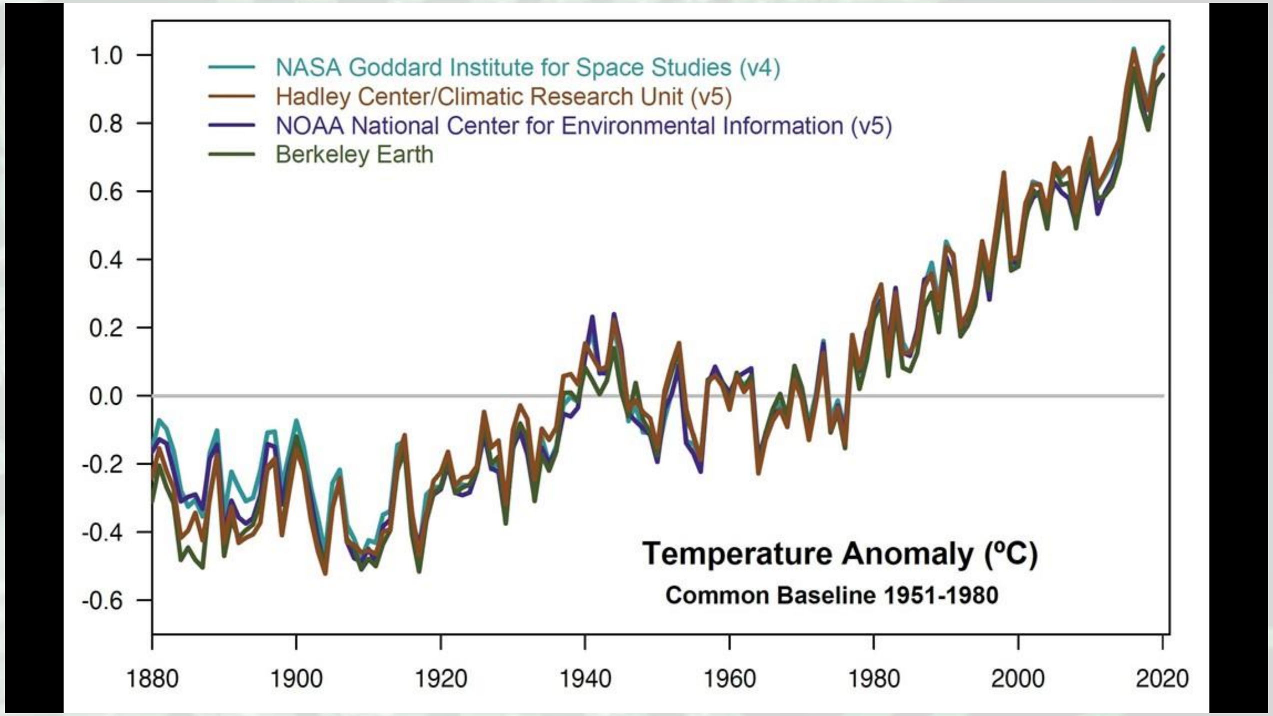
Advancing Net Zero Competition

Existing Building Category
Registration number: 277909

Introduction:
Alarming hot temperature records

Recently both local and global temperature statistics demonstrate the hottest values in records, suggesting we must take serious actions in reduction of emission of carbon dioxide which is the major contributing factor to global warming.

Source: The Standard

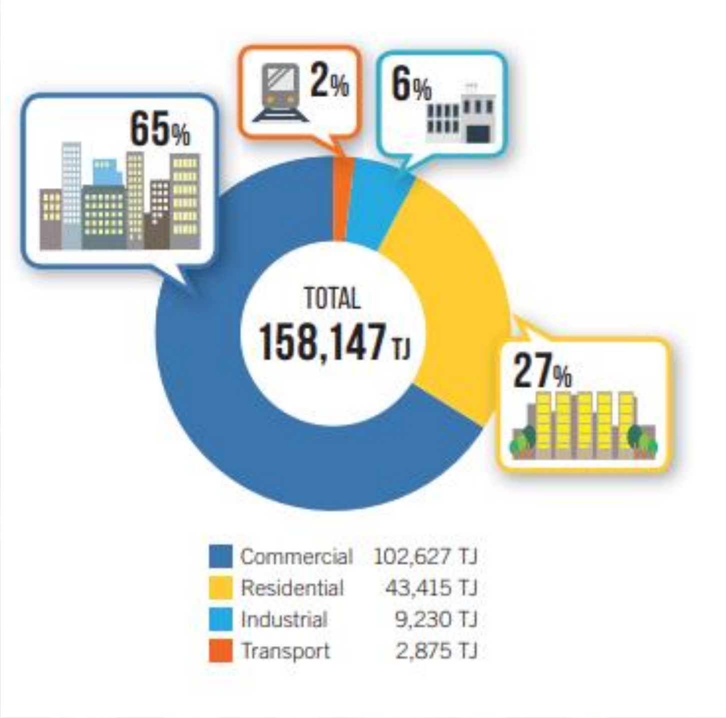


Source: NASA GISS/Gavin Schmidt
https://www.nasa.gov/press-release/2020-tied-for-warmest-year-on-record-nasa-analysis-shows

Introduction:

Solution for advancing carbon net zero for commercial building

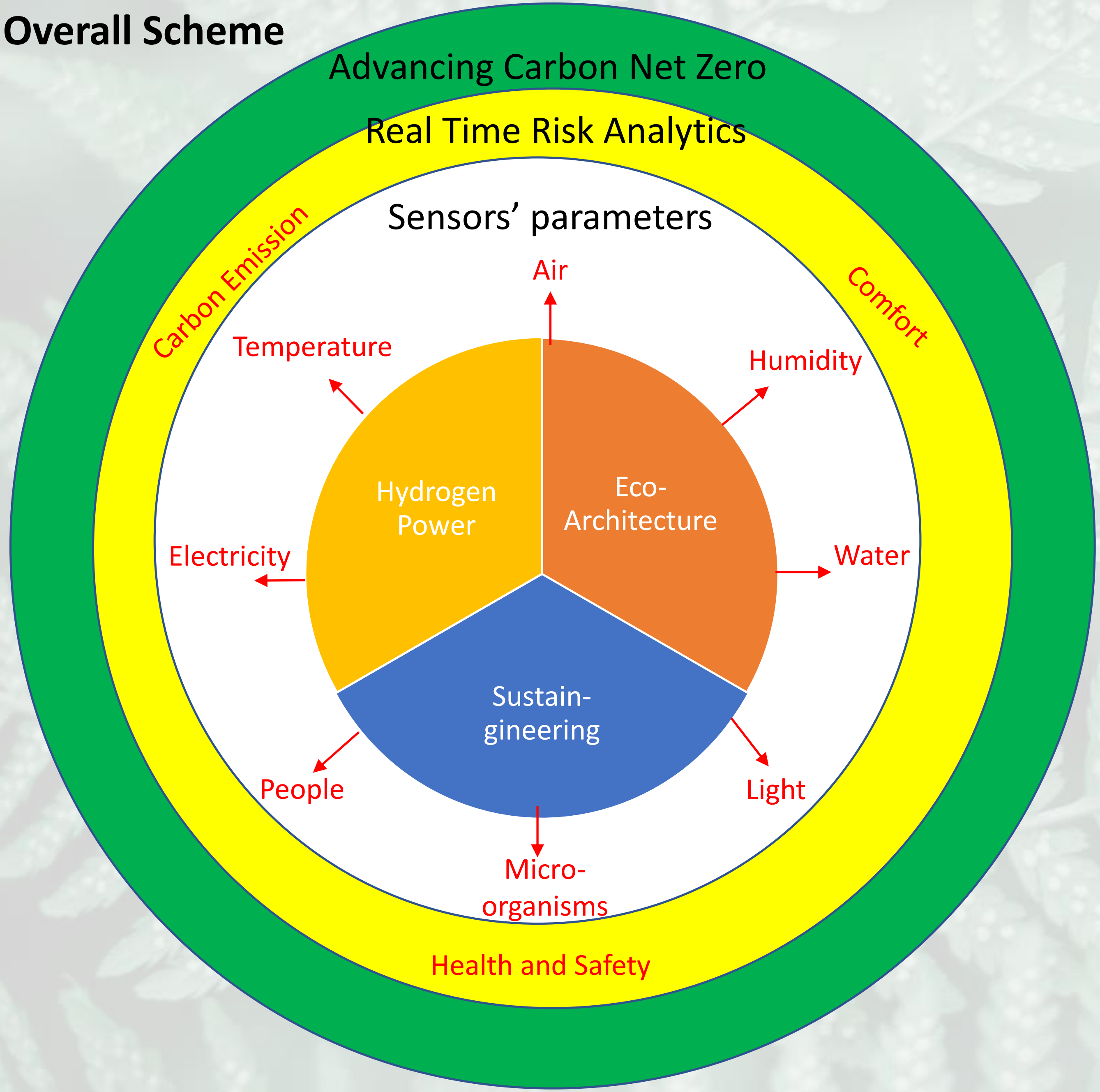
Over 60% of carbon dioxide emissions in Hong Kong are attributable to electricity generation, about 65% of electricity are consumed by buildings from commercial sectors. Therefore it is crucial to reduce carbon emissions from commercial buildings against global warming.



Source: Environment Bureau (2017), Hong Kong's Climate Action Plan 2030+

Our work focuses on Oxford House, a representable Grade-A office tower constructed in 1990s. We will illustrate new technologies and management scheme to support the acceleration of carbon neutral in buildings.

Advancing Carbon Net Zero: Overall Scheme



We propose 3 pillars of technologies for carbon reduction in cooperating with risk factors:

- Hydrogen Power
- Eco-Architecture
- Sustain-gineering

In order to advancing carbon net zero for commercial building in balance with operation and well-being of building users, 3 risk factors from a batch of sensors' measurements provide the indicators:

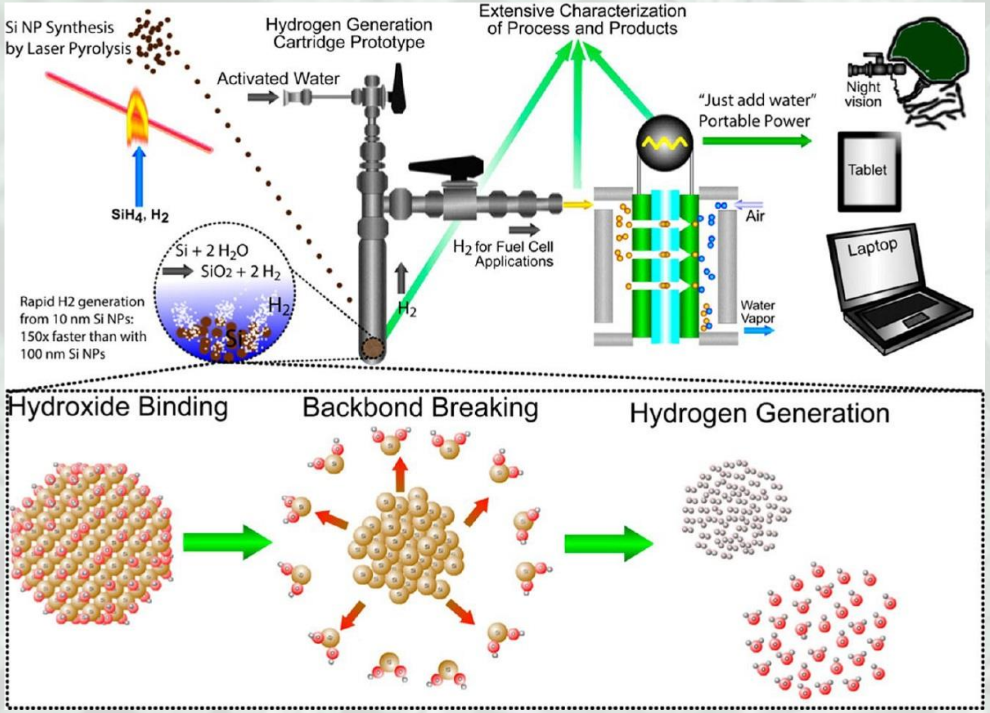
- Carbon Emission
- Health and Safety
- Comfort

Hydrogen Power:
Production of hydrogen from Si+ nanopowder and water

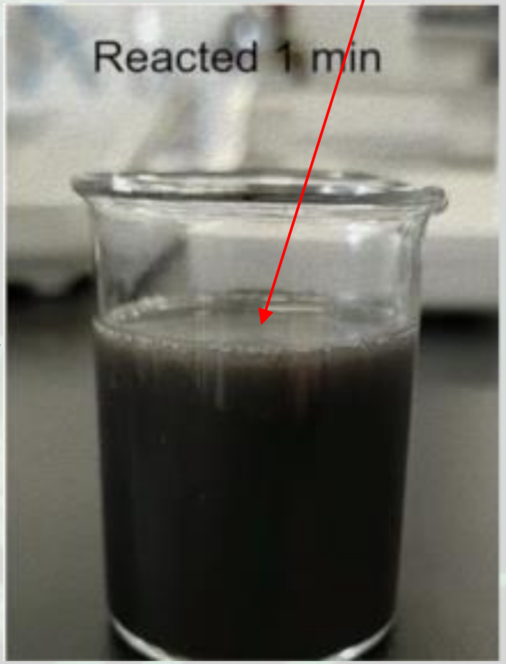
Silicon (Si+) nanopowder reacts with water molecules to form hydrogen gas

$$Si + 2H_2O \rightarrow SiO_2 + 2H_2$$

Addition of silicon nanopowders to water can produce hydrogen at moderate temperature (0-80°C)



Credit: Folarin Erogbogbo, et al. ©2013 American Chemical Society



Layer of hydrogen gas bubbles

Credit: EPRO Advance Technology
Source: https://www.epro-atech.com/si-to-generate-hydrogen-economy

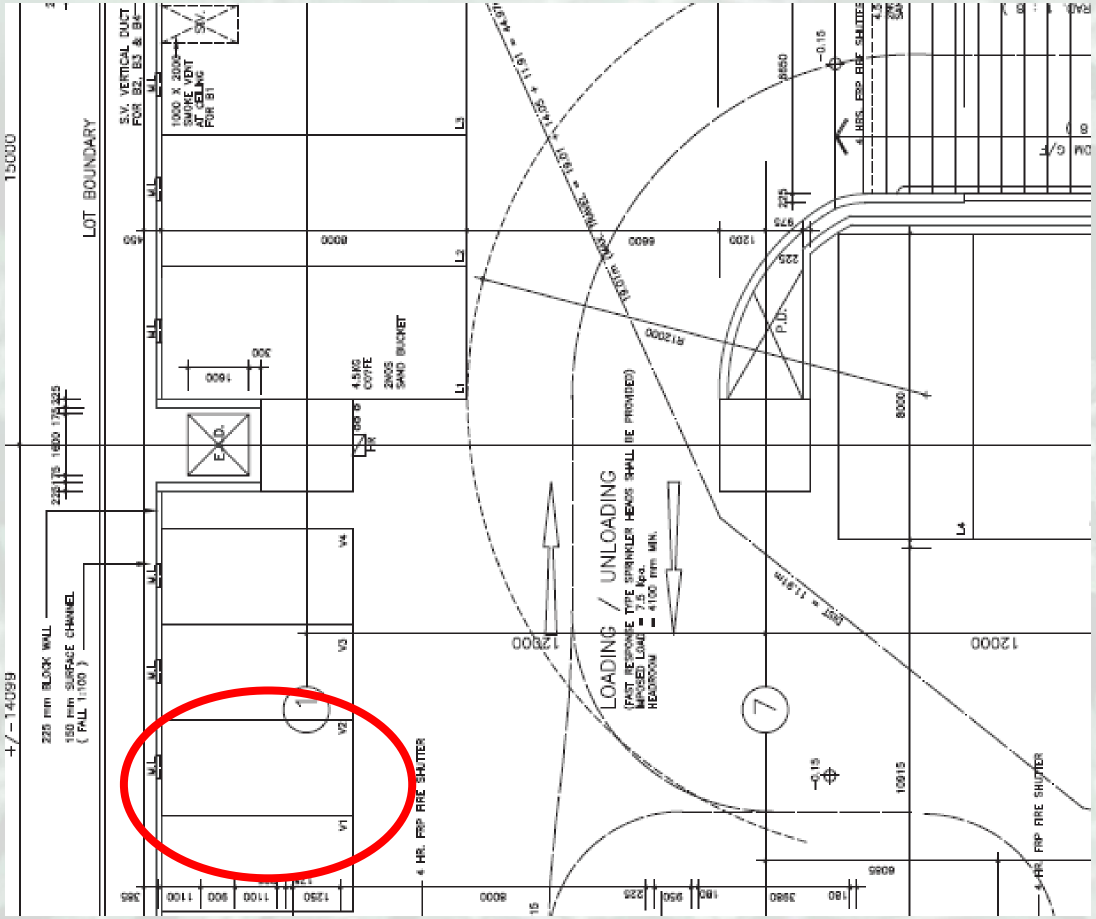
Hydrogen Power:
High energy density of hydrogen from silicon

H_2 produced in 20 ft container of Si+ (kg)	3,000
Energy density of 1 kg H_2 (kWh)	33.3
Electricity energy generated from 1 kg H_2 (kWh, assuming 67% efficiency)	20
Electricity from 20 ft container of Si+ (kWh)	**60,000**
Average daily electricity in Oxford House in 2019 (kWh)	**20,176**
Peak season daily electricity in Oxford House in 2019 (kWh)	**24,662**

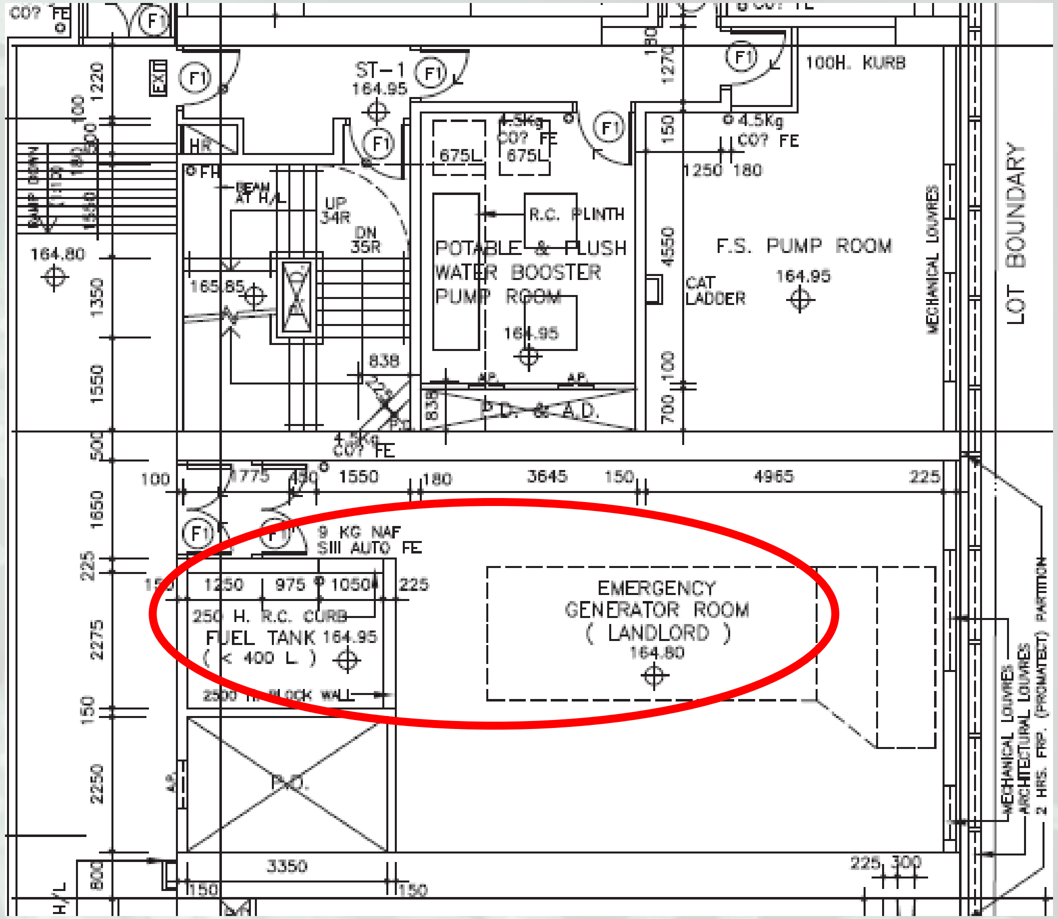
By standard 20 ft container with transportable Si cartridges, electricity generated is sufficient for **2-3 days energy consumption of Oxford House**.

Si can be refilled by transportation of container truck for every 2-3 days, just like waste disposal with garbage truck.

Hydrogen Power:
Replacement of grid electricity and emergency power by hydrogen



20 ft container silicon and hydrogen generation system, can be located at truck loading space at B1/F



Replacement of diesel fuel used in emergency power by hydrogen energy

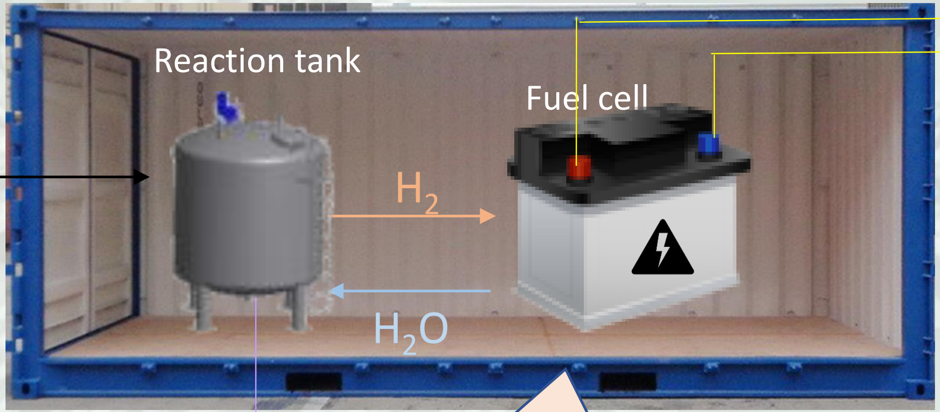
Hydrogen Power:

Electricity generation by hydrogen fuel cell

With high energy density of hydrogen, grid electricity can be replaced by hydrogen fuel cell in which hydrogen is produced on-demand to drive electric generator

Si+ cartridge in 20 ft container, daily replacement for unused Si+ nanopowder

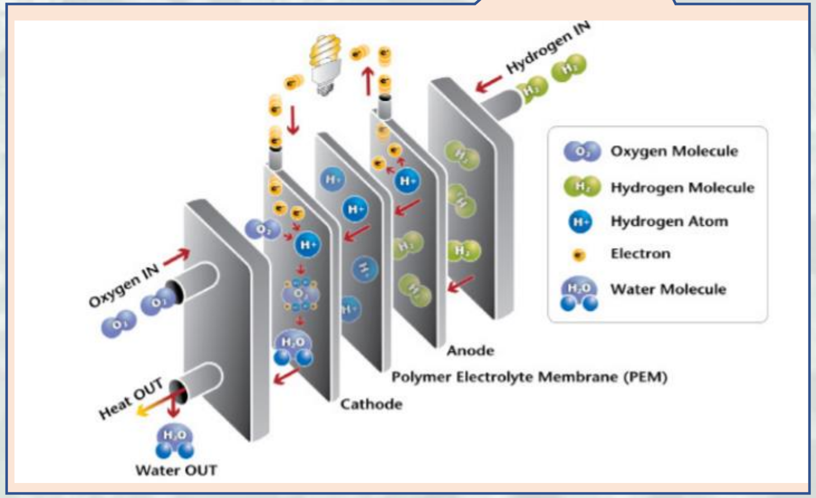
Si+



Converter

Building Power System

SiO_2



$SiO_2 + 2NaOH \rightarrow Na_2SiO_3$

By-product can be used to produce sodium silicate for formulation of cements, passive fire protection, adhesives, production of silica gel etc.

Source of fuel cell schematic diagram: Zhou, et al. (2014) Polybenzimidazole-Based Polymer Electrolyte Membranes for High-Temperature Fuel Cells: Current Status and Prospects. Energies 2021, 14, 135. https:// doi.org/10.3390/en14010135

Hydrogen Power:
Advantages of Hydrogen Power

- Less carbon emission from energy consumption on hydrogen production compared to electrolysis as silicon reacts at moderate temperature

- Carbon emission mainly from silicon smelting and transportation of silicon

- Resolved the issue of storage and transportation of liquified hydrogen as the hydrogen production is on demand basis from silicon

- Compared to combustion of natural gas/coal at power plant, no carbon emission during combustion of hydrogen

$$H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (g)$$

Photo credit: Michael Wilson@Unsplash

Eco-Architecture Strategy 01:
Reduce cooling load and operating carbon at circulation area

- Open up the glass box entrance and the level of bridge connection.
- Increase the permeability of the building envelope.
- Increase the shade provided by the roof instead of using glass.
- More plantation to increase shade and localized moisture, absorb CO_2 and enhance visual comfort.
- Integration of spraying of water droplets to absorb the summer heat.
- Use high volume pendant fans with motion sensors to increase air convection when more people walk pass the common areas.
- Modify the design of the circular skylight for hot air to escape.

Exterior view of the existing glass box entrance to Oxford House

Proposed opening up of the glass box to create an urban pocket garden, enhance accessibility to flat roof

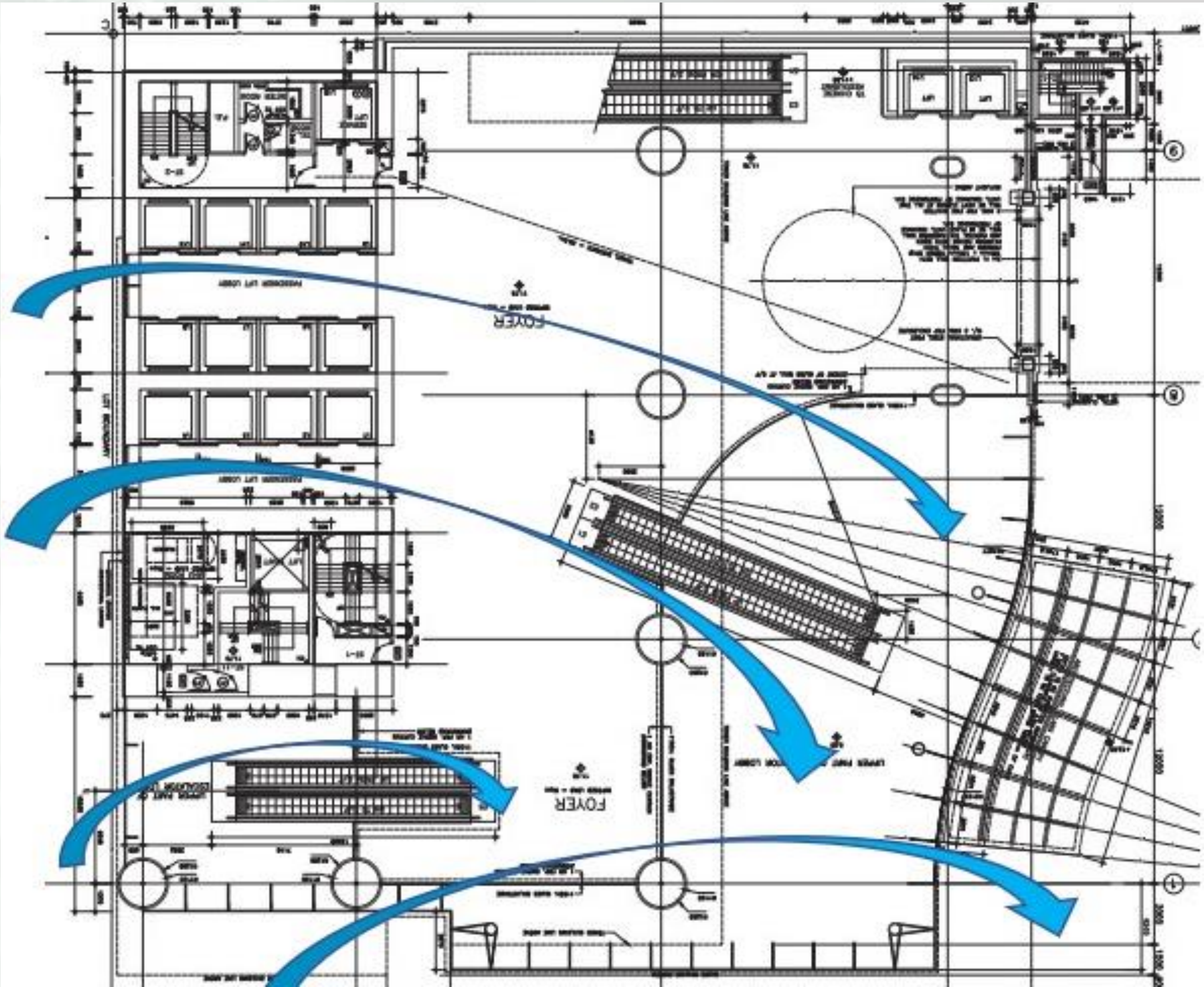
Eco-Architecture Strategy 01:
Reduce cooling load and operating carbon at circulation area

Reference examples of opening up a natural ventilated podium garden and an indoor greenery promenade at Robinson Tower designed by Architect KPF in the City Centre of Singapore. (Source: https://www.kpf.com/projects/18-robinson)

Eco-Architecture Strategy 01:
Reduce cooling load and operating carbon at circulation area

- Open window wall at the lobby level on G/F and 1/F to introduce natural ventilation and increase permeability of the building envelope.

- Fresh air directly flows into the lobbies on the G/F and 1/F, majorly from North and East wings where less blockage of ventilation by other buildings occurs.



Eco-Architecture Strategy 01:
Reduce cooling load and operating carbon at circulation area

Pendant fans above solar blades to improve the air circulation and comfort. The fan speed can be regulated by motion sensors in response to the pedestrian traffic.

Solar blades beneath glass roof to reduce solar gain and direct glare

Operable aluminum louvres at high level to enable air circulation. This is equipped with rain sensors and can be closed when there is severe wind-driven rain.

Skylight can be modified to enhance air circulation

Link bridge: from MVAC cooled internal space to natural ventilated green space

The existing skylight at the 1/F common area

Row of plants near the window wall to help regulating the indoor climate, as well as enhancing the aesthetics value and mental health being.

Lowered glass wall with low-E coating.

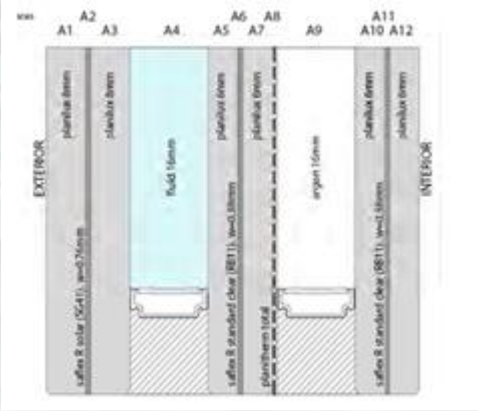
Eco-Architecture Strategy 02:

Adaptive façade in lieu of traditional curtain wall system to reduce operational carbon for the office tower

Unlike the traditional closed system, adaptive facades can seize the opportunity to save energy by adapting to prevailing weather conditions, and support comfort levels by immediately responding to occupants' needs and preferences (Loonen et al, 2013, cited in TU, 2018). In recent years, technological research has been investigating the process of exchange that concerns the energy flows that have passed and exchanged right through the envelope (Altomonte, 2008, cited in TU, 2018).

Component options may include:

- Architectural fins on the south and west facades to provide shades and harvest solar energy through built-in PV cells.
- Insulating glazing unit filled up with a water-glycol fluid circulating within one of the Insulating Glass Units (IGU) cavities.



Schematic section of IGU filled with glycol fluid


Exterior view of Oxford House, west elevation.


Reference example of nicely designed façade with horizontal fins. (WAVE by SOMA Architects)

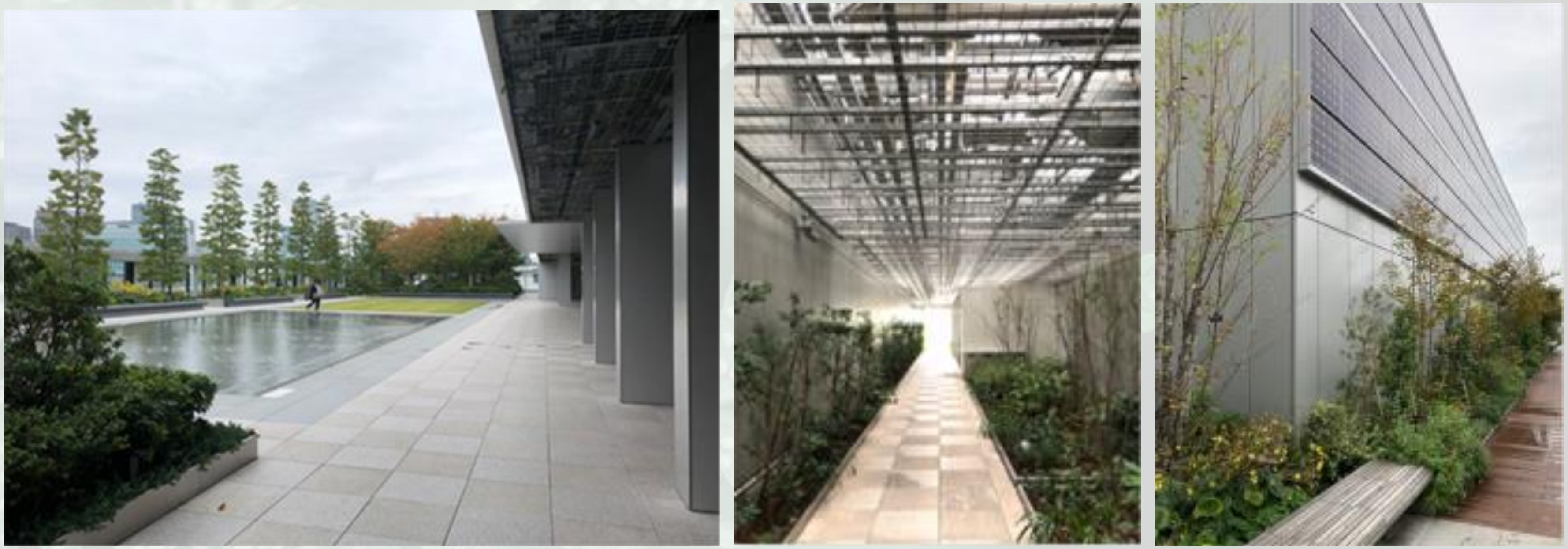

Install PV panels on the southern solid wall of Oxford House.


Reference example of integrated PV cells with the canopy in the California Academy of Sciences designed by Renzo Piano.

Reference:
Aelenei, L., et al, 2018. Case Studies – Adaptive Façade Network. TU Delft Open. Ed:2018.

Eco-Architecture Strategy 03:
Green + Blue roof

Though the majority of the roof of Oxford House has been occupied by the MVAC condensers, we may try to relocate them to one storey higher. The new deck for the condensers shall be constructed of steel grating so that daylight can still fall onto the main roof. The main roof can be converted to a green garden with water body and made accessible to the tenants.



Reference example of elevating the mechanical plants at roof level to gain extra space for a roof garden at Ginza Six, Tokyo.

Eco-Architecture Strategy 04:
Spatial optimization + Adjustable indoor comfort

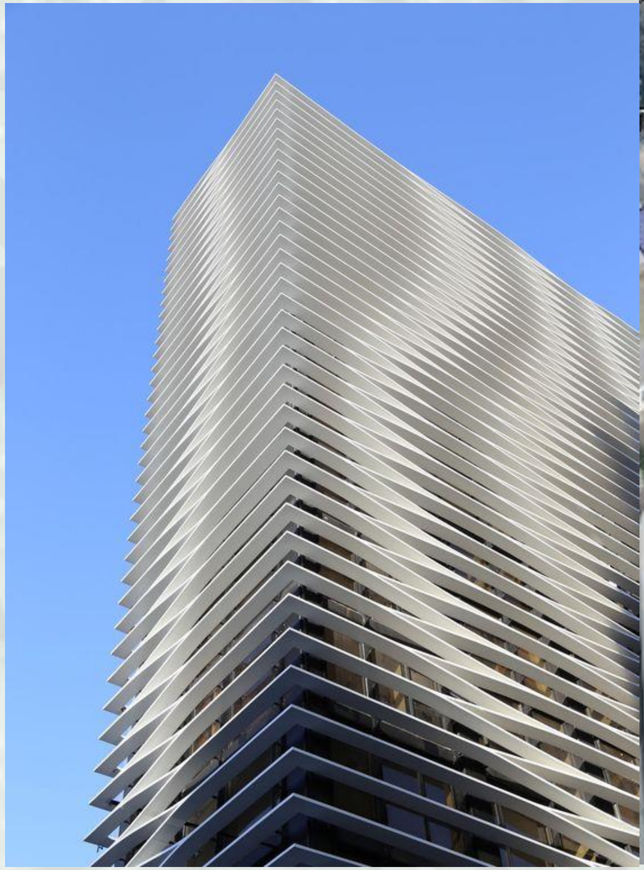
Application of mobile working cubicle for better utilization of office area and flexible moving to a space away from over solar heat gain.

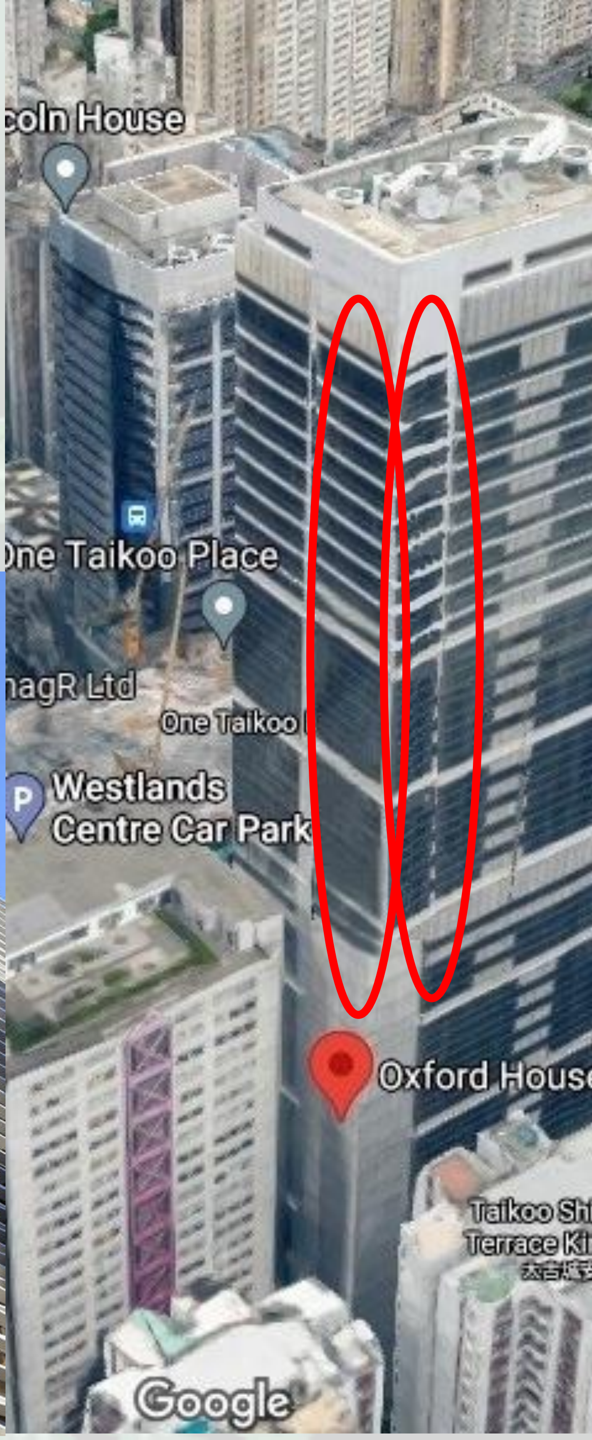
(Source of illustrative picture: Pinterest.)

Source of background picture - https://www.kpf.com/projects/18-robinson.
Annotations are added by the author of this slide.

Sustain-gineering Strategy 01:
Solar Power

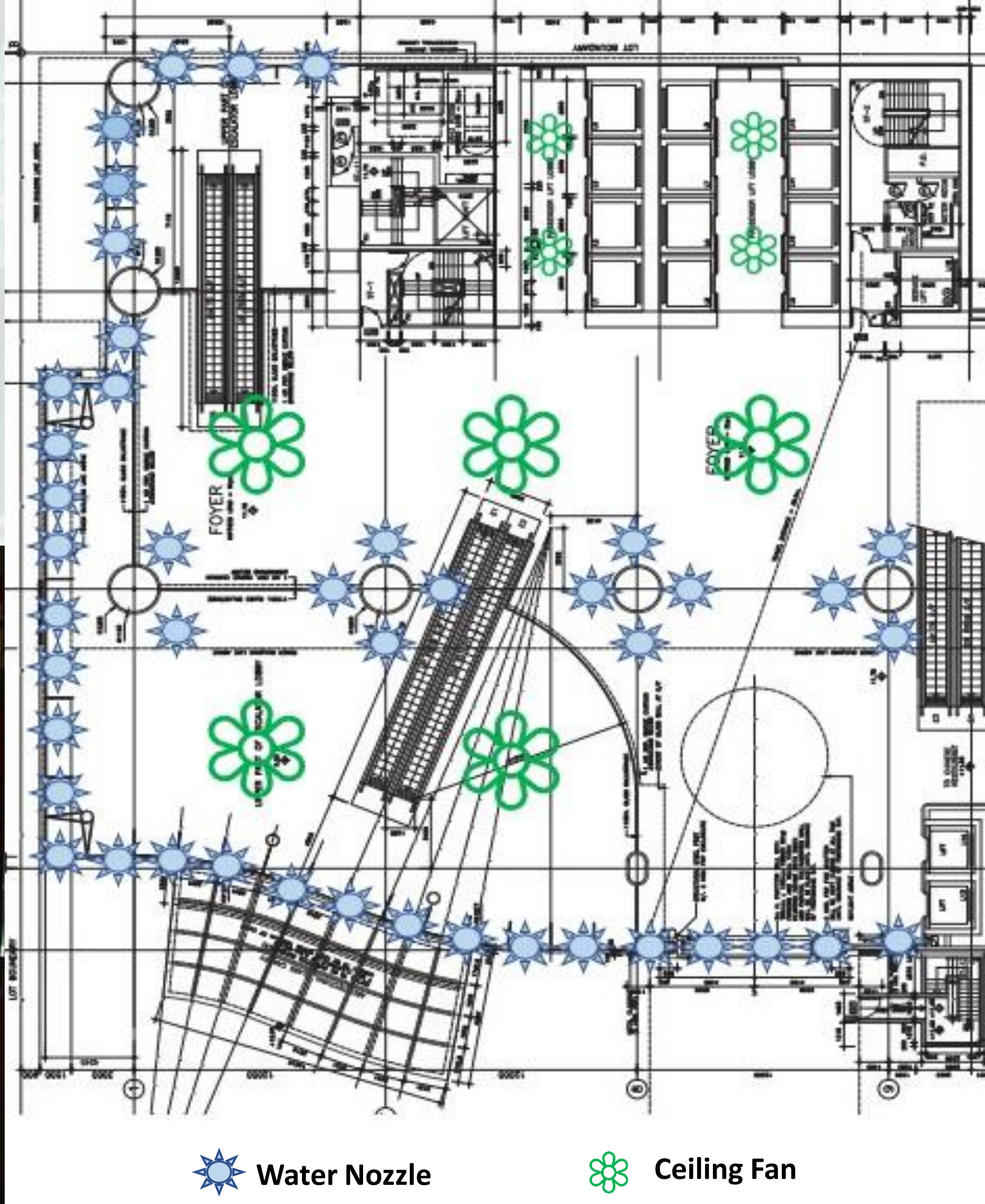
- Solar Panel Wall on South and East side from 21st Floor to 40th Floor
- Solar Panel on Architectural Fins on external wall
- Matching design to adjacent façade
- Large area of Solar Panel on Solid Wall (75m x 18m), Architectural Fins (45 sqm x 40 storeys)
- Estimated generation of 280k kWh per year





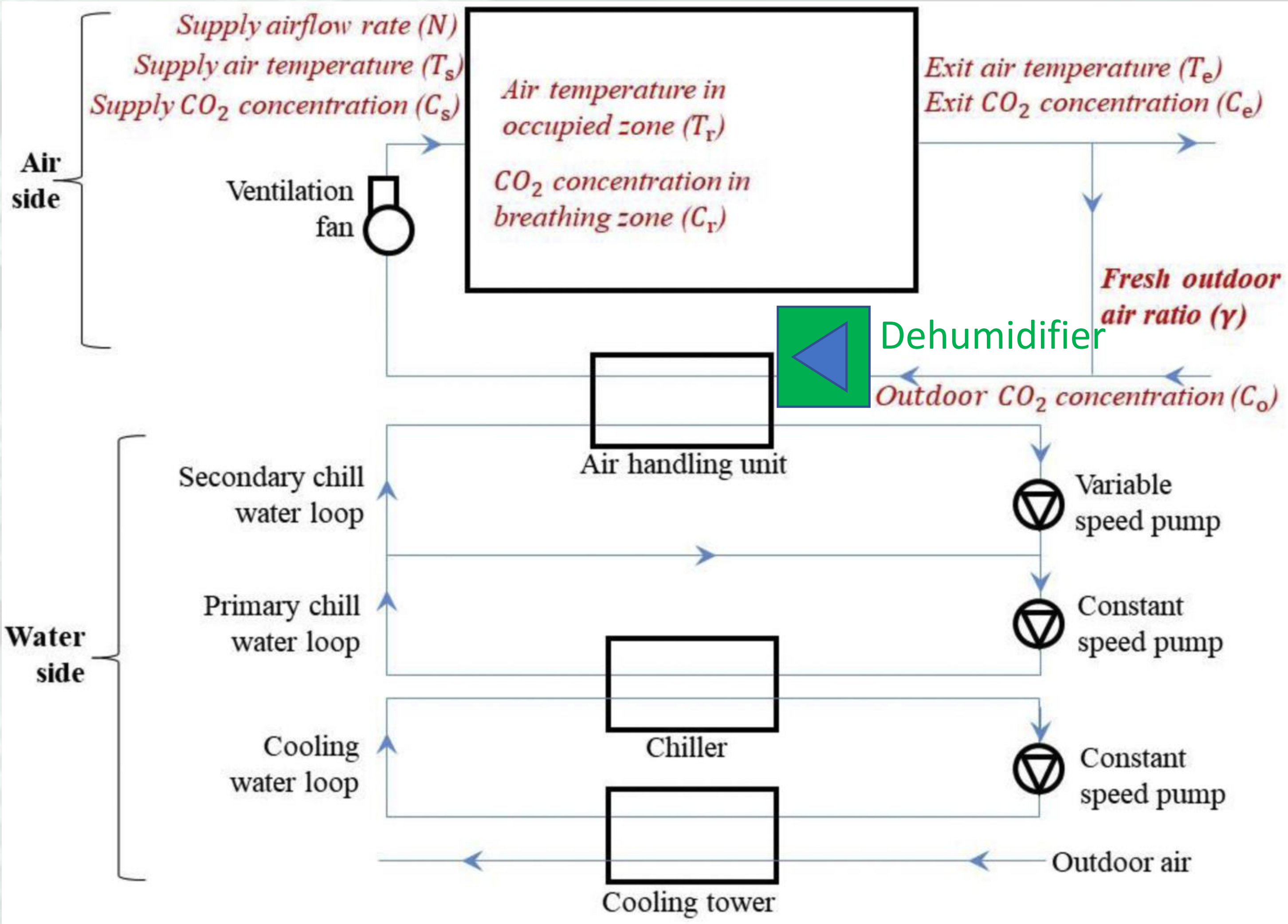
Sustain-gineering Strategy 02:
Water Mist Cooling System

- Water Mist Cooling System on Ground and First Floor
- Extensive Network of Water Mist Spraying Nozzles at perimeter, top of restaurants and major pillars
- Large Ceiling Fans at 1st Floor and Lift Lobby
- Enhancement of Passive Cooling of Ground and First Floor
- Estimated temperature drop between 3 to 8 degree Celsius



Sustain-gineering Strategy 03:
Pre-dry Outdoor Air

- Human comfort level of Humidity is around 40% - 60%
- Hong Kong is very humid with average RH between 76% - 81% in the last 20 years
- Reducing humidity can increase comfort without the need of a low temperature
- Installation of Dehumidifier before AHU on each office floor to remove moisture



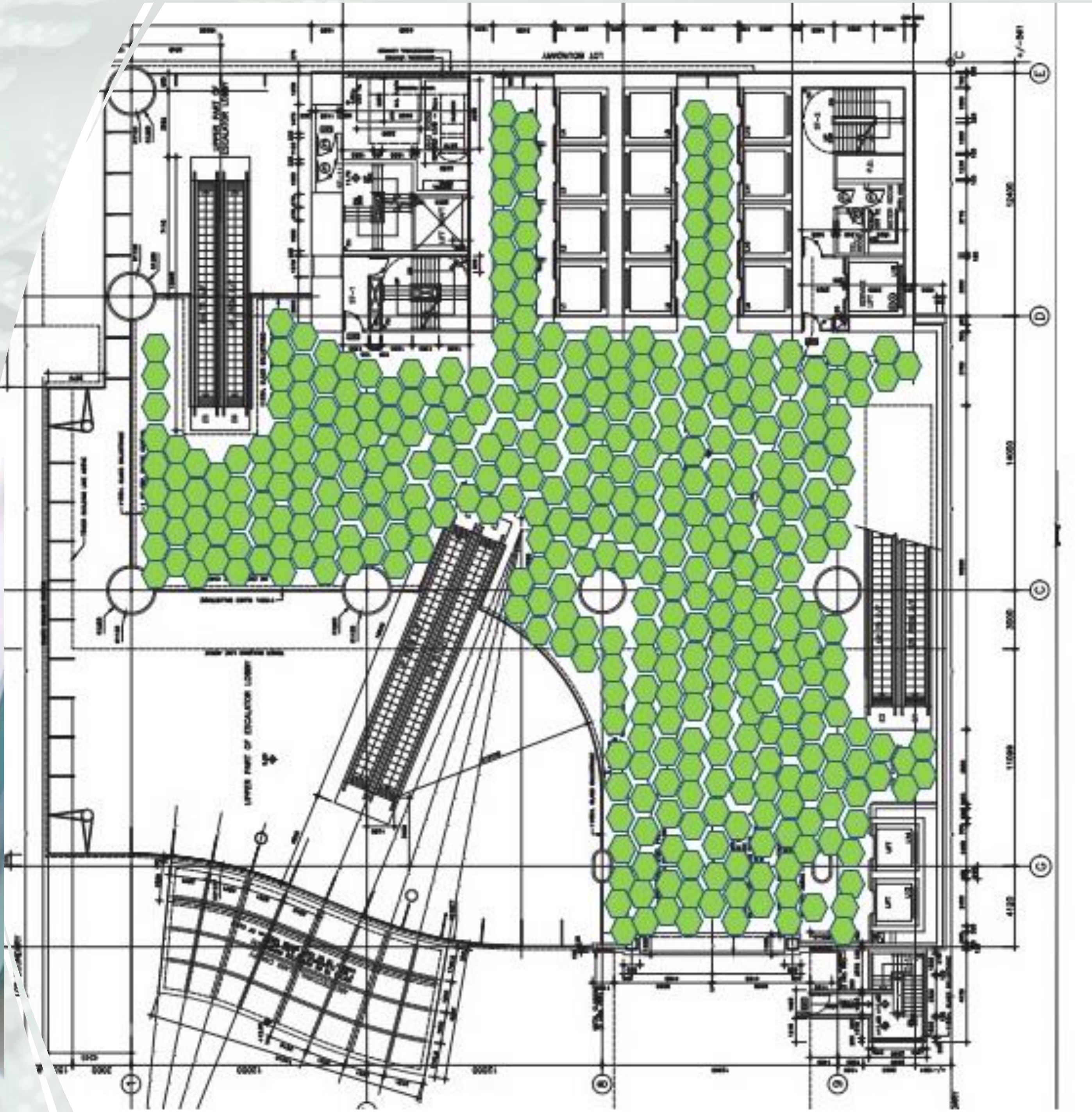
Source of diagram: Yong et al.(2019) , Optimization on fresh outdoor air ratio of air conditioning system with stratum ventilation for both targeted indoor air quality and maximal energy saving

Sustain-gineering Strategy 04:

Piezoelectric Human Power

- Piezoelectric tile Walkway on Ground Floor, First Floor and All Lift Lobbies
- Encourage healthy lifestyle
- Promote energy awareness for advancing carbon net zero to the occupants and visitors
- Estimated generation of 600 kWh per year

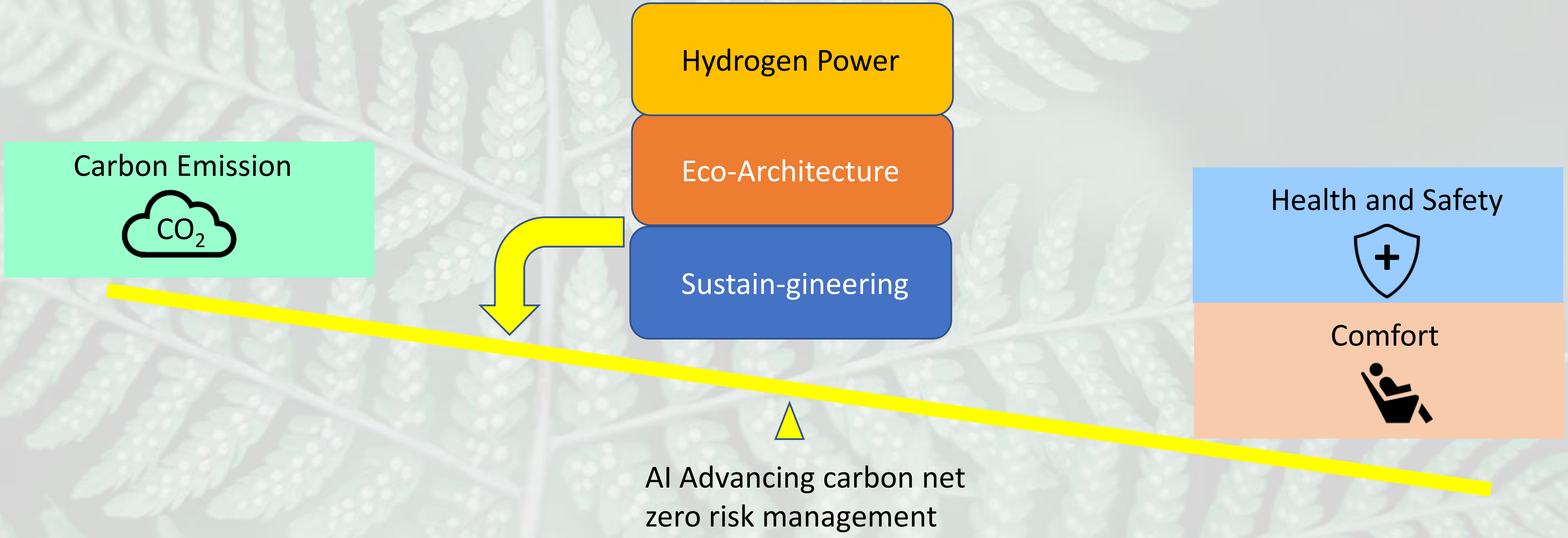
Photo credit: Courtesy of Pavegen



Advancing net zero risk management :

Balance of carbon emission with Health and Safety, Comfort

While making progress towards carbon neutral, well-being of tenants and other occupants should not be compromised through cutting all energy usage. AI risk management system is adopted to manage the 3 risk factors in Carbon Emission, Health and Safety, such that the execution of 3 pillars of main strategies: Hydrogen Power, Eco-Architecture, Sustain-gineering can be adjusted to optimize the carbon emission and well-being of occupants.



Advancing net zero risk management :

Factors and parameters

Sensors

Electricity | Air | Temperature | Light | Waste

People | Micro-organisms | Humidity | Water

Factors

Carbon emission CO_2	Health and Safety	Comfort

Parameters

Carbon emission:

- Electricity generation
  - Main Grid
  - Hydrogen
  - Solar
  - Piezoelectric
- Consumption
  - Usage intensity

Health and Safety:

- Ventilation/person
- Micro-organisms
- Air pollutants

Comfort:

- Temperature
- Humidity
- Light
- Occupants’ density

Strategies

Hydrogen Power	Eco-Architecture	Sustain-gineering

Advancing net zero risk management :

Carbon Emission Risk

Baseline carbon emission levels

- Local energy intensity from baseline year (eg: 2019) in consideration of:
    - Location(eg: floor, zone)
    - Season
    - Time
- Baseline local carbon emission intensity for zones in the building

Actual carbon emission levels

Generation

- Proportion of energy sources for electricity
    - Main Grid
    - Hydrogen
    - Solar
    - Piezoelectric

Consumption

- Energy usage intensity monitored by power meter

Carbon Emission Risk levels

- Boundaries of risk levels determined by carbon reduction science-based target from the baseline year
- Provide the progression of carbon reduction

Low	Reduction well beyond target
Medium	Reduction meets target
High	Reduction lags behind target

Advancing net zero risk management:
Health and Safety Risk

Ventilation per person	Micro-organisms	Air pollutants
• Sufficient fresh air for occupants • Prevent the risk of airborne transmission (eg: Covid19)	• Mould and bacterial levels in air samples monitored through sensors	• Excessive concentrations of pollutants like PM2.5, Formaldehyde, VOC affects health of occupants

Health and Safety Risk levels

Ventilation rate reference to ASHARE and university study on airborne transmission[1]

Low	Ventilation rate over 10 L/s/person
Medium	Ventilation rate at 3-10 L/s/person
High	Ventilation rate below 3 L/s/person

Airborne bacterial level follows indoor IAQ guide from HK EPD

Low	<500 cfu/m3
Medium	Ventilation rate at 3-10 L/s/person
High	>1000 cfu/m3

Indoor air pollutants level follows indoor IAQ guide from HK EPD

Low	Beyond levels of Excellent class
Medium	Beyond levels of Good class
High	Below levels of Good class

Reference:
1. Yuguo Li, 2020, SARS-CoV-2 airborne transmission is opportunistic and ventilation works (Media Conference)
2. Indoor Air Quality Management Group, EPD, Gov't of HKSAR, 2019, A Guide on Indoor Air Quality Certification Scheme

Advancing net zero risk management:
Comfort Risk

Temperature & humidity	Light	Occupants' density
• Thermal comfort monitored to ensure ideal environment in support of health, well-being and productivity	• Ensure lighting environment to improve mood and productivity of employees	• Prevent over-crowding which is beyond design of building services (eg: HVAC, lift) • Ensure sufficient social distancing for prevention of Covid19

Comfort Risk levels

PMV levels according to ANSI/ASHRAE Standard 55-2017

Low	-0.25<PMV<0.25
Medium	-0.5≤PMV≤-0.25 or 0.25≤PMV≤0.5
High	PMV beyond range of -0.5 and 0.5

International lighting standard for common space, eg: IES LM-83-12

Low	Average sDA $_{300,50\%}$ for 75-90% of floor area
Medium	Average sDA $_{300,50\%}$ for 75-90% of floor area
High	Average sDA 300,50% for < 75% of floor area

Density according to CIBSE Guide D, and social distancing guideline

Low	>10 m^2/person
Medium	2-10 m^2/person
High	<2 m^2/person

Advancing net zero risk management: Cycle of monitoring and actions

AI Advancing Net Zero Risk Management Platform

Monitoring

IoT sensors continuously monitor the building

Evaluation

Computation of Carbon Emission, Health and Safety, Comfort Risk

Alert

Raises alert to property manager for areas under high risk

Investigation

With aids of sensors data, identify the sources of high risk, eg: appliances with high energy usage

Decision

Find the optimized actions on appliances/ energy sources for maximize carbon reduction while minimize risk in Health and Safety, Comfort

Action

Execute the optimized actions, like adjustment of Water Mist Cooling System, proportion of energy sources

Carbon reduction achievement

	2019	Target
HVAC water	2,203,154	1,607,000
HVAC air	647,642	473,000
Lighting	534,656	435,000
Lift and transportation	650,802	552,000
Tennant	3,328,072	2,427,000
Total	7,364,326	5,494,000

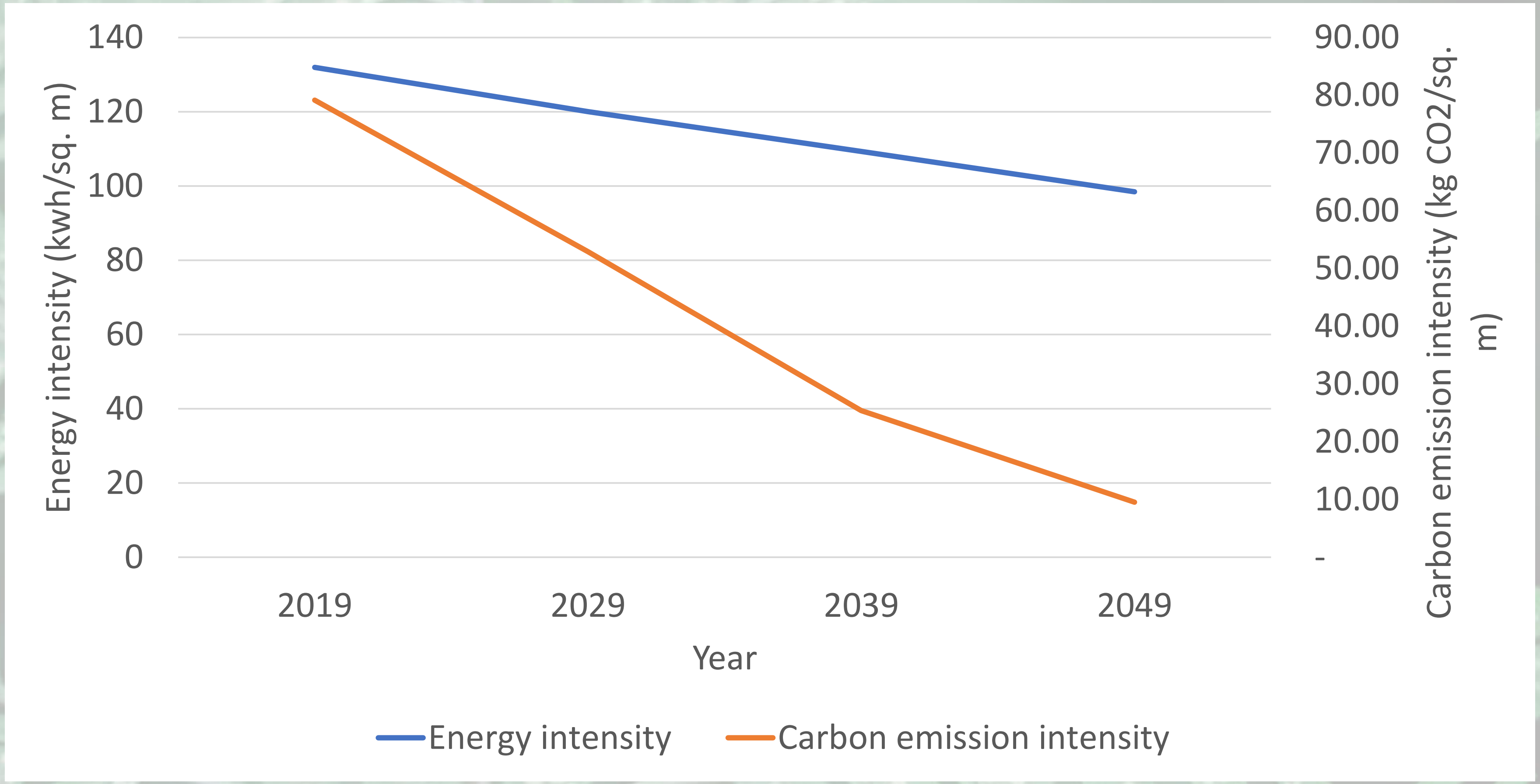
Annual electricity consumption of Oxford House in 2019(kWh)	7,364,326
Targeted annual electricity consumption (kWh)	5,494,000
Targeted annual electricity intensity achieved (kWh per sq. m)	98.41

Electricity from new sources	Energy output per year (kWh)	Carbon emission(kgCO_2-e)*
Hydrogen Power	5,276,109	521,651
Solar Power	280,061	11,076
Piezoelectric Power	595	118
Total	5,556,765	532,845

Carbon emission intensity of Oxford House in 2019(kgCO_2-e/sq. m)	79.15
Estimated target carbon emission intensity(kgCO_2-e/sq. m)	9.54

*Emission factor from: Hydrogen power: 0.1kg/KWh, Solar power: 0.04 kg/KWh, Piezoelectric Power: 0.2kg/KWh

Trajectory of advancing net zero



Conclusion

Achievement in carbon reduction by innovative energy sources and architectures

Convenient management of energy and indoor environment

Maintenance of well-being of occupants and visitors

Promotion of awareness of energy saving and healthy lifestyle