Sustainable Urbanisation: Decarbonising Southeast Asia's Built Environment

The case for built environments that are both regenerative and function as carbon storage vehicles

hello tomorrow ASIA PACIFIC

We need to rethink our cities.

Transforming our Built Environment

The building and construction industry plays an integral role in orchestrating and materialising our transition towar-ds sustainable urbanisation. As things stand, the built environment/ construction sector is responsible for more greenhouse gas (GHGs) emissions than any other sector of the economy — more than transportation, agriculture, and industry[1].

1 **Sustainable Brands, Operating vs Embodied Carbon in the Built Environment, 18th November 2020**
https://sustainablebrands.com/read/product-service-design-innovation/operating-vs-embodied-carbon-in-the-built-environment-the-difference-and-why-it-matters

More than half of the world's population lives in cities and the problem compounds as this number continues to rise dramatically. Consequently, players in the built environment sector bear the dual burdens of ushering humanity into the largest wave of urban growth in human history while drastically reducing its carbon footprint.

Buildings contribute to carbon emissions on multiple fronts: in how we extract and transform natural resources, how we construct buildings, how we use them, and how we dispose of them.

To keep up with the demands of urbanisation, the global building floor area is expected to double in footprint by 2060[2], or 230B m² of new floor area added to our global building stock[3]. This is concerning because on a global scale the construction sector is already responsible for 36% of energy consumption, 38% of energy-related carbon dioxide (CO_2) emissions, and 50% of resource consumption and materials extracted[4].

We view this as a 230B m² opportunity to build greener cities by leveraging emerging technologies to develop solutions that are not just more sustainable, but that are regenerative.

Progress has commenced – we are seeing architecture, design, and technology take inspiration from nature to green our cities. Smart technologies such as digital twins are also helping us improve our transportation, air quality, energy consumption, urban planning etc.

While promising, the progress needed is still both profound and radical. Sustainability along the building and construction value chain needs to be addressed on multiple levels. A holistic view of the built environment's whole carbon life cycle is a necessary framework from which to understand the carbon contribution of each segment in this supply chain (Fig. 1).

Seen through the prism of deep technology, each element within the cycle holds its own set of technological challenges and opportunities for improvement. Not merely at the individual level, but at the system level to ensure that the integration of new technologies benefits all stakeholders. From an innovation perspective, these trends present a unique opportunity to maximise the potential for emerging technologies to better material, construction techniques, and production methods.

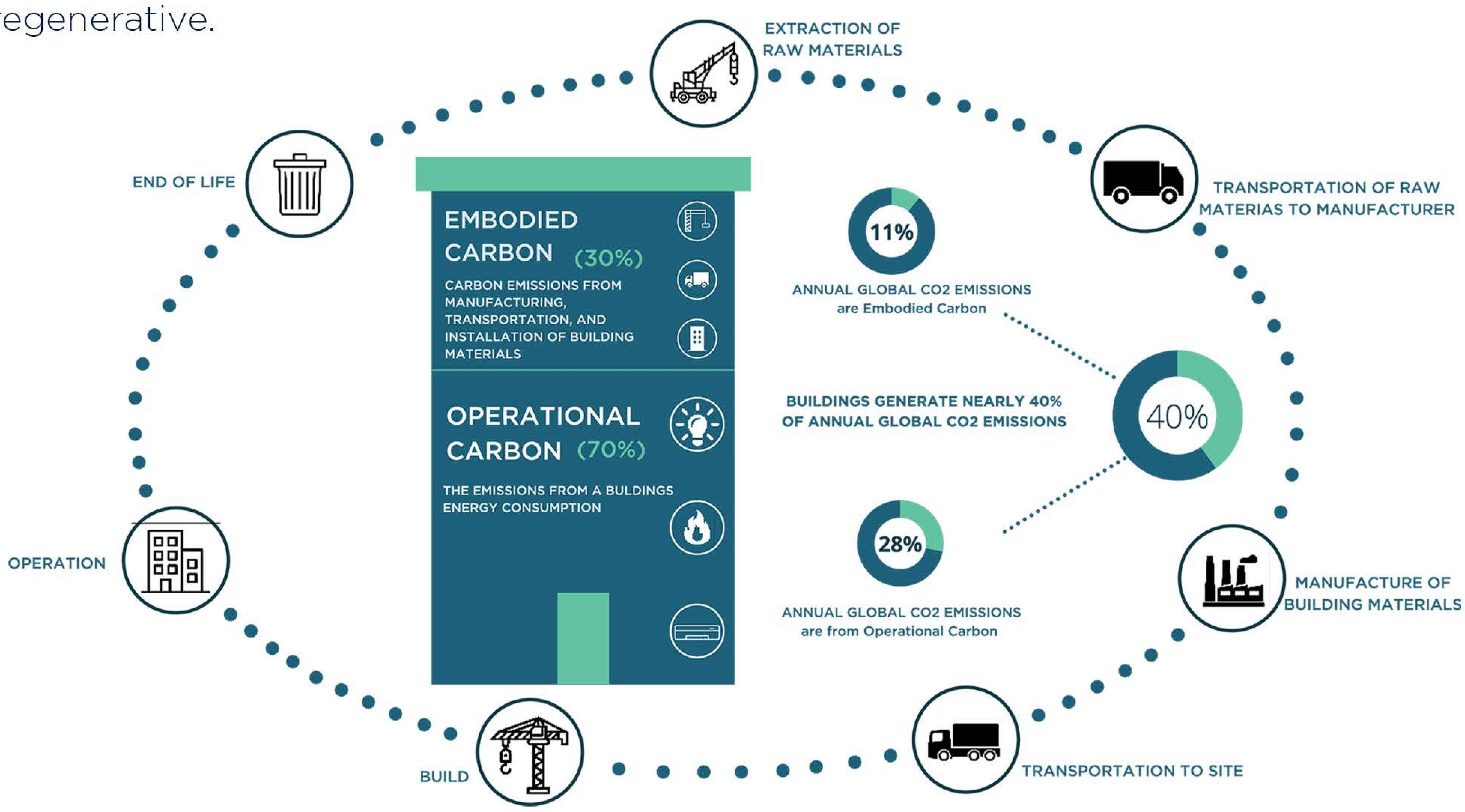

Figure 1. The Whole Carbon Life Cycle
Source: Hello Tomorrow Asia Pacific

2 **GlobalABC Regional Roadmap for Buildings and Construction in Asia 2020-2050**
https://globalabc.org/our-work/forging-regional-pathways-global-and-regional-roadmap
3 **Architecture 2030, Why the Building Sector?**
https://architecture2030.org/why-the-building-sector/
4 **WorldGBC Advancing Net Zero Status Report 2021, 10th June 2021**
https://issuu.com/vburrows/docs/worldgbc_anz_status_report_2021_issuu/8

We set our scopes on Southeast Asia as a diverse case study for the developing world. Southeast Asia exemplifies this segment of the global population making the rural-urban transition, with 100M more people expected to migrate to cities by 2030, with medium-sized cities forecast to drive 40% of the region's growth. As a ripple effect on the built environment front, the region is positioned to take on a significant part of the global new build demand. Continued growth in floor area could represent nearly half of the world's new construction by 2040[5].

Southeast Asian countries face a set of unique circumstances within the building and construction economic value chain, and challenges which are specific to the region. They are exceptionally sensitive to manufacturing and export policies of other countries, and to economic fluctuations.

The global COVID-19 pandemic has only accentuated this reality with raw material shortages and the unprecedented strain on global demands.

The region is also particularly vulnerable to the ill-effects of climate change[6]. Rising sea levels threaten all major cities in the region including Jakarta, Bangkok, Singapore, and Manila.

Naturally, regulatory frameworks (building codes, green certifications, etc.) vary significantly from one country to another, presenting challenges for the transferability of technologies. Across the region, these frameworks have also struggled to evolve with the considerable growth in demand for new buildings in today's context. Less than half of countries in Asia have mandatory or voluntary building codes or certification programmes in place[7].

5 **GlobalABC Regional Roadmap for Buildings and Construction in Asia 2020-2050, Page 9**
https://globalabc.org/our-work/forging-regional-pathways-global-and-regional-roadmap
6 **World Economic Forum, Southeast Asia to bear the brunt of worsening global climate, IPCC warns**
https://www.weforum.org/agenda/2021/08/southeast-asi-weather-extremes-global-warming-2030-ipcc-report/
7 **GlobalABC Regional Roadmap for Buildings and Construction in Asia 2020-2050, Page 22**
https://globalabc.org/our-work/forging-regional-pathways-global-and-regional-roadmap

SINGAPORE

Affectionately termed a "garden-city", faces a plethora of supply-driven and climate change-related challenges. A third of Singapore is less than 5m above sea level[8], making it highly vulnerable to the impacts of climate change. It grapples with the urban heat island effect (urban areas tend to be warmer due to the replacement of natural land cover with buildings and other infrastructure that retain or produce heat). With a high population density of 8,358 per km^2, the lack of supply of both land and materials, coupled with consistent demand, have caused housing costs to skyrocket[9].

This city-state stands out for its advanced green certification frameworks and sustainable urbanisation plan. The Building and Construction Authority is a driving force behind this and works to coordinate industry actors to achieve the Singapore Green Building Masterplan, its "80-80-80 in 2030" goal – 80% green buildings by GFA, 80% of new developments by GFA to be "Super Low Energy" buildings from 2030, and 80% improvement in energy efficiency for best-in-class green buildings by 2030.

INDONESIA

Indonesia is the world's largest archipelago country and has extensive coastlines. Jakarta, its capital and major business hub, is the fastest sinking city in the world – it sinks by almost 20cm every year largely due to excessive groundwater abstraction[10]. Urban expansion has consumed large swathes of cropland and vital ecosystems such as mangroves, which are a key source of protection from flooding.

Green buildings will present plenty of investment opportunities – not only in new construction but also in the retrofitting of existing/ older buildings. The International Finance Corporation and the Green Building Council Indonesia had set out to turn 20% of new construction projects into green initiatives in select cities by 2021[11], and have in Jakarta helped lay over 18M m^2 of new floor area, through which over 700,000 tonnes of carbon emissions have been negated.

8 **National Climate Change Secretariat, Impact of Climate Change and Adaptation Measures**
https://www.nccs.gov.sg/faqs/impact-of-climate-change-and-adaptation-measures/
9 **Worldometer Singapore**
https://www.worldometers.info/world-population/singapore-population/
10 **BBC News Indonesia, 13th August 2018**
https://www.bbc.com/news/world-asia-44636934
11 **IFC, IFC Partners with IAI and GBC Indonesia to Promote Green Buildings, Improve Climate Resilience**
https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=24887

VIETNAM

Vietnam has been incredibly appealing to energy-intensive industries like steel and cement, as industrial electricity prices are low. The country's energy production relies primarily on oil and gas, followed by hydro and wind power. Rural areas mostly subsist on agriculture and are extremely vulnerable to climate change disasters. The country's diverse geography means it is hit by typhoons, landslides, floods, and droughts, and extreme weather events are expected to worsen further[12]. Rural populations are forced to wean off agricultural dependency, moving to cities to seek alternative means of income as well as for safety.

Sustainable buildings have gained momentum in Vietnam. The Vietnam Urban Green Growth Development (VGBC) Plan 2030's primary objectives include, among others, improving urban resilience to climate change and reducing GHG emissions[13]. Under this plan, Vietnam is also advancing over 20 cities, including Hanoi, Ho Chi Minh City, and Da Nang, to become smart and sustainable cities. In 2010, the VGBC introduced a set voluntary green building rating system called LOTUS, and covers new construction, existing buildings in operation, as well as homes and small non-housing projects.

12 **Mongabay, New climate change report highlights grave dangers for Vietnam**
https://news.mongabay.com/2018/10/new-climate-change-report-highlights-grave-dangers-for-vietnam/
13 **The Global Green Growth Institute Press Release, 4th October 2018**
https://gggi.org/conference-on-implementation-of-viet-nam-urban-green-growth-development-plan-to-2030-and-circular-of-urban-green-growth-indicators/

We gathered insights from a diverse set of stakeholders, each playing a different role within Southeast Asia's built environment. Our panel comprised materials manufacturers, property developers, real estate management, and regulatory agencies. A few shared perspectives on the industry's path to sustainability stand out:

- Concerted and collective action is needed at an industry level
- The reduction in embodied carbon is difficult and must be prioritised
- Consumer behaviours and market perceptions must be changed with education
- Legislation and regulation would boost momentum and accelerate greening of the industry

Here we focus on the most pressing challenges that, in our opinion, technology has the greatest potential to help address.

DEPLETION OF OUR NATURAL RESOURCES

The built environment is built on the extraction and conversion of natural resources. These materials are finite in nature, and we tend to overlook the depletion and environmental impact associated with their extraction. Core elements include iron, aluminium, copper, clay, sand, gravel, limestone, wood, and stone.

Let's consider sand. The construction industry is the number one consumer of sand. 40-50B tonnes of sand are mined annually[14], and the environmental consequences of excessive sand mining include altering riverbeds, forcing rivers to change course, and eroding banks (leading to flooding).

14 **United Nations Environment Programme, Rising demand for sand calls for resource governance**
https://www.unep.org/news-and-stories/press-release/rising-demand-sand-calls-resource-governance

The challenge is to shift from an exploitative to a generative mindset. Our white paper Nature Co-Design: A Revolution in the Making[15], published in collaboration with the Boston Consulting Group, expounds on a design approach where biology, material science, and nanotechnology meet, leveraging nature's design principles and manufacturing capabilities at the atomic level. Solutions such as regenerative or augmented materials not only address the challenges of diminishing finite resources and climate change, but shift the paradigm and present new economic opportunities altogether. The potential for nature co-design in building and construction is profound, and will go a long way in helping countries and corporations meet their carbon reduction commitments.

REDUCING HARD-TO-EVADE EMBODIED CARBON

The production of steel and cement are particularly carbon-intensive – they are the industry's two largest sources of CO_2 emissions. Cement is notoriously difficult to decarbonise, but is second only to water as the world's most widely used commodity.

Achieving "zero embodied emissions" requires progress on several fronts, namely: material optimisation, creation of low- to zero-carbon materials, and carbon-sequestering materials and methods.

To decarbonise the sector's supply chain, the World Economic Forum and the Boston Consulting Group have identified seven areas of intervention (Fig. 2).

Carbon capture, utilisation, and storage technologies can tackle a fifth of emissions mainly from cement and steel production. This is one of the most expensive levers to develop, and currently rates the lowest in terms of maturity and technological readiness.

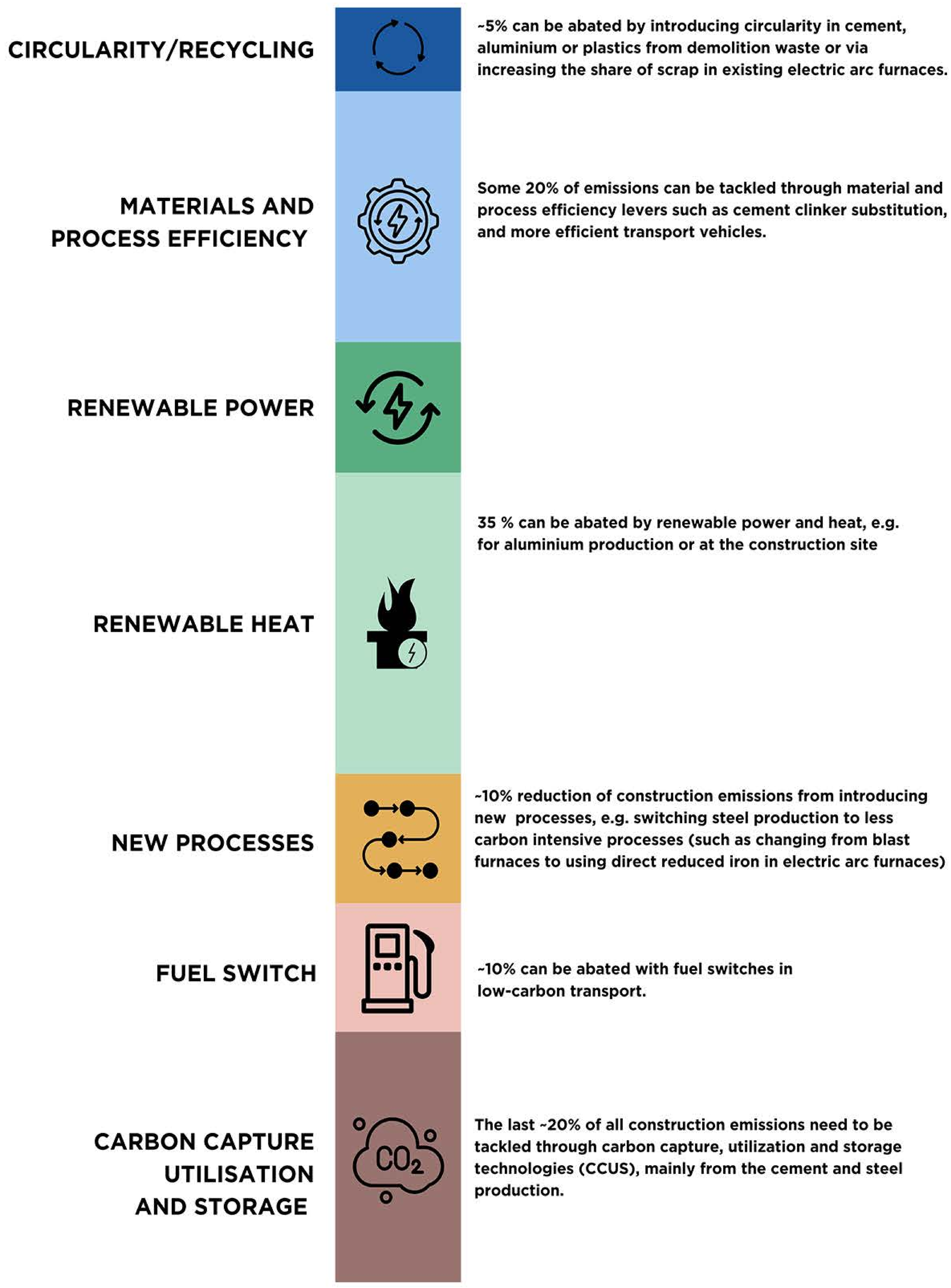

Figure 2. Decarbonising Supply Chain
Source: World Economic Forum & Boston Consulting Group
Insight Report January 2021
"Net-Zero Challenge: The supply chain opportunity"

REDUCING OPERATIONAL CARBON: UPGRADING EXISTING BUILDINGS AND CHANGING CONSUMER BEHAVIOURS

How we interact with and within our built environments is another source of carbon emissions. Operational carbon is recurring and must be accounted for during a building's entire lifecycle. It is estimated that the buildings that already exist today will continue to form two-thirds of the global building stock in 2040[16]. Unless we intervene now, and introduce significant consum-

15 **Hello Tomorrow & Boston Consulting Group, Nature Co-Design, A Revolution in the Making**
https://www.hello-tomorrow-apac.org/post/nature-co-design
16 **Architecture 2030**
https://architecture2030.org/why-the-building-sector/

ption upgrades, our existing building stock will continue to contribute substantially towards GHG emissions.

Retrofitting can help green the existing built environment, such as by optimising energy use with improved insulation, temperature management, and lighting systems, and by implementing renewable energy sources and circular resource systems.

Solutions are relatively plentiful, but often present high up-front costs and comparatively protracted payback dynamics. This makes it a multi-stakeholder process that could involve the likes of building authorities, owners, tenants, developers, financial institutions, system integrators, and other qualified professionals responsible for signing off on the integrity of structures and systems in this highly regulated environment. The age-old question remains: who is incentivised to initiate this undertaking, and more importantly, to pay for it?

In our conversation with Mr. Allen Ang (City Developments Limited, Singapore), he emphasises the importance of educating the consumer: *"operational carbon use and emissions are 50% controllable by the landlord, and 50% controllable by tenants ... behavioural changes are required of us all – the users of the buildings."*

IMPLEMENTING CIRCULAR ECONOMY PRINCIPLES

Circularisation could dramatically improve energy and waste management outcomes. Understanding the industrial ecology of our materials and waste, alongside the establishment of closed-loop systems, would offer tremendous opportunities to not only reduce emissions, but to derive value from what has traditionally been perceived as waste to be managed and disposed of.

The use of renewable/ waste energy, implementation of energy-efficient systems, and reduction of waste are all indispensable components of a sustainable value chain. Thereafter adaptability, durability, reusability, and recyclability also greatly impact the sustainability of any solution[17].

The industry tends to be highly "local" and, hence, fragmented. A circular economy, however, requires concerted collaboration that cuts across sectors. The Siam Cement Group (Thailand), for instance, is partnered with the Circular Economy in Construction Industry, a network of 21 organisations in the Thai construction sector, to drive industry-wide sustainability outcomes. They aim to reduce reliance on virgin materials by finding use of recycled materials, while also recycling/ reusing excess construction materials and making them valuable again[18].

The likes of building information modelling (BIM) could also help reduce construction waste from the outset, and aid in creating a closed-loop supply chain with zero waste-to-landfill targets.

17 Arkema & Hello Tomorrow Asia Pacific Interview
18 SCG Cement-Building Materials Co.,Ltd & Hello Tomorrow Asia Pacific Interview

Emerging trend: cognitive neuroscience and the aesthetics of the built environment

New design and construction principles, with a renewed focus on health and well-being, will reframe our relationships with our built environment. The term "urbanisation" induces mental images of soulless unfeeling boxes, stacked high in the sky, around which urbanites spend their days. Spaces aren't designed around people. Rather, people navigate the spaces on the spaces' terms. Spaces are designed to optimise the amount of lettable floor area, to facilitate as many persons living in a given amount of space, with primary needs met wherever possible.

In the wake of lockdowns brought about by the global COVID-19 pandemic, occupants, regulators, and developers have started rethinking the spaces in which we live. When freedom of mobility is restricted, the spaces we confine ourselves to need to be designed, above all, around our collective physical, mental, and emotional health.

*"**Neuroaesthetics is defined as "the cognitive neuroscience of aesthetic experience."** It's a field that seeks to understand the neural basis behind people's experiences of aesthetics, extending beyond beauty and art to the built environment. Beginning with mental health architecture, there is a growing trend: **designing spaces based on neuroaesthetics to improve our mental processes and well-being.***

*In some ways it's simple. **Architecture and design elements can elicit specific cognitive and emotional responses.** Curved contours, for instance, are perceived to be more pleasant than rectilinear contours, activating part of the brain's reward system. In other ways, because it's the brain we're talking about, neuroaesthetics can be just as complex as any other area of neuroscience."*[19]

The most forward-looking of developers and designers we have conversed with have begun paying attention to how inhabitants' living environments may affect them, and concepts such as biophilic design are increasingly being tapped upon. While this thought deviates from the main direction of this paper, the authors would like to encourage readers with influence in this space to consider the possible opportunities that emerge from this point.

19 **Neo.Life, Neuroaesthetics: Mental Health Facilities of the Future**
https://neo.life/2021/10/neuroaesthetics-mental-health-facilities-of-the-future/

Despite the challenges, some promising solutions from our Hello Tomorrow start-up network certainly bring hope of a more liveable and sustainable built environment.

Carbon Built

They cost-effectively produce concrete using CO_2 emissions (derived from a range of industrial sources and emerging direct air capture solutions), and work with reduced proportions of traditional Portland cement, while increasing the use of low-cost and low-carbon supplementary cementitious and filler materials. Concrete is cured through the incorporation of CO_2 in a process that does not require expensive capture, compression, or purification of the CO_2, or high temperatures, or elevated pressure.

With their lower-carbon formulation and by embedding CO_2 in the curing process, Carbon Built reduces concrete's carbon footprint while maintaining the high-performance specifications required for safety, and using concrete as a long-term store of carbon. Being price-competitive, this presents a compelling solution that significantly reduces the amount of embodied carbon (by >60%) of new building structures.

Brimstone Energy

Process emissions from the production of some of the world's most common building materials (such as cement, steel and aluminium) are difficult to decarbonise. Process emissions are a result of chemical reactions, and require entirely new chemical reactions for decarbonisation.

In our quest for low-carbon substitutes of our most-used materials, an oft overlooked aspect is how these materials work together. For example, ordinary Portland cement mixed with supplementary cementitious materials results in a protective alkaline environment that prevents steel from corroding, while steel provides strength and flexibility within concrete for as long as it does not corrode.

Brimstone Energy works on changing the chemistry of production without actually changing the end product, so the exact same material is produced while reducing CO_2 emissions and costs.

Compair
Apart from the usual suspects in the form of cement and steel, composites also feature prominently in the built environment – from insulation panels to external building envelopes.

Compair's unique self-healing high-durability resin reduces maintenance cost and manufacturing defects, and extends the lifetime of composites. By applying heat to problematic areas, the healable resin allows the composite to autonomously heal cracks and delaminations, regaining 100% of its original mechanical properties in minutes.

Their product and the underlying technology are an exciting foray into regenerative materials and engineering for future buildings. The material is also more easily recyclable, promoting circularity of new composite structures.

SolCold
With no energy required, SolCold's nano-technological material is no thicker than a sheet of paper, and harnesses heat from the sun to cool surfaces, rather than allowing it to warm. Once applied, the sunlight triggers a laser cooling of solids reaction in the material, providing its cooling effect. They use monochromatic and coherent laser light to cool crystals and semiconductors. A key change introduced to the technique enables using sunlight as the power source, replacing the laser.

There are numerous applications for this material, ranging from fabrics to thin film, and cover sheets to multilayer paints. We can envision reducing the operational carbon emissions such as from domestic built-in appliances which are used to keep a building warm, cool, or ventilated.

If integrated early on, in the conception and design phase of a project, alternative materials can play a significant role in reducing our carbon footprints.

Nexii
Imagine using a fraction of the building materials, a fraction of the transportation, and a fraction of the building time to assemble ultra high-performance buildings. Nexii has surpassed Passive House energy efficiency performance levels, building up to 24 stories in a quarter the time – at the humble price of wood-frame construction. By combining innovative materials and technologies, advanced engineering and design, and precision manufacturing and assembly, Nexii is shaking up construction at a global scale.

Their proprietary material is an alternative to steel and concrete, used to form panels and roofs with concrete-like strength and to create an airtight, energy-efficient thermal envelope for better insulation and reduced heating/ cooling requirements. Their pre-manufactured panels are made of an ultra-high-performance composite with an insulating core, and manufactured using integrated BIM systems.

A version of the panels suitable for retrofits is also in the works, and will feature high-performance, low-embodied carbon insulation, structural support, and window and doors to comprise a fully unitised exterior retrofit panel.

With their capacity to address both embodied and operational carbon, the life span cost and impact on the environment is reduced significantly.

Our deep dive into the necessary evolution of how we build and how we interact with our built environments has left us with mixed feelings.

Quantifying the industry's whole carbon life cycle footprint, especially in light of the impending doubling of global demand, has been daunting. Southeast Asia is first in line to grapple with this conundrum as the pressures from urbanisation and climate change are particularly pronounced. Our cradle-to-grave approach to analysing the built environment has revealed that carbon emissions are deeply embedded throughout the supply chain. Remedying this requires collective action at all levels – global, national, industry, and consumer – but is hugely challenging to orchestrate.

On the other hand, there is real optimism as we see that the building materials of the future, revolutionary construction techniques, and advanced climate mitigation technologies are rising to meet these challenges. Progessive actors are leading the pack, and can wield great influence on how we conceive and build our cities. In this sense our path towards sustainable urbanisation is well underway and the most promising technological advancements are allowing us to radically transform our built environment.

Now more than ever, we must hasten the integration of these new materials, techniques, and technologies into our built environments, while continually striving for and supporting more advancements thereof. For impact to be made, we must do so at scale. From our view of the innovation spectrum we see the winning trifecta as:

- **Reducing** the extraction of natural resources and carbon-intensive manufacturing processes. We must wean off of "classical" materials of the built environment, and instead look towards material optimisation, and low- to zero-carbon materials and alternative materials.

- **Retrofitting** existing buildings and implementing circular economy principles throughout the industry.

- Deliberately **sequestering** carbon within our built environments, such as through the design of carbon sequestering sites, and the use of carbon sequestering materials.

End Notes

This concludes our three-part series on Sustainable Urbanisation, produced by Hello Tomorrow Asia Pacific and supported by the Singapore Global Network. Here we expound on the opportunities (and necessity) for city-living to be gentler on our planet, and highlight emerging deep-tech innovations making it possible.

Hello Tomorrow Asia Pacific (part of a global non-profit) is on a mission to accelerate deep technologies to solve our most pressing industrial, environmental and societal challenges. Its world-renowned **Global Challenge** unearths and embraces these start-up solutions at their earliest stages, projecting them forward for maximum impact.

For more information, please visit: **hello-tomorrow-apac.org**

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