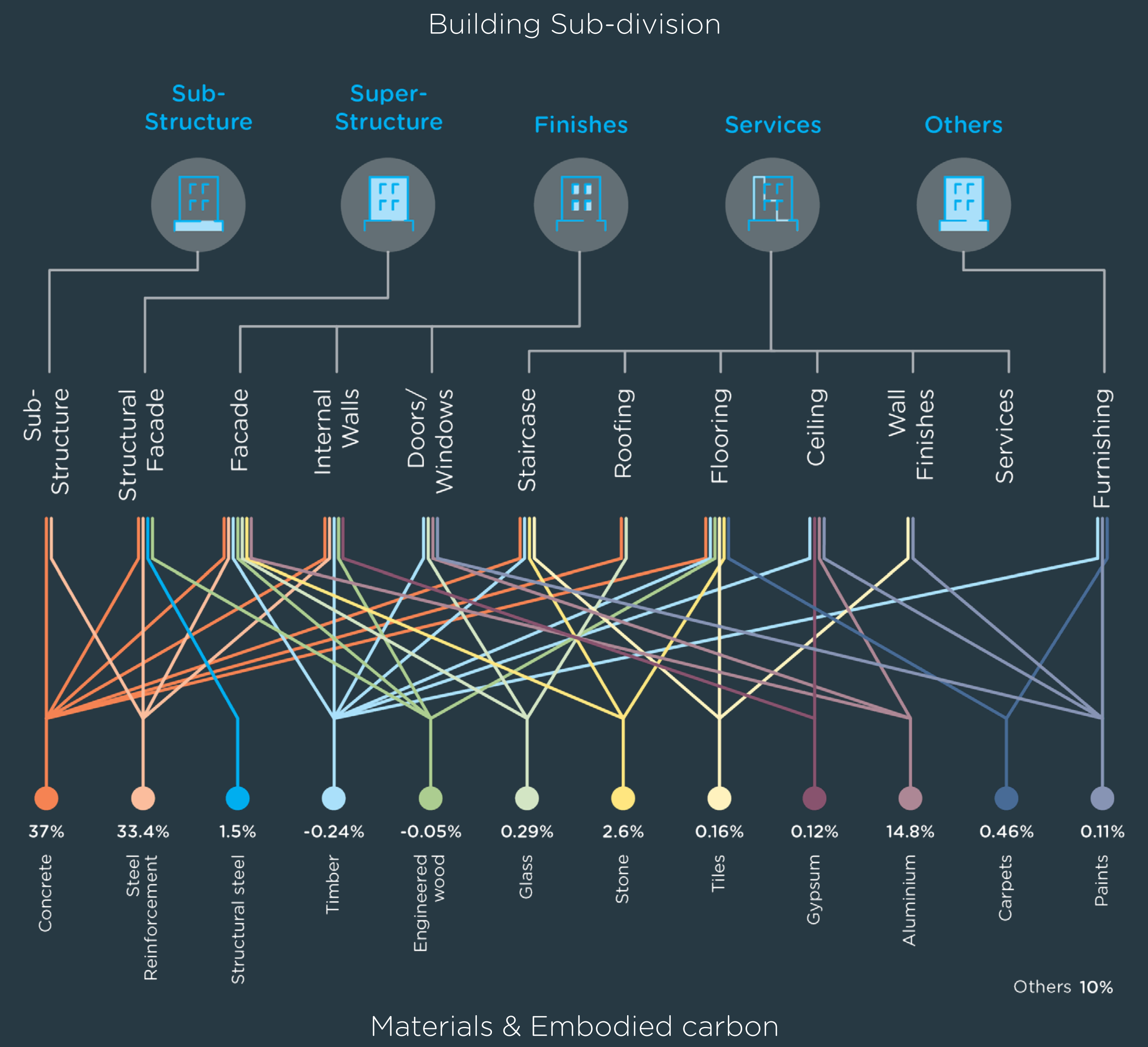
two main contributors of CO_2

Concrete & Steel >70%

Concrete
37%

Steel
35%

"Over 2/3rd of all carbon in most buildings come from 2 materials!"



Carbon Matrix
The Embodied Carbon (EC) distribution of Hotel Equatorial, in Malaysia

Materials

Traditional Materials

The embodied carbon associated with the creation of new construction materials has started to come under a lot more scrutiny, as its relative contribution to a building's whole-life carbon has grown following the progress in reducing operational carbon. There is now a vast swathe of guidance and information on the embodied carbon of materials. However despite this awakening, 20th century engineering materials still dominated, with concrete and steel making up the majority of the carbon in new materials.

Concrete and steel are also some of the most difficult materials to decarbonise, they both require energy-intensive processes that traditionally involved burning large quantities of fossil fuels. Cement is the active ingredient of concrete, which also represents the majority of the embodied carbon. The production of conventional Portland cement requires high temperatures, mainly met through the burning of fossil fuels.

There is a huge amount of research going on to identify other materials that can replace traditional cement, some based on innovations in existing technology and some developing wholly new chemistry. However, the biggest challenge in concrete is the sheer volume produced and used, at relatively low cost. The materials of traditional cement are abundant and there is a vast existing infrastructure in place. Technologies that seek to disrupt or replace this face many challenges.

Primary steel production is still dominated by the blast furnace, utilising metallurgical coal to provide enough heat to extract the iron from ore and provide the carbon to create the alloy of steel. The remelting of recycled steel offers a longer-term solution to meet our apparently insatiable demand for steel; however, we still require primary steel, and there will always be a need for some high-performance primary steel. There are technical routes to produce low-and-even zero-carbon primary steel using hydrogen, which has been produced using renewable power. Several steel manufacturers are developing the associated technology for this, and a pilot facility was launched in Sweden in 2023.

In addition to efforts to fundamentally reduce carbon in the production of concrete and steel, both industries are also targeting Carbon Capture and Storage (CCS) technology to achieve their long-term net zero goals. While this technology presents significant technical and commercial challenges, it may be a necessary step in continuing to utilise the benefits of these materials and stay within our 1.5 degree carbon budget.

SMU Connexion (MKPL Architects)
A five-storey institutional building designed as a net zero energy building and constructed using mass engineered timber.

Photo credit: Singapore Management University

World of Volvo, Gothenburg, Sweden by Henning Larsen, Optima Engineering, BRA Group and Wiehag

Modern meets tradition: Sweden's rich heritage of wooden architecture is blended with innovative glulam construction.

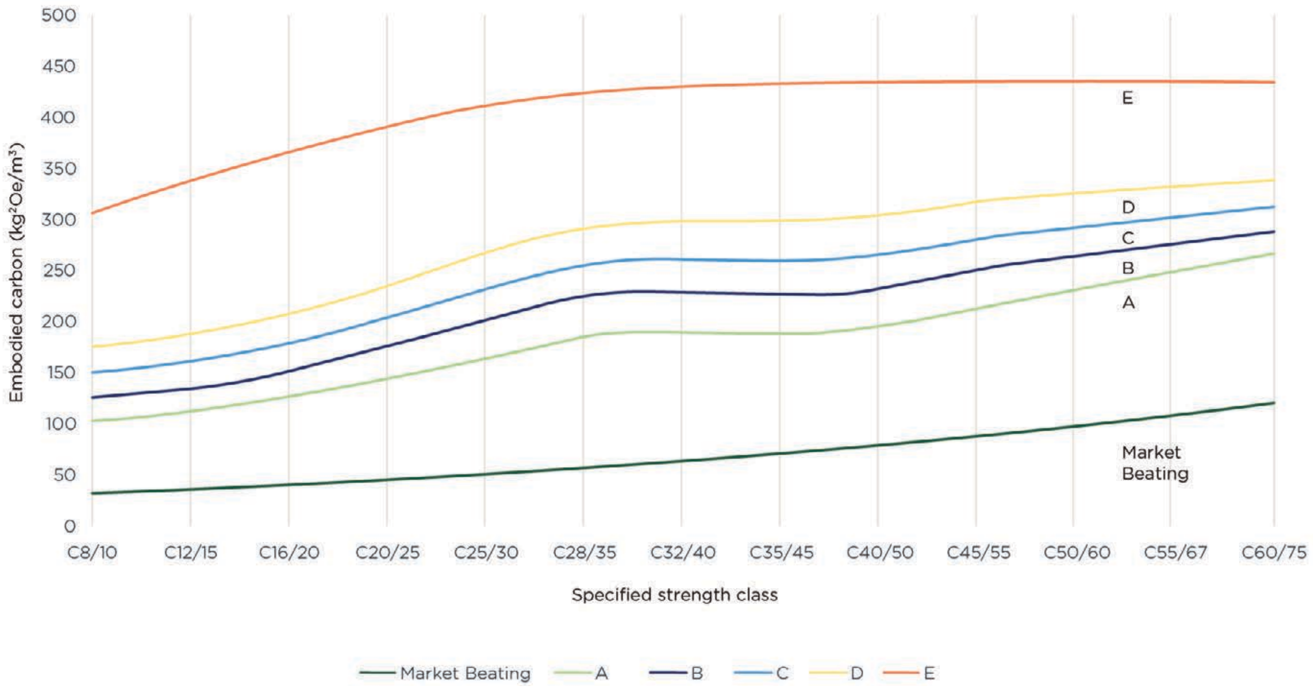
Alternative Materials

While it is important to decarbonise traditional engineering materials we must also strive to use less common, lower carbon materials as well. Particularly, where these can offer other benefits, such as carbon sequestration, improved air quality, enhanced biodiversity and broader positive sustainability impacts.

In this respect, timber plays a key role in replacing some of the higher carbon materials in construction. There is a lot of good information on use of timber, in industrialized forms such as Cross-Laminated, Glulaminated or others. Examples of successful deployment of these as structural materials in buildings are aplenty. (see SMU Connexion, and World of Volvo featured here)

Mycelium-based materials are low-cost, lightweight, biodegradable, fire-resistant, acoustic, and thermal insulators. When combined with an organic mixture to create an innovative building structure or material, mycelium can grow without requiring any additional energy input. Furthermore, at the end of the structure's life cycle, it can be composted, resulting in zero waste or by-products.

Another example is Bamboo Veneer Lumber (BVL), a high-performance structural lumber synthesized from bamboo fibres and a bio-compatible binder. It is suitable for constructing modular prefab buildings' structural beam applications. BVL is up to 3 times stronger and more dimensionally stable than timber. It is weather-resistant and resistant to decay and rot.



Carbon intensity benchmark for concrete based on specified strength class

Source: LCCG Market Benchmark for Embodied Carbon, Normal Weight Concrete, LCA Stages A1 to A3 (2023 Version 2.1)

This figure is the Low Carbon Concrete Group's carbon intensity benchmark for concrete based on real mix data from the UK. Following publication in the Low Carbon Concrete Routemap, of which Ramboll is a co-author of, the LCCG's carbon benchmark has become a key reference to understanding carbon in concrete. Whilst a concrete mix must be assessed in the context of project-specific criteria, the benchmark helps to inform its relative performance and focuses attention on its embodied carbon. Ramboll has started to use this benchmark to specify carbon performance for concrete as part of a project-specific lower-carbon concrete plan which sets out all opportunities to save carbon on a project.

Decarbonisation through Behavioural Change

As the world wrestles with climate change, our approach at Ramboll's SMART Futures revolves around leveraging SMART technologies and behavioural design techniques to transform human interactions with our surroundings. A sustainable future depends not just on the design of our built environment, but on how we engage with it.

Imagine a building where user decisions are subtly steered towards greener choices. For instance, by integrating real-time weather data with SMART technologies, we can encourage users to open a window instead of relying on air conditioning, providing contextually relevant nudges for sustainable action.

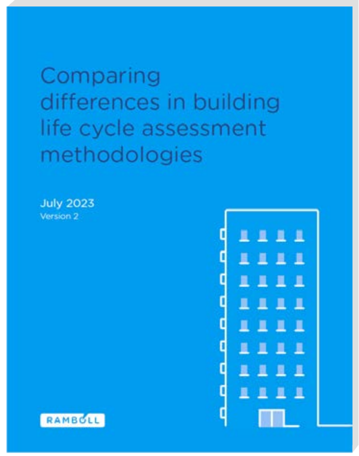
With a focus on individual projects for our clients, we have conceptualised tools like a Carbon Wallet application for a healthcare client in Singapore. This unique initiative turns sustainability into a compelling, interactive endeavour, making being green not just appealing but almost addictive.

Collaborating with architects, Ramboll brings a thorough understanding of user behaviour to the design process. We select materials and propose designs that psychologically trigger sustainable behaviours. Our goal is not just reduced energy consumption or waste; it's about inducing a deep-seated change in how people perceive and relate to their environment.

Closing the gap isn't just about design; it is about redefining lifestyles and driving behavioural change towards a decarbonised future.

Fusing technology with natural beauty
This data-driven holographic sculpture resonates with urban dwellers, reflecting the community's environmental impact and inspiring a shift in perception and behaviour towards a more regenerative relationship with our surroundings.

Delivering Decarbonisation



Ramboll's whitepaper - LCA of Buildings
Comparing differences in building life cycle assessment methodologies

Scan this QR Code for the full document

We cannot meet our decarbonisation goals without the ability to easily and consistently measure the carbon associated with the materials and operation of our built environment. Furthermore, we must have a clear trajectory for decarbonisation that aligns with our carbon budget. Ramboll's carbon assessment and LCA experts across the globe have been working together for several years to develop a reliable internal benchmarking database which allows us to collect our carbon assessment data and accommodate a large number of different measurement methodologies. Ramboll's white paper on this topic has provided insight on the significance of different methodologies and what they can mean when comparing different designs or buildings.

We have set out clear strategic goals for the decarbonisation of buildings designed by us: This is relative to our 2021 designs and is applicable to all buildings over 1000m[2].

We call this the #Ramboll50%

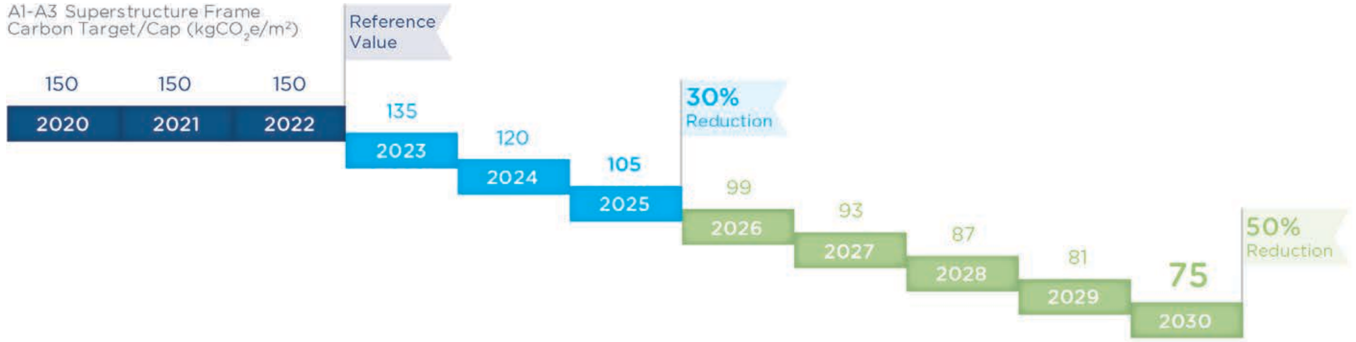
Many other industry players, some with genuine, self-motivation, and conscientious concern for the environment, have made similar pledges.

This is a good start.

Such commitments to reduction are now in urgent need of hard, fixed, and verifiable numbers on the actual quantitative amount of embodied and operational carbons of the projects we are engaged with. A 50% reduction in embodied carbon by a certain date in the future, is meaningless and can smack of potential "green washing", if this is not directly linked to a specific number.

The question is 50% of what? When do we know we have achieved 50% if we do not actually have a defined and reliable starting number? How do we know we have arrived, if we do not have a defined destination?

Of Small Steps and Giant Leaps



A voluntary carbon reduction commitment by Ramboll

To respond to such valid and plausible questions and concerns, Ramboll is committing to a hard limit/ceiling on the embodied carbon of all our building projects. Our 2021 reference value is: 150kg CO_2e/m^2 GFA.

This relates to:

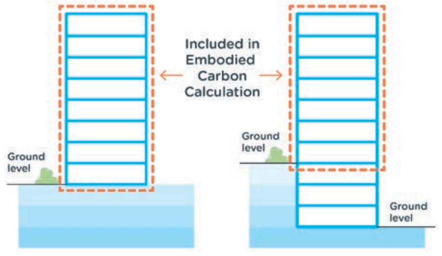
- Stages A1 to A3 cradle-to-gate of LCA,
- Portions of the structural frame that are above ground level,
- Residential buildings with spans of up to 6m, and up to 10-storey high,
- In areas with low to moderate wind speeds, and no seismicity.

Appropriate "multipliers" are also devised to account for other building genres, like taller buildings, offices and mixed developments, buildings with larger spans, etc.

While many of our current building designs, particularly those in the Nordics, are doing better than these limits, we encourage all our buildings globally to work within these limits, and invite all our industry partners to join us on this small step, helping to transform this into a giant leap as we expand the scope of this commitment to all disciplines, and all stages of LCA.

We will include additional aspects of the building in the future as carbon assessment becomes more mature. Our targets reflect the fact that different markets, locations and clients are starting the decarbonisation journey at different points, but the ambition of reduction is the same for all.

Our target is not a minimum performance level; we see it as a ceiling that we must stay below of. We do not have all the answers yet, but we are building the skills, tools and capabilities to partner with our clients to ensure that we all collectively work within our shrinking carbon budget.



Embodied Carbon Calculation
Superstructure above Ground level is included in our computation of Embodied Carbon

Ramboll is a global engineering, architecture and consultancy company founded in Denmark in 1945. Across the world, our 18,000 experts create sustainable solutions.

We combine local experience with a global knowledge base to create sustainable cities and societies, driving positive change for our clients, stakeholders and society. We enable our stakeholders to realise their goals and navigate the transition to a more sustainable future.

Bright ideas. Sustainable change.

DESIGN is a periodical publication by the Design Excellence Board (DEB) within the Buildings Market in Ramboll.

The publication promotes and articulates latest ideas on matters relating to design, technology, environment and ethos within the design industry and the built environment, at large. It aims to address key issues facing contemporary design professionals, including our evolving relationship with the natural environment; as well as pressing political and social agendas for the built environment.

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