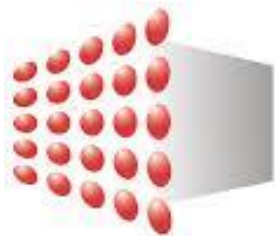


# Rethinking Cooling – Reducing Operational Carbon in Tropical Urban Buildings



ENERGY  
STUDIES  
INSTITUTE

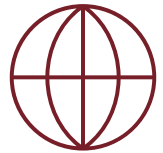


June 5 2026

# Agenda

1. Tropical Cooling
2. Comfort and Cooling
3. Rethinking Cooling
  - Flexible & Occupant-Centric Comfort
  - District Cooling Application
  - Intelligent & Adaptive Operations
  - Passive Design & High-Performance Envelope
4. Key Takeaways

# South-East Asian Climate



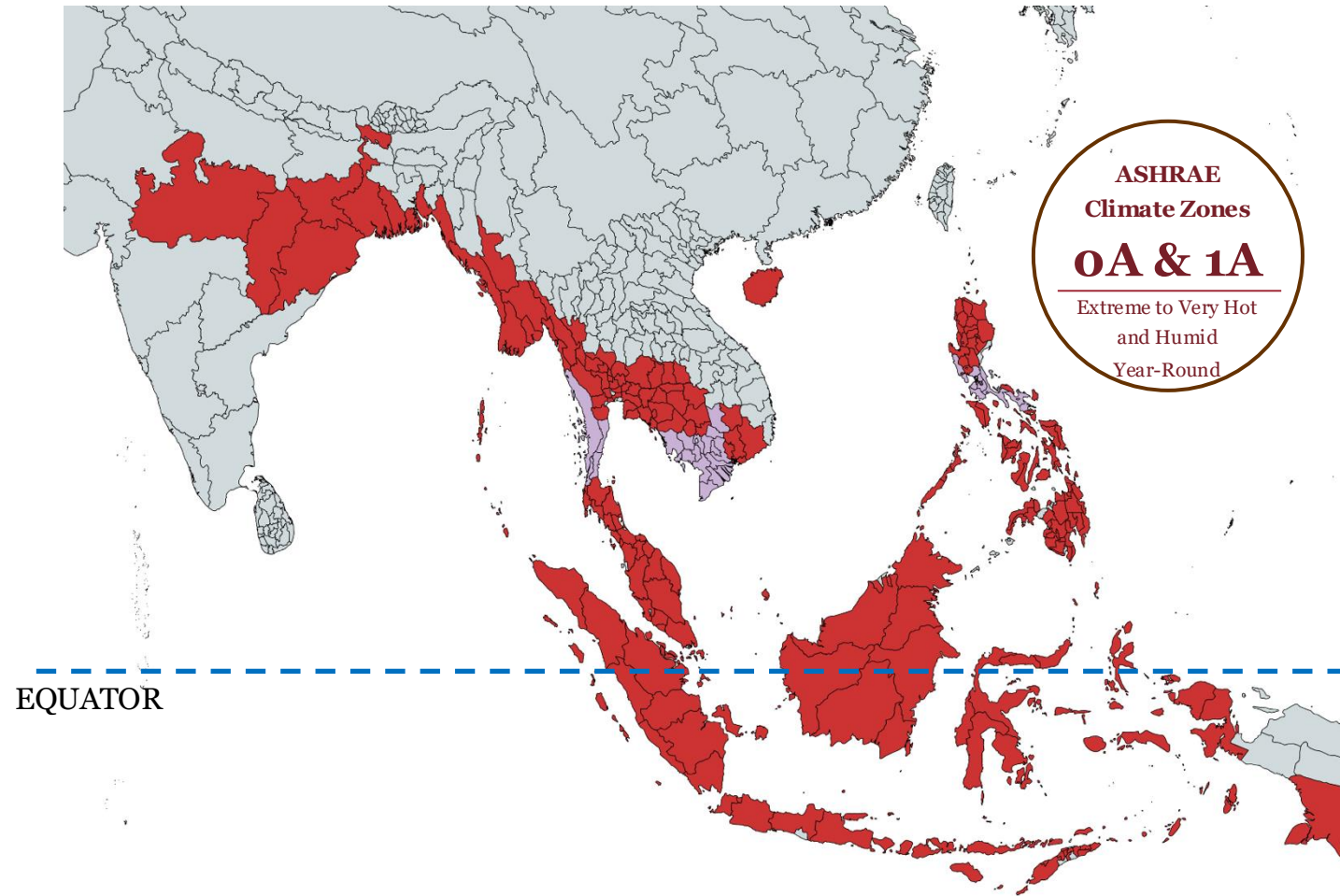
**SEA sits on the equator,**  
Placing the region within ASHRAE climate  
**Zones 0A and 1A**



**Extreme Heat, High Humidity.**  
Consistent high temperature and humidity  
levels throughout the year.



**Cooling is a Necessity**  
for a habitable and productive indoor  
environment



# Tropical Cooling



**Year-Round Demand**  
(~8,760 cooling hours)



**Humidity  
Dominated Load**

## Cooling Load Composition



**Temperate**  
Temperature  
Dominates

**80%**  
Sensible

**20**



**Tropical**  
Humidity  
Dominates

**40%**  
Sensible

**60%**  
Latent

# Tropical Cooling – Urban Heat Island Effect



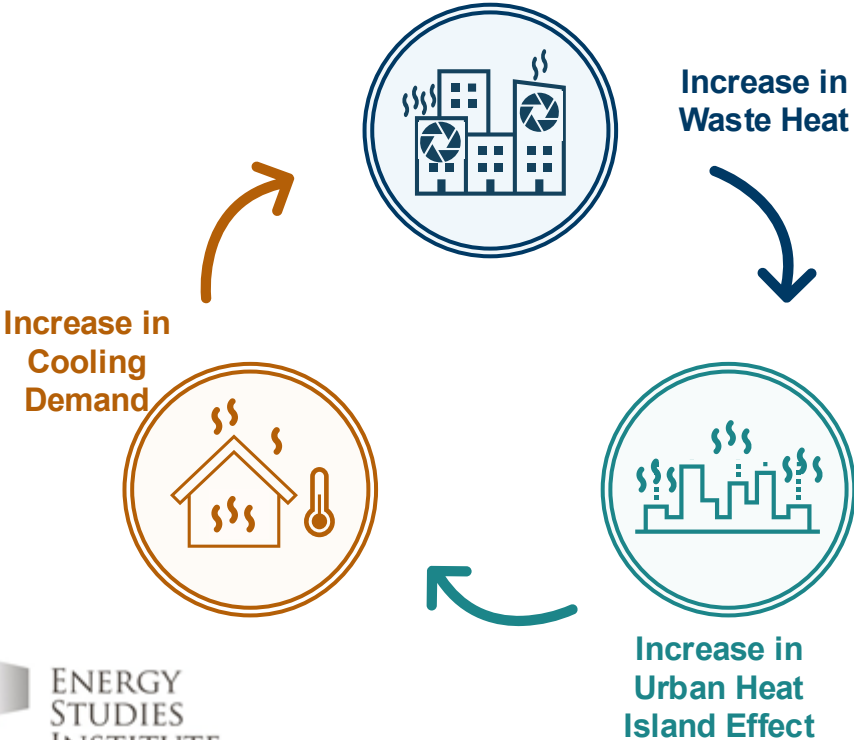
**Year-Round Demand**  
(~8,760 cooling hours)



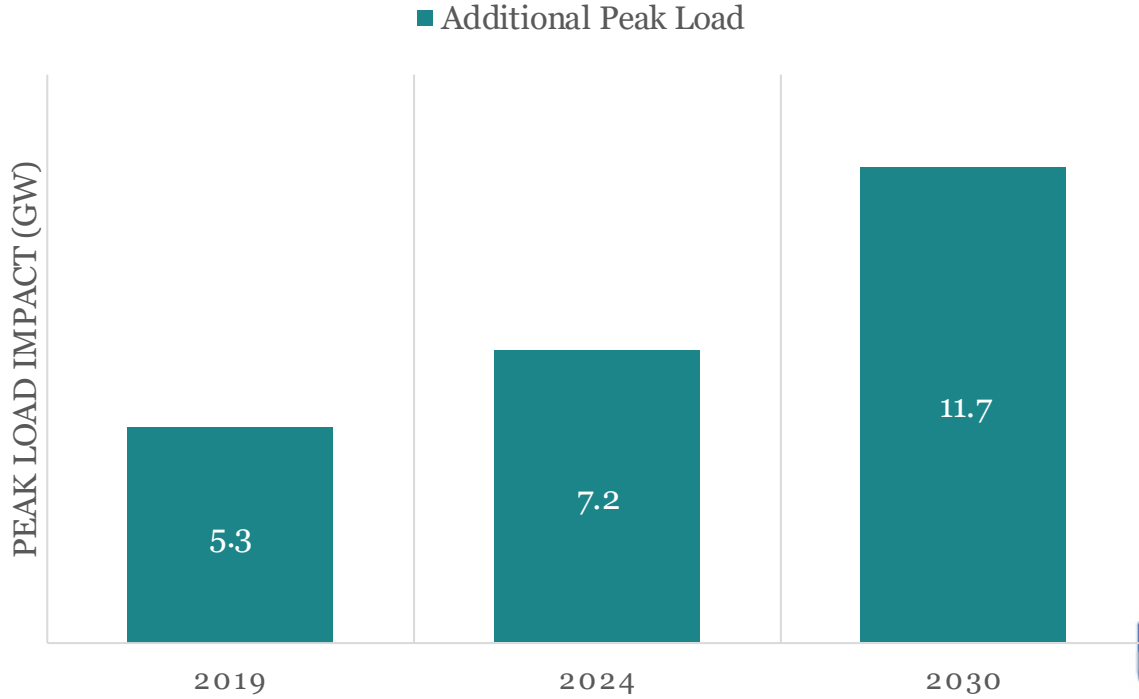
**Humidity Dominated Load**



**Urban Heat Island Effect can be as high as 7°C**



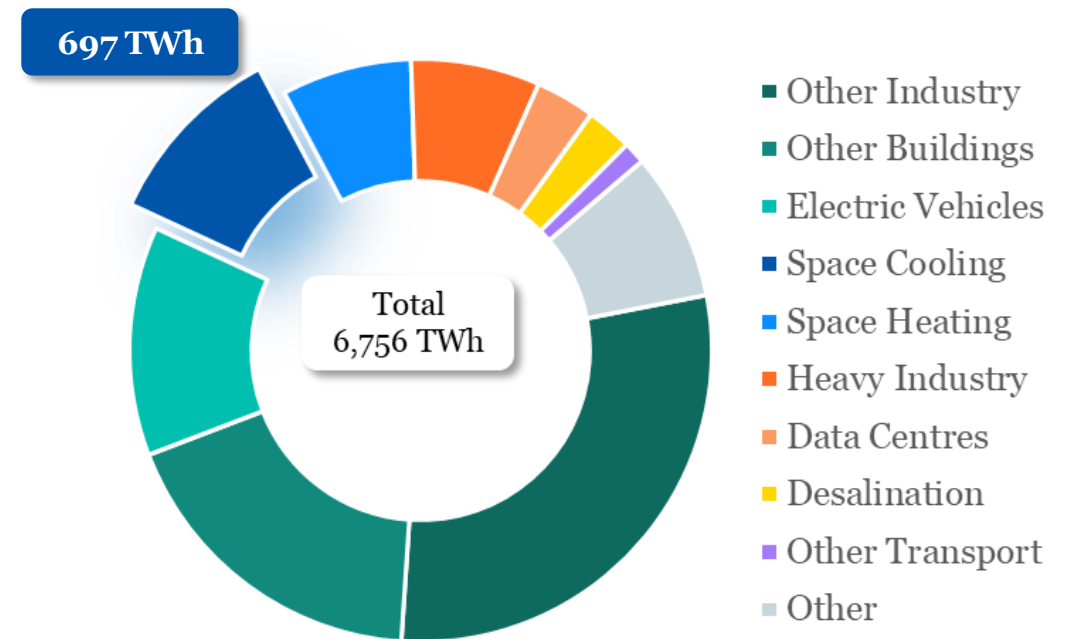
ADDITIONAL PEAK LOAD CAUSED BY AND OUTDOOR TEMPERATURE INCREASE OF 1°C, 2019-2030



# Global Cooling Growth

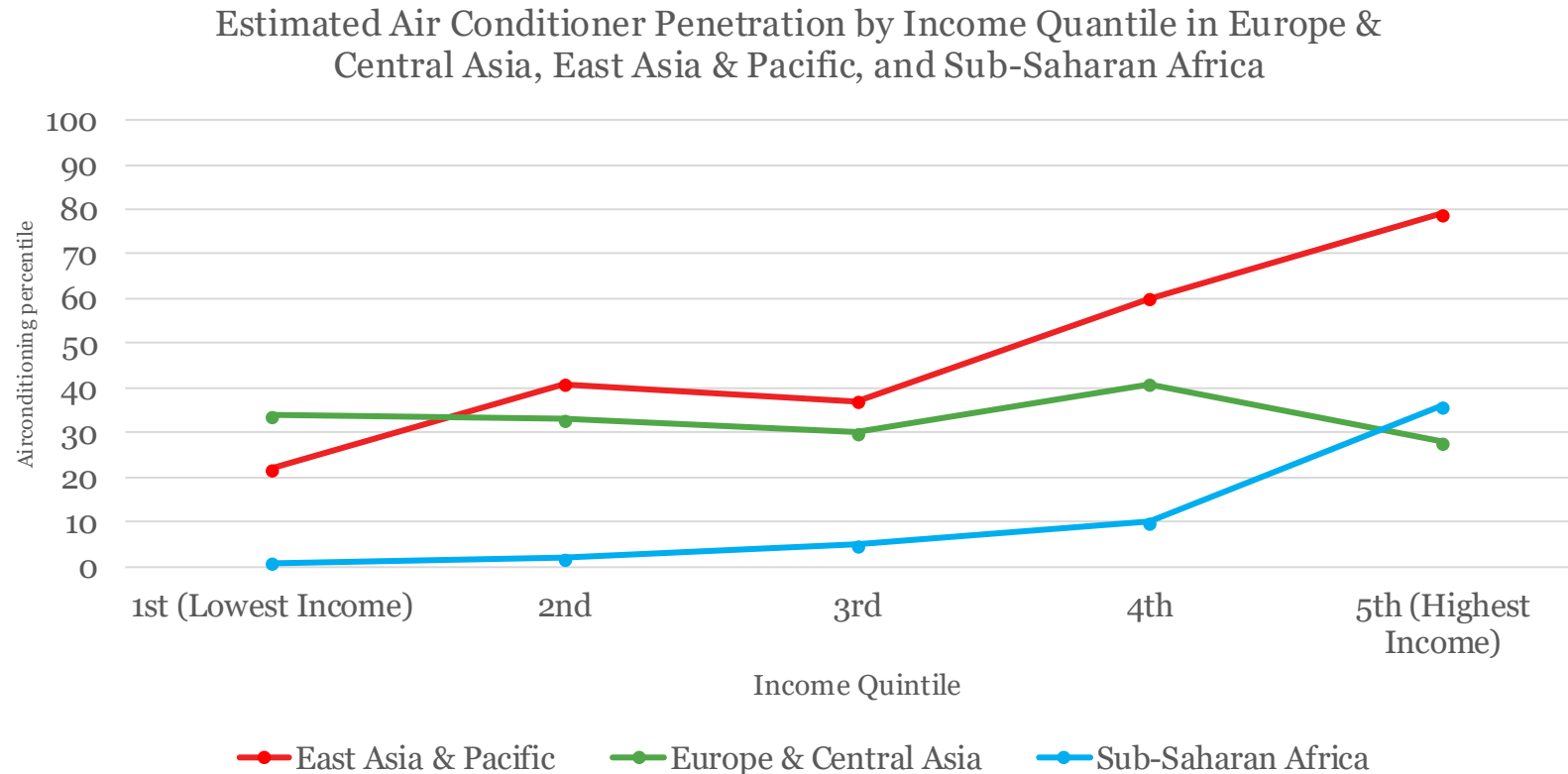
- Space cooling is now the fastest-growing source of building energy demand globally at around  $\sim 4\%$  annual growth to 2035
- Produce around 7.2 BtCO<sub>2</sub>e by 2050 under business-as-usual scenario

Global Growth in Final Electricity Demand



# Air Conditioning Stock Projection

- About 3.5 billion people live in regions with high temperatures, yet only about 15% of them own an air conditioner
- The stock of air conditioners is set to increase ninefold between 2020 and 2040



# Singapore's Cooling Perspective

- Buildings account for about **20%** of Singapore's national carbon emissions and play a significant role in towards national decarbonization goals.
- Cooling consumes **40-60%** of building energy

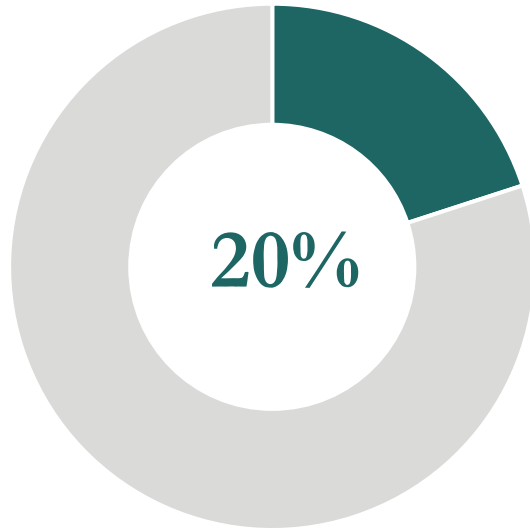
## Share of National Carbon Emissions



**20%**

### Buildings

Buildings account for about **20%** of Singapore's national carbon emissions



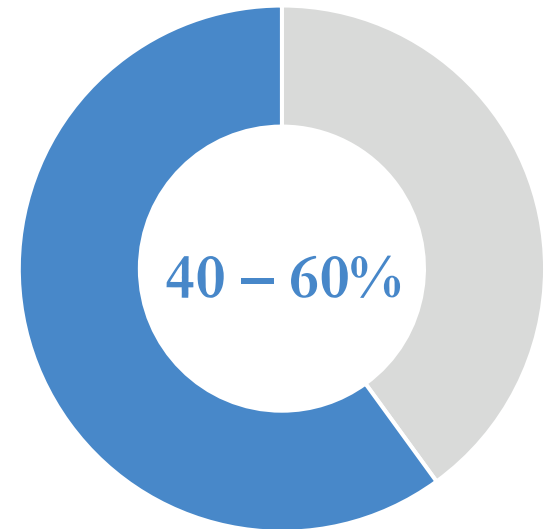
## Share of Building Energy Consumption



**40 – 60%**

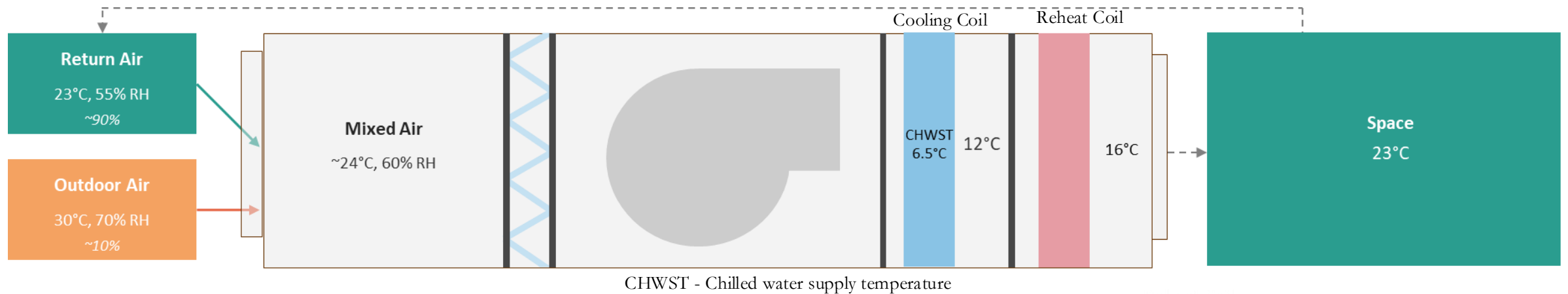
### Cooling

Cooling consumes 40 – 60% of building energy



# Conventional Cooling Using an AHU

## Air Handling Unit with Outside Air



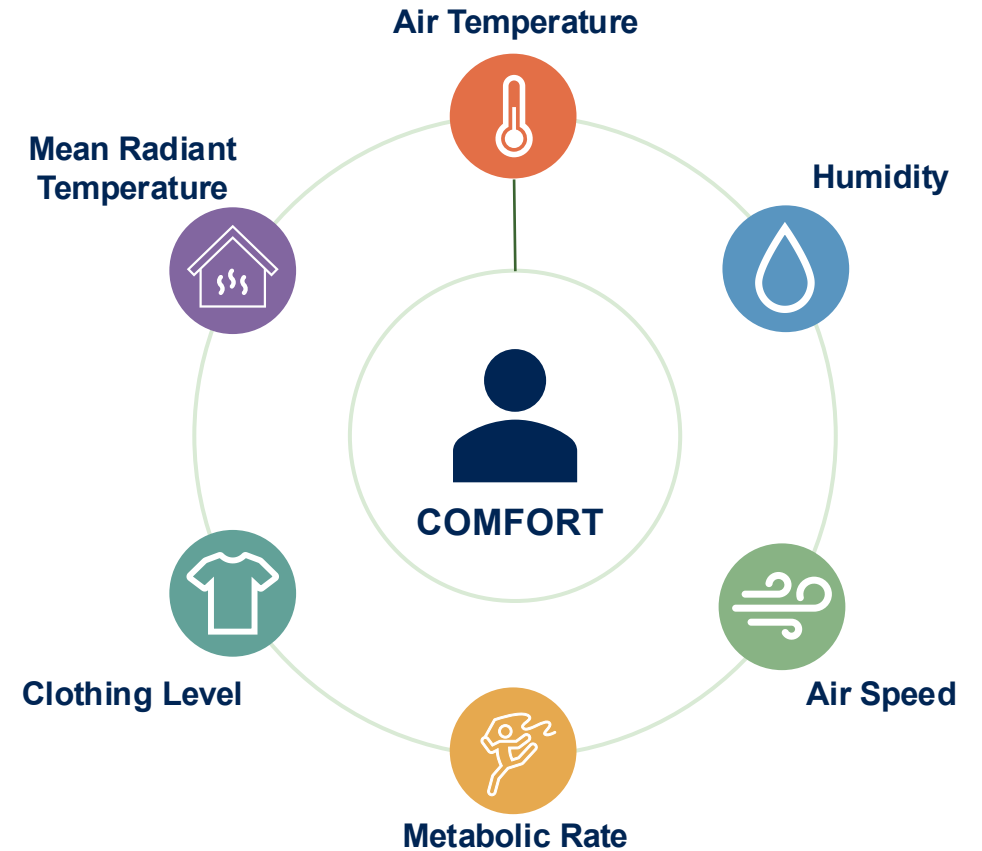
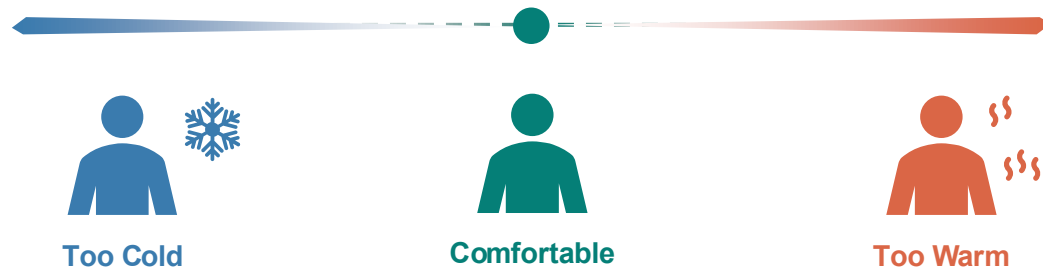
To control humidity, conventional AHUs often **cool air below** the required supply temperature and subsequently **reheat it**.



This process incurs an avoidable penalty of approximately **4.1 kJ/kg** air (~14% of total cooling load), with an additional **4.1 kJ/kg** required for reheat.

# Comfort and Cooling

- Vast majority of commercial buildings are controlled by thermostats.
- Basic air temperature comparison to determine the output of the HVAC system.



# Rethinking Cooling

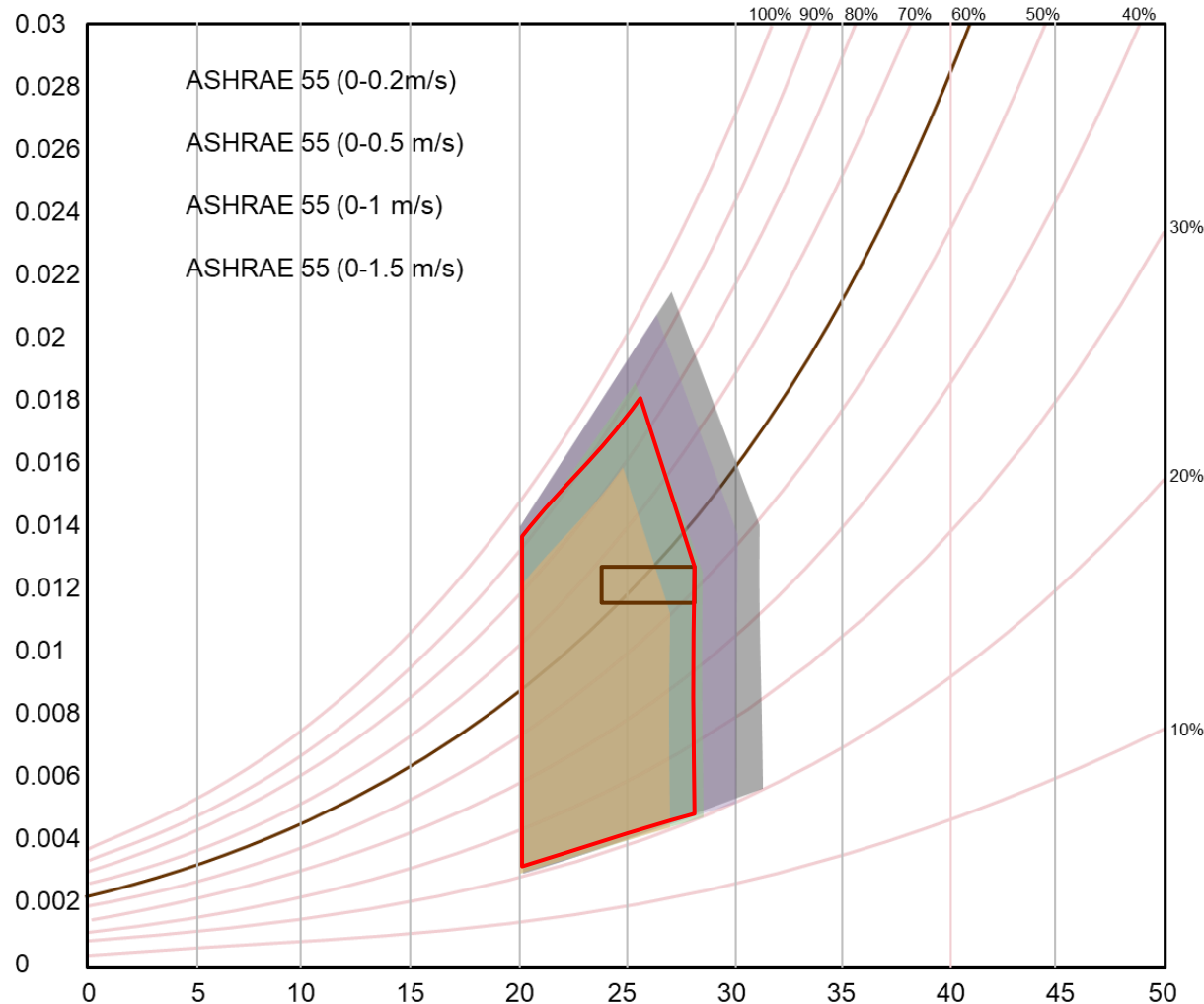
Reducing Cooling Load and Demand through Design and Operation

1. Flexible & Occupant-Centric Comfort
2. District Cooling Application
3. Intelligent & Adaptive Operations
4. Passive Design & High-Performance Envelope

# Flexible & Occupant-Centric Comfort



# Flexible & Occupant-Centric Comfort



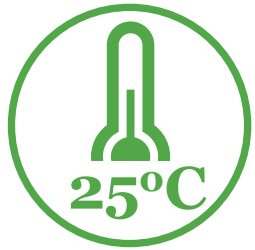
- Increase in air movement expands acceptable comfort limits under ASHRAE 55
- Up to 12% energy savings per 1° C increase in temperature setpoint (23° C → 25° C), with no increase in occupant discomfort.

# Go 25 National Movement

**GO**  
**25** 

## Go 25 National Movement

Setting indoor temperatures at 25°C The Go 25 Pledge is a voluntary industry initiative promoting more sustainable cooling practices. It encourages building owners, businesses, and organizations to commit to:



1

### Set Indoor Temperatures at 25°C or Higher

Setting indoor temperatures at 25° C or higher, or as close to 25° C as possible if it cannot be achieved without compromising comfort due to infrastructural constraints.



3

### Provide Alternatives & Encourage Adaptation

Provide alternatives such as fans and encourage relaxed dress codes



2

### Adjust Temperature Gradually

Adjust temperature gradually to ease transition for occupants



4

### Display and Promote the Pledge

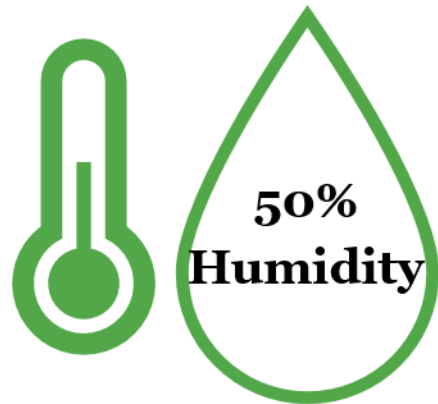
Display indoor temperatures and promote the pledge publicly via Go 25 toolkit

# Go 25 National Movement: Humidity Control

**GO  
25** 

## Go 25 National Movement

Setting indoor temperatures at 25°C The Go 25 Pledge is a voluntary industry initiative promoting more sustainable cooling practices. It encourages building owners, businesses, and organizations to commit to:



### Enhanced Evaporative Cooling from Skin

At 50% RH, sweat evaporates more effectively aiding in natural body cool.



### Air Feels Lighter and Fresher

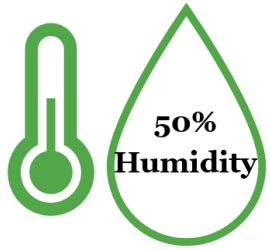
Maintaining 50% RH helps reduce that “heavy” or “clammy” feel of humidity.



### Better Productivity and Well-being

Occupants in dry environments report higher comfort and focus.

# Go 25 National Movement: Humidity Control



## Enhanced Evaporative Cooling from Skin

At 50% RH, sweat evaporates more effectively aiding in natural body cool.



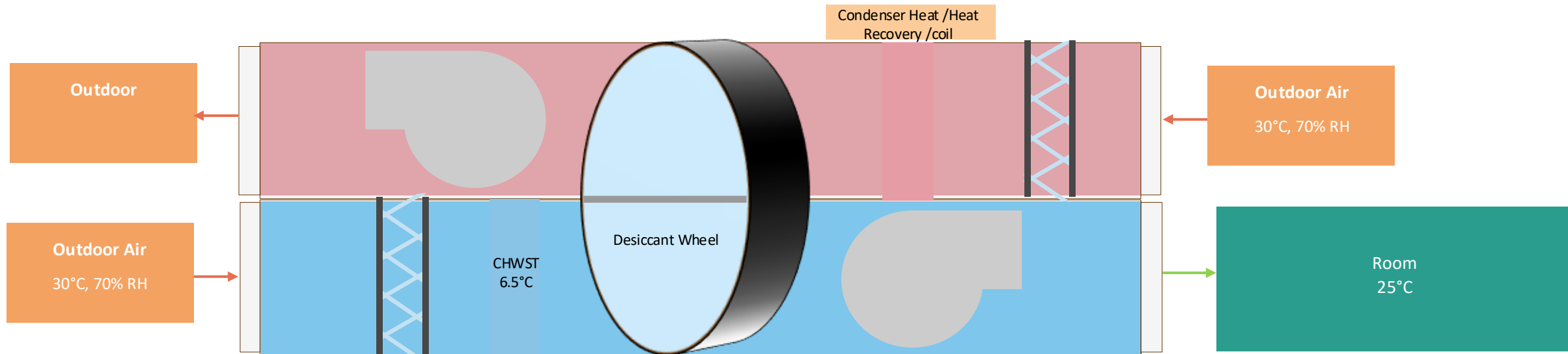
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Maintaining 50% RH helps reduce that “heavy” or “clammy” feel of humidity.

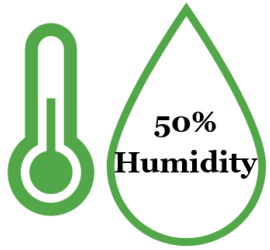


## Better Productivity and Well-being

Occupants in dry environments report higher comfort and focus.



# Go 25 National Movement: Sensible Load



## Enhanced Evaporative Cooling from Skin

At 50% RH, sweat evaporates more effectively aiding in natural body cool.



## Air Feels Lighter and Fresher

Maintaining 50% RH helps reduce that “heavy” or “clammy” feel of humidity.



## Better Productivity and Well-being

Occupants in dry environments report higher comfort and focus.



# District Cooling Application

A decorative graphic consisting of a solid red horizontal bar that transitions into a series of three parallel white lines on a dark background to the right.



# Singapore District Cooling System (Greenfield)

## Marina Bay District Cooling System

World's largest underground district cooling network at the point of constriction

## One Bangkok District Cooling System



**75,000 RT** by 2027 with full plant augmentation reaching 90,000 RT.

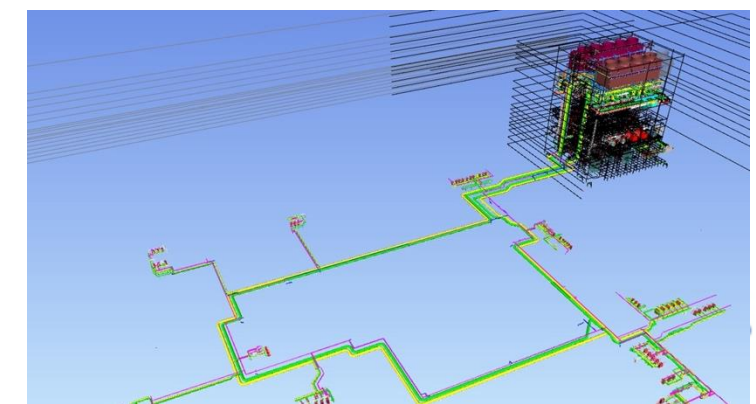
**25,000 tonnes** annual reduction in carbon emissions



**32k MWh/year** energy savings

**35,540 tCO<sub>2</sub>/year** carbon reduction

**3.7 Mm<sup>3</sup>/year** water savings



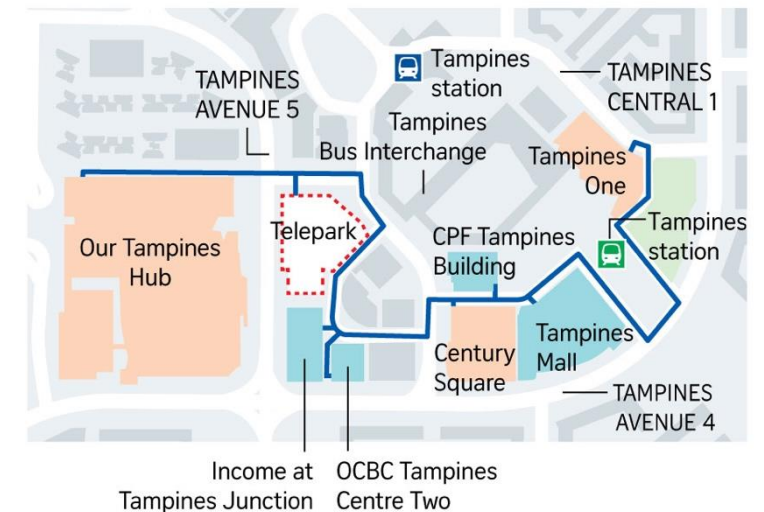
Source: Source: One Bangkok, Sustainability & Smart City; Shinryo, District Cooling System; Shinryo, One Bangkok DCS Project

# Tampines District Cooling System (Brownfield)

## First Brownfield DCS of Singapore



- Brownfield Development
- **10,500 RT** Cooling Capacity
- **1,000 tonnes** annual reduction in CO<sub>2</sub>
- **2.3M kWh** annual energy savings

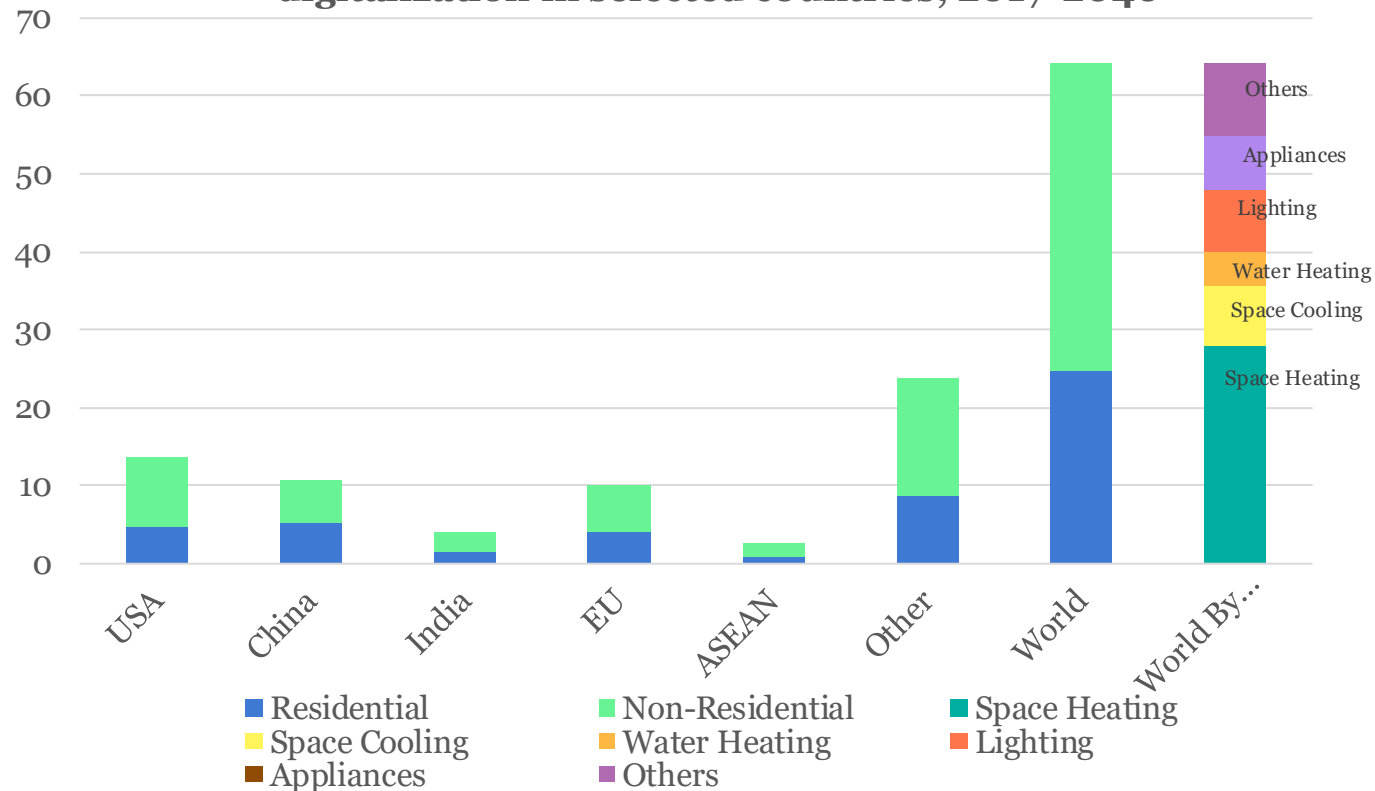


# Intelligent & Adaptive Operations



# Intelligent & Adaptive Operations

Cumulative energy savings in buildings from widespread digitalization in selected countries, 2017-2040



- **~30%** of commercial building energy is wasted due to poor HVAC controls.
- **Up to 10%** lower building energy use through digitalization
- **3–5%** lower global energy demand enabled by smart building technologies

# Digital Twin Model of the Keppel Bay Tower

IES developed a performance Digital twin model of the super-efficient Green Mark Platinum Keppel Bay tower Building and achieve:



7%

**Additional Annual Energy Savings**

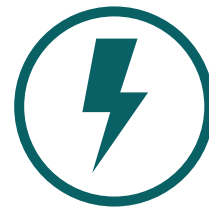
Achieved from better operation and control using the Performance Digital Twin

OVER  
30%



**Overall Energy Savings**

Equivalent to **2.2 million** kWh/year



EUI of  
<115

kWh/m<sup>2</sup>-year

Almost 50% more energy-efficient compared to typical Singapore office buildings

OVER  
2,400

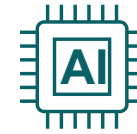


**Tonnes of CO<sub>2</sub>e reduced annually**

# Airbus Asia Training Center with GET



## GET Control Smart Cooling System



AI-powered micro-climate control



Smart dampers and wireless sensors



Cooling adjusted based on:

- Occupancy
- Weather conditions
- Real-time temperature variations



**48.8%**

**Electrical Energy Reduction**  
(Pilot deployment)



**~20%**

**Cooling Energy Reduction**  
(Pilot Deployment)



**70t**

**Reduction Annual Scope 2 Emissions**  
(Pilot Deployment)

# Passive Design & High-Performance Envelope

A decorative graphic element consisting of a solid red horizontal bar that transitions into a white background. On the right side, there are several thin, parallel white lines of varying lengths, creating a stepped or layered effect.

# Sustainable Cooling Hierarchy

1



## MINIMIZE COOLING LOADS (PASSIVE BUILDING DESIGN)

Wall/roof design – Glazing – Shading –  
Insulation – Natural Ventilation – Plug & Lighting  
Loads



6-9 °C

Indoor temperature  
reduction from  
combined passive  
measures.

2



## USE LOW-ENERGY COOLING (FANS IN PLACE OF AC)

Fans – Evaporative Coolers – Hybrid fan-AC  
systems -



&gt;30%

Hybrid approaches cut energy  
use vs conventional AC; tiers  
1+2 together reduce 2050  
installed cooling capacity by  
41% (68 – 40 TW)

3



## MAXIMIZE EQUIPMENT ENERGY EFFICIENCY (NEW AND EXISTING)

Variable-speed compressors – improved controls  
and maintenance – Best-in-class chillers



45%

Doubling AC efficiency  
cuts demand by 45% vs  
baseline by 2050 ( IEA  
Efficiency Cooling  
Scenario)

4



## IMPLEMENT RAPID PHASE-DOWN OF HFC REFRIGERANTS

Kigali Amendment implementation



~1/3

Of cooling's 4.1 Gt CO<sub>2</sub>e  
emissions in 2022 comes from  
refrigerant leakage. Phase-down  
directly removes this fraction

UP TO

80%

Reduction in cooling demand from  
insulation and exterior shading alone  
(IEA)

# Sengkang Grand Mall



## Opened 2023:

Integrated with Sengkang Grand Residences



## Main Atrium Mechanical Ventilated

With large overhead fans; no AC in common areas



## Air-conditioning

Restricted to individual tenants

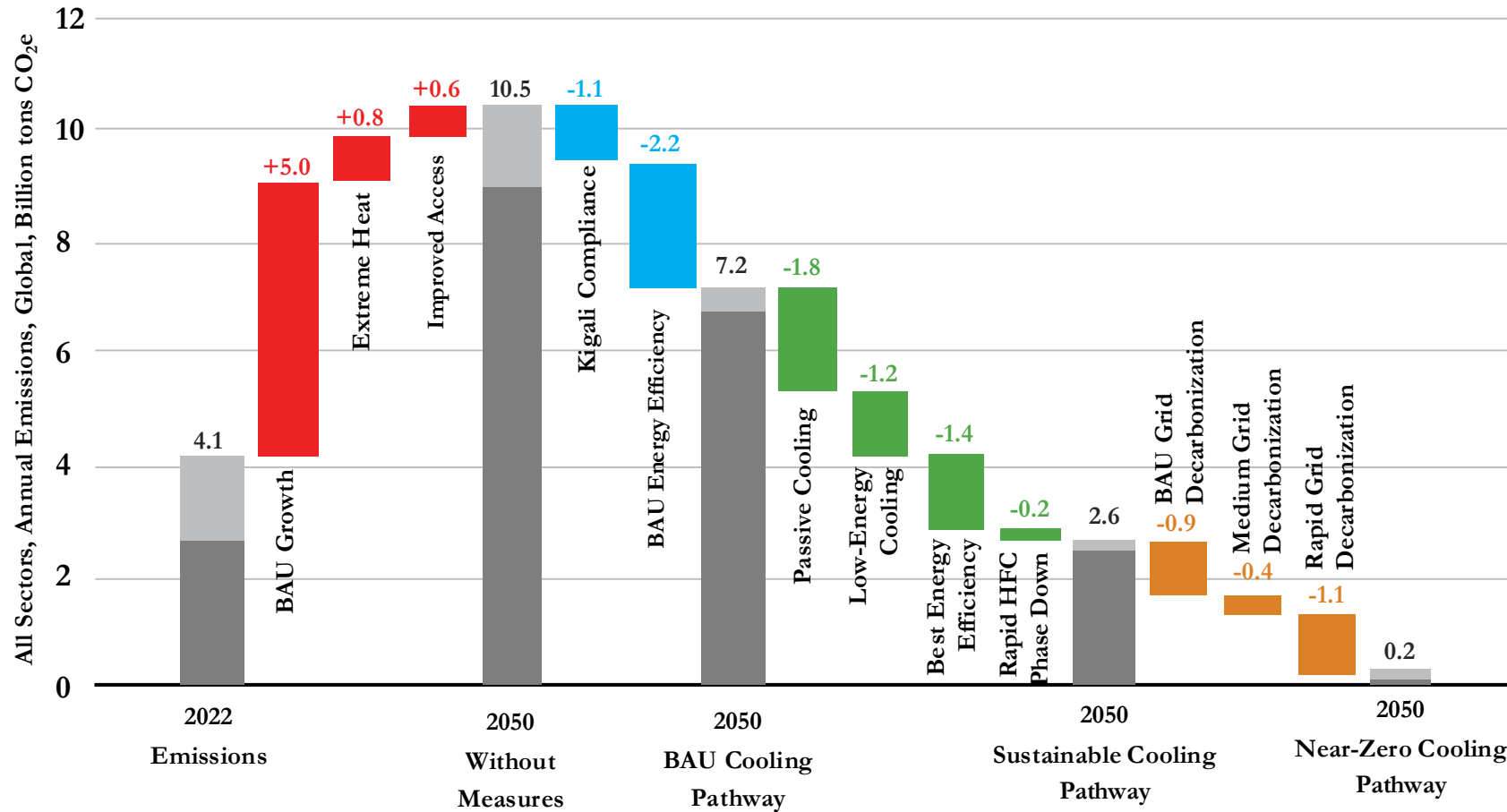
## Mechanically Ventilated Atrium

Common areas rely on natural ventilation and large overhead fans, eliminating the need for air-conditioning in the mall's central atrium.

**Reduced cooling demand before cooling is supplied**

Source: EdgeProp, Sengkang Grand Residences Sustainability Award

# Modelled Pathway to Near-zero GHG Emissions from Cooling in 2050



- Indirect (Energy) Emissions
- Direct (Refrigerant) Emissions
- Growth
- BAU Cooling Measures
- Sustainable Cooling Measures
- Grid Decarbonization

# Key Takeaways

- Cooling is becoming a necessity, not a luxury.
  - Demand will continue to grow, making efficient cooling non-negotiable.
- Reduce demand before supplying cooling.
  - Passive design remains the most effective and sustainable cooling strategy.
- Existing buildings can still achieve significant savings.
  - Hybrid cooling approaches provide a practical pathway for retrofits.
- Sustainable cooling is a systems challenge.
  - Success will come not from a single breakthrough technology, but from the integration of design, technology, operations, infrastructure, and people.

# Thank You



LinkedIn: Christian Allen E. Jimenez

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