

SIEW 2023



Roundtable: Net-Zero Buildings in Singapore, is it achievable?

27 October 2023

Opportunities and Challenges

Presented by

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with contributions from
SIT Engineering Cluster



Why Buildings important?



Building sector globally responsible for 35% of energy consumption, 38% of energy related carbon emissions, 50% of resource consumption, and expected to double in total footprint by 2060

Quoted from the World Green Building Council



Technologies can deliver significant energy saving and reduce carbon emissions



Decarbonizing buildings requires strong policy action to drive behaviour and technology shifts



People with competent green skills required to implement clean energy technologies and to comply with performance standards and building codes, to realise Net Zero Emissions by 2050

Importance of Net Zero Buildings in Sustainable Development

Net Zero Buildings are important and required the pointers below to work;

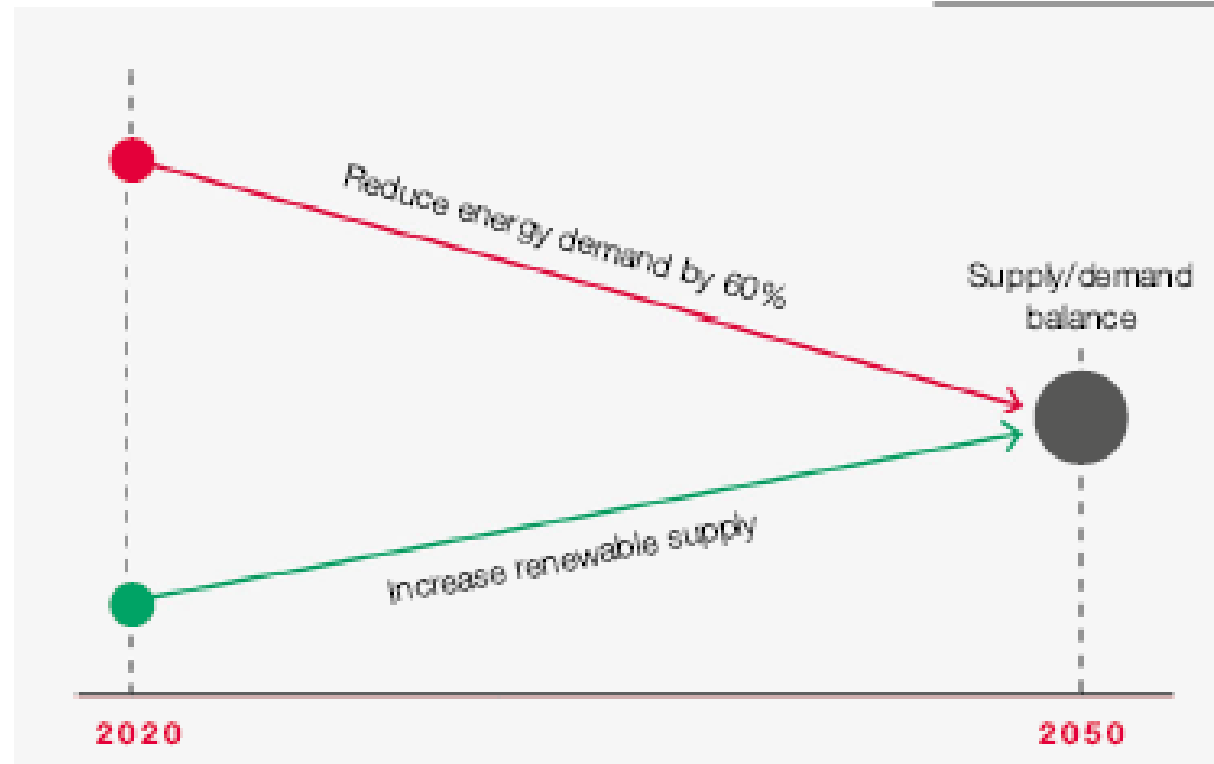
- Climate Change Mitigation
- Energy Conservation
- Resource Efficiency
- Reduced Environmental Impact
- Enhanced Resilience
- Technology Innovation
- Economic Benefit
- Improved thermal comfort
- Leadership and Inspiration
- Global Sustainable Development Goals

Preventing stranded assets: the link between carbon performance and value

The market has begun to price in operational carbon performance. But embodied carbon is still largely ignored by regulators and the market.

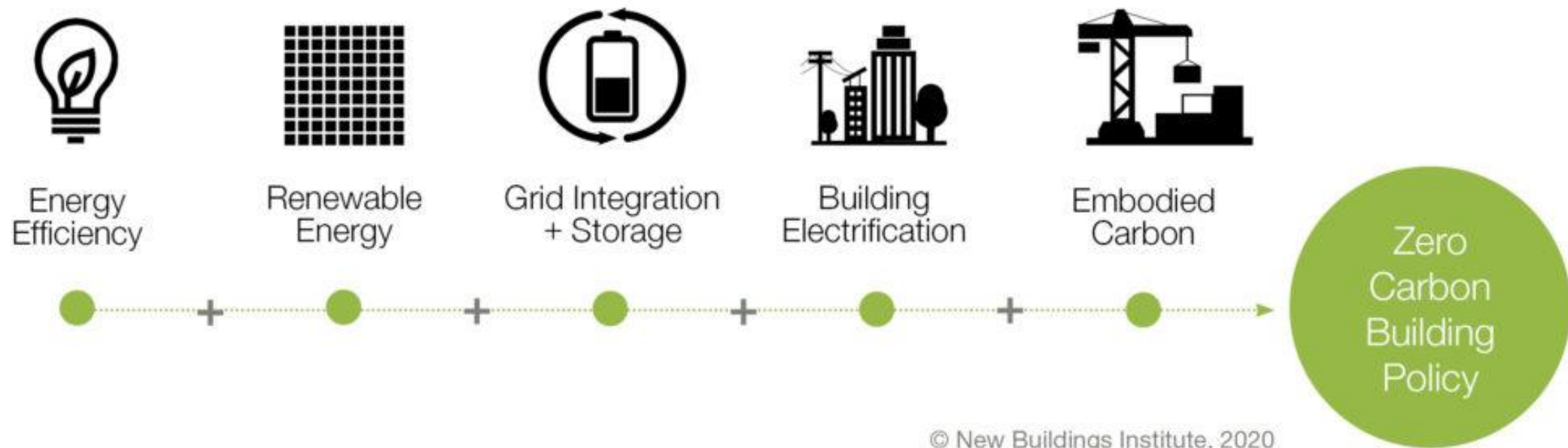
Net zero buildings: where do we stand?

The building industry is responsible for 38%, or around 14 gigatons, of all energy-related GHG emissions each year. This calls on the built environment industry to adopt a whole life-cycle approach to assessing the greenhouse gas (GHG) emissions from buildings.



From Net Zero Energy to Net Zero Carbon Building

The Five Foundations of Zero Carbon Building Policies

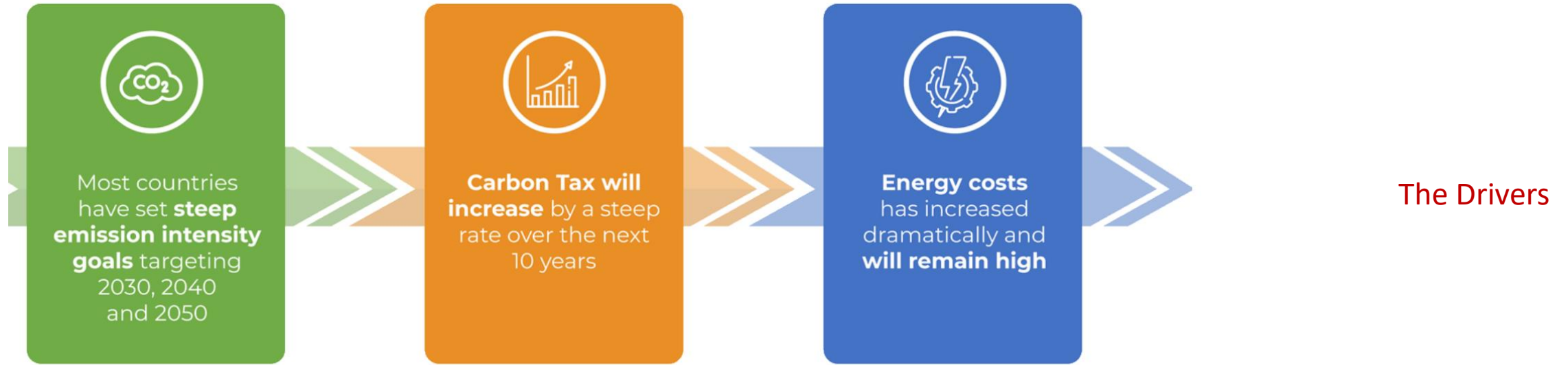


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Source: [NBI](#)

Sustainability starts from tackling buildings

DEMAND DRIVERS POINTING THE WAY TOWARDS SUSTAINABILITY



WHY BUILDINGS ARE THE FOUNDATION OF AN ENERGY-EFFICIENT FUTURE

- Buildings generate 40% of the global energy consumption & 33% of the global greenhouse gas emissions (GHG)
- One degree change in heating or cooling makes 5% savings on energy
- $1^{\circ}\Delta = 5\%$ Savings

Characteristics of Net-Zero Buildings



A net-zero building is designed and operated to minimize its carbon footprint and energy consumption. The primary goal of a net-zero building is to achieve a balance between the energy it consumes and the energy it produces or offsets.



Energy consumption reduction: Net-zero buildings are highly energy-efficient and incorporate various strategies to minimize energy use. This includes using advanced insulation, energy-efficient appliances, and incorporating passive design principles.



Renewable energy generation: To achieve net-zero status, these buildings typically generate their energy through renewable sources such as solar panels, wind turbines, or geothermal systems.



Energy offset: If a net-zero building cannot generate enough renewable energy on-site to meet its needs, it may purchase clean energy credits or offset its remaining carbon emissions through other means.

Characteristics of Net-Carbon Buildings

A net-carbon building goes a step further by not only considering energy consumption but also addressing the overall carbon emissions associated with its construction, operation, and lifecycle.

Carbon footprint reduction: Net-carbon buildings aim to reduce their carbon emissions throughout their entire lifecycle, including the materials used in construction, transportation of materials, and energy consumption during operation.

Carbon offset and sequestration: In addition to energy-related carbon emissions, net-carbon buildings may also focus on carbon offsetting and carbon sequestration. This can involve using carbon offset credits, implementing carbon capture and storage (CCS) technologies, or incorporating carbon-absorbing materials in construction.

Comprehensive approach: Net-carbon buildings adopt a more comprehensive approach to sustainability, considering not only energy but also the embodied carbon in materials and the building's overall contribution to reducing greenhouse gas emissions.

Perspectives of Net-Zero

Net zero
whole life
carbon

Net zero
operational
carbon

Upfront
(embodied)
carbon

Zero carbon

Residual
emission

Emission
reduction
offset

Net-zero operational carbon vs whole life carbon

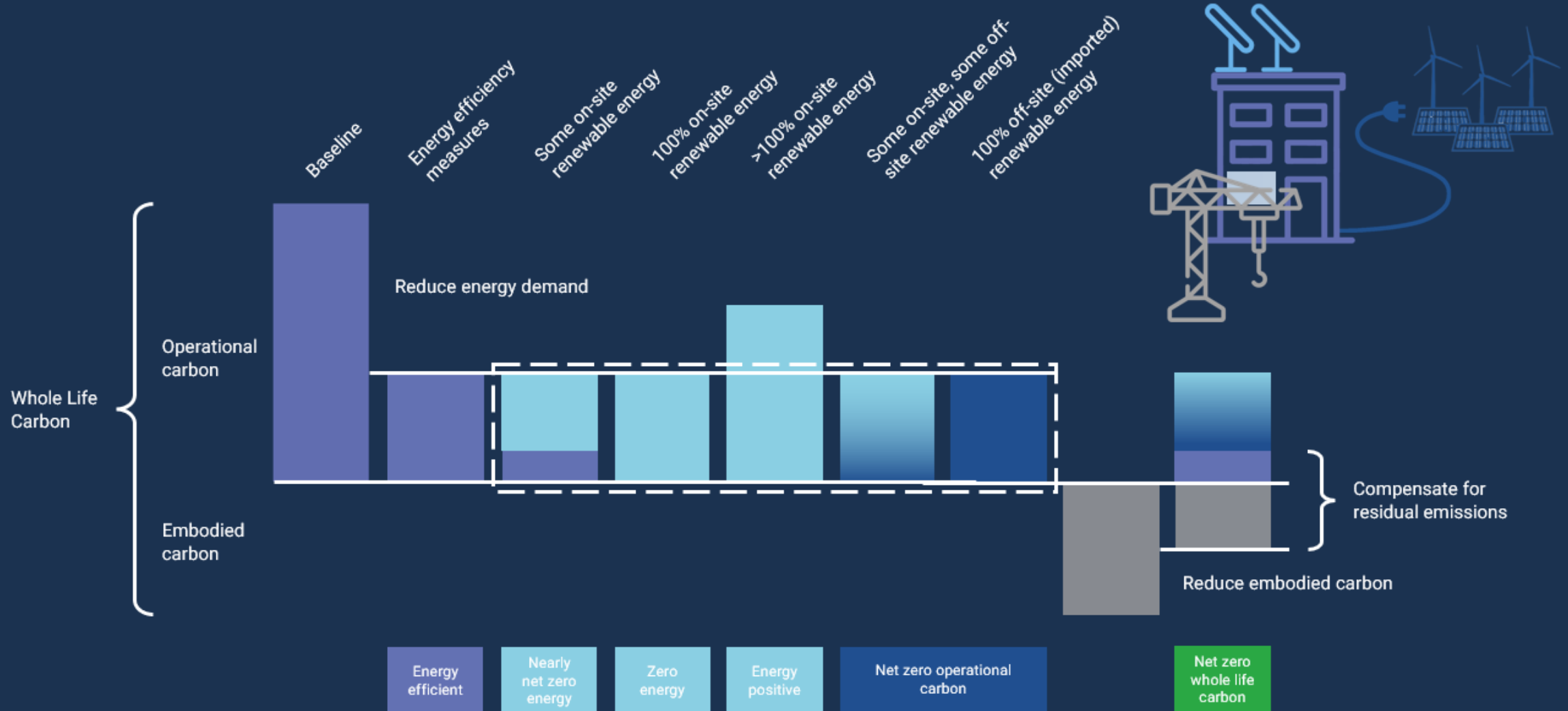


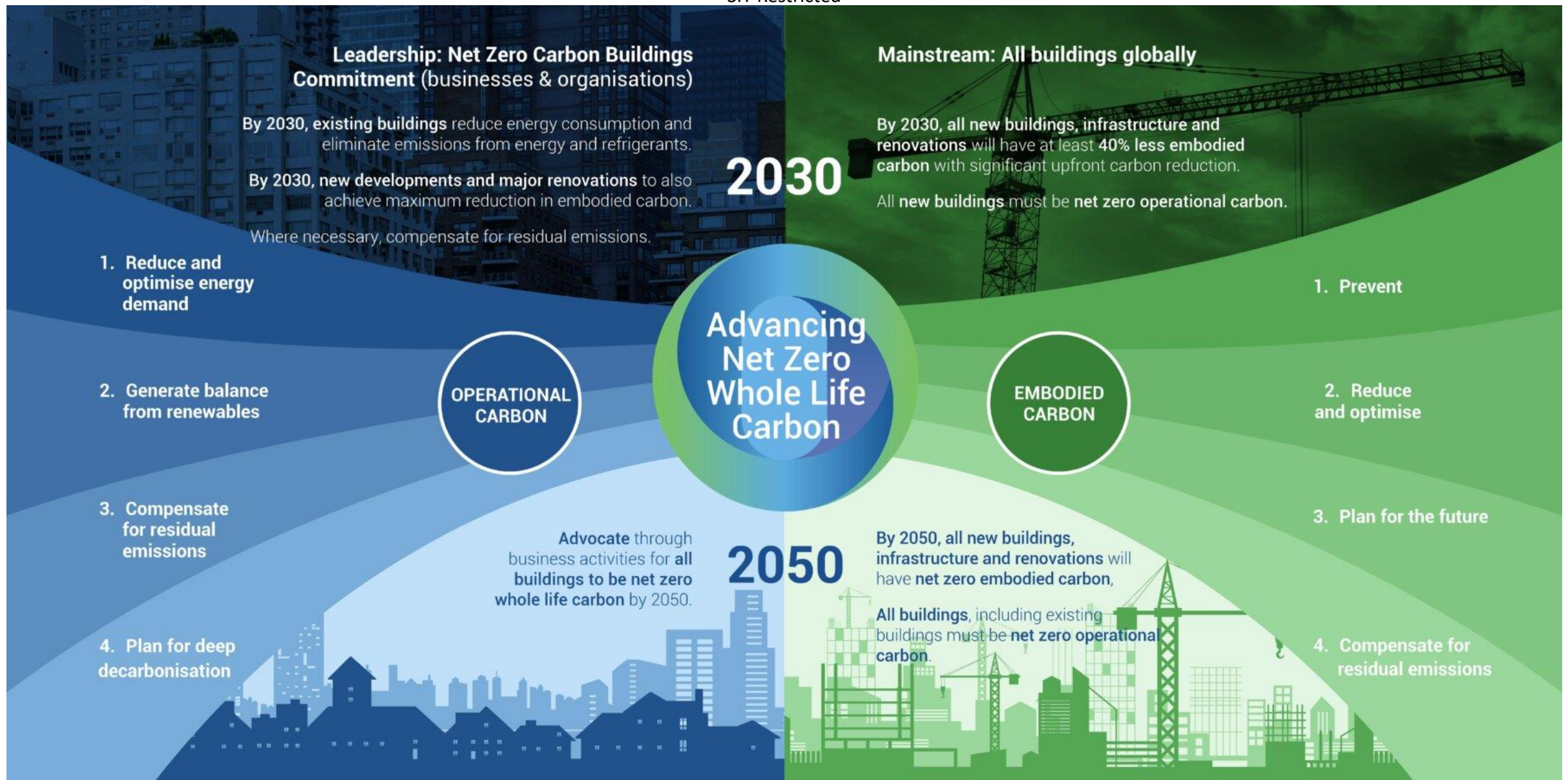
"Net-zero operational carbon" refers to a state in which a building or facility has effectively reduced or offset its carbon emissions associated with its day-to-day operations to the point where the emissions are virtually eliminated or balanced by various mitigation measures. This concept is closely related to efforts to combat climate change and reduce greenhouse gas emissions.



"Net-zero whole life carbon" refers to a concept in sustainable construction and building design that aims to balance or offset the carbon emissions associated with a building's entire lifecycle, including not only its operational phase but also the embodied carbon emissions related to materials, construction, maintenance, and demolition

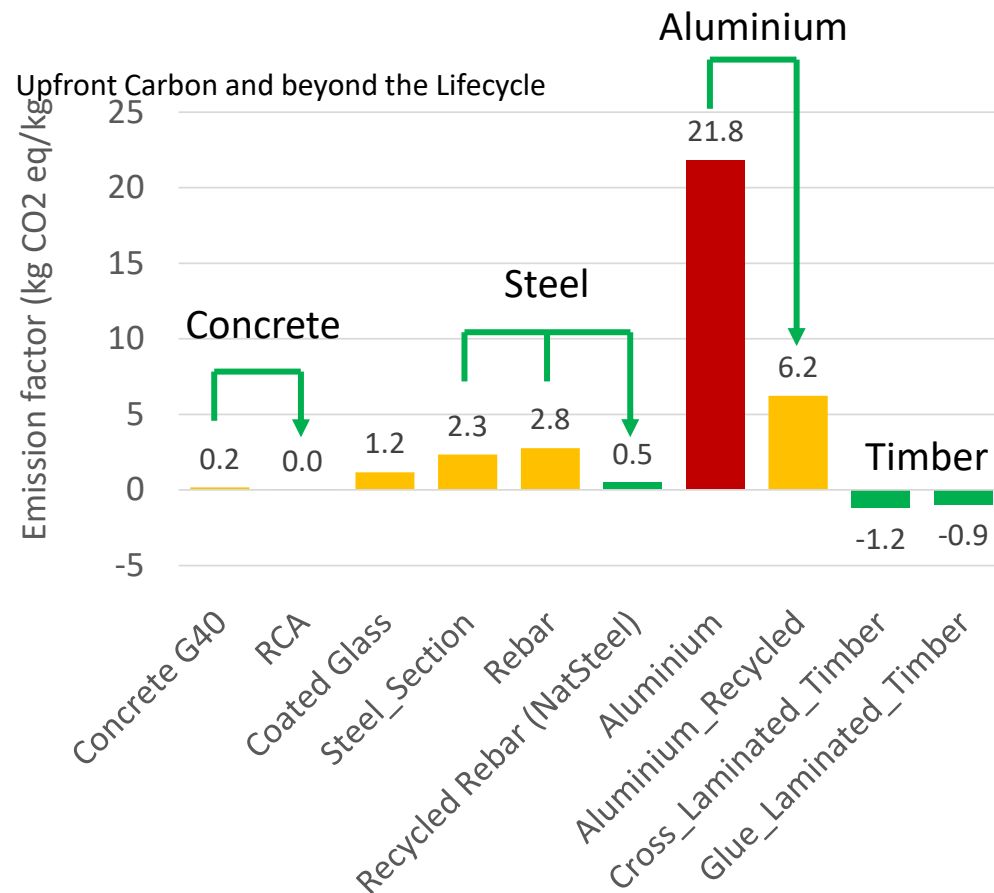
Definitions: Net Zero Carbon Buildings



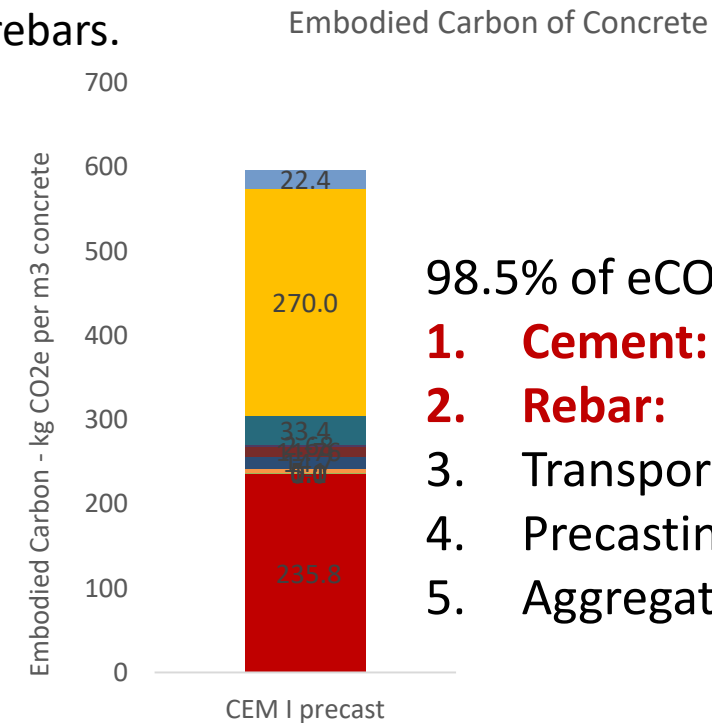


Current status – Embodied Carbon of Common Construction Materials

While timber products show negative eCO₂ in the carbon calculators, the expected application is still limited in SG.

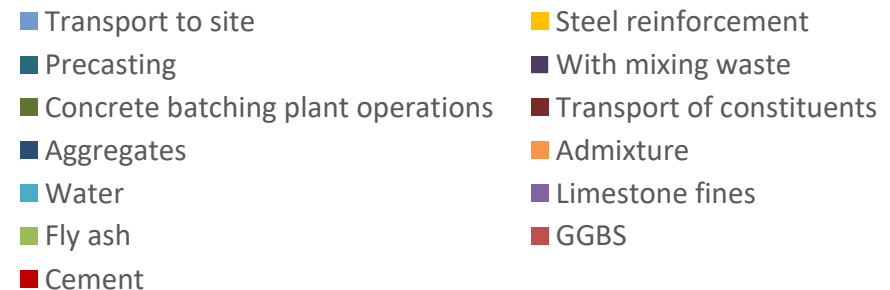


Reinforced concrete structures will still dominate. The key to decarbonize construction is within concrete and rebars.



98.5% of eCO₂ comes from:

- 1. Cement: 39.5%**
- 2. Rebar: 45.2%**
3. Transport: 5.7%
4. Precasting: 5.6%
5. Aggregates: 3.4%



Source:

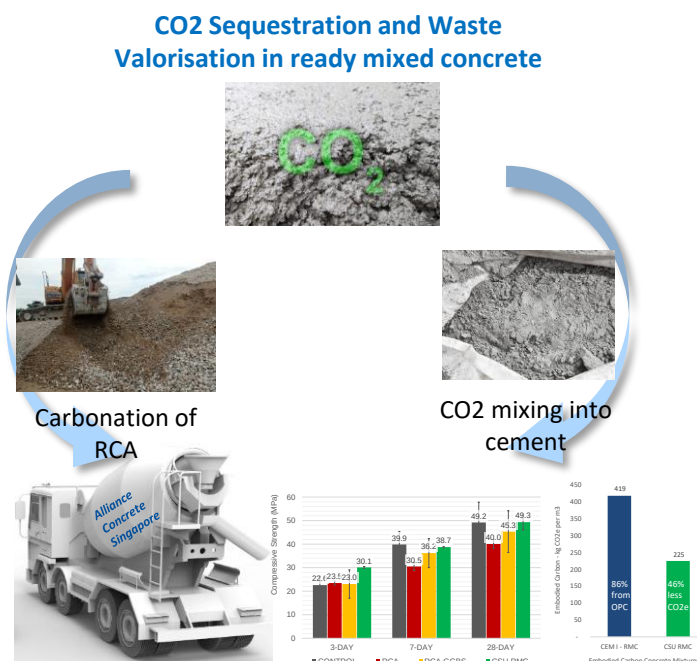
1. NUS-ESI (2022), Building Embodied Carbon Calculator (BECC)
2. BRE (2021), Environmental Production Declaration (EPD) for 1 tonne steel reinforcing bar/coil – NatSteel Holdings Pte Ltd.

What Can We Do Now: Decarbonize the Materials and Optimize the Structural Design

It is practical to target 60-70% reduction in eCO₂ for now. There is still long way to go to fully remove the embodied carbon. To achieve net zero building, negative operation carbon is required to offset the eCO₂ associated with building construction.

Ultra-low carbon concrete

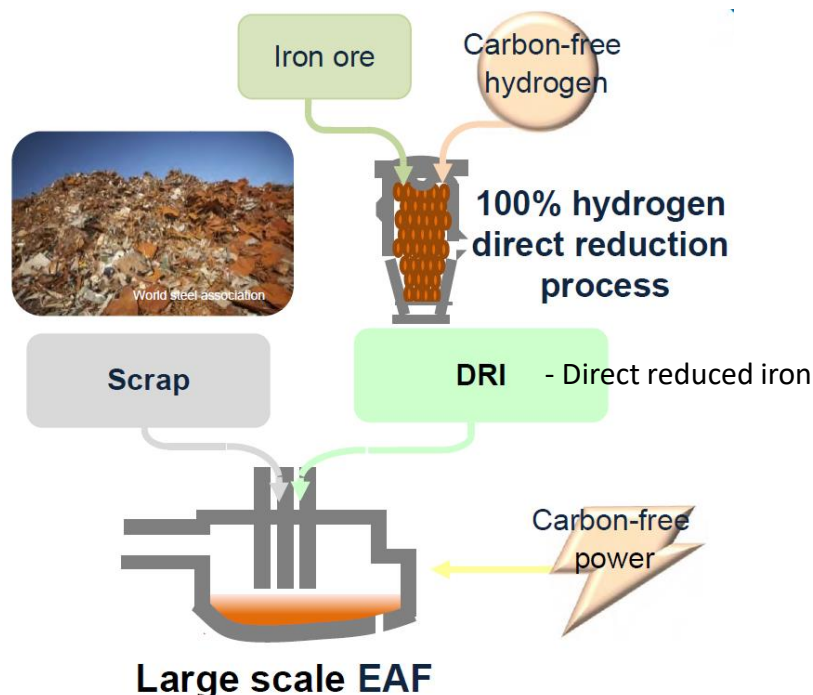
Carbon capture and utilization together with supplementary cementitious materials



From 0.2 -> 0.1 t-CO₂/t structural concrete

Ultra-low carbon rebar

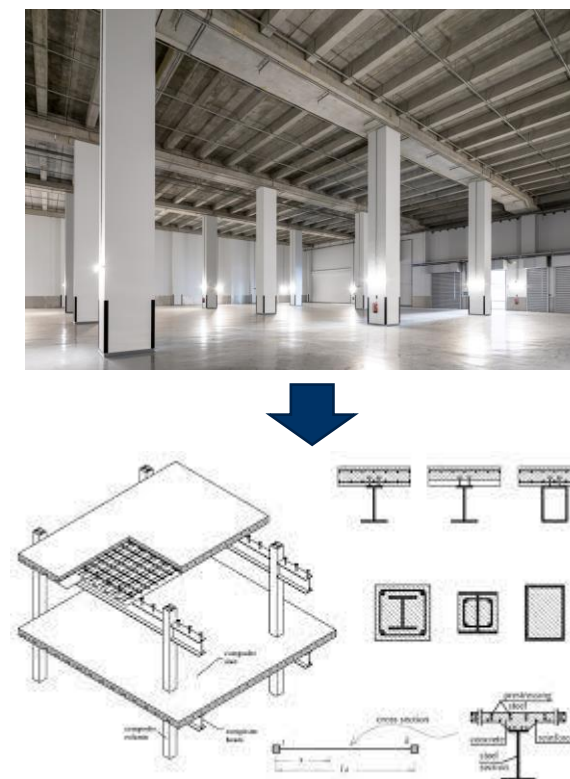
Use rebars produced by 100% scrap metals with electric arc furnace



E.g., NatSteel Rebar EPD
From 2.8 -> 0.5 t-CO₂/t-steel

Structural optimization

concrete/steel/timber composite structures that use materials more efficiently

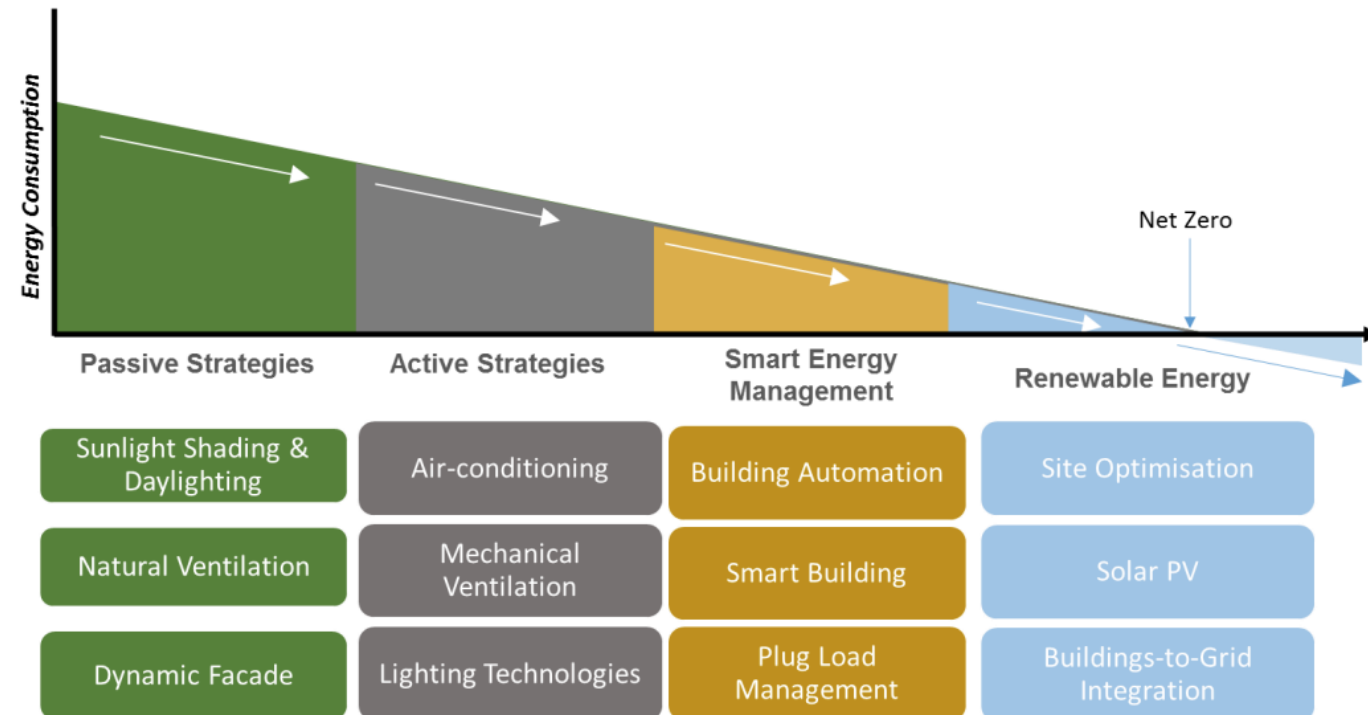


Reduce impact and input of raw materials with optimized design

What we are very familiar with.....

Super Low Energy Building (SLEB) and Net Zero Energy Building (NZEB)

- To reach the Net-ZEB goal, two important analyses must be conducted at the design stage:
 - to **reduce building energy demand** using passive solutions and energy efficient systems;
 - to **generate sufficient** electricity by **renewable energy systems** to achieve the desired energy balance



Source: [BCA](#)

HVAC using Smart Damper

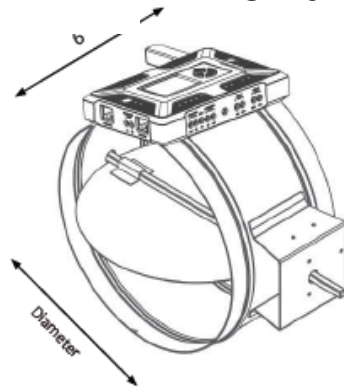
Objectives of project:

- Creating the micro zones to achieve better thermal comfort and energy savings.
- To isolate the zones where air condition is not required during certain period of time (e.g., classrooms)
- Equipped with smart damper closer to the supply diffuser to control locally.

Smart node for micro-zones

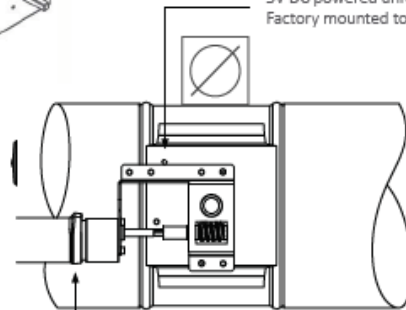


Smart Damper



75F° Smart Node™ shown
for mounting placement
(sold separately)

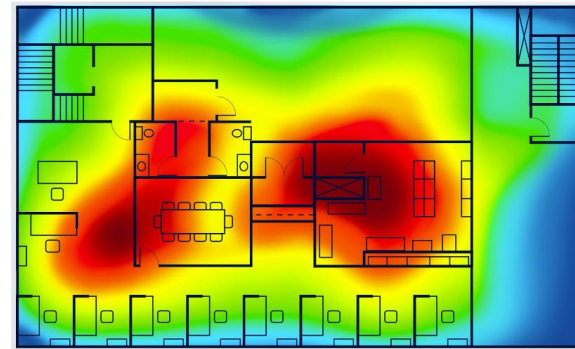
5V DC powered universal damper drive.
Factory mounted to damper.



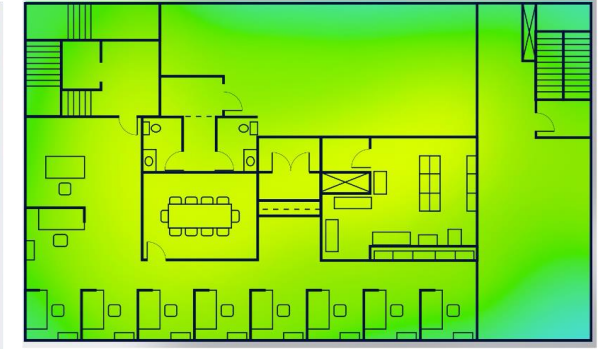
Plenum rated wiring with DC Power connector: 1' (25' extender cable available). Connector Termination Options- RJ45

One point measurement of return air temperature resulting in hot spots and cool spots in a space

Before



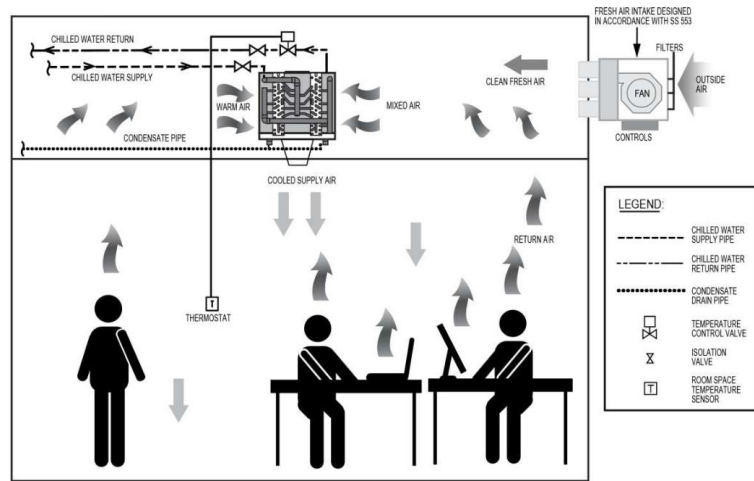
After



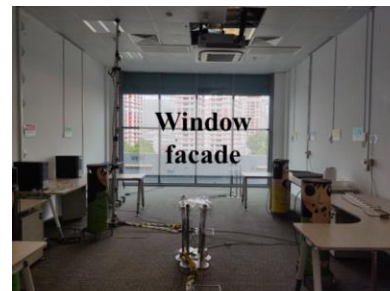
Electrical Consumption	All days	Savings
Total Electrical Energy consumption during SIT Running Phase (kWh)	2636.6	901.1 kWh
Total Electrical Energy consumption during 75F Running Phase (kWh)	1735.5	34.2%

Thermal Comfort	All days	Increase
Average thermal comfort percentage during SIT Running Phase (kWh)	49.17%	40.22%
Average thermal comfort percentage during 75F Running Phase (kWh)	89.39%	

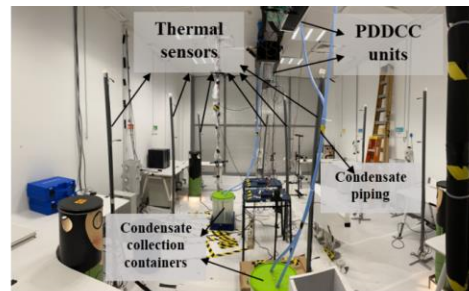
Passive Displacement Dual Cooling Coil (PDDCC)



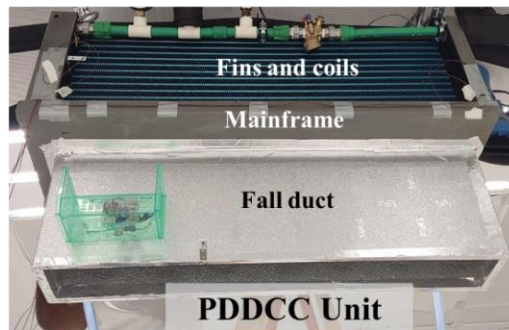
Concept of PDDCC



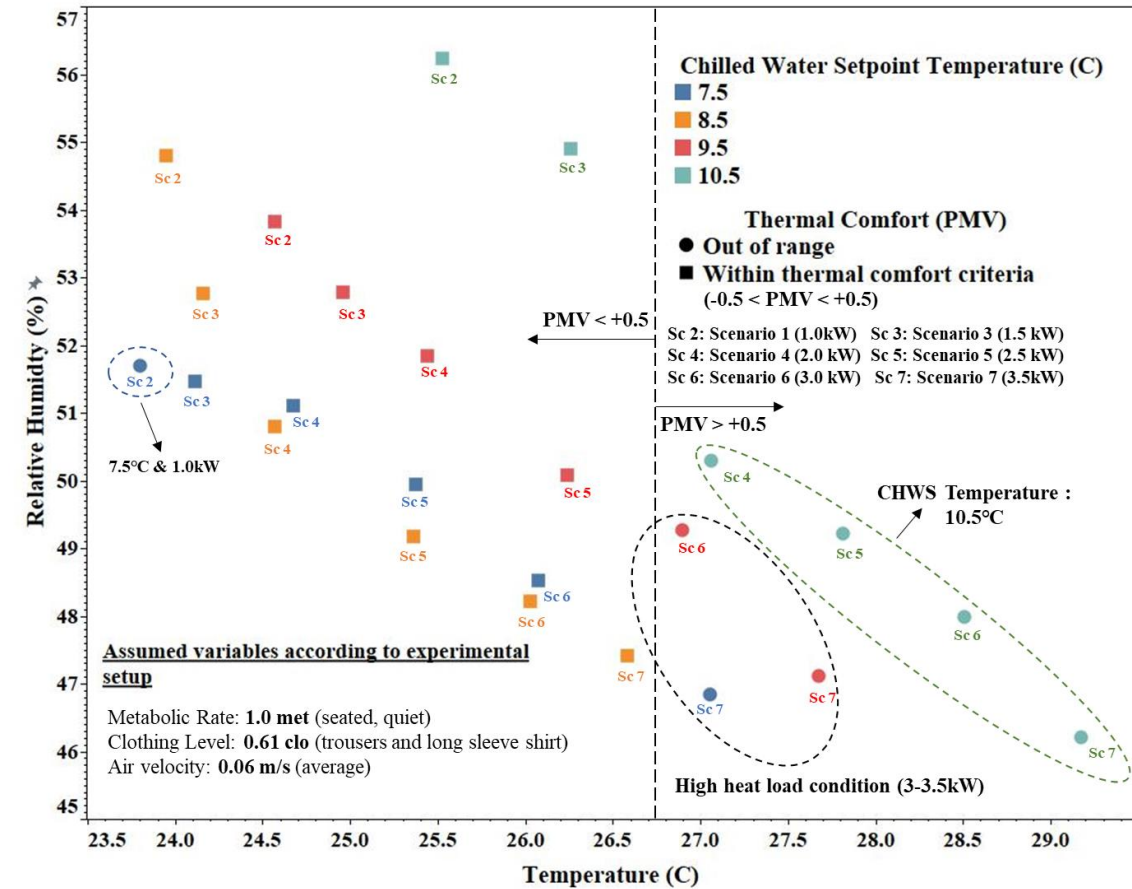
(b)



(c)



(d)



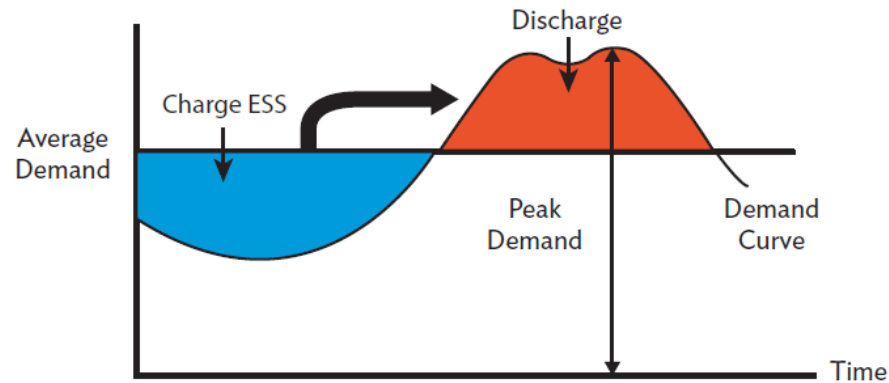
Reference:

1. TR 102:2022 Code of practice for passive displacement cooling (PDC) system for air-conditioning application
2. Building and Environment, 237, 110302, <https://doi.org/10.1016/j.buildenv.2023.110302>

Test in BCA Skylab

Peak Shaving and Load Leveling

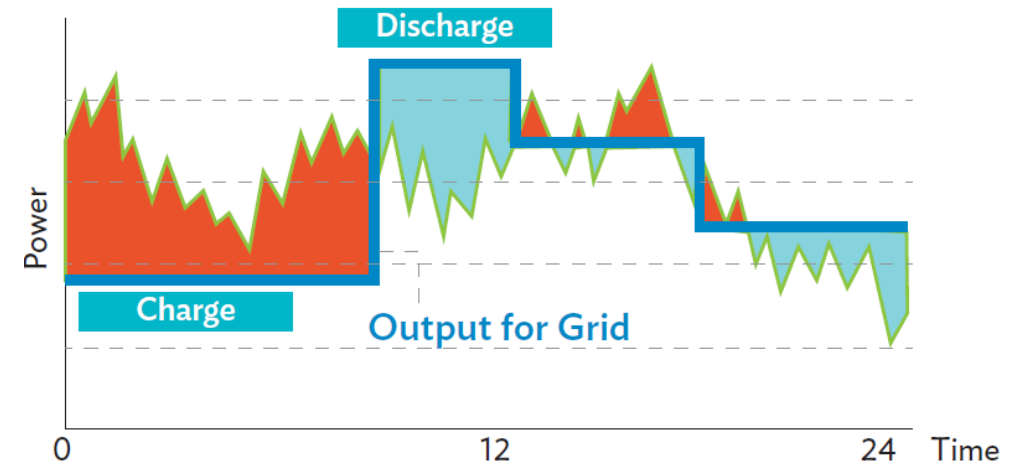
Use of Energy Storage Systems for Peak Shaving



ESS = energy storage system.

Source: Korea Battery Industry Association 2017 "Energy storage system technology and business model".

Use of Energy Storage Systems for Load Leveling



Peak shaving. The reduction of electric power demand during times when network capacity is stressed is known as peak shaving. Peak shaving helps defer investments in network expansion or network reinforcement.

Load leveling. Load leveling, refers to the process of shifting demand away from peak hours to off-peak hours. Load leveling can be performed by introducing time-of-use tariffs, whereby consumers are incentivized to shift consumption to hours of the day when tariffs are low. Behind-the-meter energy storage, its allows for load leveling without any changes to the consumer load profile.

Agrivoltaic System – System Thinking

Introduction

Singapore aims:

- **4% Total electricity demand to be powered by Solar Energy**
- **30% Local Food Production to improve the nation food security**



LAND SCARCITY



Present PV Solutions



HDB Rooftop Solar PV Floating Solar PV

Present Food Production Solutions



HDB Carpark
Rooftop Hydroponics
Farming Indoor Urban
Farming

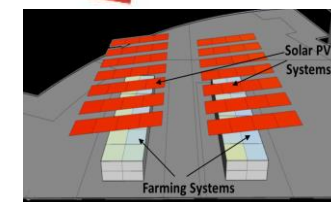
Solar PV + Farming = **AGRIVOLTAICS**

Objectives

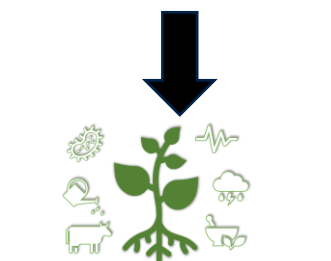
Derive optimized system design solutions beneficial for both solar PV and crops' growth on the same plot of land

Investigate how probiotics can enhance various crop species' growth under low-light conditions

Understand how shading of the solar PV system affects crops growth



Software Visualization



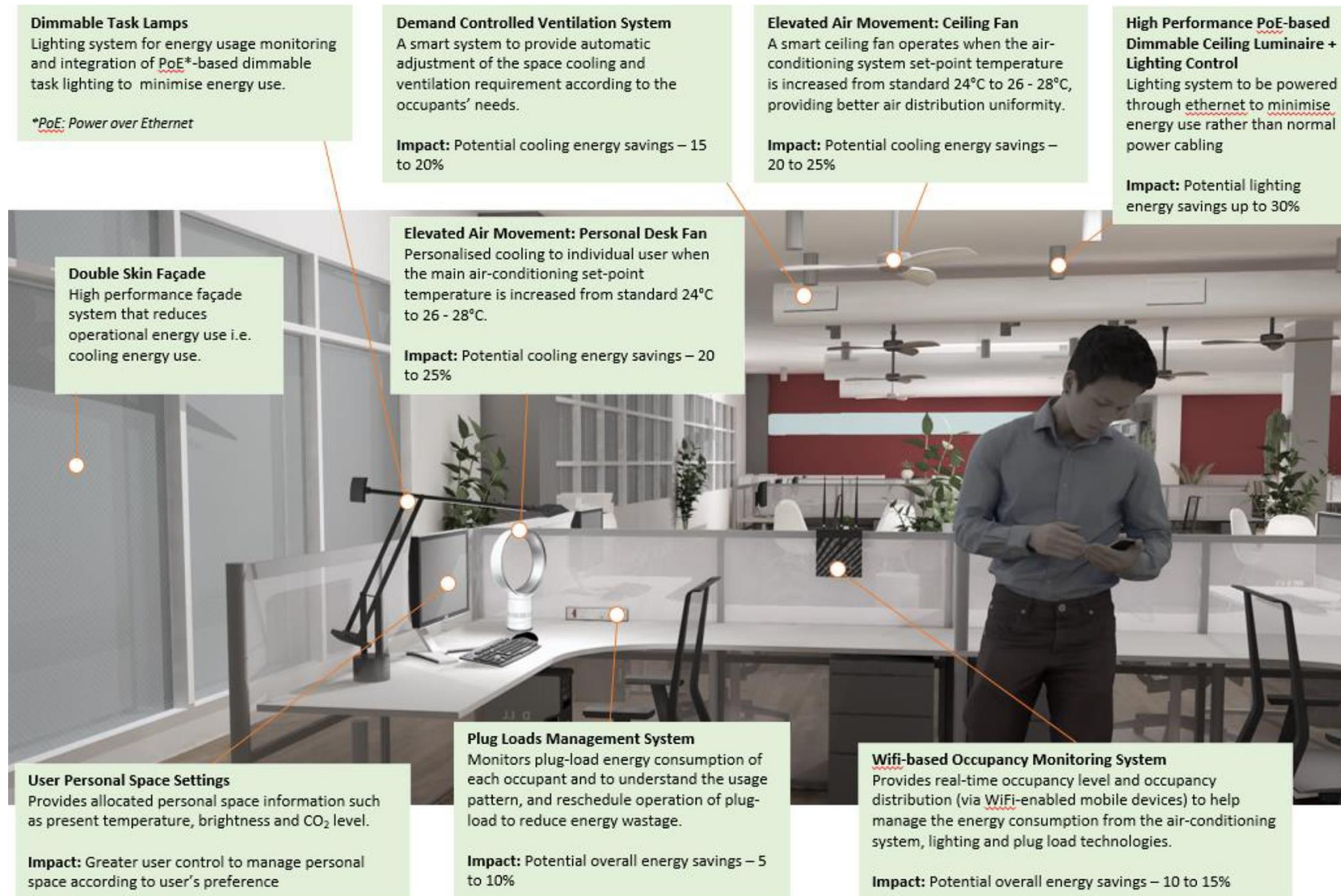
Probiotic to enhance crop performance



AT A GLANCE: KEY TECHNOLOGIES IN POSITIVE ENERGY ENHANCEMENT FOR ZEB

BCA's Zero Energy Building

This three-storey institutional building consumes as much energy as it produces through systematically incorporating innovative energy efficient and renewable technologies



Challenges and Possibilities

- Net zero energy buildings that generate 100% of their energy needs on-site are generally not feasible
- Net zero embodied carbon should be pursued as part of a whole lifecycle approach to carbon reduction that includes net zero operational carbon.
- Net zero carbon practice allows the role of offsets in facilitating the transition
- Radical cross-sector collaboration crucial
- Effective policy frameworks
- Affordability & market availability of clean and efficient building technologies
- Behavioural changes
- Green skills

IEA Recommendations

- Implement zero-carbon-ready building standards for new and existing buildings, establish enforcement and compliance procedures
- Introduce supporting information instruments and incentives to drive implementation of the regulations
- Set clear and measurable targets to drive the market transformation towards high-performing buildings
- Stimulate financing and market mechanisms to increase the affordability of best-in-class products
- Deliver public awareness campaigns encouraging behavioural changes
- Financial instruments can motivate consumers and developers to increase investment in energy-efficient solutions
- Set long-term decarbonization plans and net zero pledges

THANK YOU