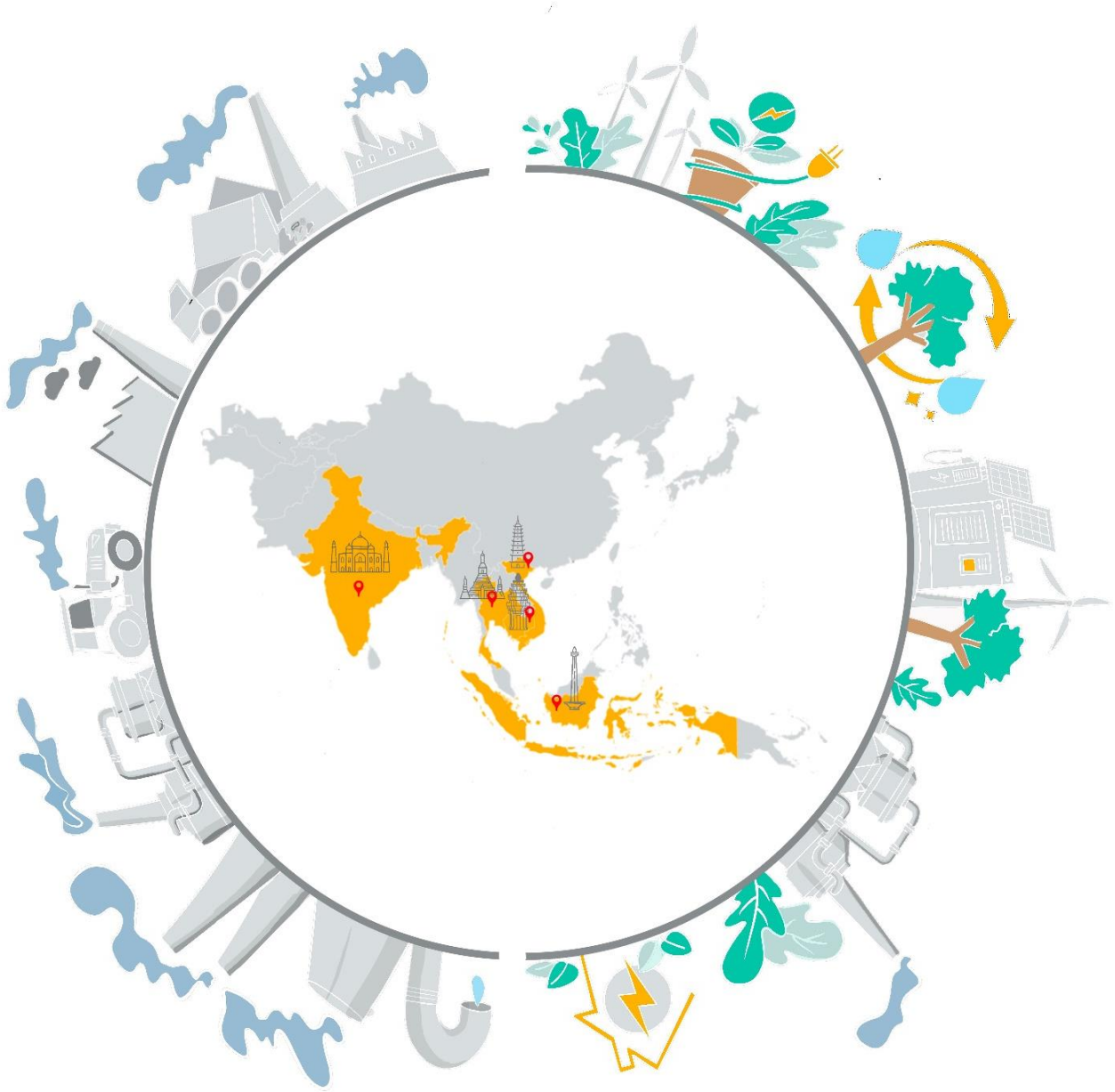


GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

1. Energy Scenario and Climate Actions in Asia

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

01 About ALCBT Project

02 Climate Change and Impacts

03 National Commitments

04 Energy Scenario

05 NDCs and Initiatives

06 Challenges and Opportunities



0.1 About the Asia Low Carbon Buildings Transition (ALCBT) Project

Objective:
Present innovative strategies to transform existing and new buildings toward carbon neutrality by 2050 or earlier. The project offers insights into sustainable building practices that improve living conditions and reduce the environmental footprint of the built environment

Rationale:

- The building and construction sector contributes significantly to global climate change, accounting for about 21% of total GHG emissions
- Embodied carbon accounts for about 10% of global energy-related GHG emissions – global floor area of buildings to double by 2060, mostly in Asia and Africa
- Buildings operations account for about 30% of final energy demand – over 20% in Asia, with space cooling as the fastest-growing end use in buildings

Sources: International Energy Agency, 2023; United Nations Environment Programme, 2024

ALCBT Project

Impact: Nationwide transition toward low carbon buildings in Asian countries, substantially reducing GHG emissions from the sector

Outcome: Technical, planning and institutional tools for low carbon buildings have been successfully implemented by key public and private sector stakeholders in **Cambodia, India, Indonesia, Thailand and Vietnam**



Key Project Participants

- National and local government
- Building industry professionals
- Financial services institutions
- Universities and academia

Project Funding: EUR 19.3 million

Target Outputs

- **Standardized tools and systems** for managing building carbon emissions
- **Enhanced capacity** of key stakeholders to deliver low carbon buildings
- **Financial pathways** established for low carbon buildings transition
- Knowledge products produced to facilitate **replication and scaling up**

Implementation period:
August 2023 – August 2028

Total 1.68 million tCO_2eq
Direct and indirect emissions reduced

Total 19,000+ people
Enhanced knowledge and capacity

EUR 140 million
Investment mobilized

ALCBT Project Structure

Project Steering Committee	Government Representatives + Industry Representatives: **Cambodia, India, Indonesia, Thailand, Vietnam** Consortium Representatives + Zukunft – Umwelt – Gesellschaft			
	Meets virtually annually, in line with annual donor reports			
Consortium Partners	Global Green Growth Institute (GGGI)	HEAT International (HEAT)	ASEAN Centre for Energy (ACE)	Energy Efficiency Services Limited (EESL)
	Meets virtually monthly to share project updates			
Technical Advisory Committee				

BUILDING ENERGY PERFORMANCE

Driving factors

*In Asia, around 50% of the buildings that will exist by 2050 are **yet to be built**, which provides great opportunity for decarbonization*



Policy Drivers

- Energy Conservation Acts, Laws or Rules
- Standards and Labeling Program – Mandatory Minimum Energy Performance Standard (MEPS)
- National Action Plan on Climate Change
- National Cooling Action Plan
- Energy Conservation Building Code
- NDC Commitments

Technology Drivers

- Upgradation of MEPS for Appliances – Standards are Raised Every Two Years for Air Conditioners
- Architectural Improvements – Passive Designs, Building Energy Management Systems
- Low Carbon Building Materials
- New Technologies – LGWP Refrigerants, Tri-generation, District Cooling Systems

Market Drivers

- Public Recognition through Green Certification – LEED, GBC, GEM, etc.
- Rising Energy Demand for Domestic, Institutional and Commercial Sectors
- Demand Side Management and Demand Response Programs by Utilities
- Bulk Procurement to Leverage Economy of Scale
- Consumer Awareness of EE Products and Increase in Per Capita Income

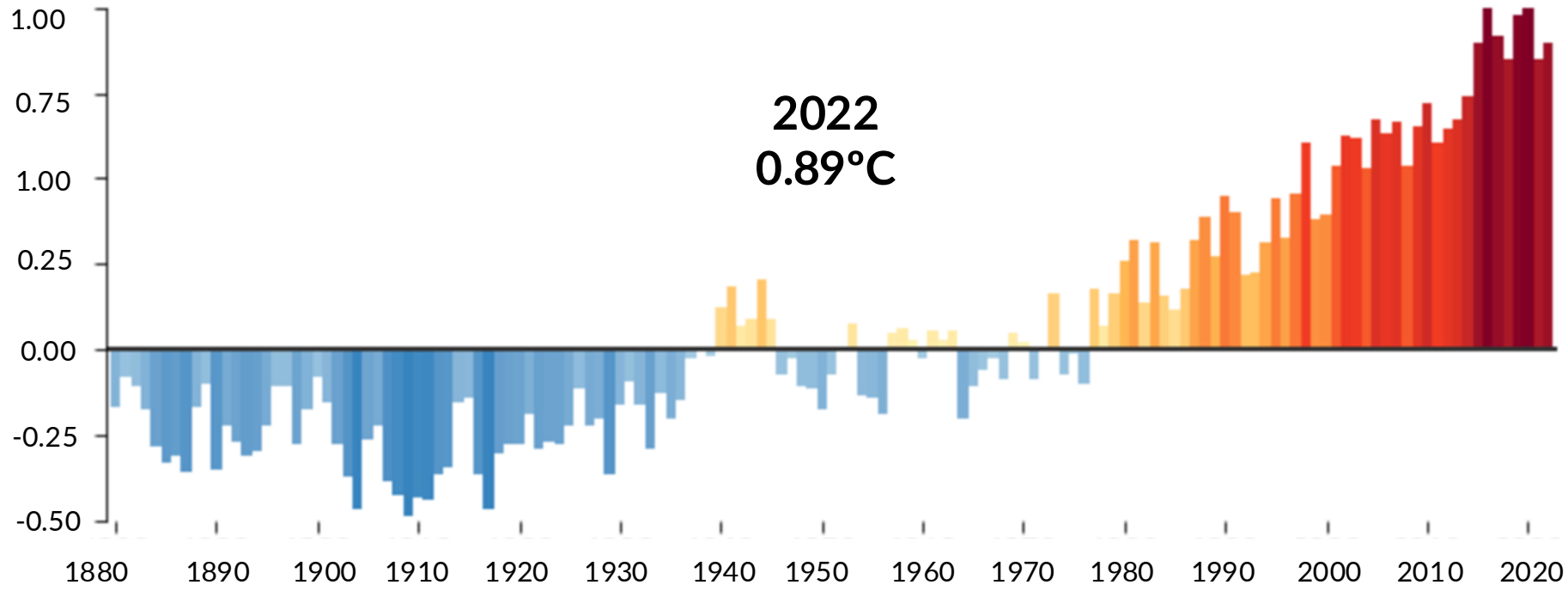
0.2 Climate Change

Impacts: Globally and in Asia



CLIMATE CHANGE

Observed 1.2°C rise in temperature since the late 19th century



Last nine years warmest on record
Global temperature anomaly (°C compared to the 1951–1980 average)

Source: NASA Earth Observatory

CLIMATE CHANGE

Increase in GHG emissions and consequences

Causes:

- Burning of fossil fuels
- Deforestation
- Industrial practices

Consequences:

- Extreme weather events
- Environmental changes
- **Severe heat and cold waves**

The World Meteorological Organization confirmed that 2023 was the warmest year on record, with global average near-surface temperature at 1.45°C (with a margin of uncertainty of ± 0.12°C) above the pre-industrial baseline

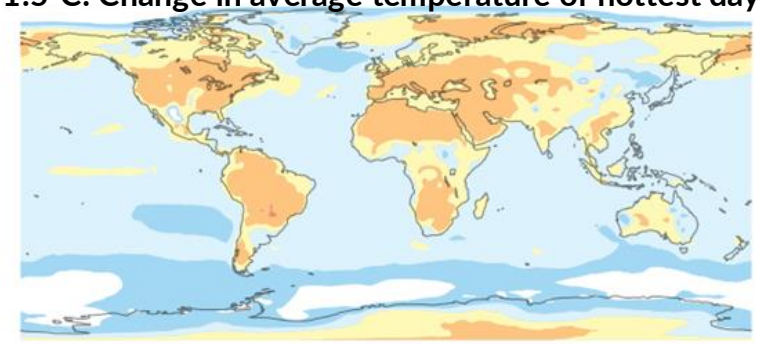


CLIMATE CHANGE

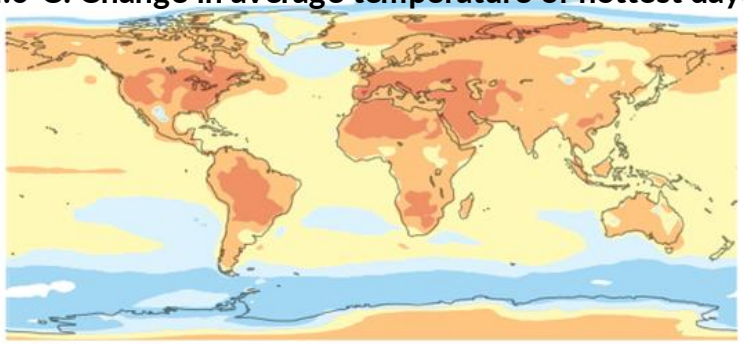
Hazards

- The impacts of climate change are being felt in both inhabited land and oceans
- An average warming of 1.5°C across the whole globe raises the risk of heatwaves and heavy rainfall events, amongst many other potential impacts
- Based on the 'pathways' identified by IPCC, two modeled scenarios with temperature rises of 1.5°C and 2°C are presented pictorially

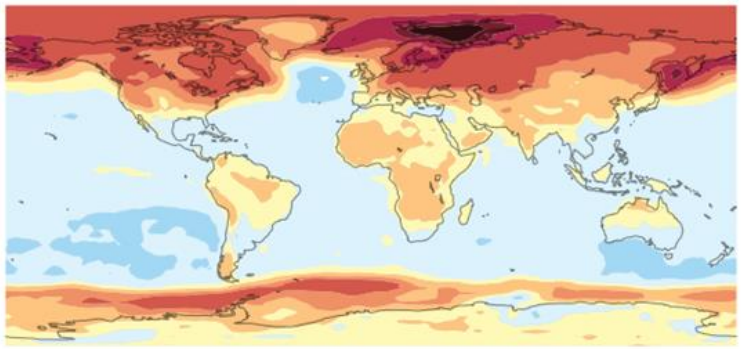
+1.5°C: Change in average temperature of hottest days



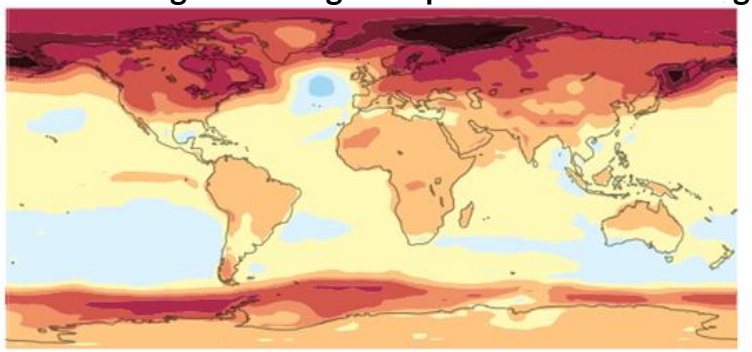
+2.0°C: Change in average temperature of hottest days

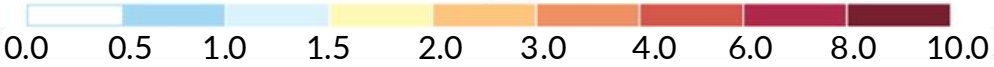


+1.5°C: Change in average temperature of coldest nights



+2.0°C: Change in average temperature of coldest nights





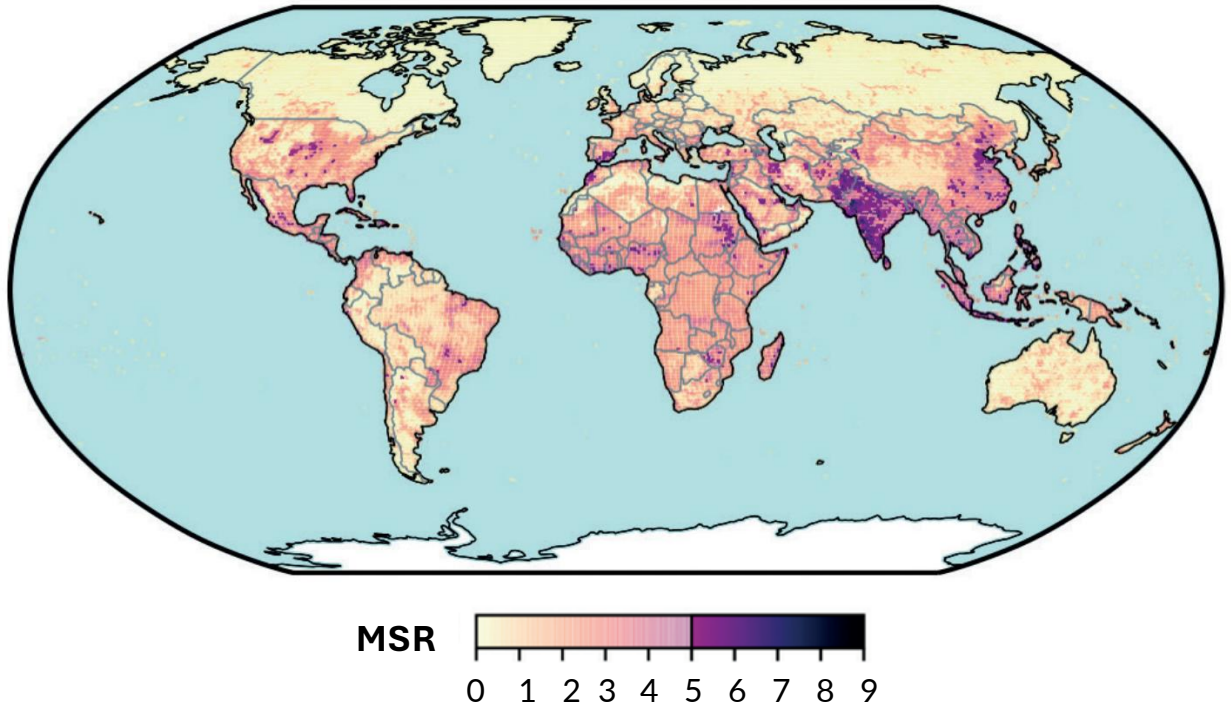
Source: Hoegh-Guldberg, O., et al., 2022

CLIMATE CHANGE

Exposure to risks

- IPCC emphasizes multi-sector risk assessment as a critical tool for understanding the wide-reaching impacts of global warming and climate change
- This approach is essential for evaluating how risk manifests and interacts across various sectors like water resources, agriculture, energy systems, health, infrastructure, economic systems and social systems
- The heat map presented here is a multi-sector risk (MSR) map for a 1.5°C temperature rise with MSR score ranging from 0–9
- Locations having a score above 4 are considered to have multi-sectoral risk due to global warming
- India is significantly impacted, and so are Cambodia, Indonesia and Vietnam

Multi-sector risk (MSR) at 1.5°C temperature rise



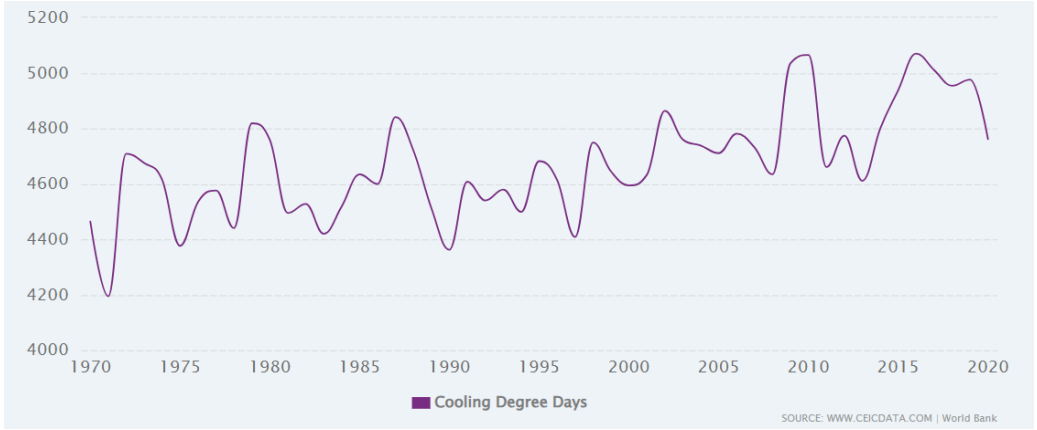
Source: Hoegh-Guldberg, O., et al., 2022

CLIMATE CHANGE

Case example: Increasing heat stress in India and potential hazards

The “Assessment of Climate Change over the Indian Region”, published by the Indian Ministry of Earth Sciences in 2020, highlights the following:

- India’s average temperature has risen by around 0.7°C during 1901–2018
- Frequency of daily precipitation extremes (rainfall intensities >150 mm per day) increased by about 75% during 1950–2015
- The frequency and spatial extent of droughts over India has increased significantly during 1951–2015
- Sea-level rise in the North Indian Ocean occurred at a rate of 3.3mm per year in the last two and half decades (1993–2017)
- Frequency of severe cyclonic storms over the Arabian Sea has increased during the post-monsoon seasons during 1998–2018



India cooling degree days 1970–2020 (an example of increasing heat stress)

Note: A cooling degree day is a measurement designed to track energy use. It is the number of degrees that a day's average temperature is above 18°C (65°F). Daily degree days are accumulated to obtain annual values

Source: https://climateknowledgeportal.worldbank.org

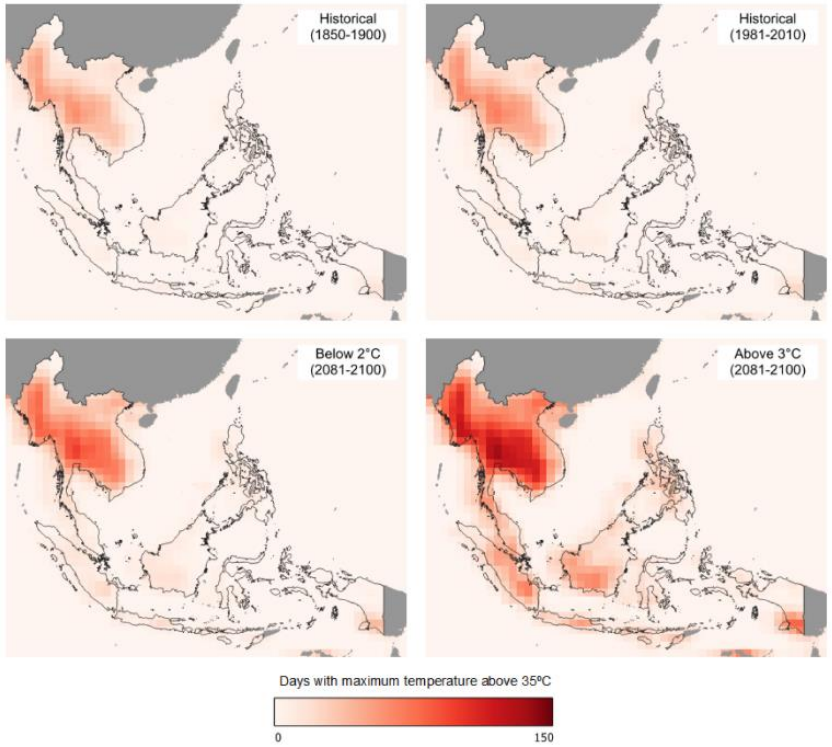
CLIMATE CHANGE IMPACT

Southeast Asia: Increasing cooling demand

IPCC studies show most of Southeast Asia has seen an ***increase in the number of warm nights, and increase in the intensity and frequency of heat waves;*** the subregion would be one of the **most exposed to extreme heat events**

Under a high-emissions scenario (above 3°C), Southeast Asia is projected to face ***48 days of maximum land temperature above 35°C***, which is almost ***four times higher*** than the pre-industrial period. In a low-emissions scenario, the projection is ***25 days***

Space cooling is one of the fastest growing electricity end uses. ***60% of households*** *are* projected to have access to space cooling and **increase in peak demand**



Change in days with maximum temperature above 35°C, 1850–1900, 1981–2010 and 2081–2100

Warm nights are defined by the IPCC as nights where the minimum temperature exceeds the 90th percentile, where the respective temperature distributions are generally defined with respect to the 1961–1990 reference period

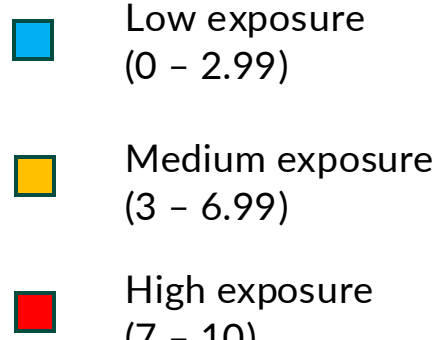
Source: International Energy Agency, 2024

CLIMATE CHANGE

Potential disasters: Cambodia, India, Indonesia, Thailand and Vietnam

- Risk assessment of exposure to natural disasters is shown on a scale of 0 to 10 for the year 2025
- Compared to the world's average, all countries in the ALCBT project have high exposure to floods, and medium to high exposure to other natural disasters

Country	Flood	Costal Flood	Drought	Tropical Cyclone
Cambodia	8.7	3.8	4.2	1.8
India	9.2	7.8	6.3	7.7
Indonesia	8.4	8.1	3.3	1.5
Thailand	9.8	5.5	5.5	1.6
Vietnam	9.9	9.6	4.2	5.9
World Average	4.5	3.5	3.4	1.6



Source: European Commission Disaster Risk Management Knowledge Centre

0.3 Energy Scenario



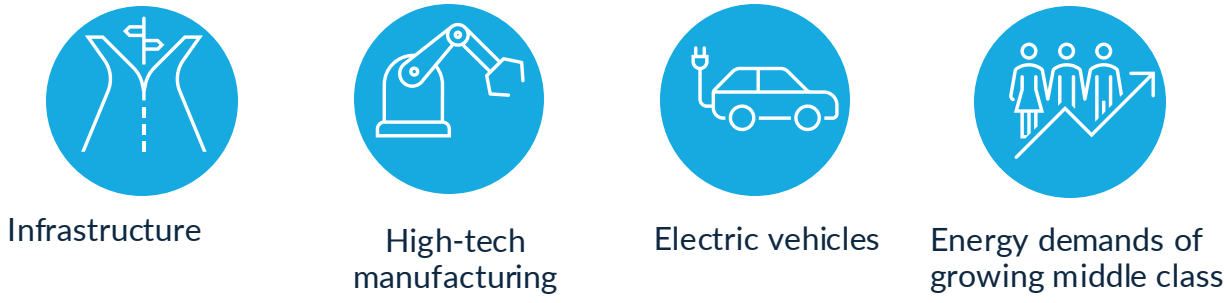
ENERGY SCENARIO

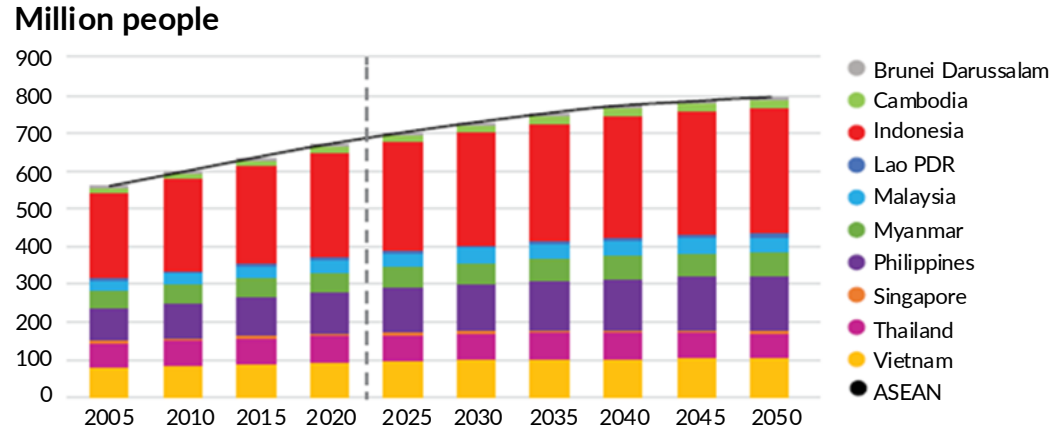
ASEAN region: Economic growth and energy demand

Southeast Asia accounts for *9% of the world's population, 6% of the world's GDP and 4% of world energy consumption*

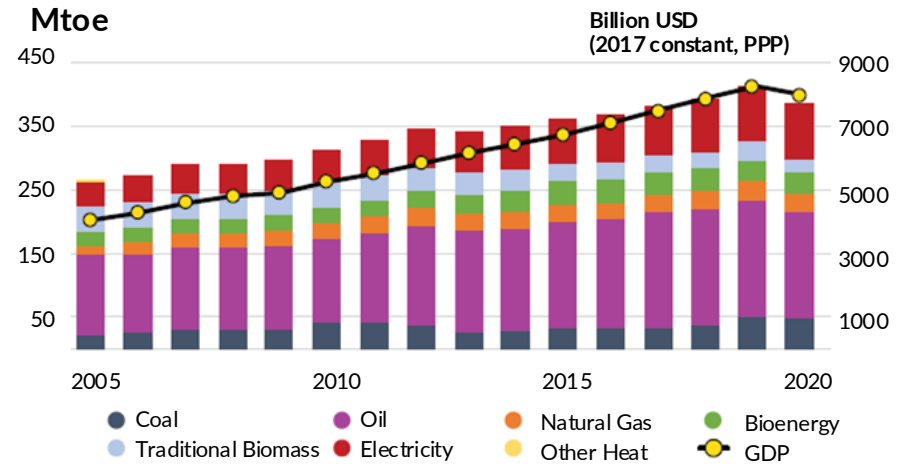
The energy demand in ASEAN region is expected to triple by 2050, from 2020 levels

Potential growth areas in ASEAN member states





Population of ASEAN member states, 2005–2050



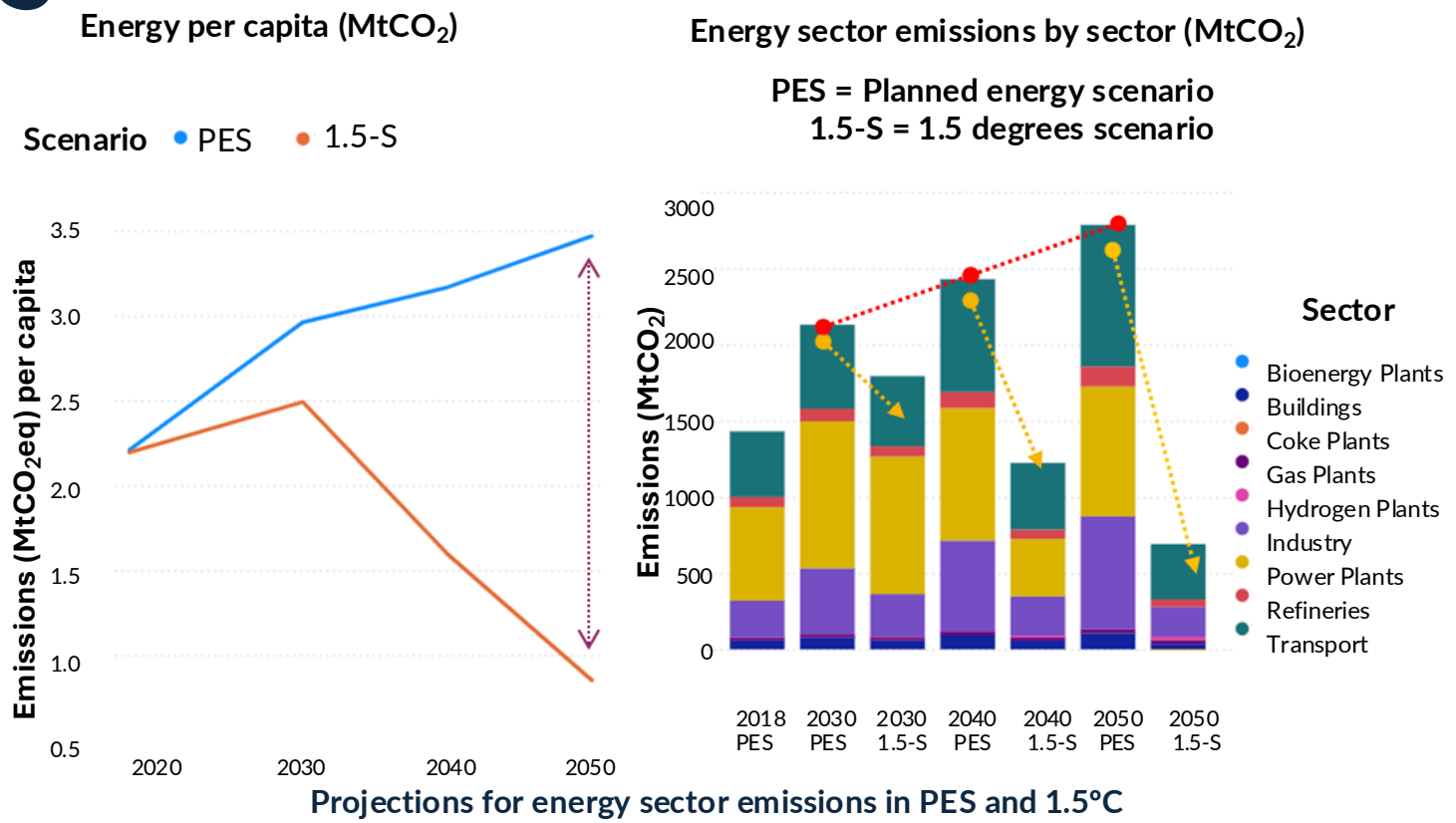
Energy demand by fuel and GDP in ASEAN, 2020–2050

Source: ASEAN Centre for Energy, 2022

ENERGY EMISSIONS

ASEAN region: Projected emissions

- *By 2050, the total CO_2-related emissions from ASEAN is expected to double from 2022 levels – mainly from the transport, power and industrial sectors*
- **Urbanization and motorization** are significant drivers to the **per capita energy demand**
- Per capita total final electricity consumption to increase by 35% by 2030 and 210% by 2050 in planned energy scenario (PES) as compared to 2018
- With the right policy and finance levers, 75% reduction can be achieved



Projections for energy sector emissions in PES and 1.5°C

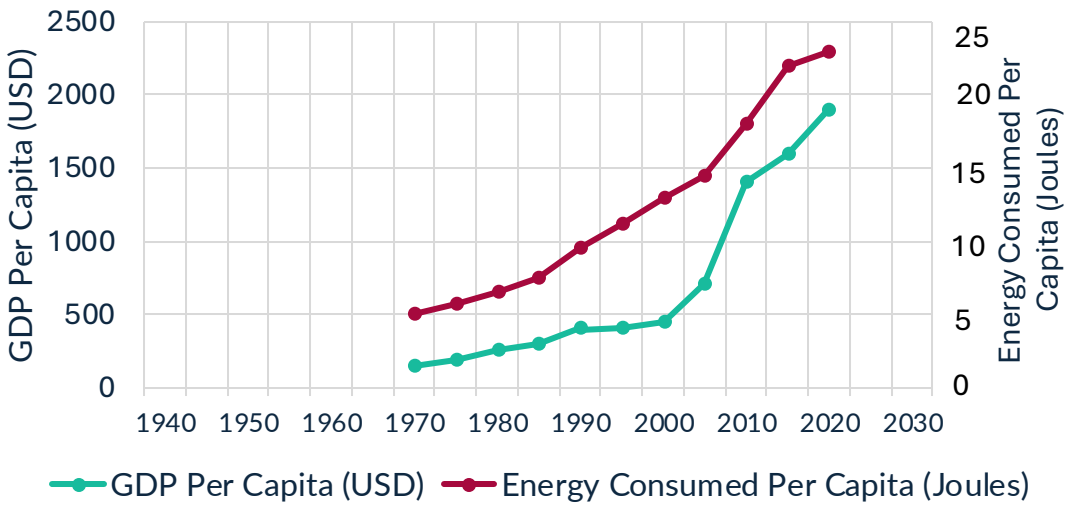
Note: The PES reflects current plans and expected objectives and policies that were approved as of the time of conducting the analysis. The energy transition scenarios are developed by IRENA from the PES. The 1.5-S is a more ambitious energy pathway and outlines options to further reduce CO_2 emissions in challenging sectors. It largely follows the World Energy Transitions Outlook scenario aiming to reach net zero emissions globally by 2050

Source: International Renewable Energy Agency, 2022

ENERGY EMISSIONS

India: Economic growth and energy demand

- **India is the fifth largest economy (USD854.7 billion** by end of March 2022, surpassing the United Kingdom, which was **USD816 billion)**
- **Third largest electricity producer (1,423 TWh) with third largest installed power capacity 429.96 GW (as of Jan 2024)**
- **India's population surpassed China in 2022 with 1.44 billion people**
- **India will peak at 1.7 billion people by early 2060, and will remain as the world's most populated country in the 21st century, according to the UN World Population Prospects Report 2024**
- Historically, the rise in GDP has resulted in a rise in energy consumption per capita
- India's energy demand will double by 2050, and is heavily dependent on fossil fuel consumption, including imports



GDP and energy consumption per capita in India

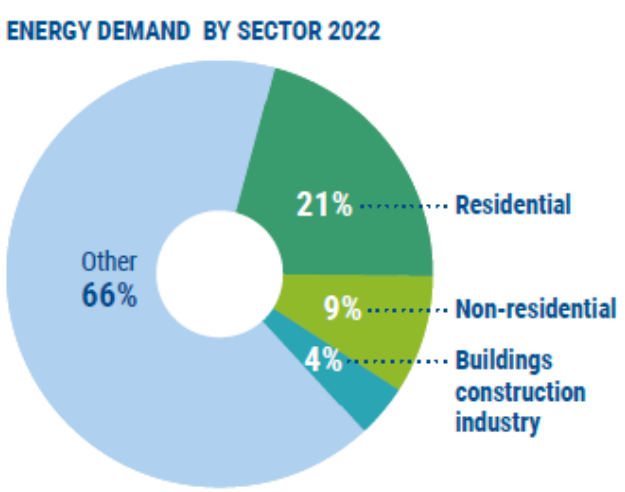
Sources: Bloomberg, Statista and UN Report

Sources: Niti Aayog; Petroleum Planning and Analysis Cell

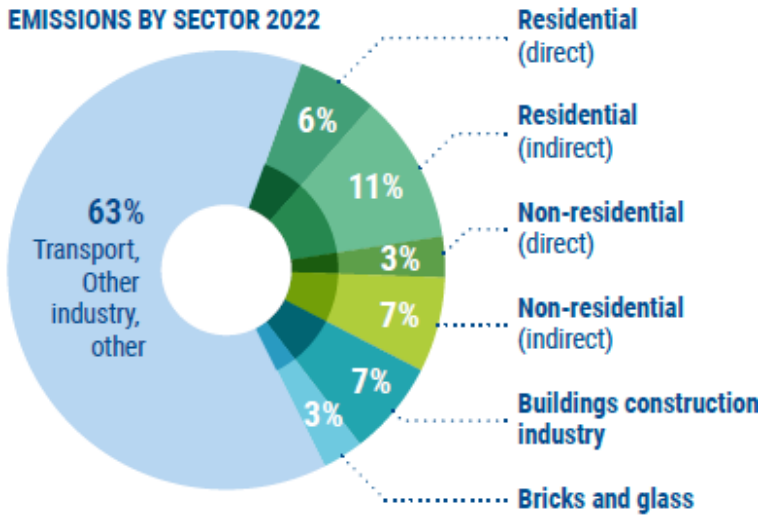
ENERGY AND CARBON EMISSIONS

Global construction and buildings industry

- Globally, buildings consume more than **30%–34% of the total energy demand** for operational requirements and production of construction materials
- In 2022, **CO_2 emissions** from buildings operations and construction reached a new high of **37% of total emissions**



Share of buildings in total final energy consumption (2022)



Share of buildings in global energy and process emissions (2022)

Source: United Nations Environment Programme, 2024

0.4 National Commitments

COP, Pledges and Commitments



GHG EMISSIONS

Plan of action for mitigation and adaptation



Mitigation

153 countries have net zero targets in NDCs, urgent strengthening of targets, and accelerated actions on coal, deforestation, methane and electric vehicles



Adaptation

Boosted efforts to deal with climate impacts, and support vulnerable countries to adapt and ***minimize loss and damage***



Finance

Mobilize public sector finance in USD millions and private sector finance in USD trillions



Collaboration

Over 40 countries endorsed the Breakthrough Agenda

Source: International Energy Agency, 2022

GLOBAL PLEDGES

Conference of Parties (COP)

United Nations Framework Convention on Climate Change (UNFCCC)

- COP is the main decision-making body of the UNFCCC
- COP28 was held in the United Arab Emirates in December 2023

- ***COP3, Kyoto Protocol:*** 37 industrialized countries and the EU committed to ***reduce their emissions by 5%*** from 1990 levels
- ***COP26, Global Methane Pledge:*** Collectively ***reduce anthropogenic methane emissions by 30%*** from 2020 levels by 2030
- ***COP28:*** Set goal to ***triple the share of renewables in energy supply*** *and* ***double the annual rate of increase in energy efficiency from 2% to 4% by 2030***
- ***COP28, Global Cooling Pledge:*** ***Endorsed by 71 countries;*** collective global targets to reduce ***cooling-related emissions by 68% by 2050,*** increase significant access to ***sustainable cooling by 2030*** and increase ***global average efficiency of new air conditioners by 50%***







Sources: UNFCCC; Global Methane Pledge; Global Cooling Pledge

STOCKTAKE FROM COP28

The four pillars

Recognition of the science that indicates **GHG emissions need to be cut by 43% by 2030**, compared to 2019 levels, to limit global warming to 1.5°C

The COP28 Presidency sets four pillars for the summit



Fast-tracking a just, orderly and equitable energy transition



Fixing climate finance



Focusing on people, lives and livelihoods



Underpinning everything with full inclusivity

Source: UNFCCC

COP PARIS AGREEMENT – 2015

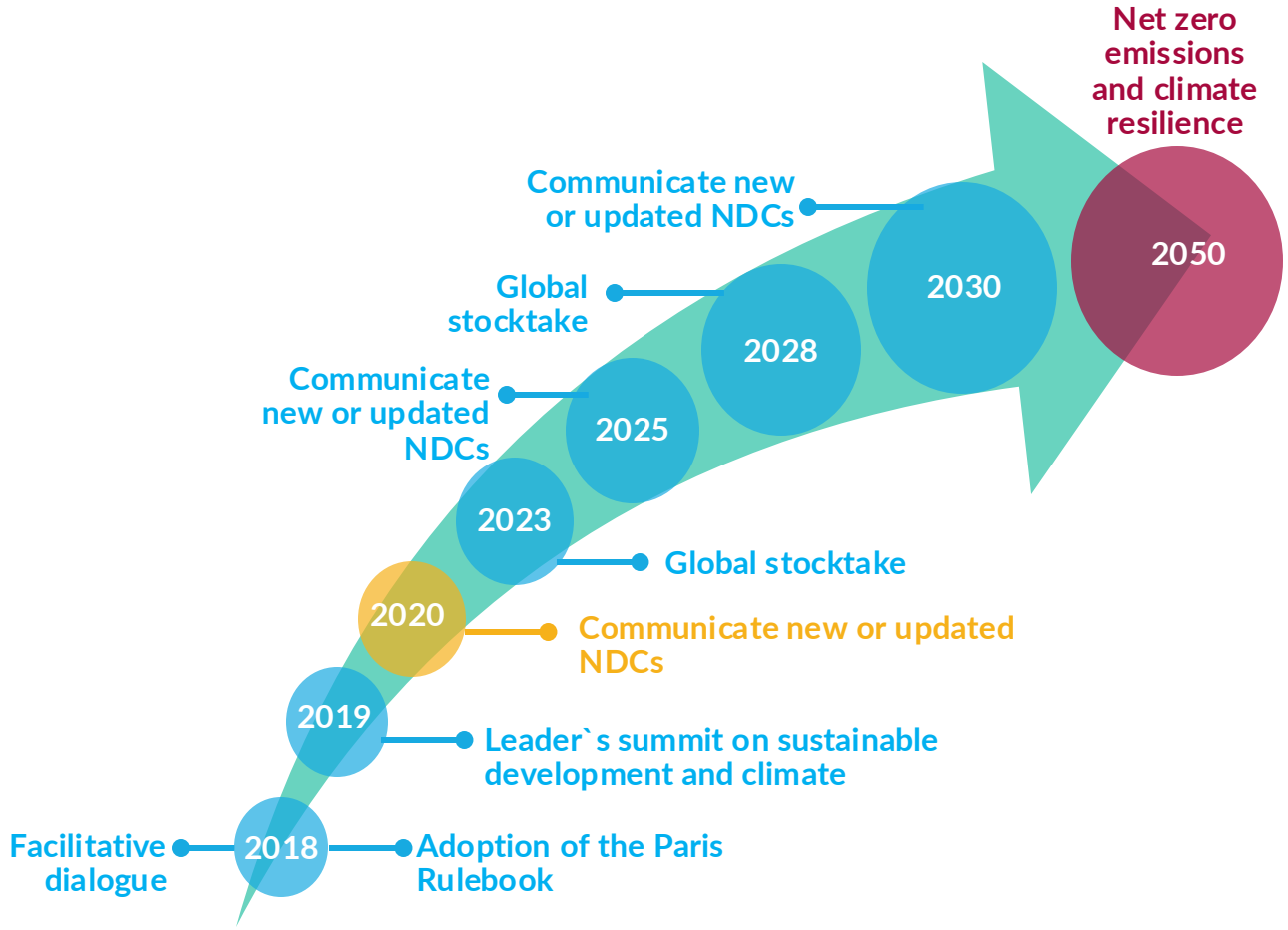
Nationally determined contributions (NDCs)

COP21, Paris (2015)

- Signed by 195 countries and ratified by 190 countries
- Holding the increase in global average temperature to well below 2°C above pre-industrial levels
- Pursuing efforts to limit temperature increase to 1.5°C above pre-industrial levels

NDCs

- Commitments from nations to UNFCCC to reduce their GHG emissions to mitigate climate change
- Revise NDCs every five years and communicate to UNFCCC



Source: Fransen, T. et al. 2017

ASEAN

Joint statement at COP28

Cambodia, Indonesia, Thailand and Vietnam are members of the Association of Southeast Asian Nations (ASEAN)

The regional targets outlined for 2025 in the ASEAN Plan of Action for Energy Cooperation are:

- ***Increase renewable energy share to 23%*** of total primary energy supply and ***35% of installed power capacity***
- ***Reduce energy intensity by 32%*** from 2005 levels



Image source: Wikipedia

Source: ASEAN Centre for Energy, 2024

ASEAN CLIMATE PLEDGES

Global RE, EE and cooling pledges

Pledge Name	Targets	ASEAN Signatories
Global Renewable Energy and Energy Efficiency Pledge	***Triple the global renewable energy generation capacity*** to at least 11,000 GW ***by 2030*** and ***double the global average annual rate of energy efficiency improvement*** from around ***2% to over 4% per year by 2030***	Brunei, Darussalam, Malaysia, Singapore and Thailand
Global Cooling Pledge	***Reduce cooling-related emissions*** by a minimum of ***68% to 2022 levels by 2050***	Brunei, Darussalam, Cambodia, Singapore, Thailand and Vietnam
Declaration on Hydrogen and Derivatives	Mutual recognition of certification of renewables and hydrogen	Malaysia and Singapore

Source: ASEAN Centre for Energy, 2024

0.5 NDCs

Cambodia, India, Indonesia, Thailand, Vietnam

Cambodia

- Updated NDC 2021: Reduction target of 41.7% from BAU scenario by 2030
- Mitigation (energy, agriculture, FOLU, industry and waste sectors) – USD5.8 billion
- Adaptation (agriculture, infrastructure and water sectors) – USD2 billion
- Long-term Strategy for Carbon Neutrality 2050

India

- Updated NDC 2021: "Panchamrit"
- Increase non-fossil fuel energy capacity to 500GW by 2030
- Meet 50% of energy requirements from renewable energy by 2030
- Reduce total projected carbon emissions by 1 billion tons by 2030
- Reduce carbon intensity of the economy to less than 45% by 2030 from 2005 levels
- Achieve net zero emissions by 2070

Indonesia

- Updated NDC 2022: 29% reduction in GHG emissions (unconditional), 41% reduction in GHG emissions (conditional) below BAU scenario
- Long-term Strategy for Low Carbon and Climate Resilience 2050
- Net zero emissions by 2060
- Energy, AFOLU, IPPU and waste sectors covered

Thailand

- Updated NDC 2022: 30% reduction in GHG emissions (unconditional), 40% reduction in GHG emissions (conditional) below BAU scenario
- Energy, agriculture, IPPU and waste sectors covered
- Long Term – Low Emission Development Strategy
- Carbon neutrality by 2050 and net zero by 2065

Vietnam

- Updated NDC 2022: 9% reduction in GHG emissions (unconditional), 27% reduction in GHG emissions (conditional) below BAU scenario from 2014 levels
- Energy, agriculture, IPPU and LULUCF sectors covered
- Plan for Implementation of the Paris Agreement in 2016, containing 68 objectives related to mitigation, adaptation, human, technical and financial resources, and MRV
- Net zero emissions by 2050

Source: NDC Partnership

BUILDING-RELATED NDCS

Cambodia, India, Indonesia, Thailand, Vietnam

Cambodia	India	Indonesia	Thailand	Vietnam
• Building codes, enforcement/certification for new buildings to reduce electricity consumption by 10% in 2030 • Improved cooling in public sector buildings to reduce 43,000 tCO_2 per year • Passive cooling in buildings to reduce 74.5 tCO_2e	• Energy and material efficiency in buildings and increase climate resilience of cities • Smart city initiatives, integrated planning of cities for mainstreaming adaptation and enhancing energy and resource efficiency, effective green building codes, and rapid developments in innovative solid and liquid waste management	• Embed energy efficiency in buildings through implementation of Green Building Code for new and existing buildings • Promote energy efficient appliances, lighting and systems in buildings • Increase blended cement by increasing the portion of alternative materials for reducing clinker to cement ratio • Promote development of climate proof cities	• Implementation of the National Energy Efficiency Plan (EEP) (2015–2036), which aims to reduce energy demand by 30% in 2036 compared to BAU trajectory • New EEP (2018–2037) aims to reduce energy intensity by 30% by 2037 compared to the baseline year 2010 • EEP (2024 version) is under review and yet to be launched	• Replace construction materials, improve the cement and chemical production processes, and reduce the consumption of hydrofluorocarbons • Improve, develop and apply technology in manufacturing construction materials • Reduce clinker content and implement other measures to reduce GHG emissions in cement production • Develop and use energy-saving construction materials and green materials in housing and commercial sectors

Source: Zhou et al., 2019

1. Cambodia

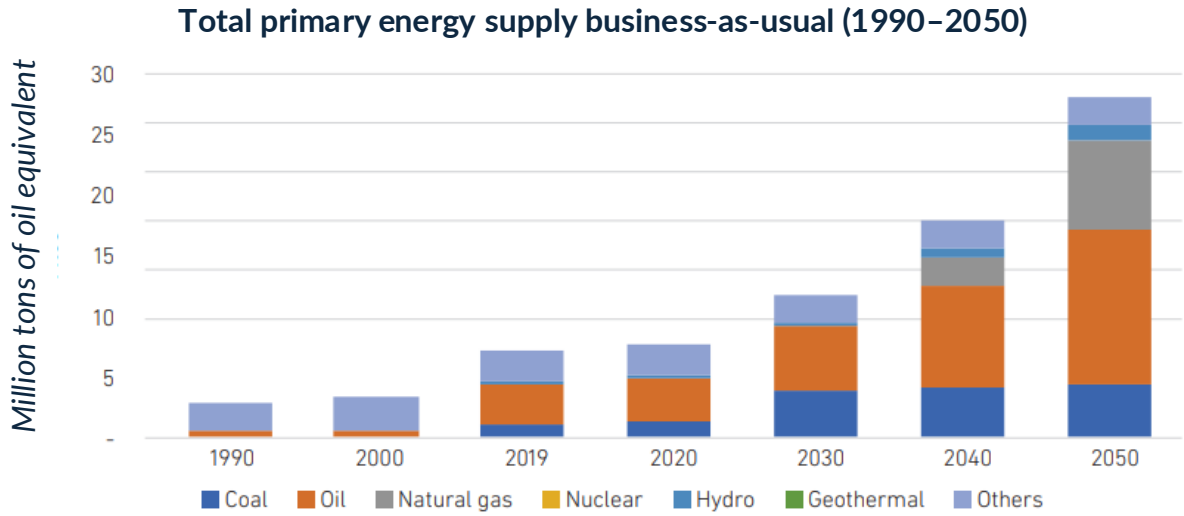


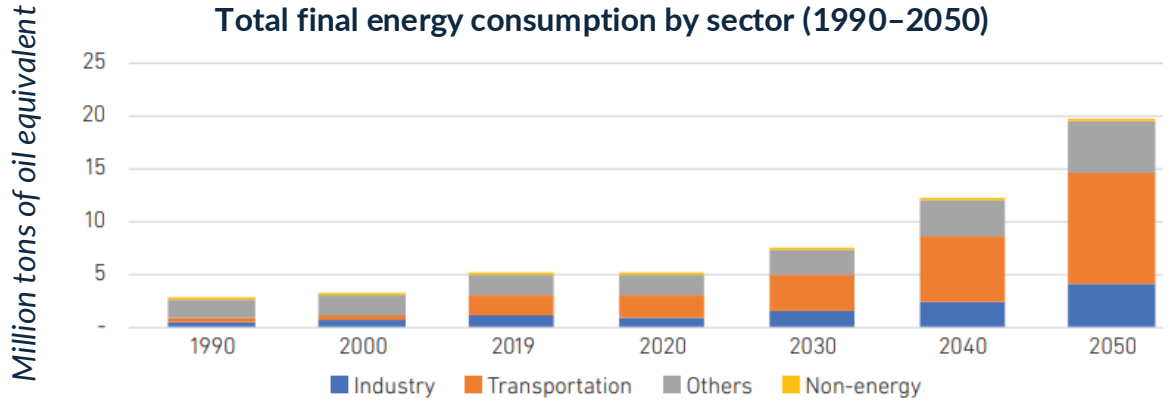
Image source: https://nowboarding.changiairport.com/travel-the-world/travel-guide-cambodia-phnom-penh.htm

ENERGY SCENARIO

Total primary energy supply

- The strongest growth in demand is projected in ***transport,*** which will increase ***fivefold*** at an annual average rate of 5.33% in 2019–2050, from 2.09 Mtoe to 10.46 Mtoe
- The demand in industry is projected to grow 4.32 times at an annual rate of 4.85%, from 0.95 Mtoe in 2019 to 4.11 Mtoe in 2050, followed by 'others' at 3.07%, from 1.91 Mtoe in 2019 to 4.88 Mtoe in 2050



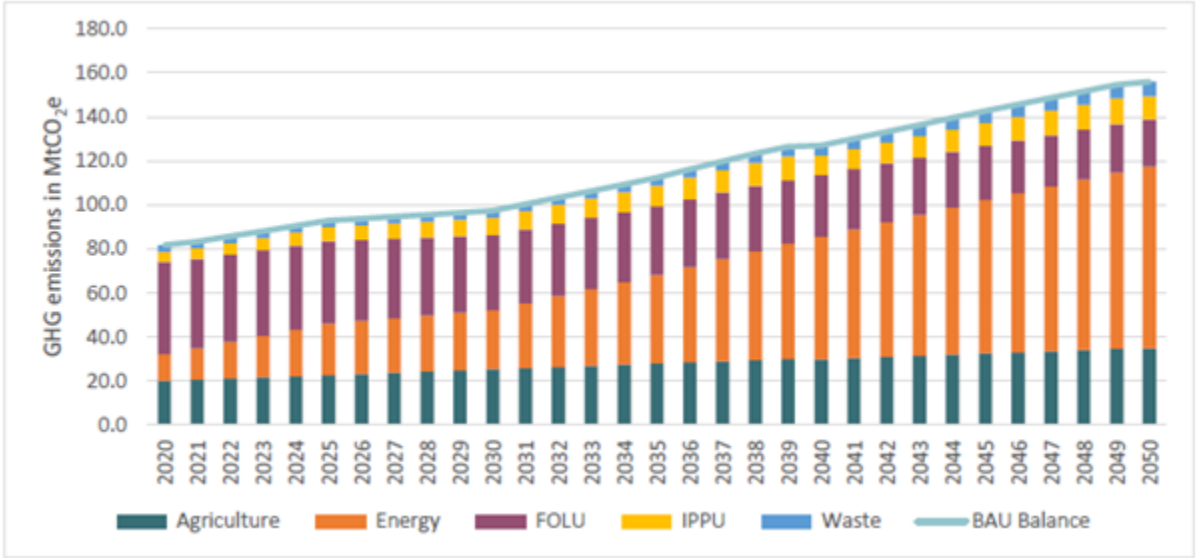


Source: Kimura et al., 2023

GHG EMISSIONS

Emissions by sector

- According to Cambodia's Long-term Strategy for Carbon Neutrality, the forestry and land use (FOLU) sector was responsible for 51 $MtCO_2e$ of emissions in 2016, the largest share of emissions in Cambodia. Deforestation is the major cause of emissions
- 2020: Largest emissions from FOLU
- BAU 2050: Largest emitter is expected to be the energy sector



GHG emissions projections in the BAU scenario by sector

Source: Government of Cambodia, 2021

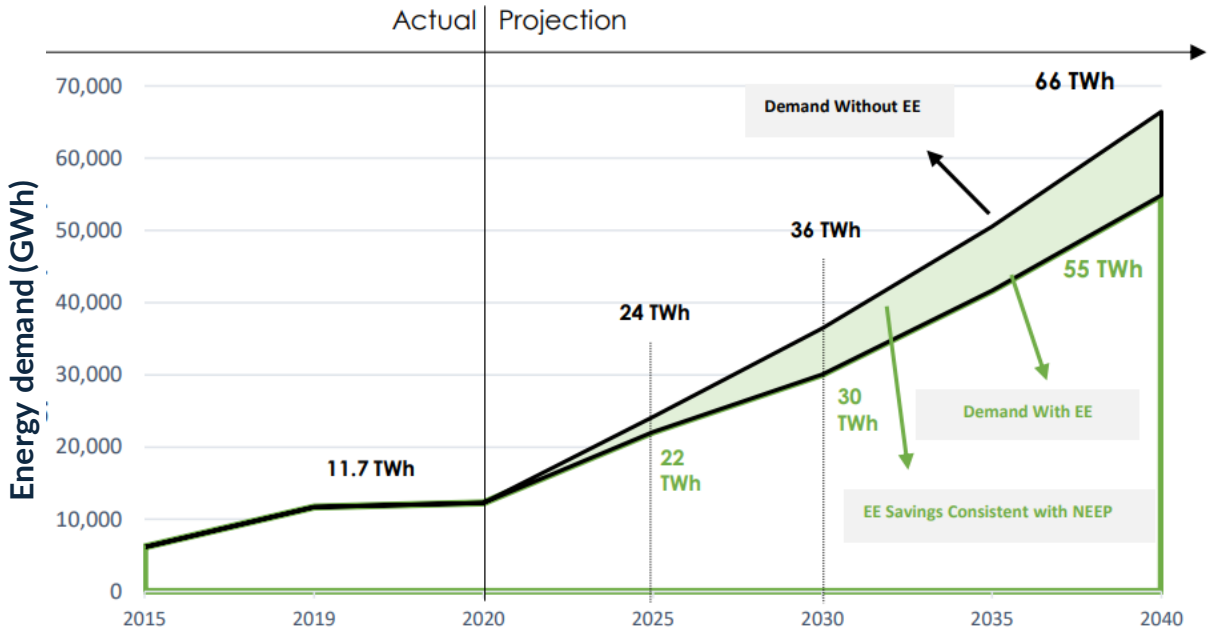
ENERGY DEMAND

2022–2040

- According to Cambodia's Power Development Masterplan (PDP) 2022–2040, the country's peak demand for electricity is expected to grow by ***7.5%–8.9% annually***. This would result in a ***peak demand of 8.9 GW by 2040***

- The PDP projects that by 2040, **63% of Cambodia's power capacity will come from renewable sources, with 32% from solar photovoltaic and 30% from hydropower**

PDP energy demand forecast (GWh/TWh)



Energy demand forecast (GWh) and average annual growth rates (%)

	Actual		Projection					Average Annual Growth Rate (%)				
GWh	2015	2019	2020	2025	2030	2035	2040	2019/2015	23/2019	2025/2019	2030/2019	2040/2019
Base (without EE)	6,144	11,705	12,290	24,184	36,465	50,405	66,187	17.50%	13.90%	12.90%	11.5%	8.8%
Base (with EE)	6,144	11,705	12,290	22,108	30,080	41,579	54,597	17.50%	9.40%	9.50%	9.4%	7.7%

GHG EMISSIONS

Cambodia emissions compared to Southeast Asian countries

- **Fastest emissions growth** rate; transition risks
- Most **carbon intensive** economy after Myanmar
- Fastest **growing sources** of GHG emissions are **electricity and heat generation**; cooling and industrial uses
- Construction industry is a **key pillar** and **significant contributor to GDP**, and will impact sectoral emissions

Cambodia has low but rapidly rising GHG emissions

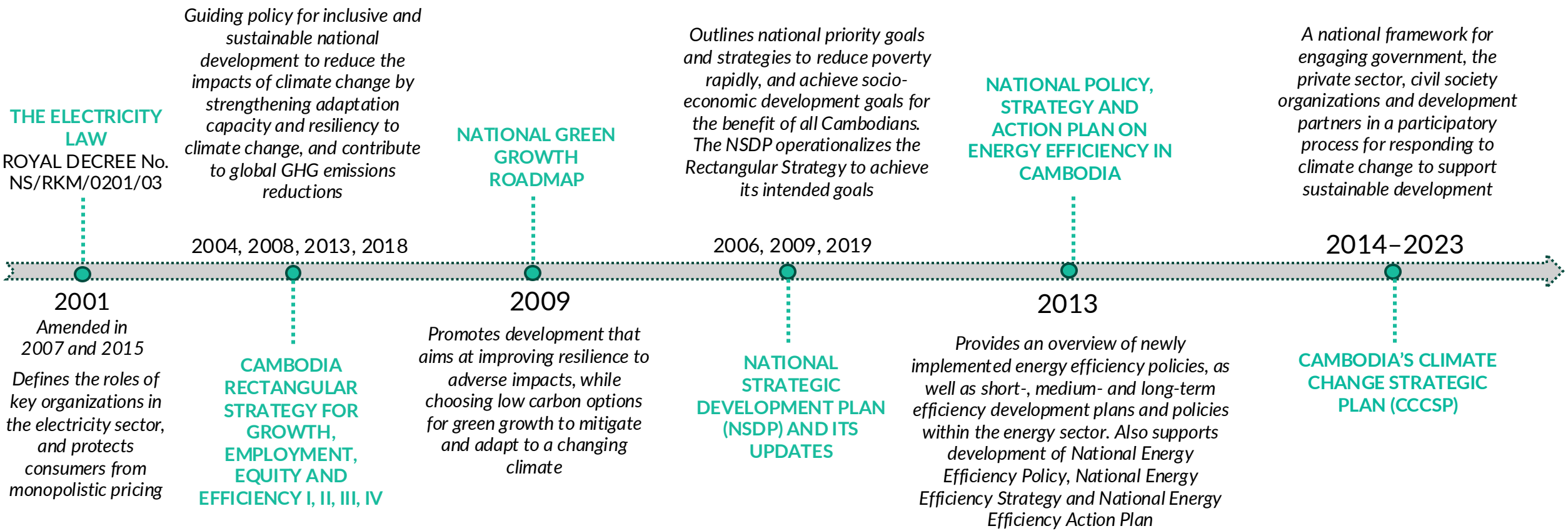
	GHG emissions per capita (tCO_2e per person)	Carbon intensity (tCO_2e per US$ million of GDP)	Total GHG emissions ($mtCO_2e$)	Annual emissions % growth rate (2010–2019)
United States	17.6	270	5771	-0.5
Malaysia	12.4	1081	396	0.8
OECD members	10.6	258	13797	-0.6
China	8.6	844	12055	2.2
Indonesia	7.2	1751	1960	6.3
Thailand	6.3	804	437	4.4
Lao	5.5	2104	39	3.6
Vietnam	4.5	1326	438	5.2
Myanmar	4.5	3537	243	0.5
Cambodia	**4.4**	**2649**	**72**	**8.2**
Philippines	2.2	628	237	3.5

Source and notes: Climate Analysis Indicators Tool. Emissions are all GHG emissions and estimates for 2019. Annual emissions growth is calculated as the compound annual growth rate.

Source: World Bank, 2023a

CAMBODIA INITIATIVES

Timeline for policies in climate and energy



Source: https://asiapacificenergy.org/apef/index.html#main/lang/en/time/[2018,2024]/geo/[]/search

CAMBODIA INITIATIVES

Timeline for policies in climate and energy

CAMBODIA'S INTENDED NATIONALLY DETERMINED CONTRIBUTION (INDC)

2016

A multi-sectoral policy document. In the INDC, Cambodia proposes a GHG mitigation contribution for 2020–2030, conditional upon the availability of support from the international community. Key sectors being energy, manufacturing and transport

A roadmap for various stakeholders, including businesses, to implement actions that will contribute to addressing climate change issues and move toward a low carbon resilient economy

2016–2018

CLIMATE CHANGE ACTION PLAN FOR MINES AND ENERGY SECTORS

CAMBODIA BASIC ENERGY PLAN

2019

Sets numerical targets for each energy issue covered by the plan. The objective of the plan is to seek an energy supply for Cambodia with the following conditions: affordability, accessibility, security (sustainable security), safety and transparency in the energy market. It covers key areas like oil, renewable energy, ***energy efficiency,*** *energy security and energy outlook*

Sets the guiding principles for the regulatory framework of the construction sector. The law ***highlights building efficiency and green building concepts*** *that ensure green development, and natural resource and environmental protection; construction quality, security and safety; and the protection of property and well-being of construction.*

Minimum energy efficiency standards are incorporated

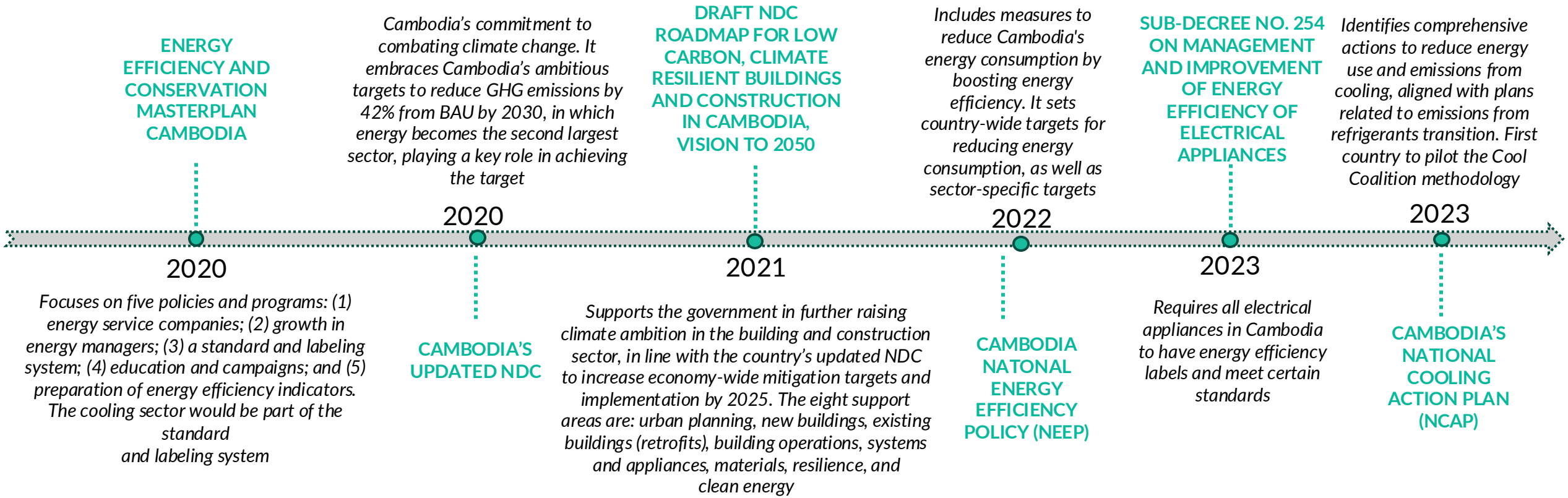
2019

CONSTRUCTION LAW

Source: https://asiapacificenergy.org/apef/index.html#main/lang/en/time/[2018,2024]/geo/[]/search

CAMBODIA INITIATIVES

Timeline for policies in climate and energy



Source: https://asiapacificenergy.org/apef/index.html#main/lang/en/time/[2018,2024]/geo/[]/search

INSTITUTIONAL MECHANISMS

Climate change policy: National committee for implementation

The institutional framework established to lead Cambodia's climate response includes:

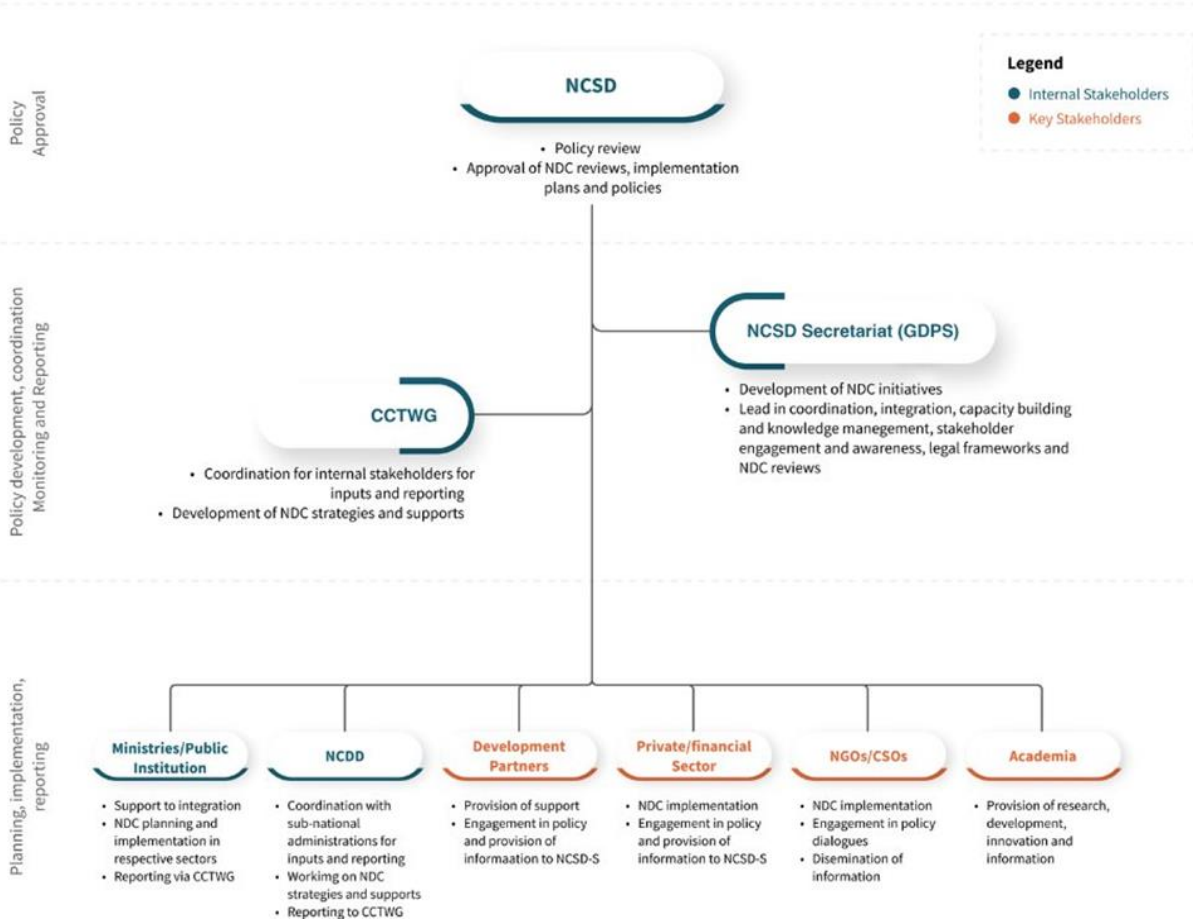
National Council for Sustainable Development (NCSD), and ***its Secretariat, General Directorate of Policy and Strategy (GDPS)*** (Royal decree no. NorSor/RorKorTor/0515/403 and sub-decree No. 59 OrNorKrar.BorKor in 2015)

Council's Climate Change Technical Working Group (CCTWG) (Prakas NO.002 S.S.R NCSD in 2017)

Specifies the roles and tasks for the development and management of climate change monitoring and evaluation (M&E) instruments, and the national M&E framework for climate change response

Policy approval: NCSD

Policy development and monitoring: GSSD and CCTWG



Source: National Council for Sustainable Development, Government of Cambodia

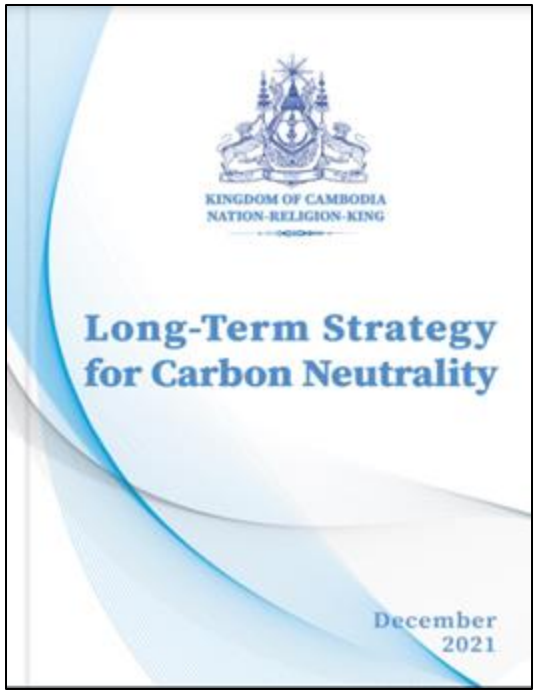
STRATEGY FOR MITIGATION

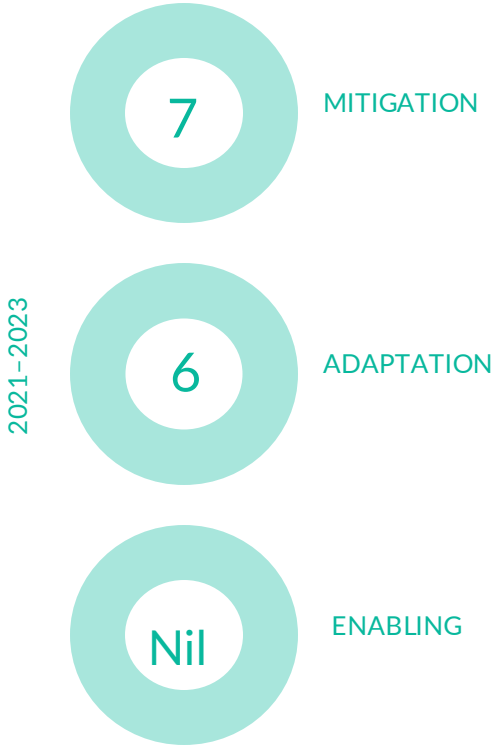
LTS4CN mitigation, adaptation and enabling actions

Cambodia's ***Long-term Strategy for Carbon Neutrality (LTS4CN)*** serves as a roadmap or vision document that outlines priority mitigation actions for each sector to achieve the country's goal of a carbon neutral economy in 2050. The strategy largely builds on the updated NDC

Mitigation actions:
33 prioritized actions in 7 sectors
7 in the construction sector
42% reduction in emissions compared to BAU

Adaptation actions:
58 prioritized actions in 11 sectors;
6 in the construction sector
Reduce vulnerability to climate change





Implementation actions in sectors that impact the building and construction industry

Source: National Council for Sustainable Development, Government of Cambodia

Source: Government of Cambodia, 2021

UPDATED NDCs

Cambodia 2021

AGRICULTURE FOLU ENERGY TRANSPORTATION INDUSTRIES WASTE

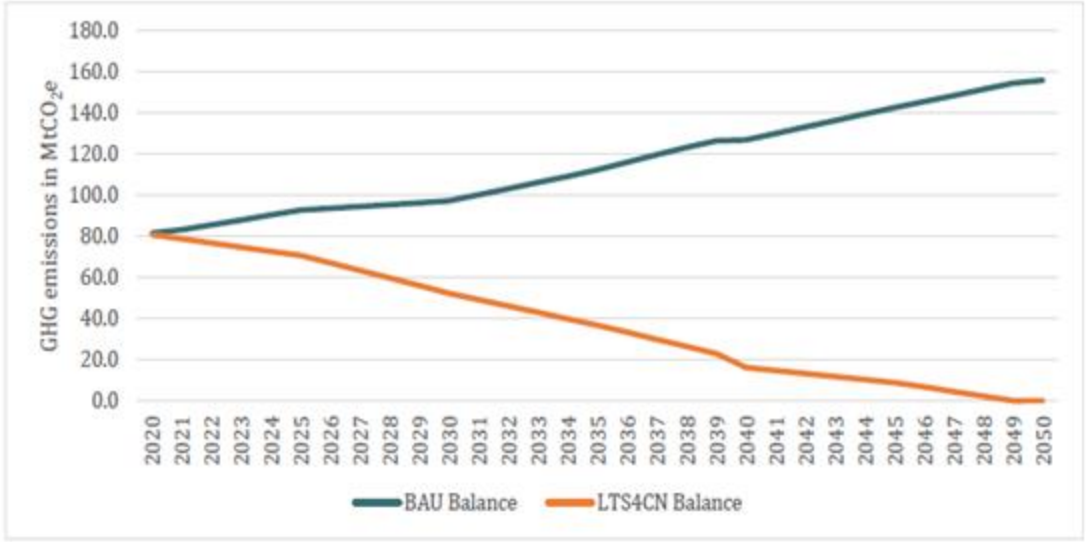


Mitigation areas of LTS4CN

42% net GHG reductions below BAU by 2030
(*conditional on international support)*

Reduction by 2030 below BAU

FOLU: 50%
Energy: 40%
Agriculture: 23%
Industry (IPPU): 42%
Waste: 18%

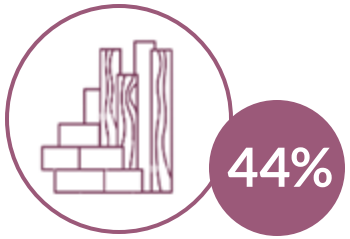


GHG emissions projections, BAU and LTS4CN scenarios

Source: Government of Cambodia, 2021

NDC MITIGATION

The building and construction sector's key mitigation actions and reduction targets by 2030



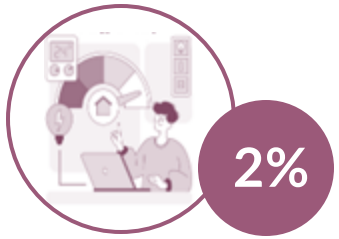
SUSTAINABLE BRICK MANUFACTURING



TOOL FOR URBAN HEAT ISLAND EFFECT



ENERGY MANAGEMENT IN INDUSTRIES



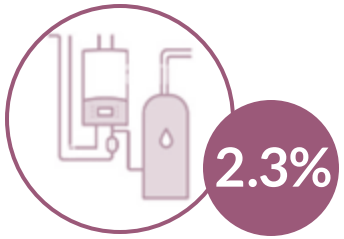
PUBLIC AWARENESS



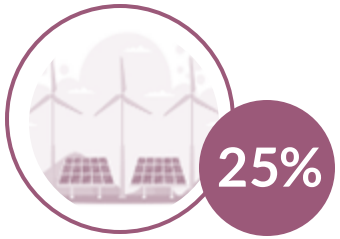
BUILDING CODE ENFORCEMENT NEW AND RETROFIT



LABELING AND MEPS



EE MOTORS AND BOILERS



RE INTEGRATION - ENERGY MIX



NCAP IMPLEMENTATION



PASSIVE COOLING SYSTEMS IN BUILDING ENERGY CODE



ADDRESSING URBAN HEAT ISLAND EFFECT IN CITIES

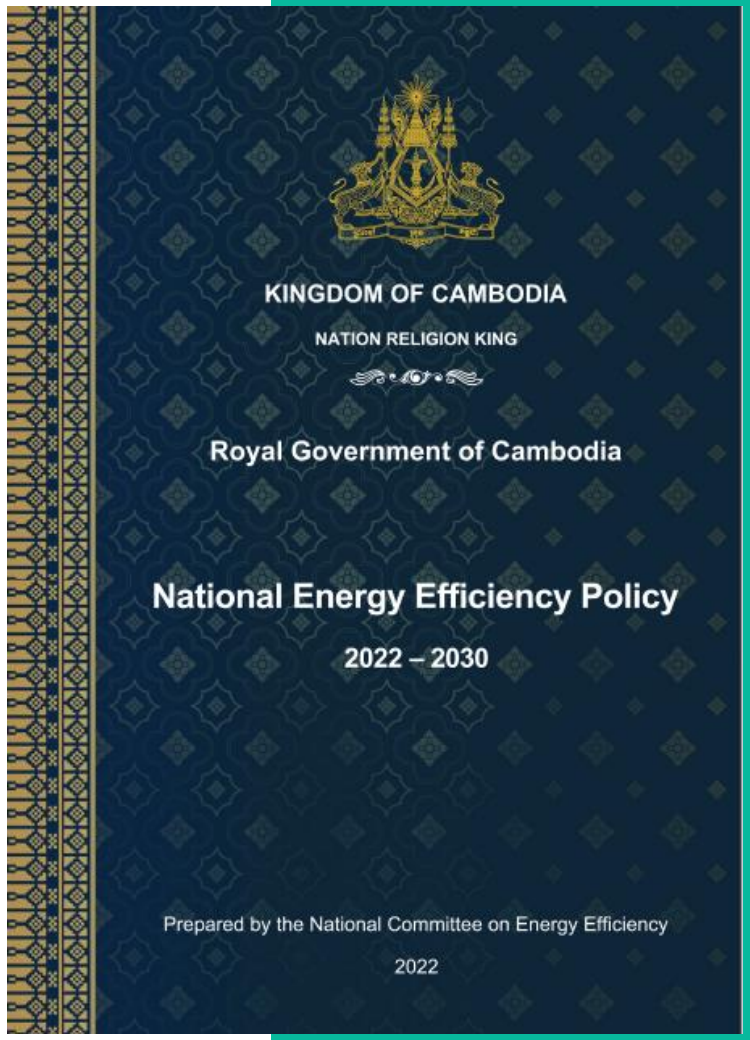
Source: NDC Partnership

NEEP

National Energy Efficiency Policy 2022–2030

Vision

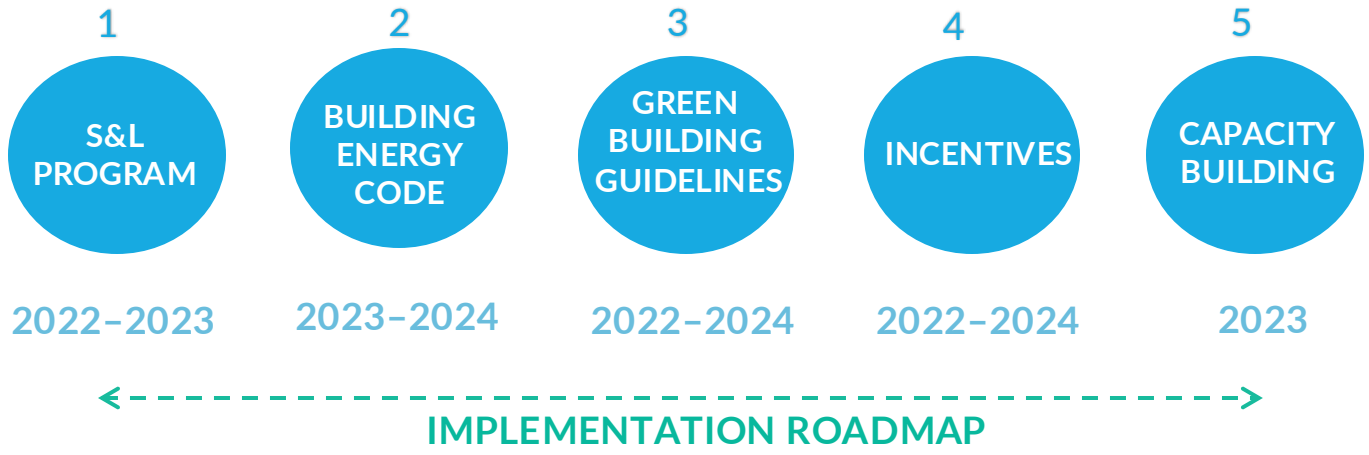
Transform energy consumption in Cambodia by adopting energy efficiency, thereby contributing to a strong, vibrant and competitive economy while fostering sustainable development

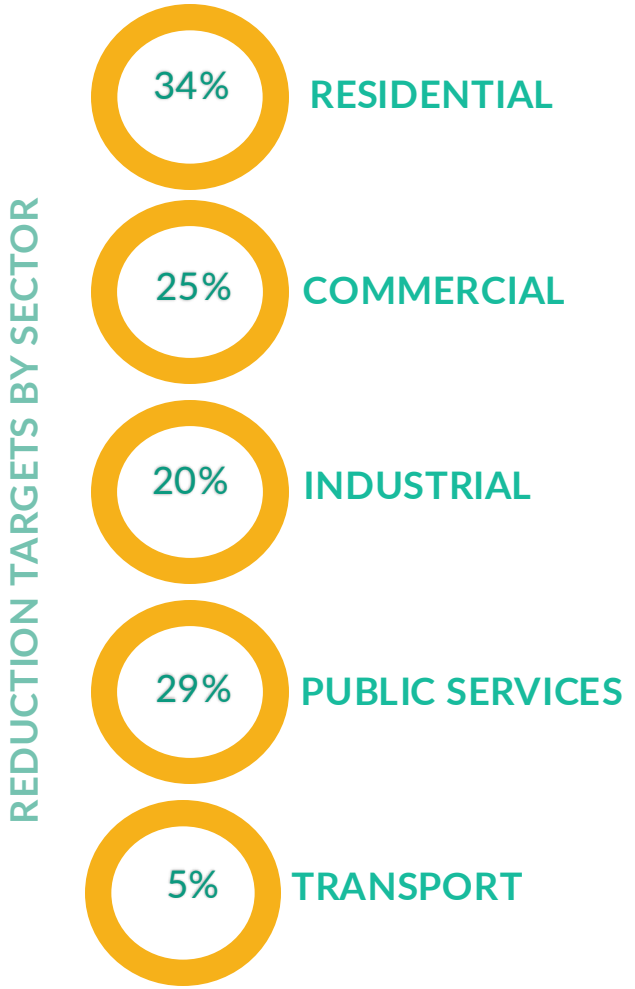


Source: National Committee on Energy Efficiency, Government of Cambodia, 2022

BUILDING SECTOR

National targets and strategic pillars





Source: National Committee on Energy Efficiency, Government of Cambodia, 2022

INSTITUTIONAL STRUCTURE

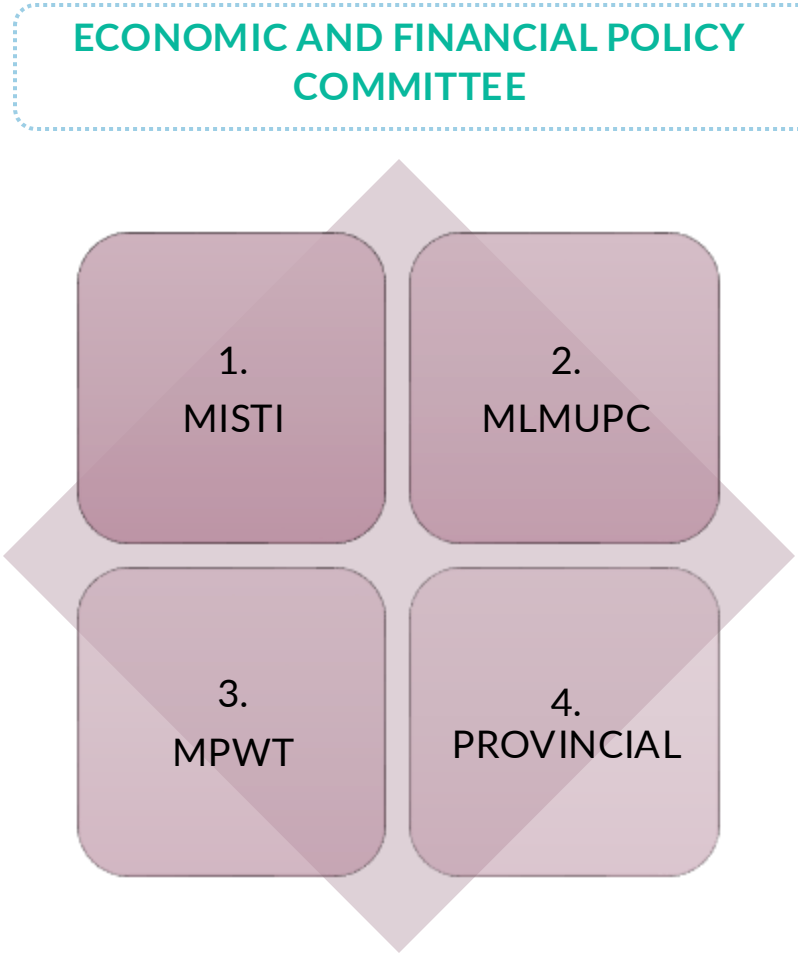
NEEP

1. Subnational Committee on Energy Efficiency led by Ministry of Industry, Science, Technology and Innovation (MISTI)
Formulate and implement Sectoral Energy Efficiency Action Plan in industry

2. Subnational Committee on Energy Efficiency led by Ministry of Land Management, Urban Planning and Construction (MLMUPC)
Formulate and implement Sectoral Energy Efficiency Action Plan in buildings

3. Subnational Committee on Energy Efficiency led by Ministry of Public Works and Transport (MPWT)
Formulate and implement Sectoral Energy Efficiency Action Plan in public works and transport

4. Subnational Committee on Energy Efficiency led by capital and provincial administrations
Formulate and implement Sectoral Energy Efficiency Action Plan in integration with capital and provincial administrative bodies



Governance Structure of NEEP

EE PROGRAMS AND PROJECTS

Cambodia

PASSIVE COOLING IN CAMBODIA

MINISTRY OF ENVIRONMENT + COOL COALITION + ESCAP

- Policy interventions through the inclusion of passive cooling solutions in building energy regulations
- Demonstration of passive cooling applications in buildings
- Delivery of awareness raising and capacity building for large-scale replication
- Support the inclusion of GHG emissions reductions from passive cooling solutions in the next cycle target for Cambodia's NDC

ENERGY EFFICIENCY CONTEST

CCCSP + CUBE

- Creation of EE building contest with a target of minimum 25 participant buildings in the first year
- Behavioral change tools and materials adapted to the local Cambodian context
- A social media campaign targeting many beneficiaries
- Student involvement through youth associations
- Sharing of best practices between universities
- Capacity building of researchers from the Institute of Technology of Cambodia to create a pool of experts on EE in Cambodia
- Policy advisory report and meetings with relevant governmental institutions to share the results of the contest and put forward the EE agenda

Sources: Cool Coalition; National Council for Sustainable Development, Government of Cambodia

EE PROGRAMS AND PROJECTS

Cambodia

PILOTING ENERGY EFFICIENCY IN BUILDINGS AND SOLAR MICRO GRIDS

- Walk-through audits in five government buildings
- Installation of real-time energy monitoring equipment (hardware and software)
- Analysis of building energy data and selection of feasible EE measures for implementation
- Consultation with planning and finance departments and the Ministry of Economy and Finance
- Develop EE procurement guidelines
- Technical support implementation of EE measures
- Guidelines for building energy management (BEM)
- Develop training package and conduct training of trainers
- Pilot BEM training for facility managers



Source: National Council for Sustainable Development, Government of Cambodia

EE IN THE COOLING SECTOR

Initiatives in building and industry

CAMBODIA'S NATIONAL COOLING ACTION PLAN (NCAP)

POWER DEVELOPMENT MASTERPLAN 2022–2040

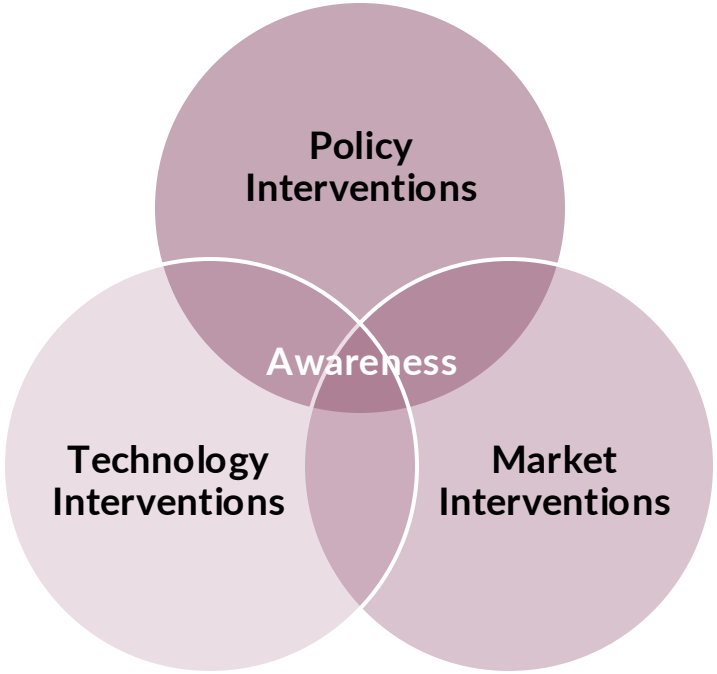




NATIONAL COOLING ACTION PLAN

Proposed short-term (5 years) and mid-term (10 years) policy interventions

- Establish and enforce building codes / certification for new buildings and those under major renovation
- Reduce dependency on air conditioning in public sector buildings
- Adopt minimum energy performance standards (MEPS) and energy labels for air conditioning



Source: Ministry of Environment, Government of Cambodia, 2022

WAY FORWARD

Addressing policy and institutional barriers

- Strengthen governance framework on energy efficiency, including institutional mandates, roles and mechanisms for coordination among government agencies
- Develop sector-specific policies and regulations to foster investments in energy efficiency (e.g., in the form of codes, labels and standards)
- Develop market mechanisms and regulations to support the development of energy efficiency services and energy audits, in particular a building energy code, empanelment of ESCOs and the accreditation of energy auditors
- Establish a framework and enforcement mechanism for the measurement, reporting and verification of energy consumption in large consumer segments, including industries and buildings
- Ensure the availability of sub-sectoral data and data sharing mechanisms on energy consumption across line ministries
- Establish an accreditation framework for energy auditors and managers
- Strengthen capacities of government agencies both at the national and subnational level to identify, develop and implement energy efficiency projects
- Provide fiscal and financial incentives to support and reward the adoption of energy efficiency



Source: National Committee on Energy Efficiency, Government of Cambodia, 2022

WAY FORWARD

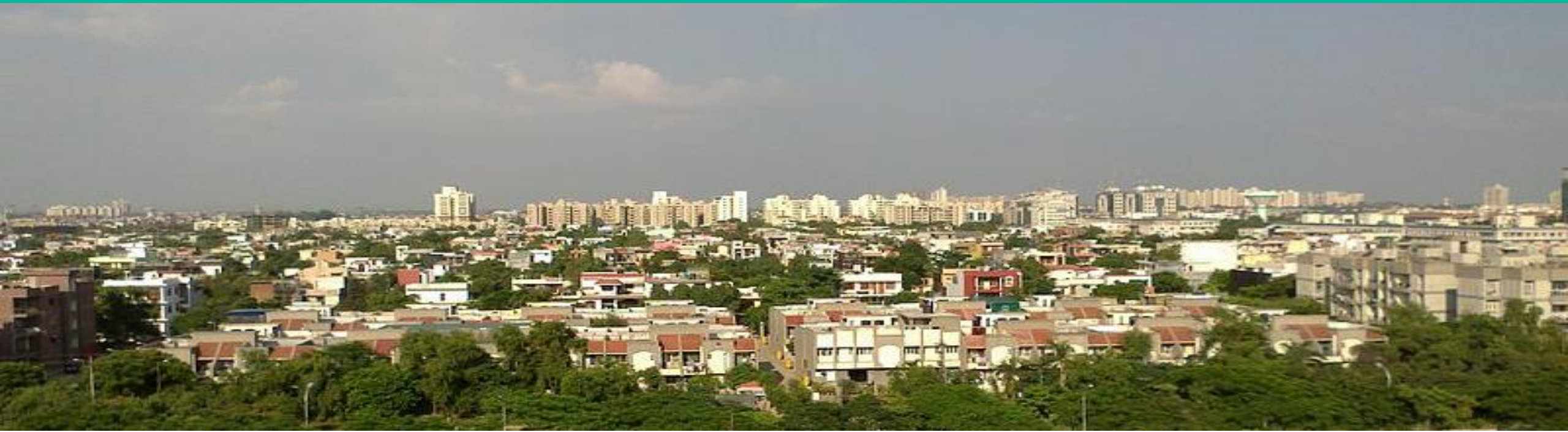
Opportunities

- Insufficient supply, high electricity prices and grid insecurity make Cambodia a highly suitable market for energy efficiency initiatives. The Cambodia Climate Change Strategic Plan (CCCSP) stresses the importance of EE in the residential and real estate sector
- The General Department of Energy, Ministry of Mines and Energy, and Economic Research Institute for ASEAN and East Asia to come up with the Energy Efficiency and Conservation Masterplan for Cambodia that focuses on five policies and programs: (1) energy service companies; (2) growth in energy managers; (3) a standard and labeling system; (4) education and campaigns; and (5) preparation of energy efficiency indicators
- Development of the Building Energy Code



Source: National Committee on Energy Efficiency, Government of Cambodia, 2022

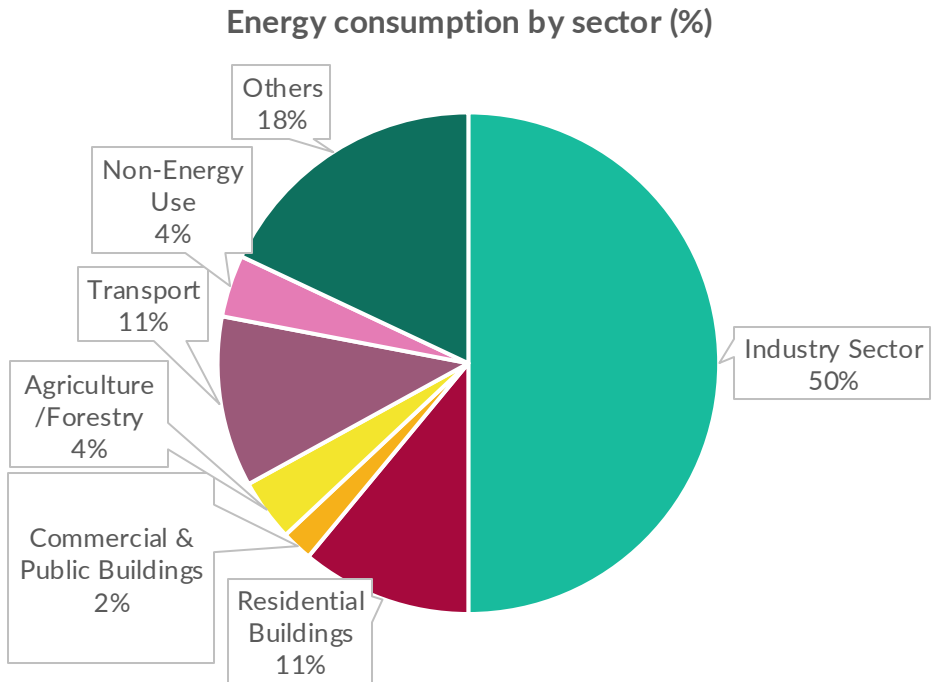
2. India



ENERGY SCENARIO

Energy consumption in different sectors (2022–2023)

- The industrial sector was the largest energy consumer with more than half of TFEC (50.59%)
- Residential, commercial and public buildings accounted for 13% of TFEC
- Agriculture and forestry, non-energy uses, and others accounted for 26% of TFEC
- The transport sector accounted for 11% of TFEC



Total final energy consumption (TFEC) by major sectors In the Indian economy

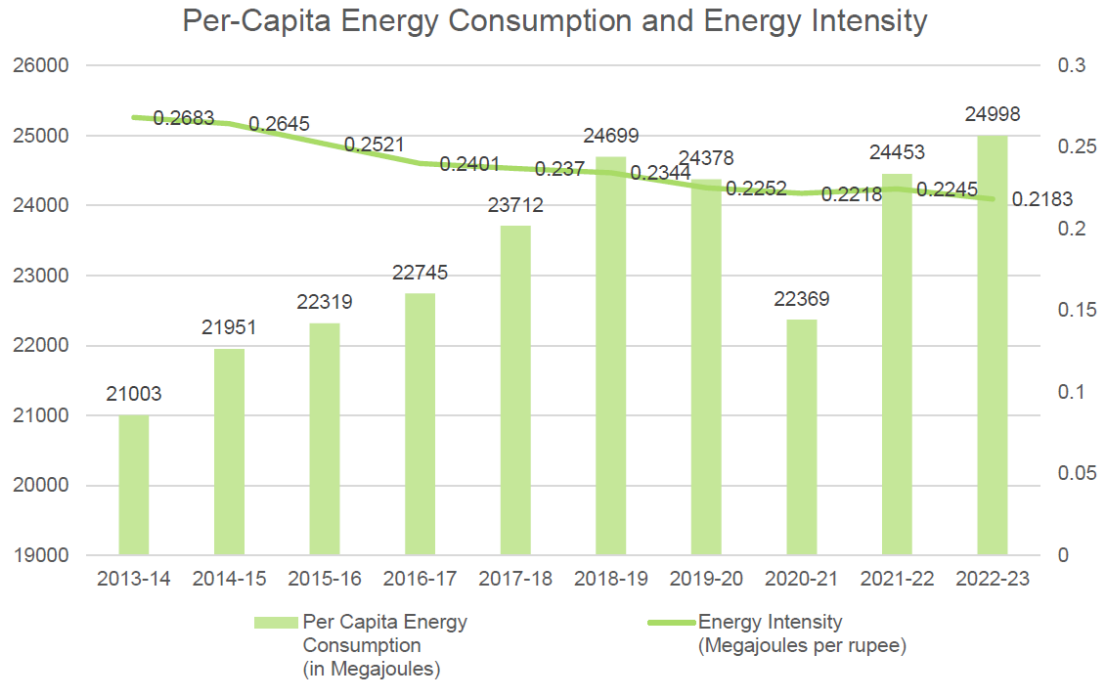
Source: Ministry of Power and Bureau of Energy Efficiency, Government of India, 2023

ENERGY SCENARIO

Per capita energy consumption and energy intensity

Total final energy consumption in India (2022–2023)

- India's energy intensity decreased from 0.2683 megajoules per rupee in FY 2013–2014 to 0.2183 (P) megajoules in FY 2022–2023, which is a ***significant improvement of 18.65%***
- *India successfully reduced emissions intensity vis-à-vis its GDP by 33% between 2005 and 2019*, ***thus achieving the initial NDC target for 2030, 11 years ahead of schedule.*** This decline is attributed to the ***deployment of energy efficiency programs,*** among other factors
- India achieved ***40% of installed electric power capacity through non-fossil fuel sources, nine years ahead of the target for 2030.*** Between 2017 and 2023, India ***added around 100 GW of installed electric power capacity; 80% of this capacity is attributed to non-fossil fuel-based resources***



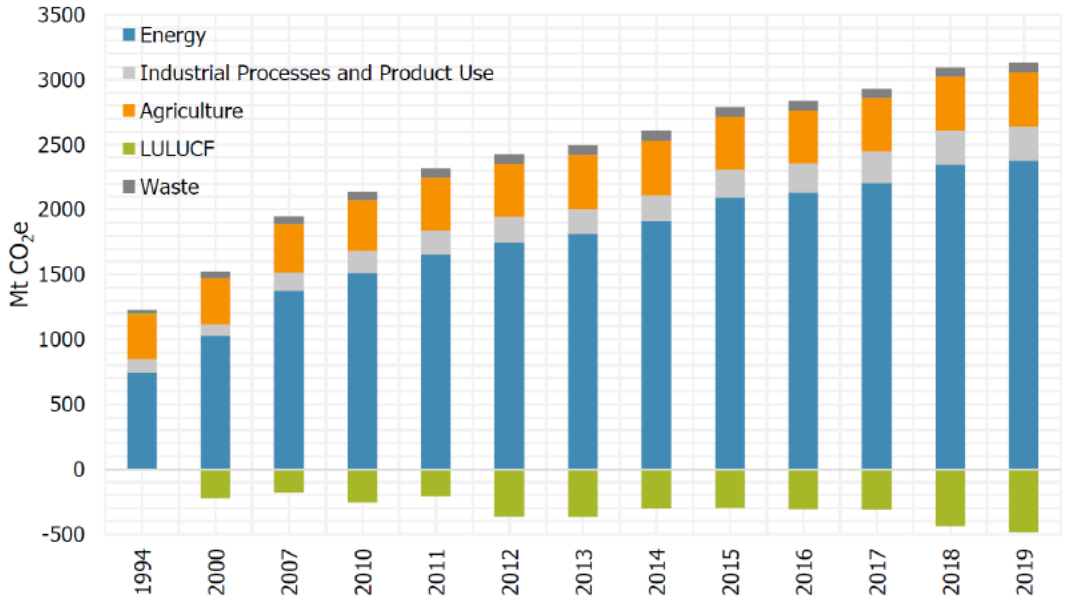
Energy intensity and per capita consumption trend

Sources: Ministry of Power and Bureau of Energy Efficiency, Government of India. 2023; COP28 National Statement by Union Minister for Environment, Forest and Climate Change, Shri Bhupender Yadav

GHG EMISSIONS

As per India's Third National Communication to UNFCCC

- In 2019, India's total GHG emissions, excluding LULUCF was **3,132 $MtCO_2e$,** and **2,647 $MtCO_2e$** including LULUCF
- Total national emissions (including LULUCF) increased by **4.56%** with respect to the total national emissions of **2016,** and by **115.42% since 1994**
- From **1994 to 2019**, total CO_2e emissions (without LULUCF) increased by **158%**
- The **energy sector** had the highest emissions growth of **219%** due to continuous increase of fossil fuel combustion



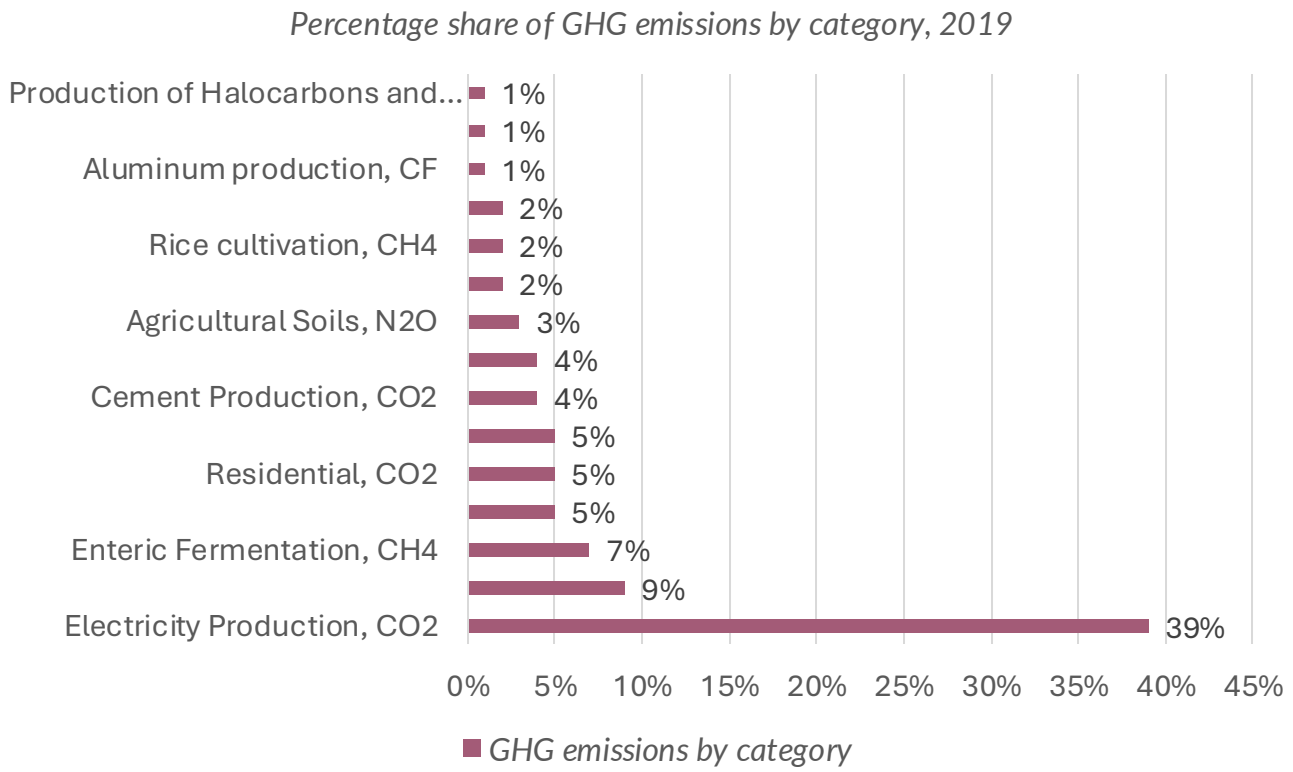
Sector-wise national GHG emissions in $MtCO_2e$ (1994–2019)

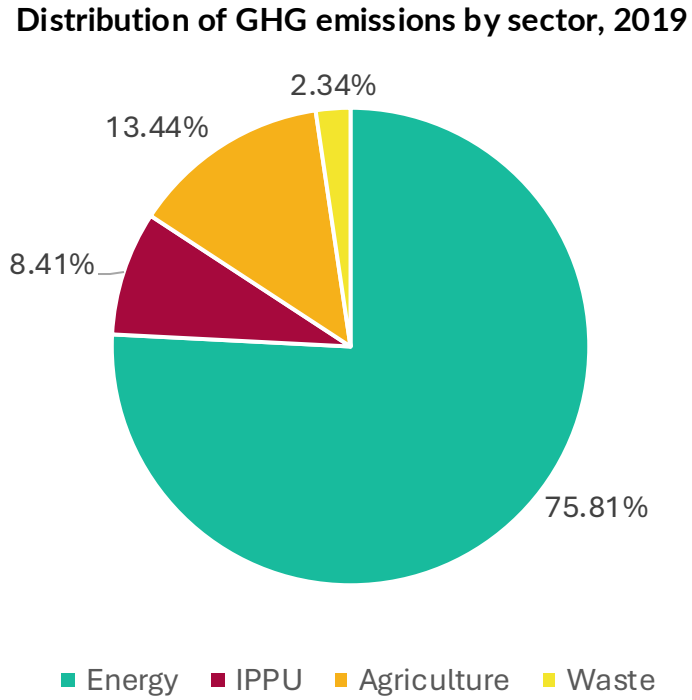
Sources: MoEF, 2004; MoEF, 2010; MoEF, 2012; MoEFCC, 2016; MoEFCC, 2018; MoEFCC, 2021

Source: MoEFCC, 2023b

GHG EMISSIONS

As per India's Third National Communication to UNFCCC





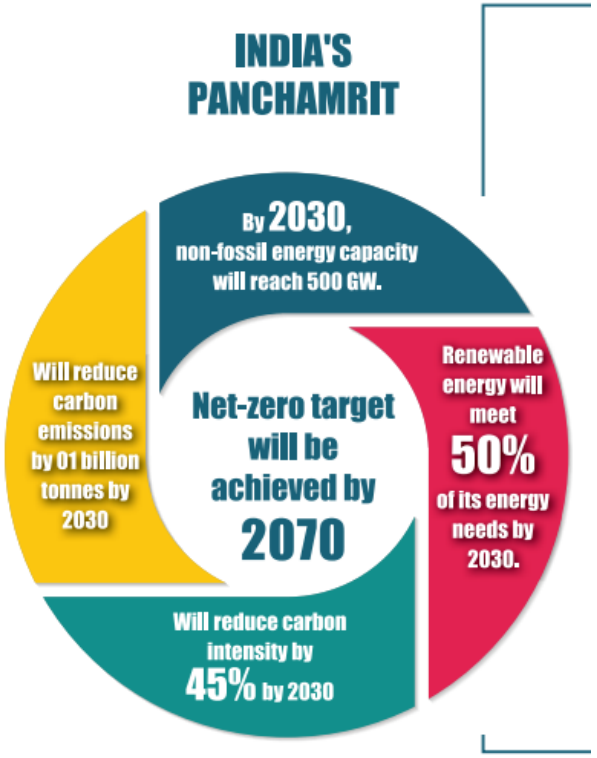
The energy sector is the major contributor to emissions at 75.81%, followed by agriculture sector (13.44%), IPPU sector (8.41%) and waste sector (2.34%)

Source: MoEFCC, 2023b

UPDATED NDCs

India's updated NDCs under Paris Agreement (2021–2030)

- Put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation, including through ***a mass movement for 'Lifestyle for Environment' (LIFE) as a key to combating climate change***
- ***Adopt a climate friendly and a cleaner path*** than the one followed by others at corresponding level of economic development
- ***Reduce emissions intensity of its GDP by 45% by 2030***, from 2005 level
- ***Achieve about 50%*** cumulative electric power installed capacity from non-fossil-fuel-based energy resources by 2030, with the help of technology transfer and low-cost international finance, including from Green Climate Fund
- ***Create an additional carbon sink of 2.5 to 3 billion tons of CO_2*** equivalent through additional forest and tree cover by 2030
- Better adapt to climate change by ***enhancing investments in development programs*** in sectors vulnerable to climate change
- ***Mobilize domestic funds, as well as new and additional funds*** from developed countries to implement mitigation and adaptation actions in view of the resource required and the resource gap
- ***Build capacities***, and create domestic framework and international architecture for quick diffusion of cutting-edge climate technology in India and for joint collaborative research and development for such future technologies



India's announcement at COP26, Glasgow
Source: Central Bureau of Communication

Source: MoEFCC, 2022b

LT-LEDS

India's Long Term – Low Emission Development Strategy

At COP26 in 2021, India announced its target to ***achieve net zero by 2070***

India formulated and submitted its ***Long-term Low Greenhouse Gas Emission Development Strategies (LT-LEDS)*** to the UNFCCC in November 2022

India's LT-LEDS involves seven key strategic transitions, namely:

(i) ***Low carbon development of electricity systems*** consistent with development

(ii) Developing an ***integrated, efficient, inclusive low carbon transport system***

(iii) Promoting ***adaptation in urban design, energy and material-efficiency in buildings, and sustainable urbanization***

(iv) Promoting economy-wide ***decoupling of growth from emissions and development*** of an efficient, innovative low-emissions industrial system

(v) ***CO_2 removal*** and related engineering solutions

(vi) ***Enhancing forest and vegetation cover*** consistent with socio-economic and ecological considerations

(vii) ***Economic and financial aspects of low carbon development*** and long-term transition to net zero by 2070

NDC MITIGATION

National action plans on climate change: Eight missions

National Solar Mission

To enhance solar electricity generation

National Mission for Green India

Afforestation to increase carbon sinks

National Mission for Sustainable Habitats

To reduce emissions in cities

National Mission on Enhanced Energy Efficiency

To improve energy efficiency in all sectors

National Mission for Sustainable Agriculture

To enhance agricultural productivity

National Cooling Plan

Reduction in cooling demand, refrigerant transition, enhancing energy efficiency and better technology

National Water Mission

To evolve strategies for climate resilience in agriculture through new and traditional technology amalgamation, and deploying climate finance and insurance

National Mission for Sustaining the Himalayan Ecosystem

To suggest management measures and bridge gaps for sustaining and safeguarding the Himalayan glaciers and ecosystem

National Mission for Strategic Knowledge on Climate Change

To address the challenges of climate change through knowledge exchange and technology development

GHG MITIGATION

Overview of mitigation measures across emission-intensive sectors



Power Sector

- Renewable Purchase Obligations (RPOs) and Renewable Energy Certificates (RECs)
- Green Power Access Policy (2022)
- National Mission for Highly-efficient Photovoltaic Modules
- Development of Mega and Ultra Mega and Solar Parks



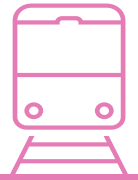
Industrial Sector

- Perform, Achieve and Trade (PAT) Scheme
- National Motor Replacement Program (NMRP)
- Green Hydrogen Mission



Residential Sector

- Standards and Labeling (S&L)
- UJALA and Street Light National Program (SLNP)
- Eco Niwas Samhita
- Municipal Energy Efficient Program (MEEP)
- Building Energy Efficiency Project (BEEP) and ESEAP
- PM Surya Ghar Yojana



Transport Sector

- Faster Adoption and Manufacturing of Electric Vehicles (FAME 1.0 and 2.0)
- Corporate Average Fuel Economy Norms
- 100% Railways Electrification
- Emission Norms PLI for Automotives
- Advanced Chemistry Cells



Commercial Sector

- Energy Conservation Building Code (ECBC)
- National Cooling Action Plan



Agricultural Sector

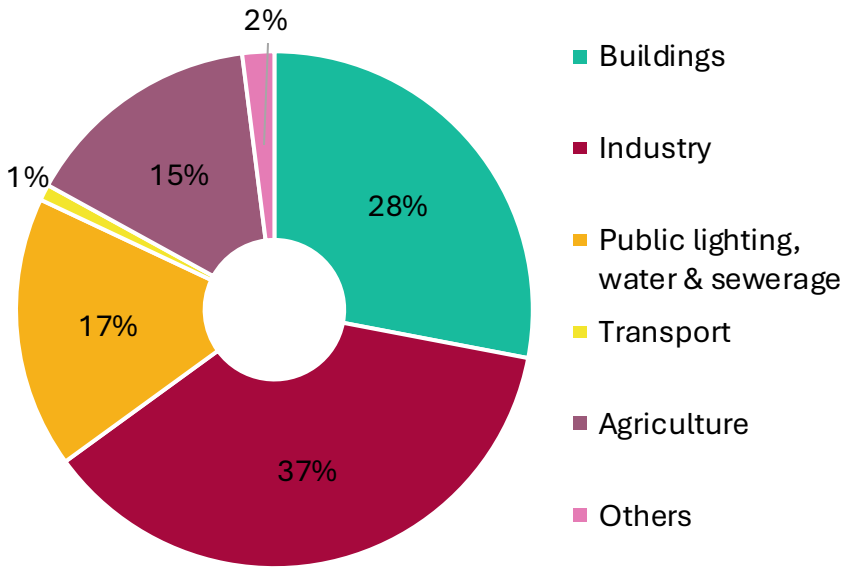
- PM KUSUM (Solar Power)
- SAMARTH (Skills Development)
- National Livestock Mission

ELECTRICITY DEMAND

Sectoral demand

- The share of industrial electrical energy demand increased from 37% in FY 2020–2021 to 40% in FY 2023–2024
- Electricity is the major source of energy for buildings. Electrical energy demand of the building sector increased from 28% in FY 2020–2021 to 33% in FY 2023–2024
- ***By 2030, the energy consumption in the building sector is expected to surpass that in the industrial sector***

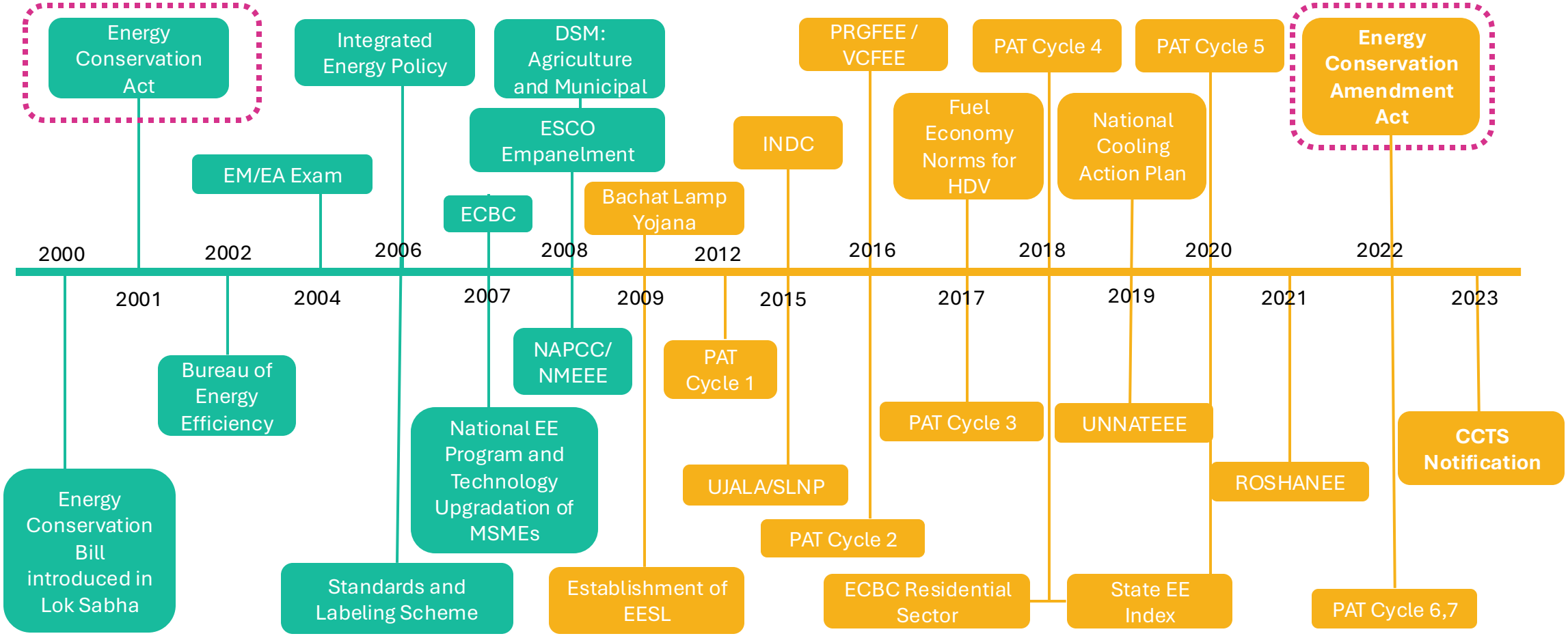
Electricity consumption in India by sector (FY 2020–2021)



Source: Central Electricity Authority, Government of India, 2023

INDIA INITIATIVES

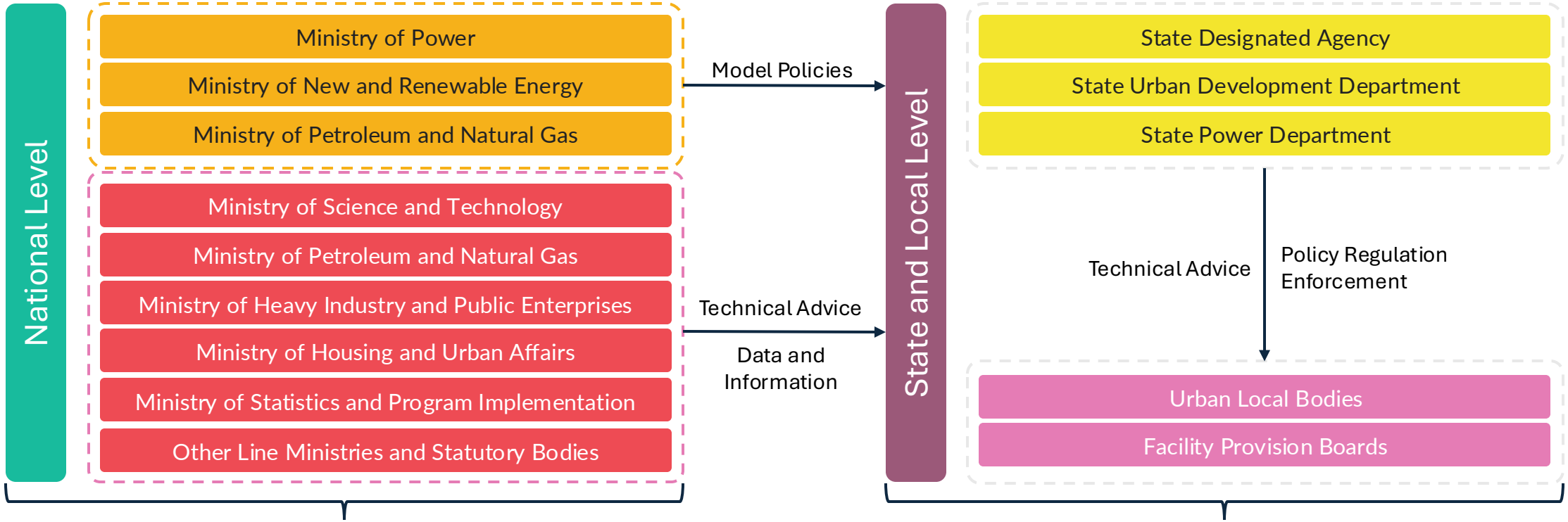
Timeline since the Energy Conservation Act 2001



Source: Ministry of New and Renewable Energy, Government of India, 2023

INSTITUTIONAL STRUCTURE

For energy efficiency policy-making at national, state and local levels



Roles and Responsibilities

- Formulate policies
- Allocate funds
- Determine national goals
- Guide states and national bodies

Roles and Responsibilities

- Develop masterplans
- Adapt and amend laws and regulations

Source: Green Building Performance Network, 2022

ENERGY CONSERVATION ACT 2001

Landmark legislation for energy efficiency

This Act provides a legal framework, institutional arrangement and enforcement mechanisms at central and state levels. The landmark interventions through this Act include:

Designated Agencies

Establishment of the Bureau of Energy Efficiency and State Designated Agencies

Mandatory Norms

Energy Consumption Targets for Energy Intensive Industries and Commercial Buildings (Designated Consumers)

Codes

Energy Conservation Building Code Prescribing Energy Performance Indices for Buildings

★★☆

Appliances: Energy Performance Standards (STAR Ratings)

Capacity Building: Certification Examinations for Energy Professionals (Energy Auditors and Energy Managers)

Research and Development

Promotion of Research and Development and Innovative Financing

Empowerment of State Governments – Enforcement, Levies and Promotion

Source: Ministry of New and Renewable Energy, Government of India, 2023

ENERGY CONSERVATION ACT 2001

Amendments in 2022

This Act was amended in 2022 to include new emerging areas and concerns:

Buildings

Enhanced ECBC Code to Include Sustainability Features

Carbon Trading

Formulation of Carbon Trading Scheme

Transport

Minimum Energy Performance Standards

Non-fossil Fuel

Norms for Hydrogen, Renewable Energy and Other Non-fossil Sources

Regulatory Affairs

Strengthening of the State Electricity Regulatory Commissions

Source: Ministry of New and Renewable Energy, Government of India, 2023

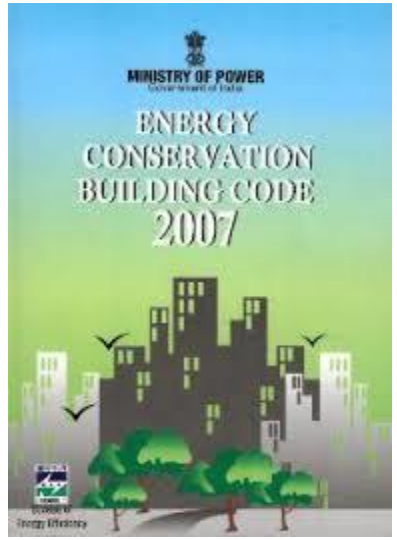
ENERGY CONSERVATION BUILDING CODE

Salient aspects

ENERGY CONSERVATION ACT 2001

HOSPITALITY	HEALTHCARE	ASSEMBLY	BUSINESS	EDUCATION	RETAIL
No star Resorts Star Hotels	Hospitals Out-patient Care	Theatres Transport Service Facilities Multiplexes	Small Offices < 10,000 sqm Medium Offices 10,000–30,000 sqm Large Offices > 30,000 sqm	Schools Colleges Universities Training Institutions	Shopping Malls Stand-alone Retails Open Gallery Malls Supermarkets

ECBC BUILDING CLASSIFICATIONS





- New buildings with connected load of 100kW and more or contract load of 120kVA
- Includes passive design features like daylighting and shading
- Includes integration of renewable energy systems
- Minimum energy efficiency standards for design and construction level
- Pathway toward net zero energy buildings

EE PROGRAMS

Mitigation measures for emission-intensive sectors

India's emissions mitigation strategy can be mapped to five highest emission-intensive sectors:

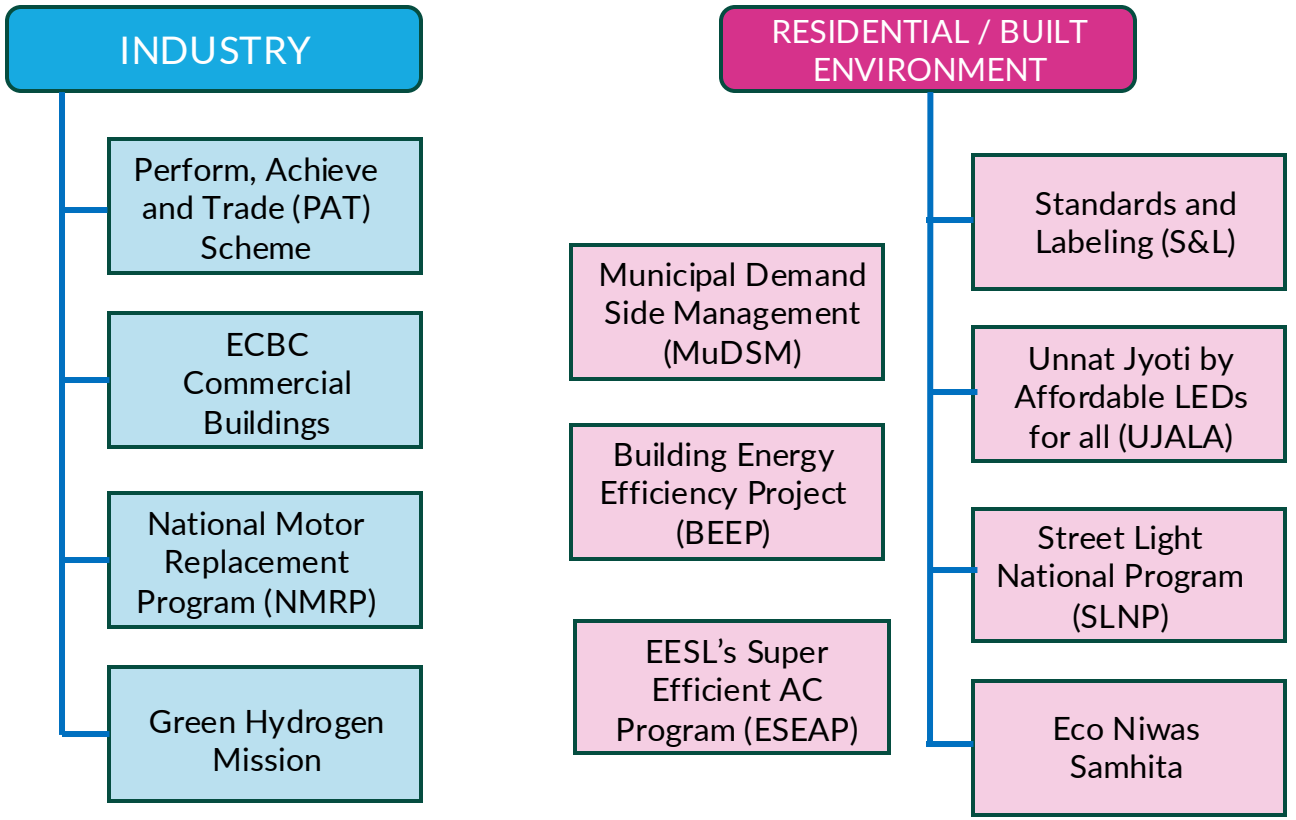
POWER

INDUSTRY

RESIDENTIAL

AGRICULTURE

TRANSPORT



Source: Chateau. J. et al., 2023

EE IN THE BUILDING SECTOR

Initiatives for improving energy efficiency

Programs and schemes for the building sector by government and industry

GUIDELINES, CODES AND STANDARDS

- Energy Conservation Building Code **(ECBC) for commercial buildings**
- Eco Niwas Samhita – **ECBC for residential buildings (Parts 1 and 2)**
- Eco Niwas Samhita Tool
- Residential Labeling Program focusing on energy efficiency

ENERGY EFFICIENCY IN EXISTING BUILDINGS

- PAT scheme for hotel buildings
- Nearly net zero in existing buildings
- Shunya labeling for net zero energy buildings and net positive energy buildings
- EESL Building Energy Efficiency Program
- BEE star rating for existing buildings

VOLUNTARY RATING SYSTEMS

- GRIHA national rating system for new and existing buildings and large developments
- LEED and IGBC rating systems for new and existing buildings
- GEM rating for buildings
- CPWD rating 'GHAR'

Source: Ministry of Power and Bureau of Energy Efficiency, Government of India, 2023

BEEP PROGRAMS

Building energy efficiency programs funded by multilateral and bilateral agencies

Indo-German Collaborations

PAT Program
Norms for industry

IGEN-EERB
Energy efficiency in residential buildings

EE – COOL
Promoting energy efficient cooling in India

EE in Finance
For MSMEs

EE Lines of Credit
Finance for EE

IGEN Energy Forum
Energy efficiency in residential buildings

DSM
Flexibilization of the Indian electricity system with demand side management (DSM)

Indo-US Collaborations

ECO Program (since 2000)
Energy conservation and commercialization

ECO II and III
- Support to BEE
- Support to Maharashtra for energy conservation and DSM
- Support to Karnataka in energy efficient lighting

PACE
Partnership to advance clean energy deployment

MAITREE
- EE in buildings
- Sustainable cooling
- Training on consumer engagement and outreach

BEEP PROGRAMS

Building energy efficiency programs funded by multilateral and bilateral agencies

Indo-UK Collaboration

IEA CETP + BEE
IEA Clean Energy Transition Program

- Cooling
- Industrial EE
- Buildings
- Energy services
- Leveraging private investment

SEAD
Super-efficient Equipment and Appliance Deployment Initiative

Indo-Swiss Collaboration

BEEP
Indo-Swiss Building Energy Efficiency Program

Integrated design process, energy efficiency and thermal comfort

LOW CARBON CEMENT

Multilateral Programs and Partnerships

GEF
Global Environment Facility

FLCTD
Facility for Low Carbon Technology Deployment

IPEEC
International Partnership for Energy Efficiency Cooperation

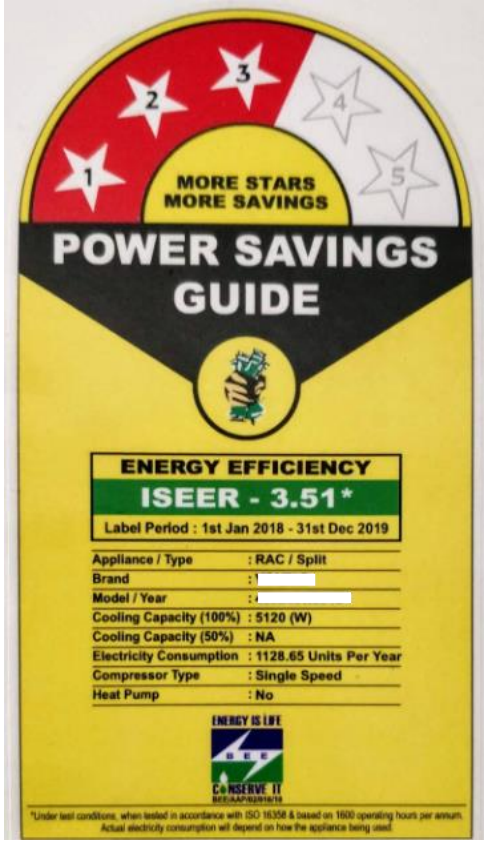
CEM
Clean Energy Ministerial

STANDARDS AND LABELING

BEE's S&L programs

Objectives

- Reduce end-use consumption of appliances without diminishing service levels
- Create awareness among consumers in making informed decision based on cost effectiveness and energy performance while purchasing appliances
- Total production for the appliances during 2022–2023 ~ 550 million.
  - Total brands registered = 3,126
  - Total models registered = 22,192
- 15,000 retailers trained under the Retailers Training Program
- Reduced 57 million tons of CO_2 emissions



S&L

Appliances covered – mandatory and voluntary

S NO	MANDATORY
1	Frost Free Refrigerator
2	Direct Cool Refrigerator
3	Deep Freezer
4	Room AC (Variable Speed)
5	Room AC (Fixed Speed)
6	RAC (Cassette, Floor Standing Tower, Ceiling Corner AC)
7	Light Commercial AC (Fixed Speed)
8	Stationary Storage Type Electric Water Heater
9	Tubular Fluorescent Lamp
10	LED Lamp
11	Ultra High Definition Television
12	Colour Television
13	Distribution Transformer
14	Ceiling Fan
15	Chiller
16	Washing Machine

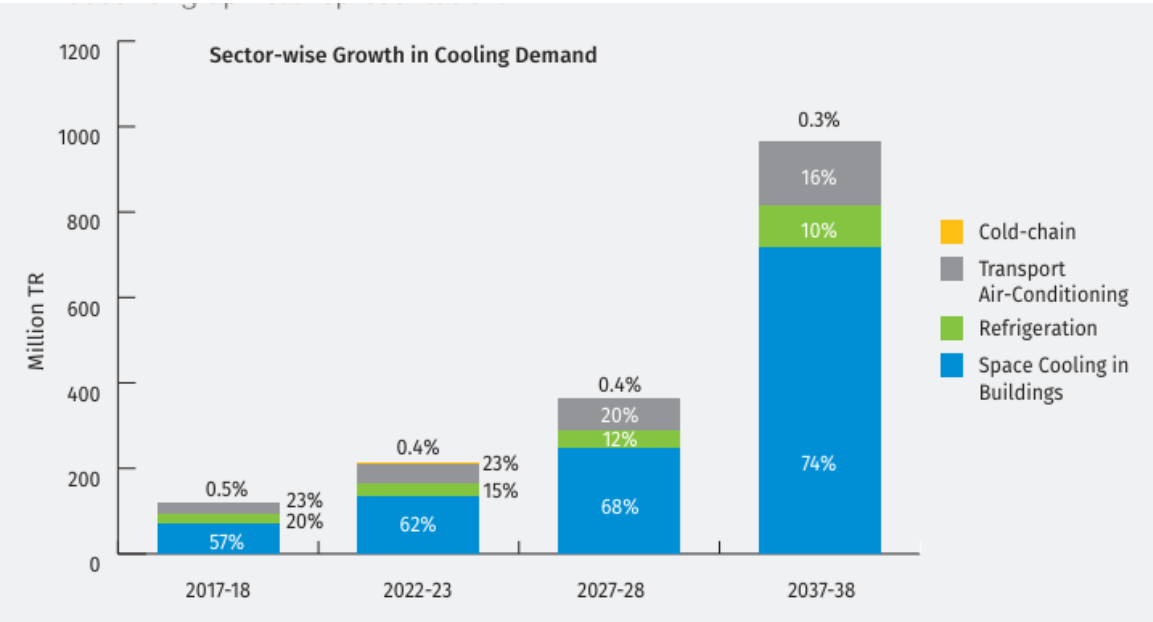
S NO	VOLUNTARY
1	General Purpose Industrial Motor
2	Submersible Pump Set
3	Domestic Gas Stove
4	Computer
5	Ballast
6	Office Automation Product
7	Diesel Engine Driven Monoset Pump for Agricultural Purposes
8	Solid State Inverter
9	Diesel Generator Set
10	Microwave Oven
11	Solar Water Heater
12	Air Compressor
13	High Energy Li-Battery
14	Tyre
15	Multi Door Refrigerator
16	Pedestal Fan, Table Fan, Wall Fan
17	Induction Hob
18	Solar Photovoltaic

INDIA COOLING ACTION PLAN

Focus areas

India is the first country to develop a comprehensive cooling action plan launched in March 2019 that focuses on:

- A long-term integrated vision to address cooling requirements in the country with the focus on urban cooling, thermal comfort and cold chains
- Reduction in cooling and refrigerant demand
- Enhancing energy efficiency



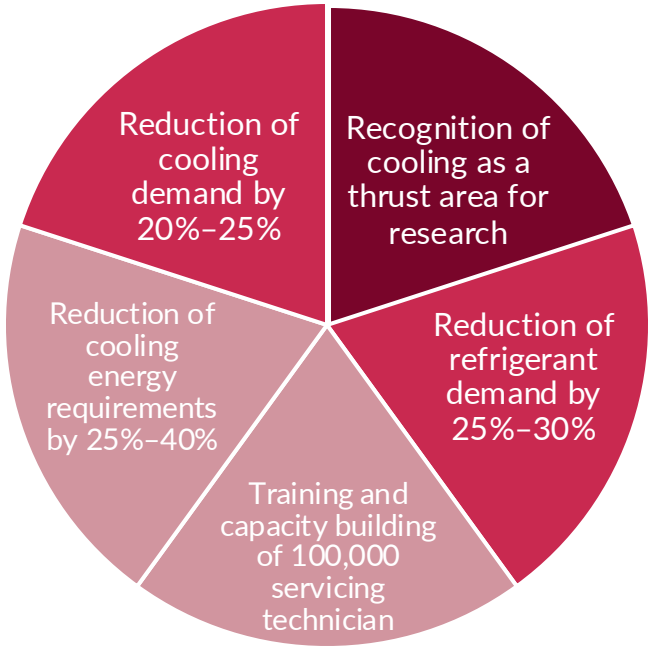
India's cooling demand across sectors

Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019

INDIA COOLING ACTION PLAN

Goals

- ***Building cooling energy consumption*** is likely to ***double in the next decade*** and increase by ***nearly four times in the next two decades (over the 2017–2018 baseline)***
- ***Building cooling energy consumption can be reduced by around 15%*** in the next decade and by around 30% in the next two decades
- Room air conditioner constitutes a dominant share of the building sector's cooling energy consumption – at around 40% in 2017–2018, and expected to grow to around 50% in 2027–2028 and 2037–2038
- Significant presence of non-refrigerant-based cooling from fans and air coolers at around 40% makes a strong case for realigning focus on fans and air coolers that will continue to be very pervasive, particularly in the residential sector, to provide thermal comfort to all



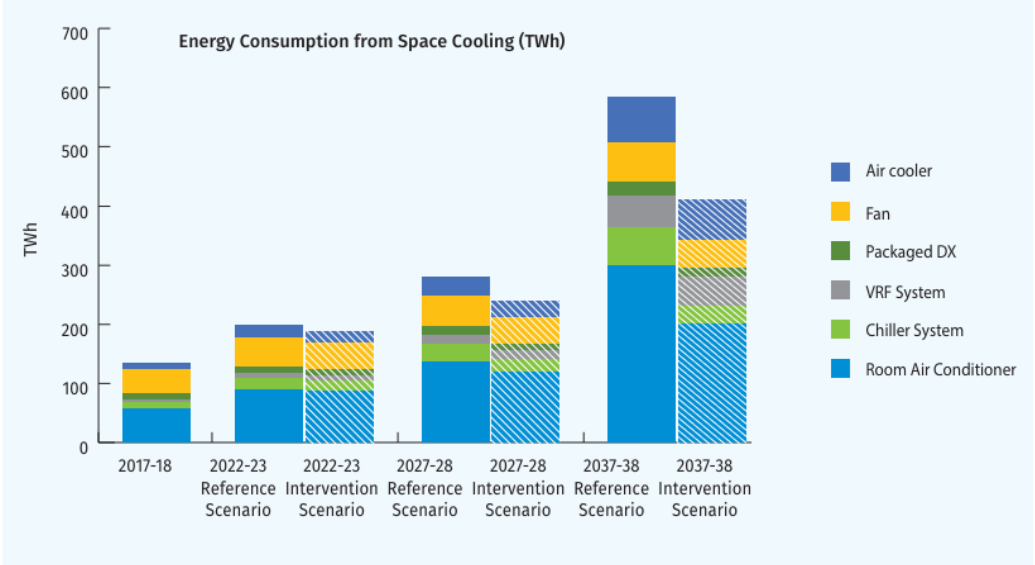
ICAP Goals by 2037–2038

Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019

INDIA COOLING ACTION PLAN

Recommendations

1. Promote wider penetration of climate-responsive built spaces to bring indoor temperatures within acceptable thermal comfort band through passive cooling, thus reducing cooling load
2. Leverage existing levels of technology to make it available for wider market adoption
3. Adopt adaptive thermal comfort-based set-point for air conditioner operation
4. Enhance operational efficiency of cooling systems
5. Develop DSM and demand response programs for enhancing energy efficiency of cooling equipment
6. Formulate and implement policies at the state level



Annual energy consumption in space cooling in buildings

Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019

INDIA COOLING ACTION PLAN

Recommendations (continued)

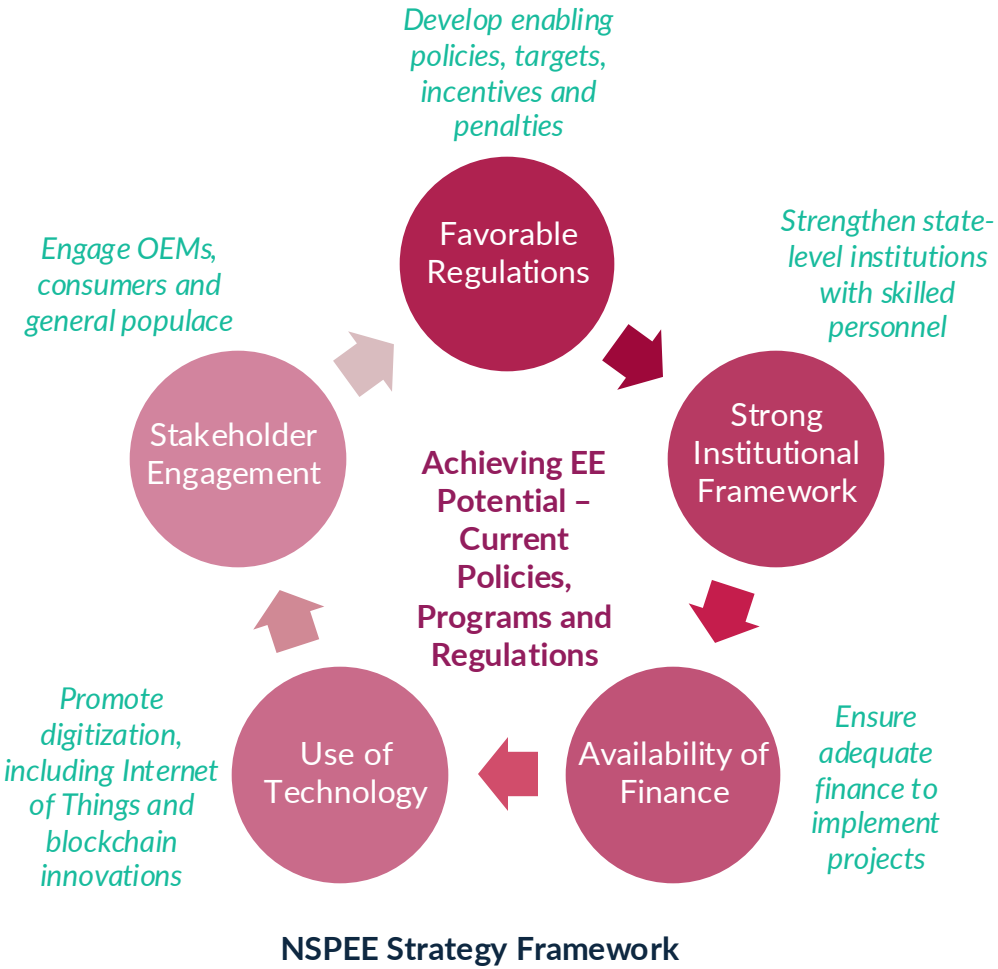
7. Form a **robust research and development team** that leverages global best practices in space cooling and existing knowledge by closely monitoring pertinent policies and technology pathways
8. **Build energy data collection** and reporting systems
9. Implement **eco-labeling program** for cooling appliances
10. Institutionalize **holistic and integrated approach for energy efficient building design of commercial buildings** with the mandate to minimize cooling needs as a condition under the environmental clearance policy
11. Encourage **development of urban heat action plans** for all cities with a population of 2.5 million or more
12. Promote use of not-in-kind technologies including trigeneration system, district cooling, thermal energy storage etc.
13. **Institutionalize installation of thermal storage with cooling systems and differential (time of day) power tariffs to minimize peak power requirements**
14. **Ensure all new constructions – both residential and commercial – are 100% ECBC compliant**
15. Periodically revise the minimum stringency levels of ECBC compliance to ECBC+ and super ECBC requirements
16. Make mandatory building automation and management systems for all new constructions with a connected load of 100 kW or greater

Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019

WAY FORWARD

Addressing challenges

- Promote awareness and knowledge about energy efficiency measures among consumers and businesses. People are not aware of the benefits of energy efficiency, and there is a lack of incentives to adopt energy efficient measures
- Promote financing for energy efficiency projects, especially upfront investments
- Enforce energy efficiency regulations
- Develop authenticated information and standard monitoring and verification protocols



NSPEE Strategy Framework

Source: Bureau of Energy Efficiency, Government of India, 2019

OPPORTUNITIES

For low carbon and green growth

Buildings:

- India's buildings and construction sector is highly carbon-intensive, contributing around one-sixth of the nation's total GHG emissions

Implementation of new building codes:

- While the ECBC 2017 and the EE label for residential buildings have been launched and notified, there is an urgent need for these programs to be implemented and enforced by the states. Processes for ECBC applications for new buildings, and monitoring after building construction, need to be developed by the states
- There is an urgent need to take action to improve the energy efficiency of the existing stock of buildings that are 30–40 years or older

Thermal comfort for all:

- India's demand for space cooling is rapidly moving away from ceiling fans to air-conditioners. India is among the first countries to launch an India Cooling Action Plan, which is now in the implementation phase



OPPORTUNITIES

For low carbon and green growth

Push for higher appliance efficiencies:

- India has made great strides in introducing energy efficiency labels for large number of appliances. The focus should now be on improving the standards and pushing for the manufacture and sale of higher star-rated appliances through appropriate incentive schemes

Promotion of net zero initiatives:

- The future of the built environment must focus on net zero in energy, water, waste and carbon
- It is important to bring net zero into policies and implementation frameworks and consider incentives for the first entrants
- Net zero must happen not just for buildings and habitats, but at an ecosystem level, so that policies, technologies, business models, skilling and green jobs creation happen in coordination
- Energy efficiency can help India become a global leader in sustainable economic development



3. Indonesia

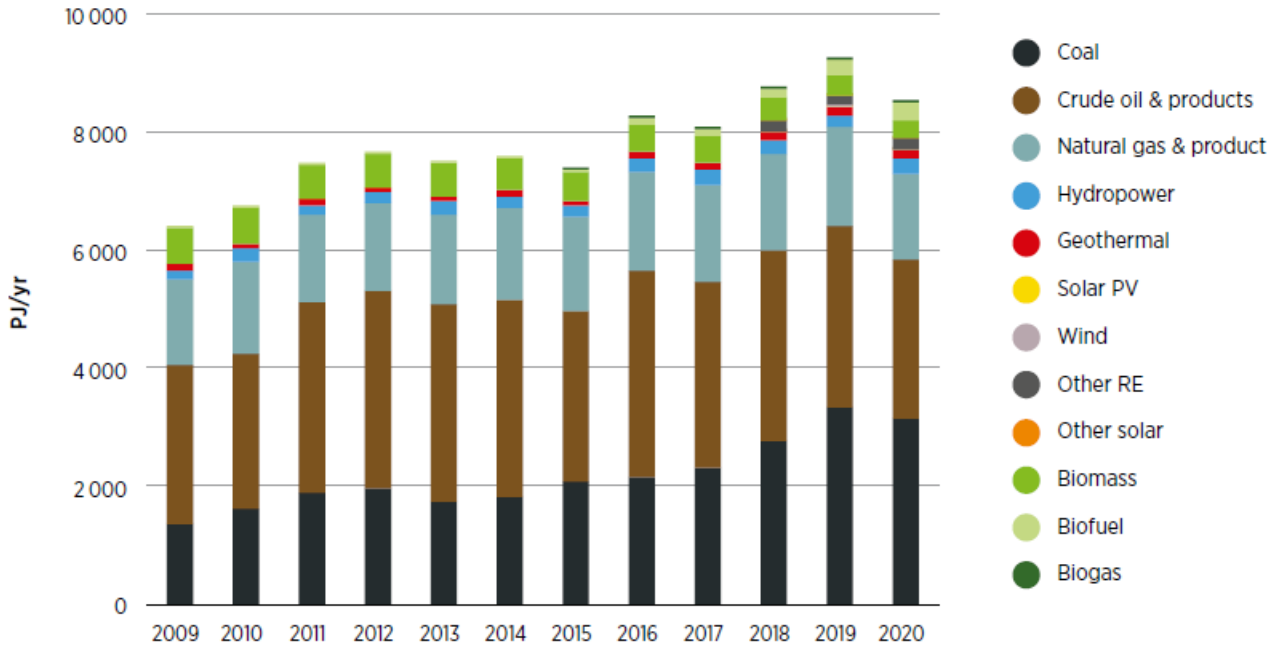


Image source: https://www.archdaily.com/1003506/indonesia-plans-to-build-its-new-capital-from-the-ground-up-to-replace-the-sinking-city-of-

ENERGY SCENARIO

Primary energy supply and consumption

- Indonesia's energy supply is still heavily **dominated by fossil fuels**
- Indonesia's historical maximum coal consumption was in 2019. **80% of the total consumption were by power plants**
- Industry is the second largest user of coal, by industries like iron, steel, metallurgy, cement, textile and fertilizer
- Indonesia has the **largest energy consumption** among ASEAN member states



Note: PJ = petajoule; RE = renewable energy.
Source: (MEMR, 2021a).

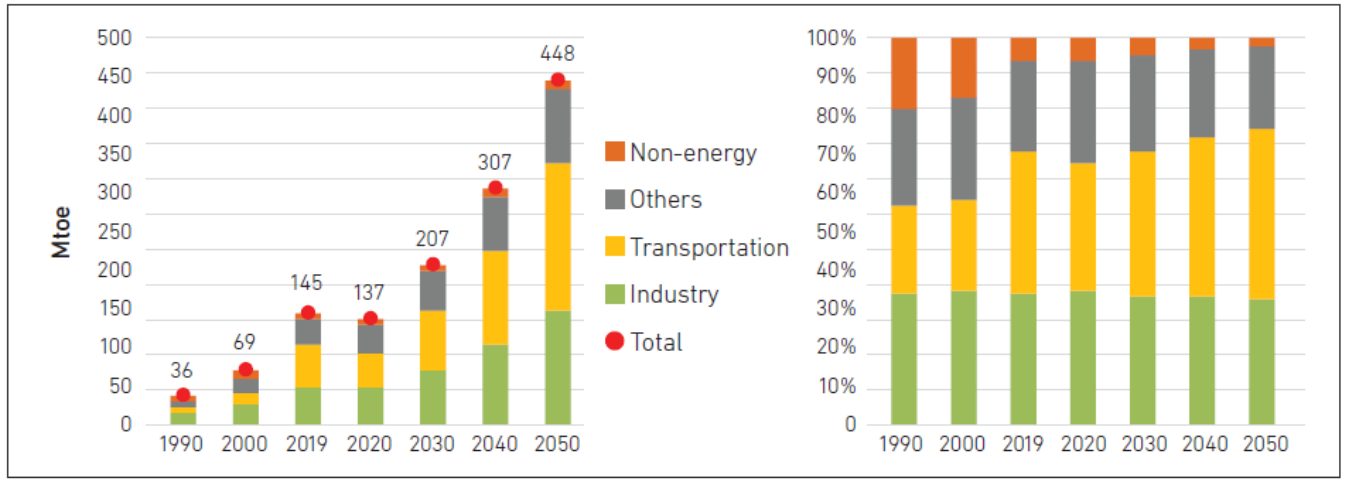
Breakdown of Indonesia's total primary energy supply, 2009–2020

Source: International Renewable Energy Agency, 2022

ENERGY SCENARIO

Total final energy consumption

- The growth in total final energy consumption (TFEC) is mainly due to the rapid increase of energy consumed by **transport and industry**
- Transport's share in TFEC increased from **22.6% in 1990 to 36.9% in 2019**. The share is expected to continue to increase to **45.9% in 2050**
- Industry had the highest share in TFEC in 1990–2005, which was then overtaken by transport
- The share of 'others' (mainly residential and commercial) in TFEC in 1990 was about 25.2% and is **expected to decrease to 21.6% in 2050**



Mtoe = million tonnes of oil equivalent.

Source: Author's calculations.

Note: Others = residential and commercial

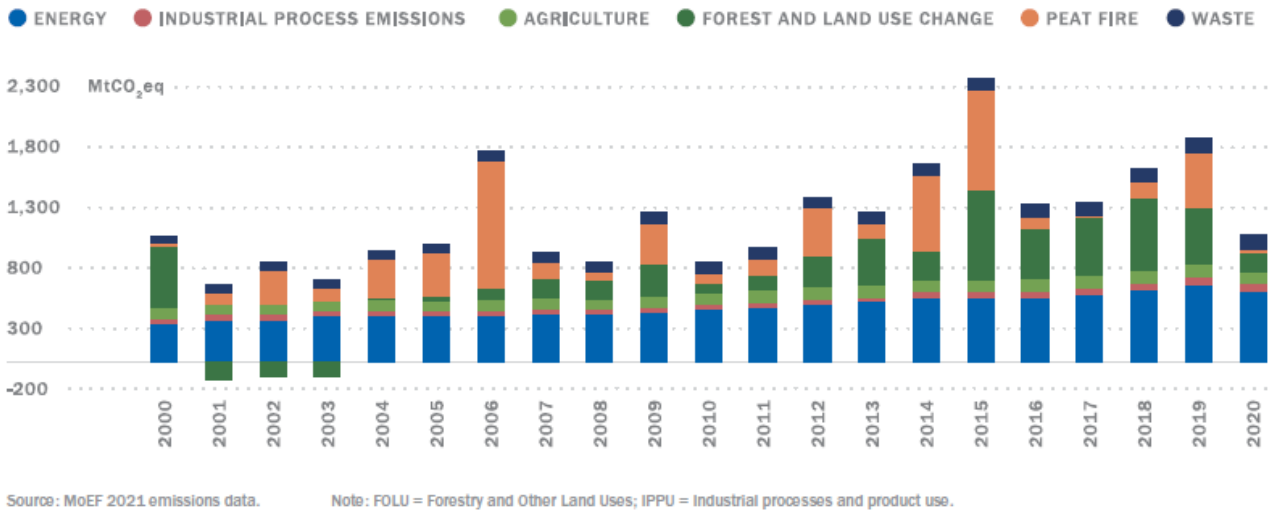
Indonesia's final energy consumption by sector, 2019–2050 (Mtoe)

Source: Kimura. S. et al., 2023

GHG EMISSIONS

By sector

- About 93% of the energy supply comes from fossil fuels, namely coal (43%), oil (31%) and gas (19%). It is the second largest source of carbon emissions
- Energy accounts for approximately 39% of GHG emissions in Indonesia in 2000–2020
- **The demand for primary energy has been driven by the electricity sector,** which has been the largest contributor to emissions from energy use
- **Building sector emissions will be dominated by space cooling and will peak by 2030 due to economic growth and urbanization**



Indonesia's GHG emissions by sector, 2000–2020 (million tCO_2eq)

Source: World Bank, 2023b

GHG EMISSIONS

Building sector in Indonesia

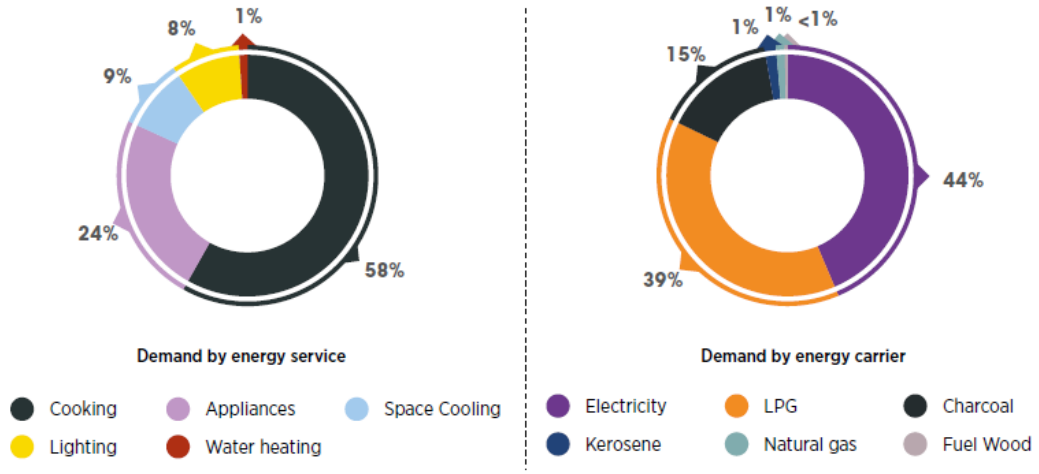
The building sector's final energy consumption is expected to **more than triple by 2050 in BAU case.** Growth in the population, economy and floor area is the main driver of building sector energy demand growth. Electrification and stringent energy efficiency implementation can lower energy demand growth

RESIDENTIAL

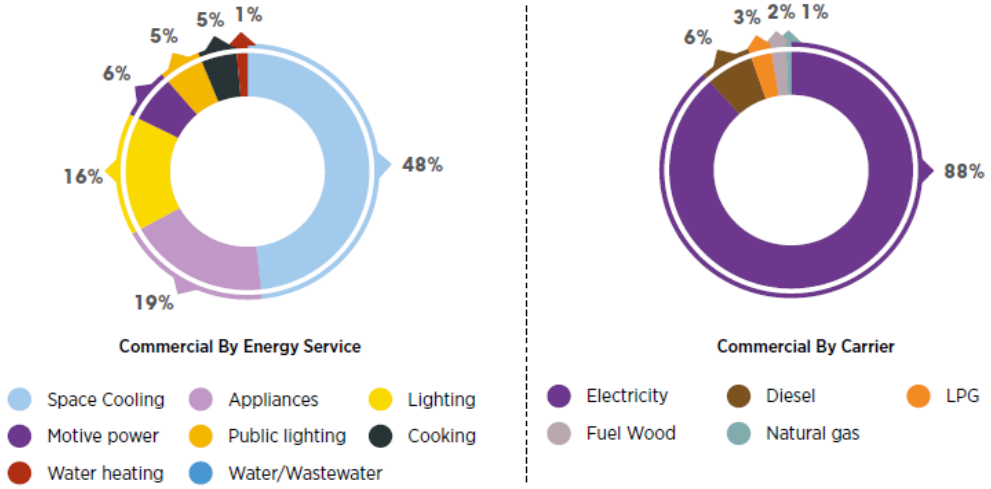
Even when the minimum energy performance standard (MEPS) of residential air conditioners and other household equipment is mandated, by 2050, space cooling is expected to dominate energy consumption in the residential subsector, comprising over **41% of total residential energy demand**, while **appliances is expected to comprise 35%**

COMMERCIAL

The demand is projected to expand almost sixfold over the next 30 years. **Cooling may consume 48%** of this electricity, and **appliances and lighting may consume 34%**



Residential buildings' energy demand, 2018

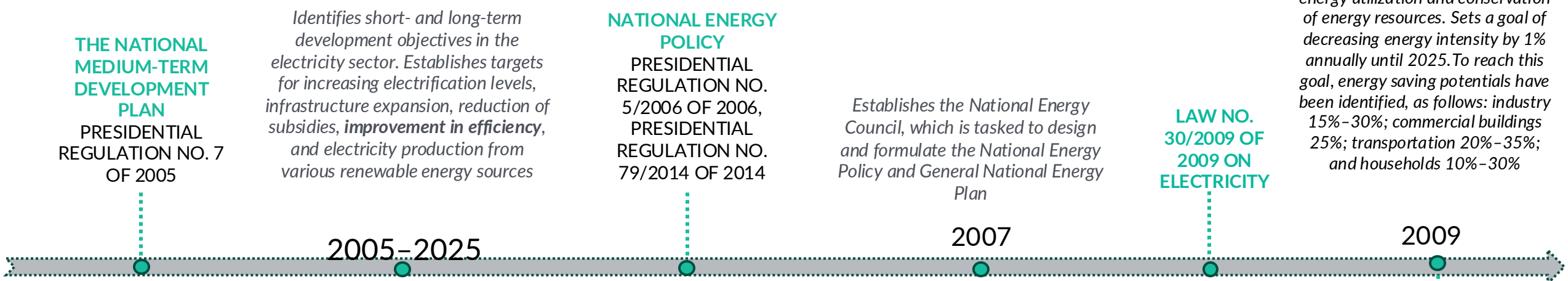


Commercial buildings' energy demand, 2018

Source: International Renewable Energy Agency, 2022

INDONESIA INITIATIVES

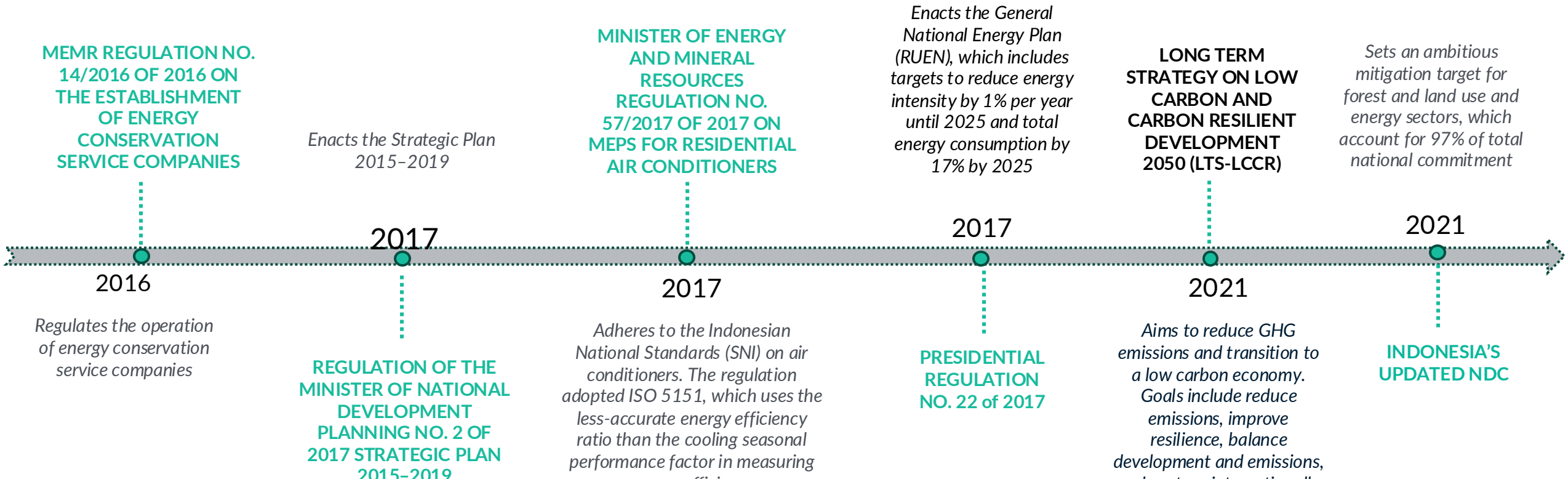
Timeline of policies in climate and energy



Sources: https://asiapacificenergy.org/apef/index.html#main/lang/en/time/[2018,2024]/geo/[]/search; Climate Action Tracker; NDC, 2022

INDONESIA INITIATIVES

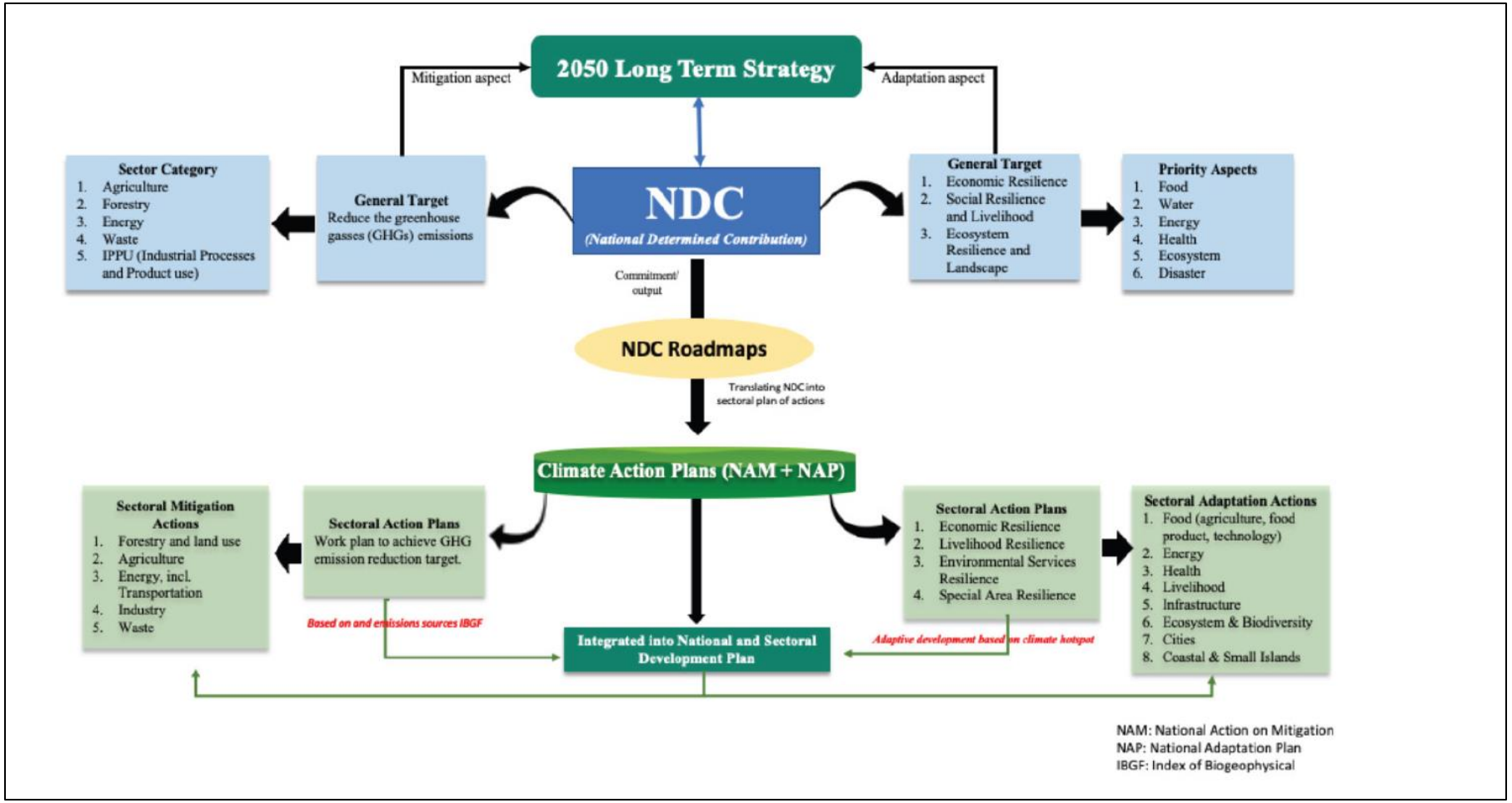
Timeline of policies in climate and energy



Source: https://asiapacificenergy.org/apef/index.html#main/lang/en/time/[2018,2024]/geo/[]/search

NDC ROADMAP

Long-Term Strategy for Low Carbon and Climate Resilience 2050



Source: Government of Indonesia, 2021

NDCs AND THE BUILDING SECTOR

Challenges

The construction and operation of buildings accounted for 21.6% of total annual energy consumption (electricity, gas and liquefied petroleum gas) in 2015

Direct emissions from Indonesia's building sector constitute 4% of energy-related CO_2 emissions

Major barriers in the implementation of GHG-reducing technologies are:

- Lack of energy efficiency policies and incentives for potential investors
- Lack of technical expertise and capacity to plan and design energy efficient construction projects, and financial issues for these projects
- Lack of financing opportunities

Source: Global Alliance for Buildings and Construction and Danish Energy Agency, 2022

INSTITUTIONAL MECHANISMS

For energy efficiency

- Ministry of Public Works and Housing (MPWH)

Responsible for policy formulation, spatial planning and public infrastructure, among others. Standards for building construction, including the regulation on green building guideline, are under the supervision of the MPWH

- Ministry of Energy and Mineral Resources (MEMR)

Responsible for administering government affairs in the fields of energy and mineral resources. The MEMR's main functions consist of formulating, determining and implementing policies and technical guidance in the training, controlling and supervising of oil and gas, electricity, minerals and coal, new energy, renewable energy, energy conservation, and geology. The MEMR also provides support and implementation of research and development in energy and mineral resources

- Green Building Council of Indonesia (GBC Indonesia)

An independent and private organization established in 2009 by professionals in the design and construction industries. GBC Indonesia collaborates with stakeholders such as architects, buildings designers, building professionals, governments and the private sector. GBC Indonesia has four main programs: market transformation, training and education, green building certification, and stakeholder engagement

Source: ASEAN Centre for Energy and Deutsche Gesellschaft für Internationale Zusammenarbeit, 2018

REGULATIONS

For energy efficiency

The following regulations are relevant to the building and construction sector in Indonesia:

- Presidential Regulation No. 22 of 2017 concerning the General National Energy Plan
- Minister of Energy and Mineral Resources Regulation No. 14 of 2012 concerning Energy Management Regulation No. 70 of 2009: End users with an annual consumption of over 6,000 TOE must implement energy management, e.g., regular energy audit, preparation of an energy plan and implementation of energy saving measures
- MEMR Regulation No. 13: Public facilities must implement EE measures to achieve a 20% reduction target
- MEMR Regulation No. 7: Minimum energy performance standards and labeling are required for air conditioning systems
- Governmental Regulation No.16/2021 on buildings
- Governmental Regulation No. 21/2021 on the assessment of green building performance
- Minister of Energy and Mineral Resources Regulation No. 18 of 2014 concerning minimum performance standards and energy saving label of self-based lamps
- Minister of Energy and Mineral Resources Regulation No. 57 of 2017 concerning minimum performance standards and energy saving label of air conditioners

Source: Global Alliance for Buildings and Construction and Danish Energy Agency, 2022

REGULATIONS

National energy efficiency standards for buildings

Indonesia has four energy standards for buildings:

- SNI 6196:2011 Energy audit procedure for building
- SNI 6197:2020 Energy conservation for lighting system in building
- SNI 6389:2020 Energy conservation for building envelope
- SNI 6390:2020 Energy conservation for air conditioning system in building

Other relevant standards include:

- SNI ISO 50001:2018 Energy management system – Requirements with usage guidelines
- SNI ISO 50002:2014 Energy audit – Requirements with guidelines for use
- SNI ISO 50006:2014 Energy management system – Measuring energy performance using energy baseline (EnB) and energy performance indicator (EnPI) – General principles and guidelines
- SNI ISO 50015:2014 Energy management system – Measurement and verification of an organization's energy performance – General principles and guidelines
- SNI ISO 50021:2019 Energy management and energy saving – General guidelines for choosing an evaluator
- SNI ISO 50046:2019 General method for predicting energy saving
- SNI 6500:2018 Fixed installation refrigeration system – Safety and environmental requirements
- SNI ISO 817:2018 Refrigerant naming and safety classification
- SNI 8476:2018 Method of assessment and testing on the performance of cool water coolers with vapor compression systems

REGULATIONS

For energy efficiency

- The Ministry of Energy and Mineral Resources released a set of Energy Efficiency Guidelines for Building Design in Indonesia, which is divided into three separate guidelines:

  i. For Developer and Building Owner
  i. Energy Efficiency Technical Guidelines
  ii. Case Study

- GREENSHIP Certification by the Green Building Council of Indonesia, introduced in 2010, is a voluntary rating tool based on rating systems widely used around the world. The GREENSHIP criteria considers five types of certification:

  i. New Building
  ii. Existing Building
  iii. Interior Space
  iv. Homes
  v. Neighborhood

GREENSHIP Certification includes four recognition achievements, namely, (i) Platinum, (ii)Gold, (iii) Silver and (iv) Bronze During its launch, 14 buildings in Indonesia were rated under GREENSHIP

REGULATIONS

For energy efficiency

- **Government Regulation No. 70 of 2009** regarding **energy conservation** is a legally-binding regulation explanatory of the Energy Law on matters of energy conservation. The regulation elucidates mandates of the Energy Law, specifically on policy and obligatory programs
  - *"By law, energy conservation is obligatory"*
  - Specific regulation for the largest energy users at above 6,000 TOE annually; they are **obliged to implement energy conservation through energy management law**
  - Easiness, incentive and disincentive:
    - Easiness in the access to information regarding energy efficient technology, their specifications and energy efficient measures; and consultation services regarding energy efficient measures
    - Government and/or regional government shall provide incentive to those that can implement and produce energy saving within a certain period
    - Disincentive will be given to those who fail to implement energy conservation through energy management

REGULATIONS

For energy efficiency

- **National Action Plan for Reducing Greenhouse Gas Emissions (RAN-GRK) Presidential Regulation No. 61/2011**
  - Mandates Indonesia's provinces to develop and submit a local action plan (RAD-GRK). RAN-GRK provides capacity building, budget, and potential participation in domestic and international markets to local governments to incentivize them to contribute to RAN-GRK's goals. This regulation is not limited to buildings but across all areas
- **MEMR Regulation No. 14/2012 on Energy Management**
  - Regulates the authority to implement energy management at the province and regency/city levels
- **MEMR Regulation No. 18/2014 on Energy Saving Label for Compact Fluorescent Lamp**
  - Obligations on energy saving labeling as described in Indonesia Standard Number 04-6958-2003 concerning *use of electric power for household needs*
- **Presidential Regulation No. 38/2015 on Government Cooperation with Business Entities in Infrastructure Procurement** (including infrastructure on energy conservation)
  - Provides additional incentives such as the availability of payment mechanism, which allows the government to commit to long-term payments for infrastructure services provided by business entities

REGULATIONS

For energy efficiency

- **Minister of Public Works and Housing Regulation No. 02/PRT/M/2015 on Green Building**
  - Aims to promote sustainability in the construction of buildings and imposes green building requirements
  - There are three compliance levels of green building requirements for new and existing buildings, that are mandatory, recommended and voluntary
- **Law No.16 of 2016 Confirmation of Paris Agreement UNFCCC**
  - Confirms the ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change, which Indonesia signed on 22 April 2016
- **MEMR Regulation No. 57/2017 Minimum Energy Performance Standards (MEPS) Implementation and Energy Saving Label for AC**
  - Stipulates that domestic producers and importers must apply MEPS and Save Energy Sign Label on air conditioning instruments that will be marketed in Indonesia *(refer to International Energy Agency and ASEAN, 2022b, pp. 32–35)*

REGULATIONS

For energy efficiency

- **Green City Action Plans (2014–2017)**
  - Outlines investment plans and policy development, institutional restructuring, capacity development and training, technical studies, and actions related to funding, financing and implementing projects *(refer to International Energy Agency and ASEAN, 2022a)*
- **Regulation of Ministry of Public Works and Housing 21/2021**
  - Regulates the administration of spatial development regulations, including the design and fixing of a guide comprising spatial development standards, processes and criteria *(refer to International Energy Agency and ASEAN, 2022a)*
- **Energy Conservation Program – Implementation based on Government Regulation No. 33 of 2023**
  - Revisions include regulations on energy audits for factory and energy efficiency labeling

POLICIES

For energy efficiency

Implementation of Mandatory Energy Management for Large Energy Users

- Energy management involves integrated activities to control energy consumption. This is undertaken to achieve effective and efficient energy utilization (maximize output in a structured and economic fashion that minimizes consumption of raw and supporting materials)
- **As a follow up to Government Regulation No. 70/2009 on Energy Conservation**, which stipulates that industries and buildings that consume greater than 6,000 TOE of energy per year should conduct energy management programs and activities, that is:
  - Appoint an energy manager
  - Prepare an energy conservation program
  - Conduct energy audits regularly
  - Implement audit result recommendations
  - Report energy conservation planning and measures to government
- **In 2019, 148 companies implemented energy management systems**

NATIONAL COOLING ACTION PLAN

Development timeline

- In 2020, the Directorate General of New Renewable Energy and Energy Conservation, with ESCAP and UNEP, started to develop the first National Cooling Action Plan (NCAP). The study conducted resulted in identification of requirements to build capacity of related stakeholders in developing recommendations, increase the engagement of related governmental bodies and ministries, and enhance commitment to implement NCAP
- Through NCAP, an initial mapping on the cooling sector, such as building space cooling, food cold chain, vaccine cold chain, cooling system for industrial process and mobile air conditioning, was conducted
- In December 2022, Indonesia ratified the Kigali Amendment to the Montreal Protocol. By 2045, it is hoped that Indonesia will succeed in reducing hydrofluorocarbon emissions by 80%
- In February 2024, a focus group discussion on NCAP was held in Jakarta to review the plan and discuss the roles of each stakeholder. It is hoped that the plan will guide climate change mitigation in the cooling sector. The plan is currently being finalized after receiving valuable inputs from the focus group discussion

CODES

For energy efficiency

Indonesia has four energy standards for buildings (Standar Nasional Indonesia/SNI):

i. Energy conservation for building envelope – SNI 03-6389-2011
ii. Energy conservation for air conditioning system in building – SNI 03-6390-2011
iii. Energy conservation for lighting system in building – SNI 03-6197-2011
iv. Energy audit procedure for building – SNI 03-6196-2011

The MEMR released a set of Energy Efficiency Guidelines for Building Design in Indonesia, which is divided into three separate guidelines, namely for Developer and Building Owner, Energy Efficiency Technical Guidelines, and Case Study

GREENSHIP Certification by the Green Building Council of Indonesia, introduced in 2010, is a voluntary rating tool based on rating systems widely used around the world. The GREENSHIP criteria considers five types of certification: (i) New Building, (ii) Existing Building, (iii) Interior Space, (iv) Homes, and (v) Neighborhood, and includes four recognition achievements namely (i) Platinum, (ii)Gold, (iii) Silver and (iv) Bronze. During its launch, 14 buildings in Indonesia were rated under GREENSHIP

BUILDING EE PROGRAMS

Creating public awareness

- Public awareness on energy conservation is promoted by MEMR, regional governments, the state-owned energy/electricity company, private companies and non-governmental organizations
- Public awareness is raised through advertisement, printed materials and the internet, and through seminars and workshop. The activities carried out so far include:
  - **Energy awards for the building and industrial sector**, including participation in the ASEAN Energy Awards
  - **Energy calculator**, a web-based application used to calculate the energy cost of household electrical appliances and provide energy saving recommendations. The benefits of an energy calculator include knowing energy use, implementing energy conservation and saving electricity bills
  - **Kampanye Potong 10% (10% Cut of Energy Use Campaign)** targets all stakeholders in the energy sector, including governmental and non-governmental organizations, industries and the public to reduce energy consumption by 10%. The program was launched in May 2016 and is funded by MEMR
  - **Konservasi Energi Goes to Campus (Energy Conservation Goes to Campuses)** aims to introduce university students to the basic principles of energy efficiency, the ISO 50001: energy management systems, and job opportunities for energy auditors and energy managers. The program is managed and funded by MEMR

WAY FORWARD

Key actions for policy, investment and design

- Improve existing building energy standards. Ensure that building standards are periodically enhanced to improve performance requirements every five years with the expectation of moving toward zero-emissions and zero-energy standards over the period of 2040–2050
- Encourage developers to use the building codes. A new building code was introduced in 2021 but it is still not fully implemented. Priority should be given to the adaption and enforcement of the code, and incentivizing building owners and developers to use it e.g., by giving advantages to developers that comply with the building code
- Encourage the use of green rating tools. Reward outstanding buildings and developers going significantly beyond the building code
- Government should ensure that all new public buildings follow the building code and targets are set to go beyond the code e.g., nearly-zero energy buildings
- Ensure funding for sustainable construction, including access to and use of financial resources to encourage private investment in sustainable buildings. Link these efforts to new and emerging consumer loan models

Source: Global Alliance for Buildings and Construction and Danish Energy Agency, 2022

WAY FORWARD

Key actions for policy, investment and design

- Increase use of building design tools. Use integrated design processes and simulation or modeling tools such as building information modeling (BIM) and energy models for ensuring high performance and cost savings. For new buildings, use of BIM and energy models may be required in the design task
- Reduce embodied carbon in building materials. Include requirements for low carbon materials in building regulations. Focus on design that uses suitable materials. Reduce the amount of carbon in building operations through the use of renewable energy
- Increase awareness and information. Increase the understanding of the benefits of sustainable buildings among consumers. Use the labeling system to promote energy efficient properties

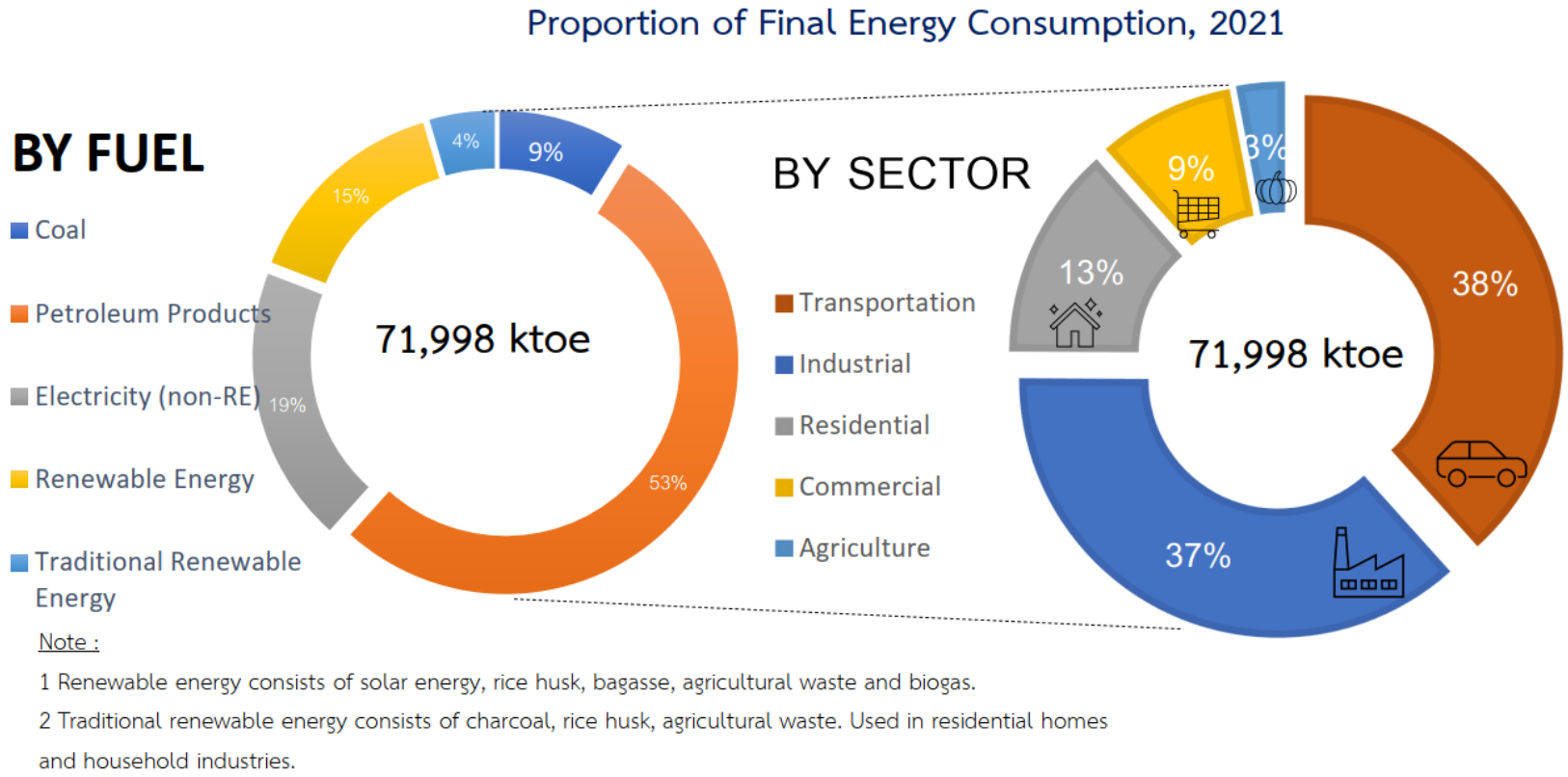
Source: Global Alliance for Buildings and Construction and Danish Energy Agency, 2022

4. Thailand



ENERGY SCENARIO

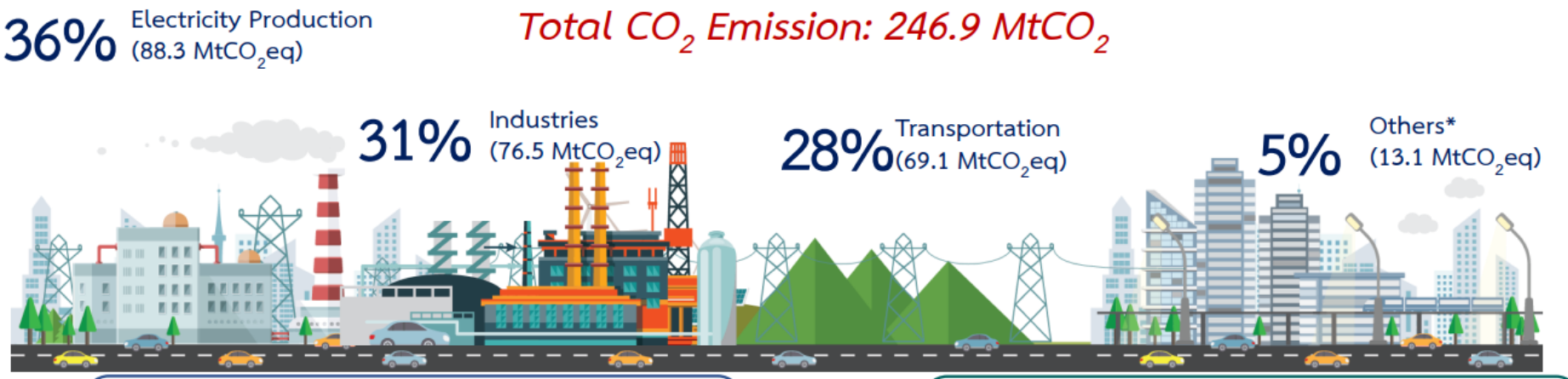
By fuel and sector, 2021



Source: Division of Energy Efficiency Promotion, Department of Alternative Energy Development and Efficiency, Ministry of Energy, Government of Thailand, 2023

CO_2 EMISSIONS

2021



2.04 $MtCO_2$/ktoe

CO_2 emission per energy consumption

Lower than global average as well as Asia, US, China, and Europe's average

3.69 tCO_2/capita

CO_2 emission per capita

Higher than Asia's average

Others* includes residential, agricultural, commercial, etc.

23.50 $kgCO_2$/MBaht

CO_2 emission per GDP

Higher than US, Europe, and global average

0.42 $kgCO_2$/kWh

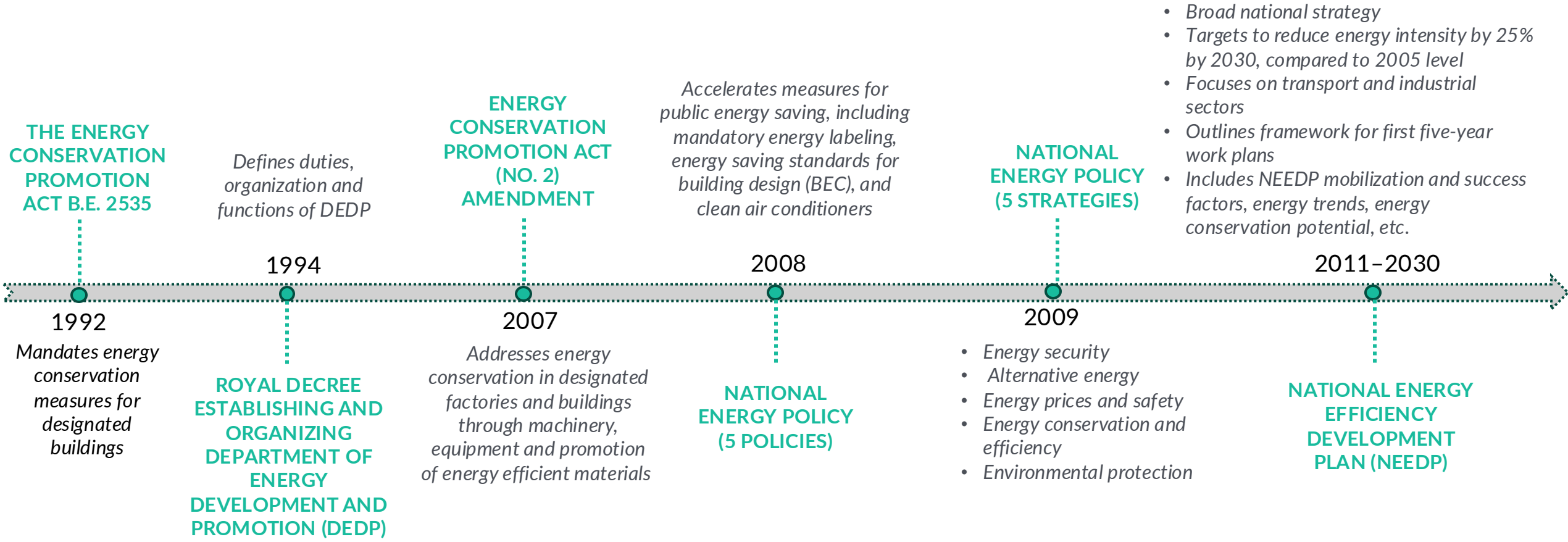
CO_2 emission per electricity production

Higher than Europe's and developed countries in America

Source: Division of Energy Efficiency Promotion, Department of Alternative Energy Development and Efficiency, Ministry of Energy, Government of Thailand, 2023

THAILAND INITIATIVES

Timeline for policies in climate and energy



Source: https://asiapacificenergy.org/apef/index.html#main/lang/en/time/[2018,2024]/geo/[]/search

THAILAND INITIATIVES

Timeline for policies in climate and energy

ENERGY EFFICIENCY PLAN (EEP)

2015–2036
Updated 2018

- Targets 36% reduction in energy intensity by 2037 compared to a baseline year of 2010
- Includes sector-specific goals across various industries, including residential, commercial and industrial sectors
- Outlines compulsory measures such as energy management standards and building codes
- Outlines voluntary measures such as labeling for energy efficient equipment and financial incentives for adopting energy-saving technologies
- Promotes integration of innovative technologies to enhance energy efficiency

CLIMATE CHANGE MASTER PLAN (CCMP)

2015–2050

Focuses on:

- *Carbon neutrality by 2050*
- *Building climate resilience*
- Reducing greenhouse gas emissions (net zero GHG emissions by 2065)
- Capacity building
- Data collection, knowledge sharing and technological development

NATIONAL ENERGY PLAN (NEP)

September 2024
Expected Launch

Integrates five key energy-related plans:

i. Power Development Plan (PDP) 2024–2037
ii. Alternative Energy Development Plan (AEDP)
iii. Energy Efficiency Plan (EEP)
iv. Gas Plan
v. Oil Plan

Aims to increase the share of renewable energy in Thailand's power generation from 36% (as of June 2024) to 51% by 2037

Sources: https://asiapacificenergy.org/apef/index.html#main/lang/en/time/[2018,2024]/geo/[]/search; https://www.preventionweb.net/publication/thailand-climate-change-master-plan-ccmp

INSTITUTIONAL MECHANISMS

National Committee on Climate Change Policy

Chairperson	Prime Minister
1st Vice Chairperson	Minister of Natural Resources and Environment (DEQP, ONEP and NCCO)
2nd Vice Chairperson	Minister of Foreign Affairs
Committee members, Permanent Secretaries of:	
1. Prime Minister's Office	15. Ministry of Higher Education, Science, Research and Innovation
2. Ministry of Finance	
3. Ministry of Foreign Affairs	16. Bangkok Metropolitan Administration
4. Ministry of Tourism and Sports	17. Office of the National Economic and Social Development Council
5. Ministry of Transport	
6. Ministry of Digital Economy and Society	18. Office of the National Water Resources
7. Ministry of Energy (DEDE and EGAT)	19. Bureau of Budget
8. Ministry of Commerce	20. 5–9 experts on law, economics, environment, science and technology, energy, or climate change
9. Ministry of Interior	
11. Ministry of Education	21. One expert from the private sector
12. Ministry of Public Health	Other invitees may include the Thailand Greenhouse Gas Management Organization (TGO), Office of Natural Resources and Environmental Policy and Planning (ONEP), and Chiang Mai University
13. Ministry of Industry	
14. Ministry of Agriculture and Cooperatives	

Source: Adapted from Office of Natural Resources and Environmental Policy and Planning, Government of Thailand, 2022a

INSTITUTIONAL MECHANISMS

Structure of the National Committee on Climate Change Policy

Secretariat: Permanent Secretary, MONRE

Assistant Secretary: Secretary-General of ONEP

Assistant Secretary: Director of Thailand Greenhouse Gas Management Organization (TGO)

Subcommittee on Climate Change Policy and Planning Integration	Subcommittee on Climate Change Knowledge and Database	Subcommittee on Climate Change Negotiation and International Cooperation	Subcommittee on Action for Climate Empowerments and Public Relations	Subcommittee on Climate Law	Subcommittee on the Mobilization of GHG Mitigation with Carbon Sequestration in LULUCF Sector	Subcommittee on the Mobilization of GHG Mitigation with CCUS Technology Implication
Working Group on GHG Mitigation Policy and Planning	Working Group on GHG Inventory and Mitigation Measures	Working Group on Climate Change Convention Conference and Negotiation				
Working Group on National Climate Change Adaptation Implementation Integration	Working Group on Climate Change Data and Modeling					
Ad-Hoc Working Group on REDD+						

Source: Office of Natural Resources and Environmental Policy and Planning, Government of Thailand, 2022a

THAILAND'S NDCs

Overview

- Thailand submitted its **second NDC in 2022**. It covers the energy, industrial processes and product use, agriculture, and waste sectors
- GHG target (**unconditional**): Reduce GHG emissions by **30%** from the projected BAU level by 2030
- GHG target (**conditional**): The level of contribution could increase up to **40%**, subject to adequate and enhanced access to technology development and transfer, financial resources, and capacity building support
- Thailand submitted a revised Long Term – Low Emission Development Strategy (**LT-LEDS**) in 2022, which aims to achieve **carbon neutrality by 2050** and **net zero GHG emissions by 2065**

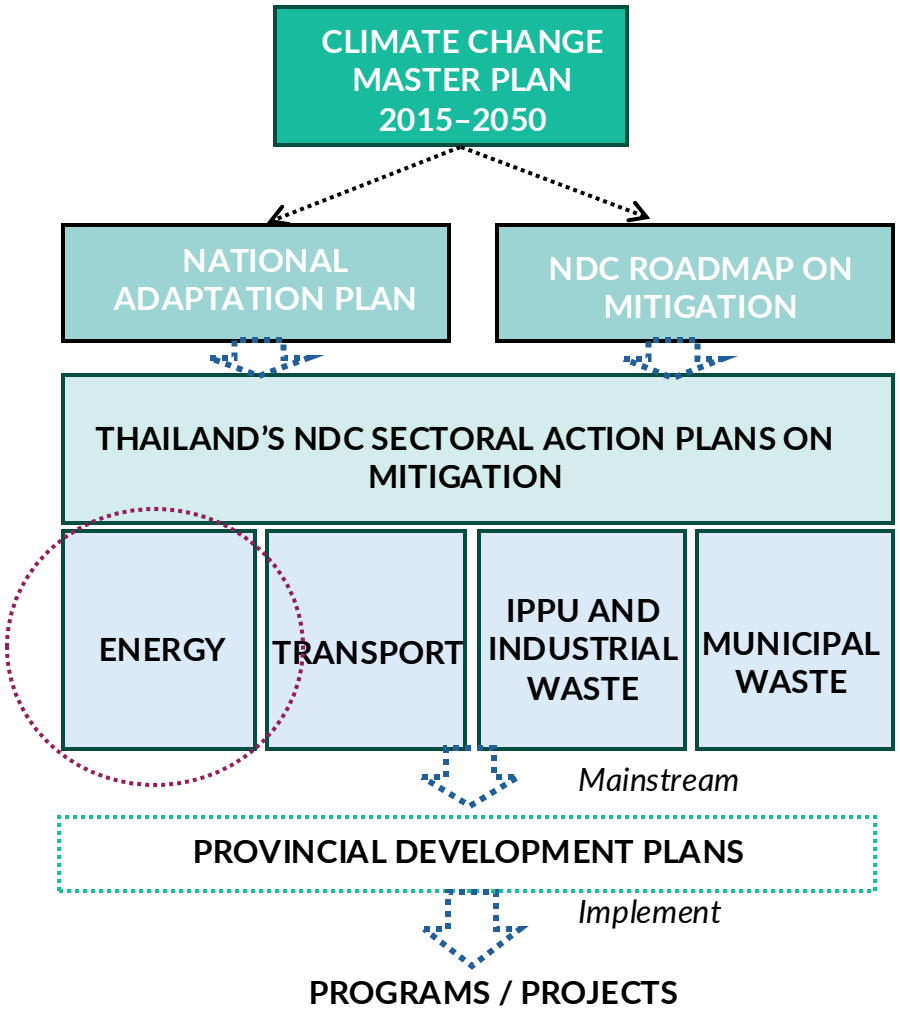
Source: https://ndcpartnership.org/country-action

NDC ROADMAP (2021–2030)

Implementation mechanisms, policies and plans

NATIONAL PLANS TO MEET MITIGATION TARGET IN NDC:

i. 12th National Economic and Social Development Plan 2017–2021
ii. Climate Change Master Plan 2015–2050
iii. Power Development Plan (PDP) 2015–2036, (2018 edition)
iv. Energy Efficiency Plan (EEP) 2015–2036, (2018 edition)
v. Alternative Energy Development Plan (AEDP) 2015–2036 (2018 edition)
vi. Thailand Smart Grid Development Master Plan 2015–2036
vii. Environmentally Sustainable Transport System Plan 2013–2030
viii. National Industrial Development Master Plan 2012–2031
ix. Waste Management Roadmap
x. Long Term Low Greenhouse Gas Emission Development Strategy



NDC Implementation of Mitigation Measures

Source: Supirak, 2021

LT-LEDS

Long Term – Low Emission Development Strategy

Building sector-related plans in the LT-LEDS include:

POWER DEVELOPMENT PLAN (PDP)

Includes developing an energy management system and energy forecast system, liberalizing the energy business, creating the wheeling charge system, and ***promoting an EV and EV charging station production and purchasing system***

ALTERNATIVE ENERGY DEVELOPMENT PLAN (AEDP)

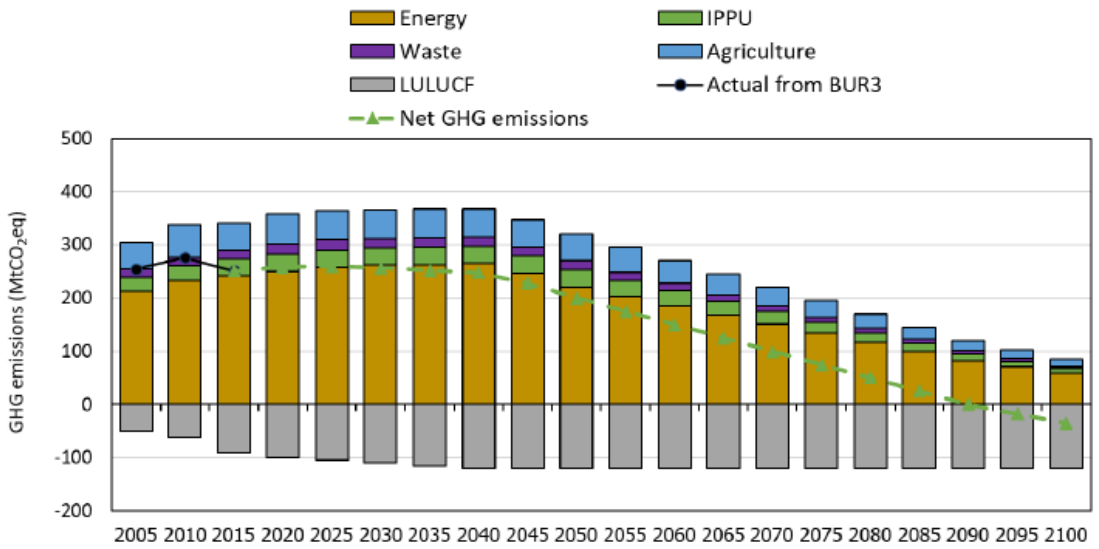
Includes developing a biocircular economy, ***carbon credits mechanism and renewable energy certificates***

ENERGY EFFICIENCY PLAN (EEP)

Seeks to ***enhance energy efficiency in buildings, industries and households, promote green industries and smart energy management***, and develop digital and EV data platforms and ***charging stations to promote electric vehicle utilization***

EEP 2018 + AEDP 2018 + PDP 2018 Rev 1 = 117.66 $MtCO_2eq$ by 2030

Including guidelines for promotion of electric vehicles (EV) as per 30@30 policy



Thailand's long term low greenhouse gas emissions scenario

Sources: Office of Natural Resources and Environmental Policy and Planning, Government of Thailand, 2022a and 2022b

NATIONAL ENERGY PLAN

Toward carbon neutrality and net zero

Mitigation targets in the National Energy Plan for the building sector

RESIDENTIAL SECTOR

- Electricity accounts for the highest energy consumption in the residential sector. ***Household air conditioners are one of the key drivers of electricity demand in Thailand. The energy efficiency improvement of energy devices*** in the residential sector will have to increase to 29% of total final energy consumption in 2050
- The ***share of renewable energy use in households*** will have to increase to ***49% of total final energy consumption in 2050***

COMMERCIAL BUILDINGS

- The ***energy efficiency improvement of energy devices*** in commercial buildings will have to ***increase to 33% of total final energy consumption in 2050***
- ***Solar water heating devices*** have to be promoted to produce hot water in hotels, condominiums and hospitals
- The share of solar water heating will have to increase to 5% of total final energy consumption in 2050



Increase renewable energy use to 50%

EV 30@30
30% of passenger cars and pickup trucks by 2030





Increase EE by 30% through use of technology and energy management

4D1E
Decarbonization, Digitalization, Decentralization, Deregulation, Electrification



Policy direction for the National Energy Plan 2024 (under consideration)

Sources: Office of Natural Resources and Environmental Policy and Planning, Government of Thailand, 2022a and 2022b

NDC SECTORAL PLAN

Energy sector (2021–2030)

- **National Climate Change Policy Committee (NCCC)** assigned the ***Energy Policy and Planning Office (EPPO)*** as the responsible agency to prepare the national greenhouse gas reduction plan 2021–2030
- **EPPO**, with Office of Natural Resources and Environmental Policy and Planning ***(ONEP)*** and Greenhouse Gas Management Organization ***(TGO)***, *identifies potential mitigation measures such as increasing energy efficiency and promoting renewable energy*
- They coordinate with the following agencies to prepare the ***action plan on national GHG emissions*** in the energy sector:
  - Department of Alternative Energy Development and Efficiency **(DEDE)**
  - Electricity Generating Authority of Thailand **(EGAT)**
  - Office of Energy Regulatory Commission **(OEC)**
  - Office of Transport Policy and Planning and Traffic **(OTP)**
  - Chiang Mai University
  - Private power producers



Overview of Thailand's NDC Roadmap and Action Plan and reduction potential

Sources: Office of Natural Resources and Environmental Policy and Planning, Government of Thailand, 2022a; Supirak, 2021

BUILDING ENERGY EFFICIENCY PROGRAMS

Implemented through energy efficiency plans in Thailand

THAI'S RATING OF ENERGY AND ENVIRONMENTAL SUSTAINABILITY (TREES)

- Developed by the Thai Green Building Institute and the Engineering Institute of Thailand
- Purpose is to elevate Thailand's construction sector to international standards

HIGH ENERGY PERFORMANCE STANDARD AND LABELING (DEDE)

- Voluntary program for rating the energy efficiency of appliances
- Provide customers with enhanced awareness on energy efficient appliances and equipment
- Voluntary labeling program to include glazing, three-phase motors, variable speed drives, and diesel and gasoline engines

ENERGY MANAGEMENT SYSTEM

- Requires designated buildings to conduct energy management and assign an energy manager, with reports to be submitted to DEDE yearly

FINANCIAL SUPPORT FOR BUILDING RETROFITS

- In 2019, DEDE set up a subsidy program for retrofitting nine types of buildings, subsidizing the cost of improving the building envelope and the roof to comply with the Building Energy Code

Thailand

Way Forward



Image source: https://ips-cambodia.com/cambodia-encourages-more-green-building

WAY FORWARD

Implementing building EE policies

- Thailand needs further support in terms **of finance, technical expertise, technology transfer and capacity building** to ensure the achievement of its Long-term Low Greenhouse Gas Emission Development Strategy (LT-LEDS) in the short-term (2025–2035), medium-term (2040–2050) and long-term (2050–2065) periods
- To ***enhance the enabling environment***, support is needed for ***developing and strengthening mechanisms, instruments and policy implementation, such as financial instruments and incentives*** to engage private sector in green investment, and ***capacity building for all stakeholders*** to ***integrate climate actions into their respective practice and plans***
- ***Build capacity*** in the public and private sectors to integrate mitigation action into their respective plans or enterprises
- ***Raise awareness on climate change,*** Thailand's LT-LEDS and NDCs among relevant stakeholders and the public at large

OPPORTUNITIES

For low carbon and green growth

Green low carbon growth in Thailand could focus on the following:

- Adjust the economic structure toward a less energy- and carbon-intensive economy
- **Transform urban areas into green livable low carbon cities through multi-sector approaches**

  The speed and scale of urbanization in Thailand presents an opportunity to build low carbon cities and attract the best talent and long-term investments needed to create new jobs in higher-value-added and less-resource-intensive industries

  Some of the key principles include ***compact urban form, efficient and clean energy, renewable energy generation, green buildings, sustainable urban transport, and efficient water and waste management***

- **Tap the energy efficiency potential through energy plans, especially in the transport, industry and building sectors**

  This includes strengthening policies and regulations, and increasing the use of fiscal measures to complement existing voluntary measures

*The Department of Climate Change and Environment (DCCE) with support from the Climate, Coastal and Marine Biodiversity (CCMB) project implemented by GIZ Thailand, has drafted **Thailand's first climate legislation**, namely the **Climate Change Act***

*The draft Climate Change Act establishes various **carbon pricing instruments, including Thailand's emissions trading system, carbon tax and carbon credit, and the National Climate Change Fund.** The draft Act also establishes mandates on climate adaptation, green taxonomy and mandatory greenhouse gas reporting*

5. Vietnam

Energy Scenario, Emissions, NDCs and BEEP



ENERGY SCENARIO

Overview

- Vietnam has transformed into one of the most dynamic economies in the world with the energy sector playing a vital role
- Vietnam has large reserves of primary energy resources and the **primary energy supply** in Vietnam is evolving and dominated by about 49% coal and 24% oil

Vietnam experienced GDP growth of 6.8% in 2017

Improved Life

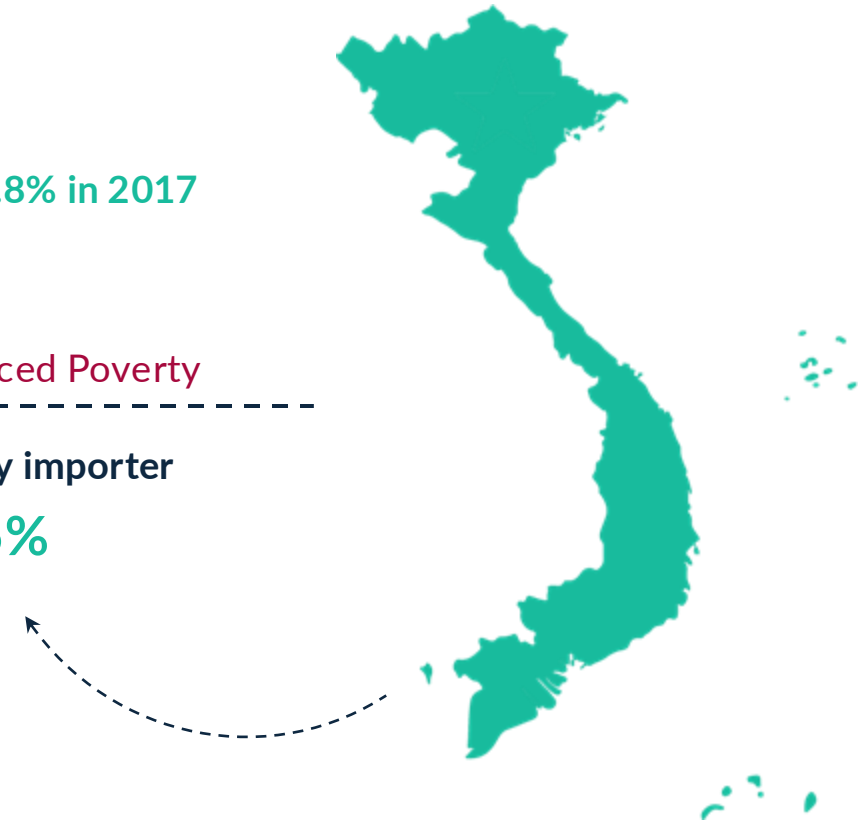


Reduced Poverty

In 2015, Vietnam became a net energy importer

with energy share at 5%

and is expected to grow



PRIMARY ENERGY SUPPLY

1990–2050

1990 — One of the poorest nations in Asia

Significant role played by energy sector

Rapid growth

2019 — One of the most dynamic economies in the world



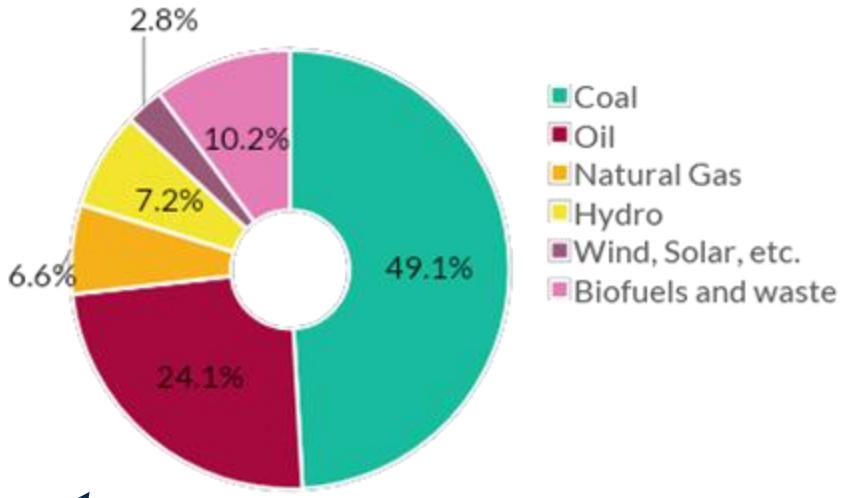
Vietnam has large reserves of primary energy resources

Primary energy supply in Vietnam is dominated by about

49% Coal | 24% Oil

of the total energy supply

Total energy supply, Vietnam, 2021

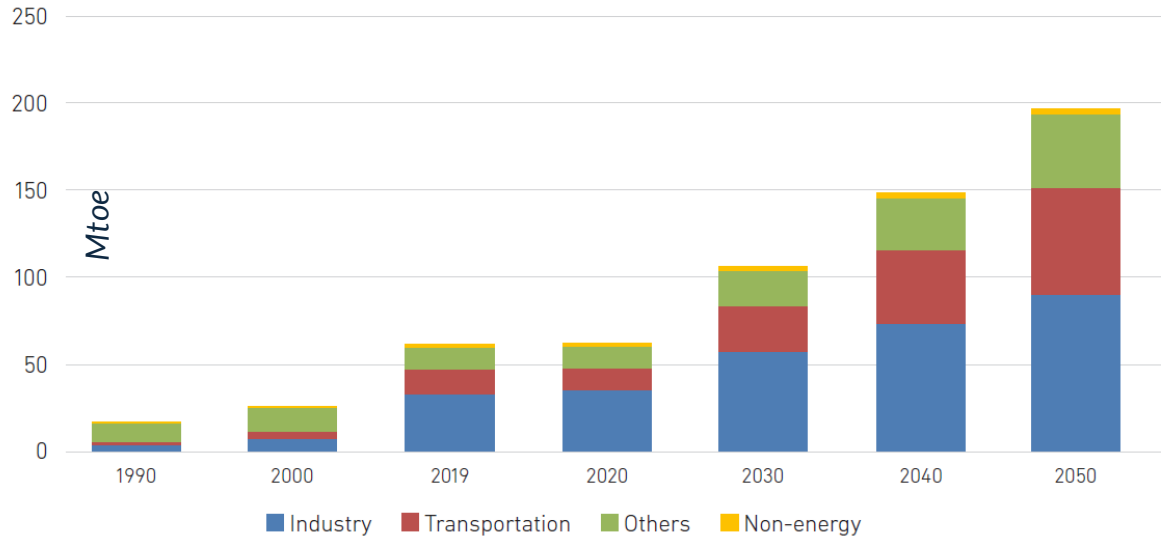


Source: International Energy Agency, 2022

ENERGY CONSUMPTION

Projected trend, business as usual

- Industry, followed by transportation, account for significant portion of total energy consumption
- This trend is expected to continue in the business-as-usual scenario



Final energy consumption by sector in the business-as-usual scenario, 1990–2050

Notes: Mtoe = Million Tons of Oil Equivalent; Others = residential and commercial sectors

Source: Kimura. S. et al., 2023

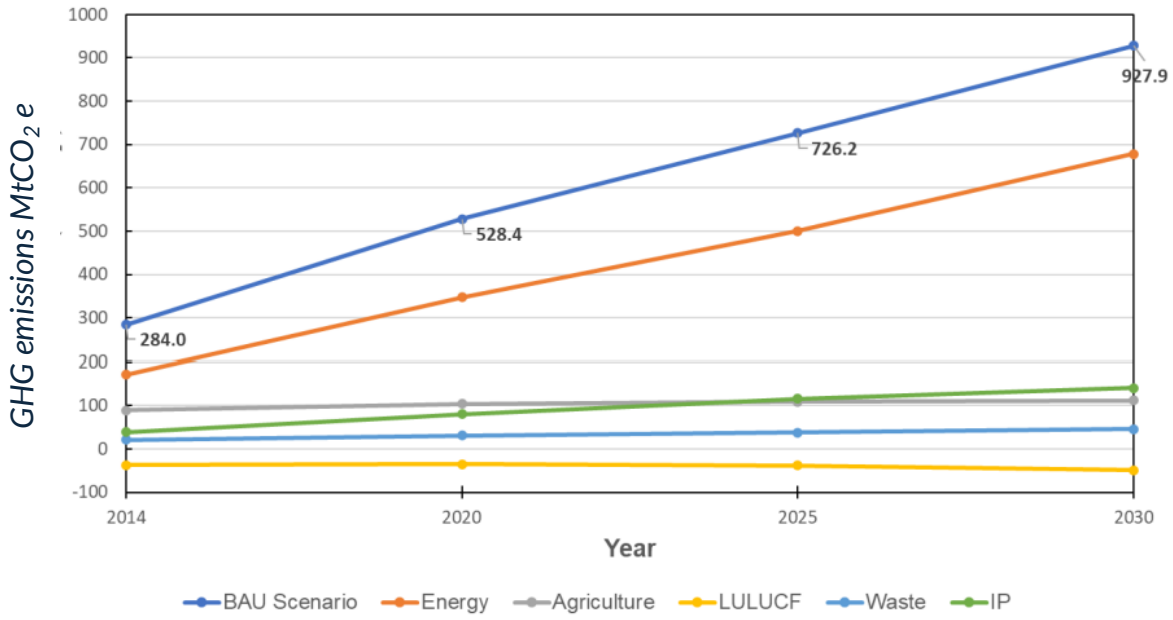
GHG EMISSIONS

Projected trend, business as usual

National measures to reduce GHG emissions for 2021–2030 have been identified for the agriculture, energy, industrial processes, LULUCF and waste sectors

Measures to reduce GHG emissions in the energy sector include:

- Use of high-efficiency air conditioning and refrigeration equipment in commercial and residential services
- Use of energy-saving lighting
- Use of solar water heaters
- Use of high-performance electrical equipment
- Use of high-efficiency refrigeration equipment in services, commerce and trade
- Improvement, development and application of technology in the production of building materials



GHG emissions in the business-as-usual scenario

Note: $MtCO_2e$ = million tons of carbon dioxide equivalent

Sources: Government of Vietnam, 2020 and 2022

CO_2 EMISSIONS

By sector



Rank of Vietnam in Asia-Pacific region

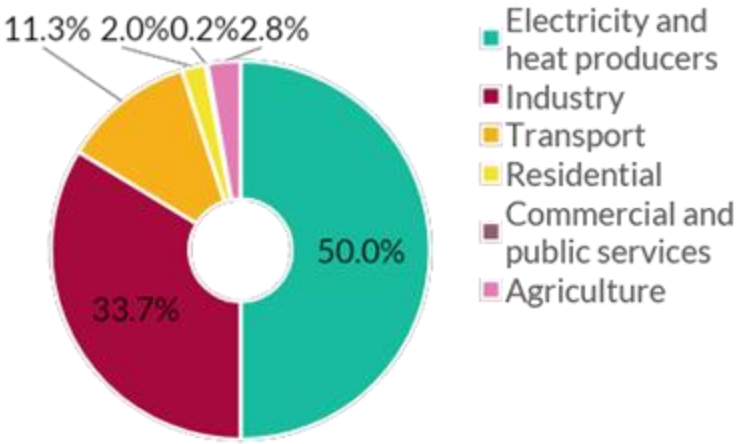
7th
for CO_2 emissions of fuel combustion

13th
for CO_2 emissions per capita

Dominant sectors for CO_2 emissions

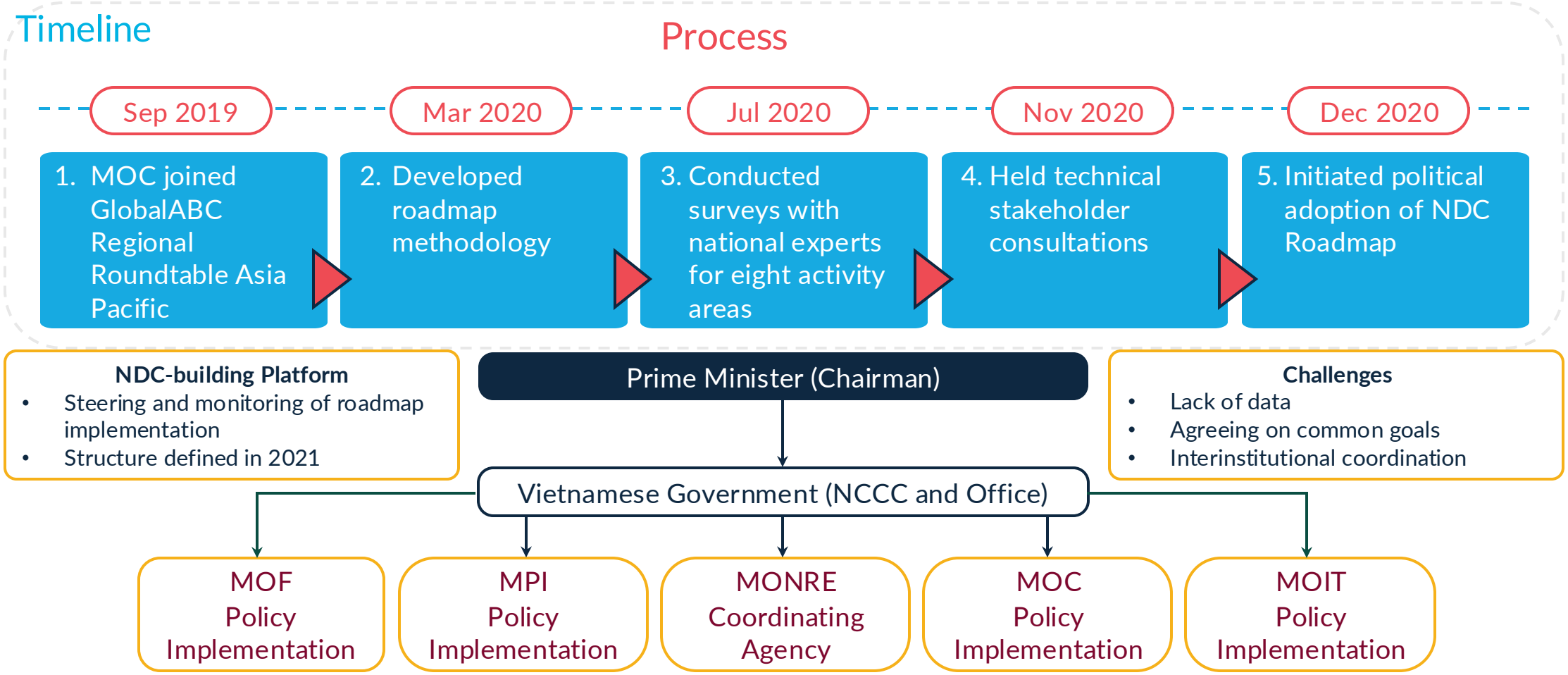
50% Electricity and Heat | 33% Industry | 11% Transport

CO2 emissions by sector, Vietnam, 2021



Source: International Energy Agency, 2022

NDC ROADMAP DEVELOPMENT



Sources: Climate Action Tracker, 2023; NDC Partnership

RESPONSE TO CLIMATE CHANGE

Overview

Implementation of energy policy in Vietnam, reinforced through National Energy Development Strategies

In February 2020, the Political Bureau issued the Orientation of Vietnam's National Energy Development Strategy to 2030 and Outlook to 2045

Three climate targets:

- Reduce greenhouse gas emissions
- Increase energy efficiency in total final energy consumption compared to the business-as-usual scenario
- Increase proportion of renewables in the energy mix

Source: PwC, 2024

RESPONSE TO CLIMATE CHANGE

Aspirations and commitments

UN Sustainable Development Goals

By 2030

Universal access to energy services

At least **32.3%** renewable energy share

Maintain at least **6% GDP** growth per annum

Vietnam's Aspiration

By 2045

High-income status country

Net Zero Commitments (COP26)

By 2040

Phase out coal

By 2050

Net zero

Revised Nationally Determined Contribution (NDC)

By 2030

Conditional NDC:
With international support:
43.5% GHG reduction compared to BAU

Unconditional NDC:
Using domestic resources:
15.8% GHG reduction compared to BAU

Source: PwC, 2024

NDC COMMITMENTS

Crucial GHG mitigation strategies

- Energy efficiency is recognized as an important mitigation strategy, covering the areas of energy production, transmission and distribution (especially for large production facilities), residential sector, trade and services, and transport

- **Vietnam's Nationally Determined Contributions (NDC)** commitments include:

  - In 2020, the commitment was to reduce GHG emissions by 8% (11.84 $MtCO_2e$) and unconditionally by 25.7% (37.83 $MtCO_2e$) through international support by 2030, compared to the business-as-usual scenario, with utilization of domestic resources
  - In 2022, the NDC commitment was updated to reduce GHG emissions by 15.8% using domestic resources and by 43.5% through bilateral and multilateral support and financing by 2030
  - Vision for 2031 to 2050 is to achieve zero emissions from the construction industry by 2050

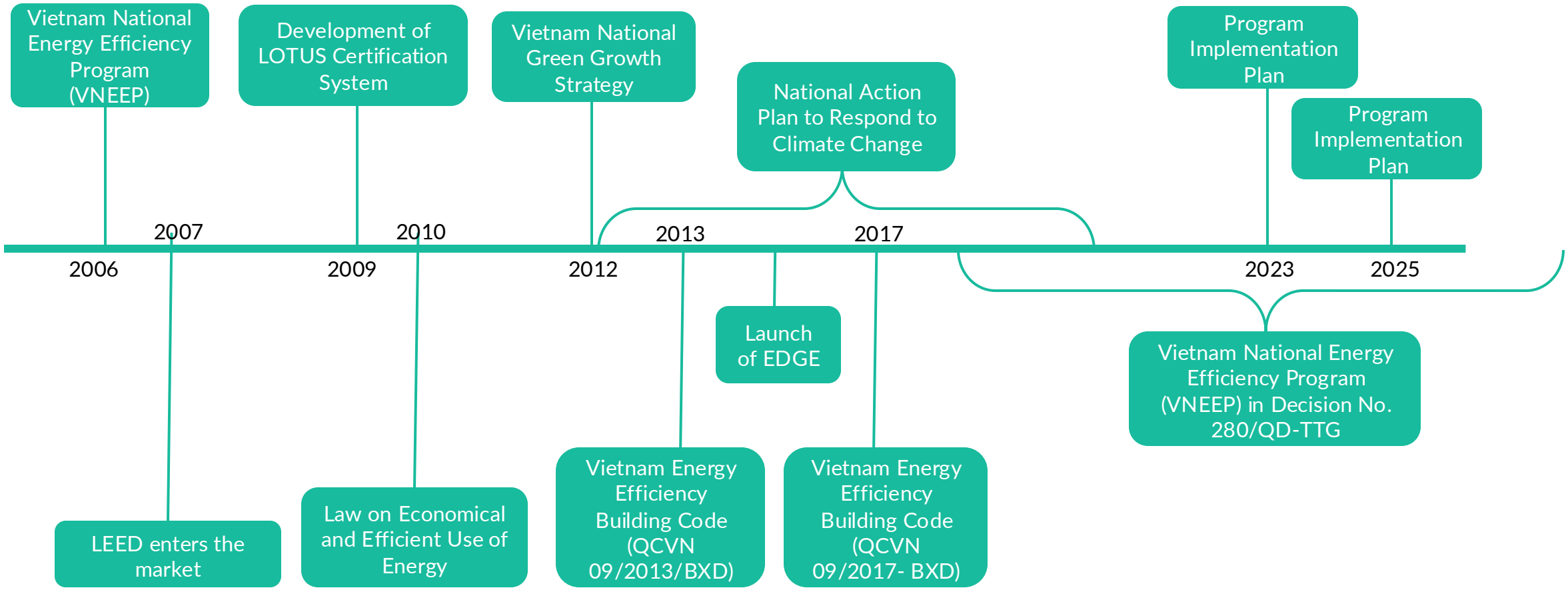


Image source: https://climatepromise.undp.org/news-and-stories/NDCs-nationally-determined-contributions-climate-change-what-you-need-to-know

Source: PwC, 2024

VIETNAM'S INITIATIVES

Energy efficiency initiatives 2006 – present



Sources: Climate Action Tracker, 2023; NDC Partnership

UPDATED NDC TARGETS

Key mitigation and adaptation measures

Urban development and housing, and energy sector

- Climate monitoring and early warning of natural disaster to adapt to climate change
- Natural disaster response and flood prevention for major cities

Creating awareness and community engagement

- Building climate-resilient communities to promote the use of local knowledge in responding to climate change

Urban planning tools for climate mitigation

- Upgrading and renovating the infrastructure of sectors in association with synchronous implementation of measures to protect the environment and adapt to climate change
- Upgrading transport facilities in areas with high disaster risk and vulnerability to climate change
- Building and upgrading water drainage systems, preventing floods caused by heavy rains, floods, spring tides and storms

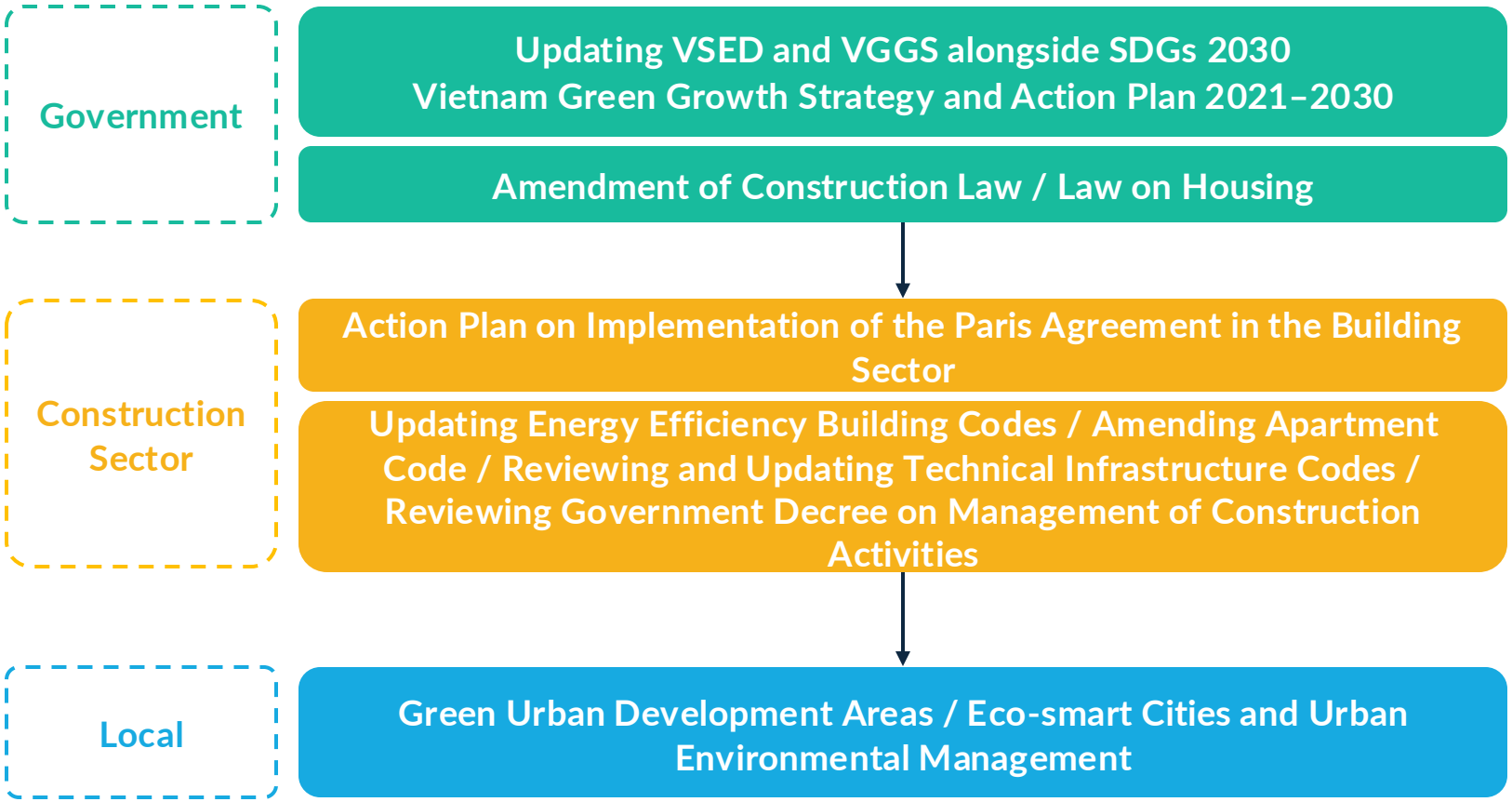
Energy usage

- Residential sector accounted for 18% of total final energy consumption in 2017
- Strong demand for increase in new social housing and affordable mid-income housing due to a growing middle-class population
- Strong projection in non-residential sector
- Vietnam's successful implementation of universal electrification and increase in use of electrical home appliances has led to energy demand in building sector

Sources: Climate Action Tracker, 2023; NDC Partnership

INSTITUTIONAL MECHANISM

Roles of stakeholders



Sources: Climate Action Tracker, 2023; NDC Partnership

INSTITUTIONAL MECHANISM

Responsible authorities

Name of institution for improving building energy efficiency	Responsibility
Ministry of Industry and Trade	Activities related to the energy sector and other industries
Ministry of Construction	Development of general construction plans and related coordination
Ministry of Planning and Investment	Sets the socio-economic development strategy and plan
The Ministry of Finance	Jurisdiction over tariffs and taxation related to energy activities
The Ministry of Natural Resources and Environment	Research and development in the fields of energy and environmental protection
Local Authorities	Construction activities within their territory

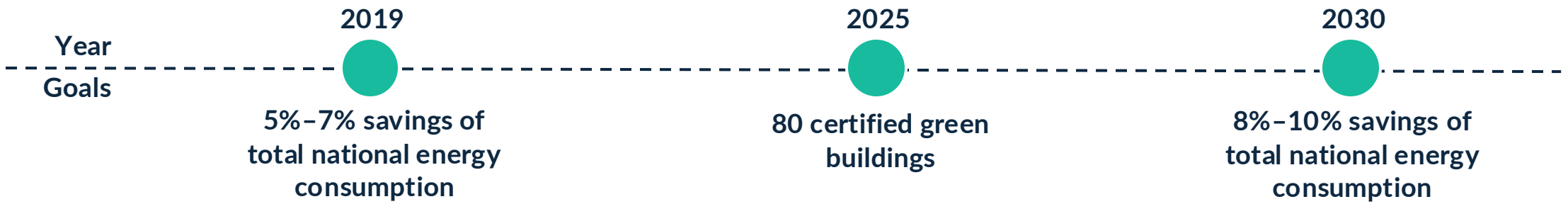
Source: Copenhagen Centre on Energy Efficiency, 2018

ENERGY EFFICIENCY IN BUILDINGS

Initiative: Vietnam National Energy Efficiency Program

Vietnam National Energy Efficiency Program (VNEEP)

- All buildings must comply with the mandatory requirements set by the National Technical Building Code on Energy Efficiency (VEEBC)
- 80 certified green buildings by 2025
- Mandatory energy labeling
- Minimum energy efficiency standards roadmap for equipment and appliances



Sources: Climate Action Tracker, 2023; NDC Partnership

ENERGY EFFICIENCY IN BUILDINGS

Initiative: National Green Growth Strategy

2012 — **National Green Growth Strategy (NGGS)**

- Includes strategies for green construction and sustainable urbanization, and is linked to the national climate change and economic policy agendas
- In the 2016 Plan for Implementation of the Paris Agreement, the government defined various mitigation actions for the construction sector in 2021–2030

Key Targets	Reduction in intensity of GHG emissions per unit of GDP	Primary energy consumption per unit of GDP	Proportion of renewable energy over total primary energy supply
By 2030	At least 15% compared to 2014 levels	1%–1.5% per year	15-20%
By 2050	At least 30% compared to 2014 levels	1% per year	25-30%

Sources: Climate Action Tracker, 2023; NDC Partnership

BUILDING ENERGY EFFICIENCY PROGRAMS

Decisions and implementation plans

2019–2023 — **Vietnam National Energy Efficiency Program (VNEEP) in Decision No. 280/QD-TTG**

Aims to achieve 8%–10% energy savings in the building sector by 2030. It promotes various strategies, including:

- **Encouraging energy efficient technologies:** Financial incentives provided for using high-performance appliances and building materials
- **Building capacity and awareness:** Focus on training architects, engineers and the public on energy efficient design and practices

2023 — **Program Implementation Plan**

Pushes the promulgation and implementation of the provincial directives on energy efficiency (2020–2025)

- **Directives:** Strengthening inspection and supervision, capacity building, and pushing the implementation of applicable regulations on energy efficiency

2025 — **Program Implementation Plan**

Aims to achieve building efficiency goals by 2025

- Save 5%–7% of total end consumption nationwide under normal economic development scenario

Sources: Climate Action Tracker, 2023; NDC Partnership

Vietnam

Way Forward



Image source: https://ips-cambodia.com/cambodia-encourages-more-green-buildings/

WAY FORWARD

Addressing challenges and barriers in the financing of green buildings

- Consolidate incentives in the building market
- Address developer hesitance to absorb additional up-front costs of green building design, when cost savings will only accrue for future owners
- Address mismatch between building longevity and the relatively short holding periods for real estate assets in investment portfolios
- Provide landlord incentives to invest in energy efficient equipment because the tenant is paying the utility bill
- Address subsidized or government-controlled energy prices
- Increase awareness, information and education on the benefits of green buildings to private owners and the public
- Promote access to design, construction material and skilled workers
- Develop guidelines and policies promoting green buildings



Source: Azhgaliyeva, D. and Rahut, D. B., 2022

WAY FORWARD

Opportunities and potential measures

Opportunities

- Country-level initiatives and EE system in place but there is a need for financing large-scale deployments
- Need for EE with increasing competition in the market (particularly for export-oriented units)
- Need for training and capacity building for auditors, systems optimization experts, SMEs, industry owners, ESCOs and other stakeholders in the ecosystem
- ESCO market is not developed so far and there is need for technology standardization and local technology suppliers

Potential Measures

- De-risk energy efficiency project-based lending
- Raise awareness and build capacity
- Engage the private sector and unlock private investments
- Implement EE standards and technical guidelines for appliances and equipment for reductions in energy consumption and GHG emissions in selected sectors
- Demonstrate demand aggregation and ESCO financing-based models in selected sectors

Source: Institute for Sustainable Communities et al., 2021

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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on the basis of a decision by the German Bundestag



GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

2.1 Understanding Building Envelope

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

01 Challenges in Building Design

02 Basics of Building Physics

03 Thermal Properties of Building Materials

04 Thermal Properties of Fenestration

05 Key Takeaways



Building Design

Challenges





BUILDING DESIGN

Challenges: HOT versus COLD climates



Hot Climates

- External surfaces (roof and walls) absorb heat from solar radiation
- Heat transfer through thermal conduction to inner surfaces
- Increased discomfort from internal heat sources and reliance on fans and air conditioning systems



Cold Climates

- Heat loss through roofs, walls and windows
- Ventilation requirements and infiltration losses lead to excessive heating needs
- Higher energy costs and reduced thermal comfort

BUILDING CONDITIONS

Commercial versus residential





COMMERCIAL BUILDINGS

- Mostly air-conditioned
- Narrow band of expected comfort
- Mostly daytime occupancy
- Air-conditioning used for longer duration and may be used throughout the year
- Heat loads in the building may have equal or more contribution from internal loads, i.e., from occupants and equipment

RESIDENTIAL BUILDINGS

- May or may not be air-conditioned
- Broader band of expected comfort
- Mostly nighttime occupancy
- Air-conditioning used intermittently during the day and mainly in summer
- Heat loads in the building dominated by external loads i.e., those from the building envelope

Building Physics

Building Envelope and Heat Transfer



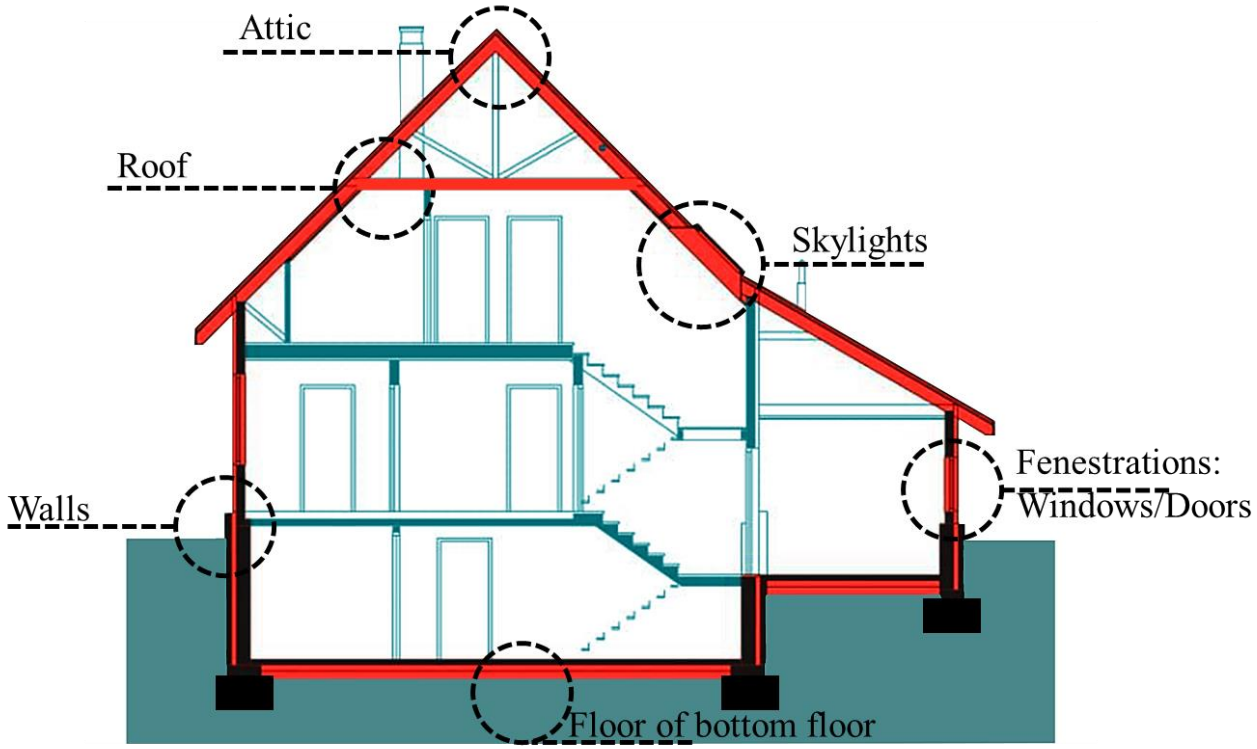
BUILDING ENVELOPE

Components

Separates exterior from interior environments

Components:

- External walls
- Roof
- Windows
- Doors
- Foundation
- Floor



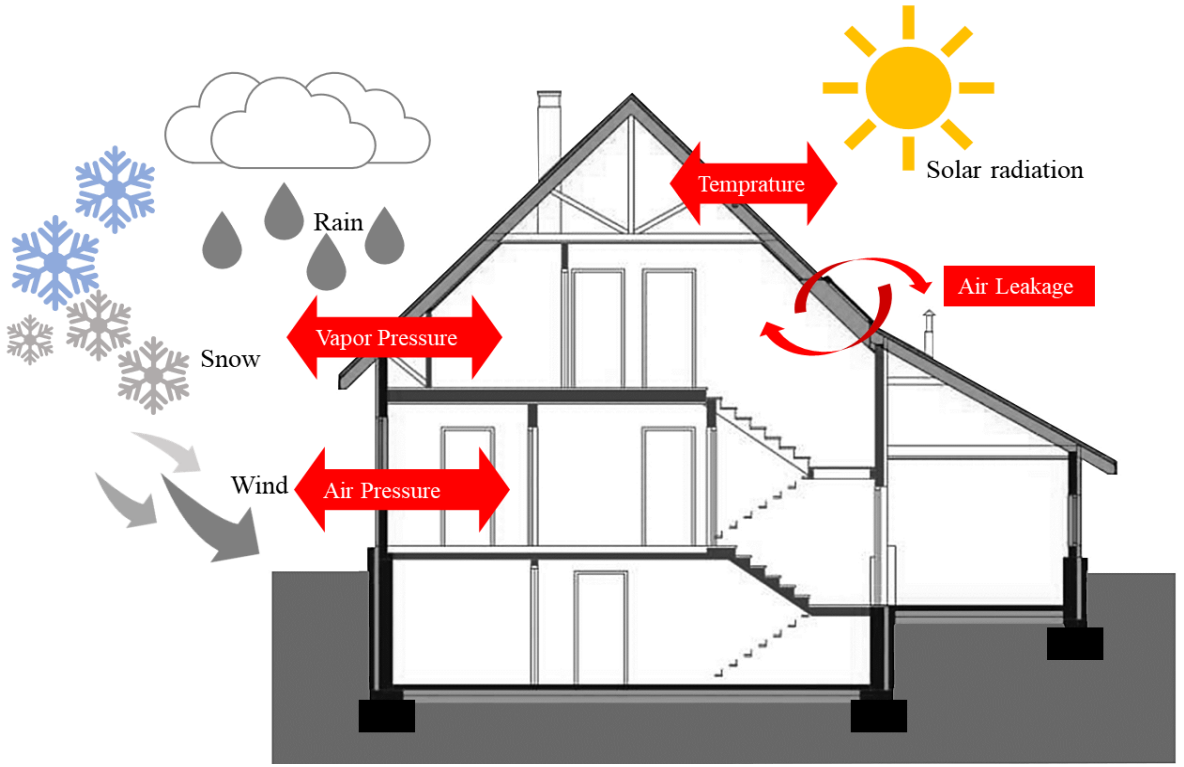
Components of a building envelope

Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

BUILDING ENVELOPE

Role and importance

- Physical protection
- Protection from rain and noise
- Light control
- Indoor climate regulation

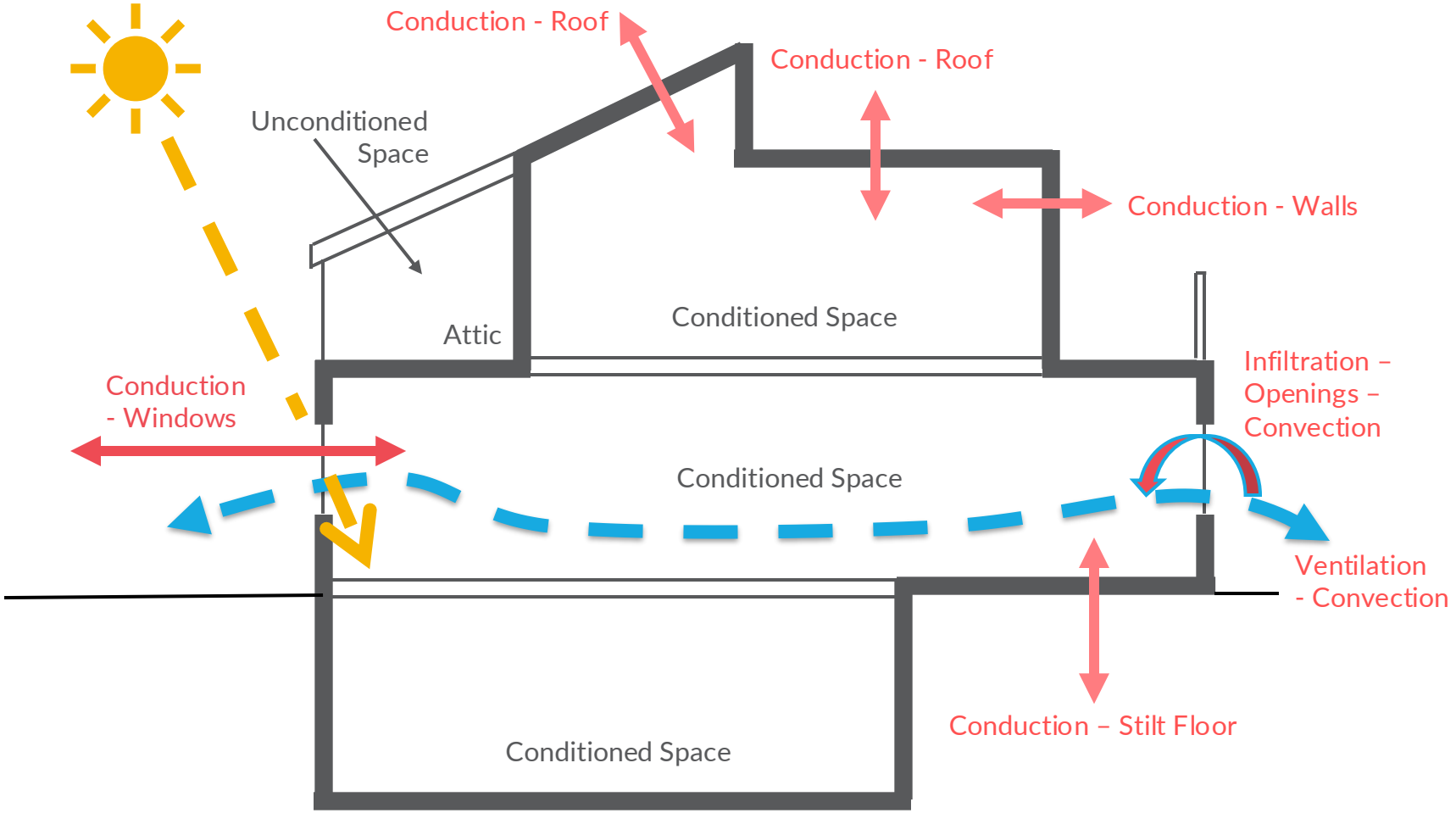


Protection from external elements through building envelope

Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

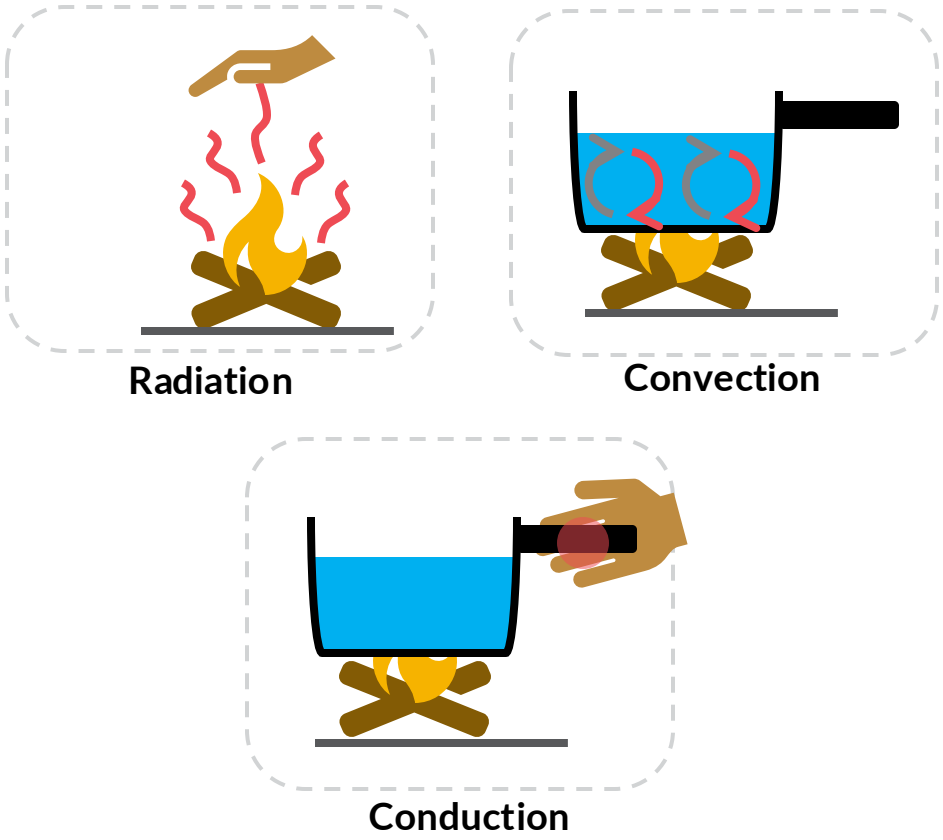
HEAT EXCHANGE IN BUILDINGS

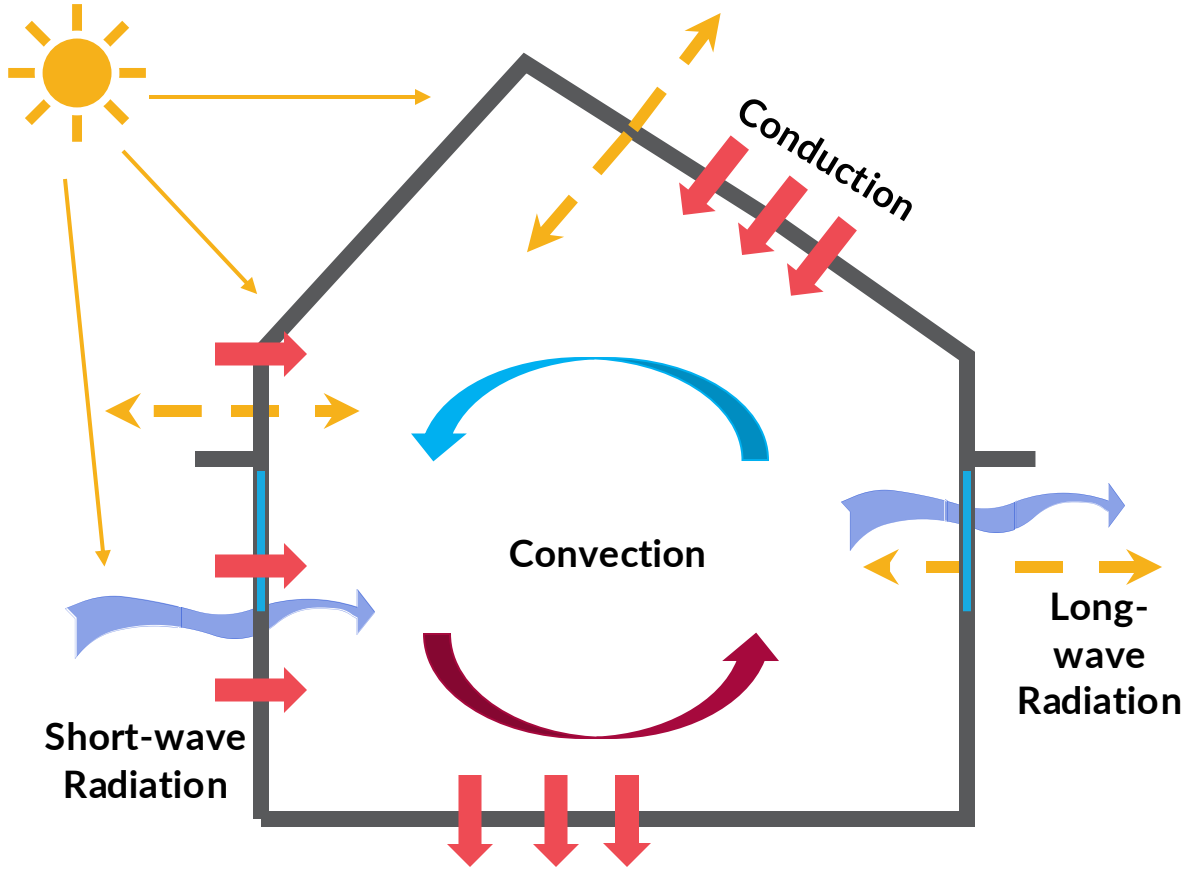
Role of building envelope



HOW HEAT TRAVELS?

Modes of heat transfer



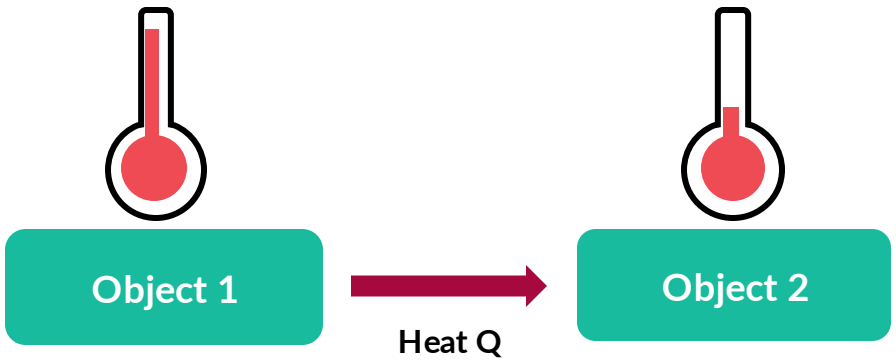


Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

HEAT TRANSFER

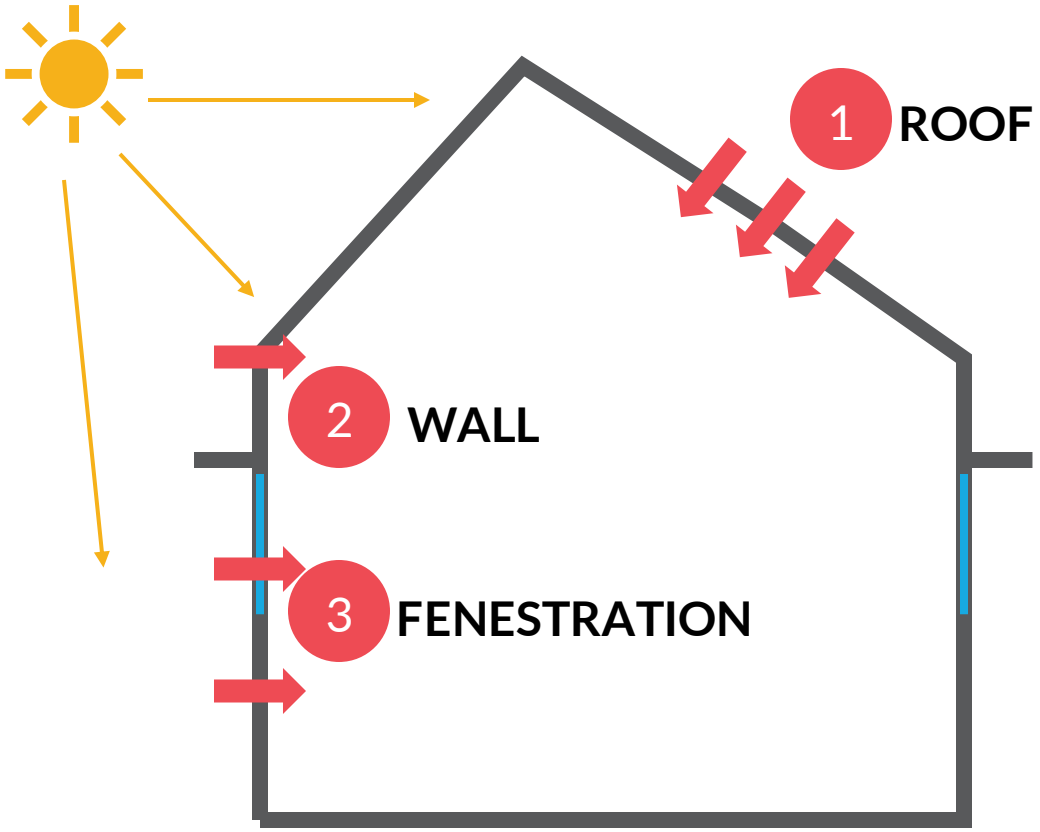
Always from higher temperature to lower temperature

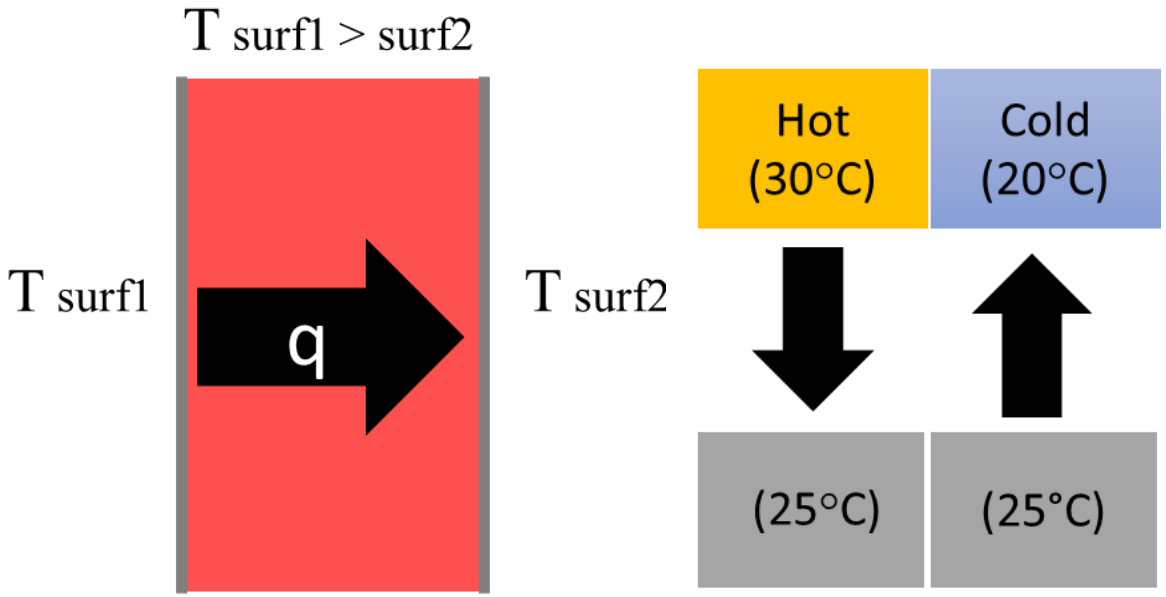
- Heat flows from a hot body to a cold body
- Heat is thermal energy
- Heat is transferred between bodies at different temperatures
- The measurement unit of heat is joule (J); kilowatt-hour (kWh) is also commonly used
- 1 joule corresponds to 0.278 x 10^{-6} kWh
- 1 kWh corresponds to 3.6 MJ (mega joules)



CONDUCTION

Heat diffusion through solids: Hot to cold

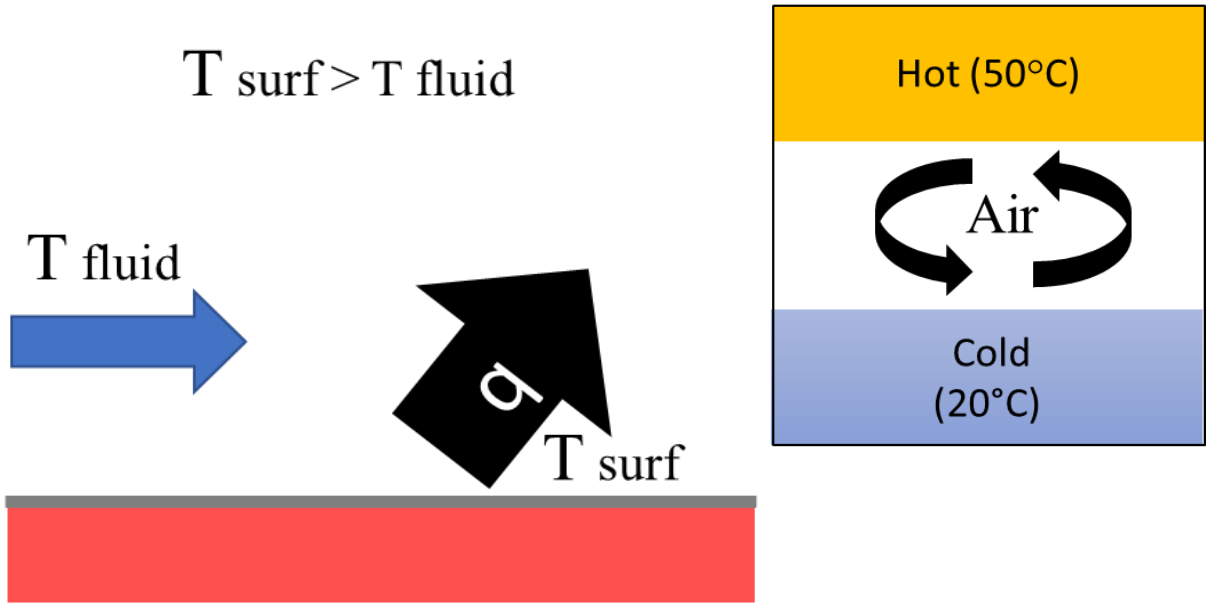


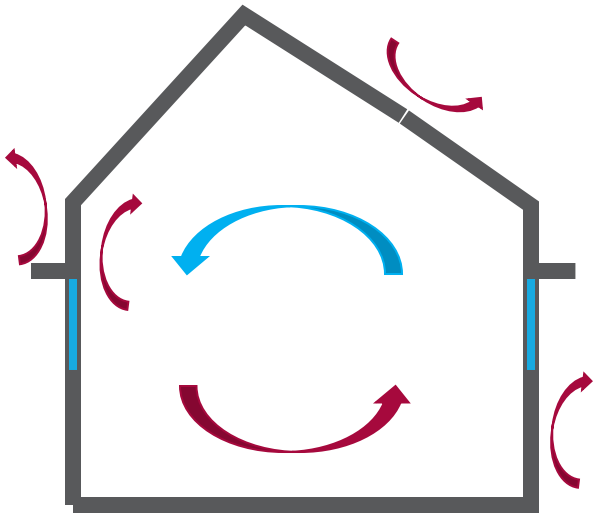


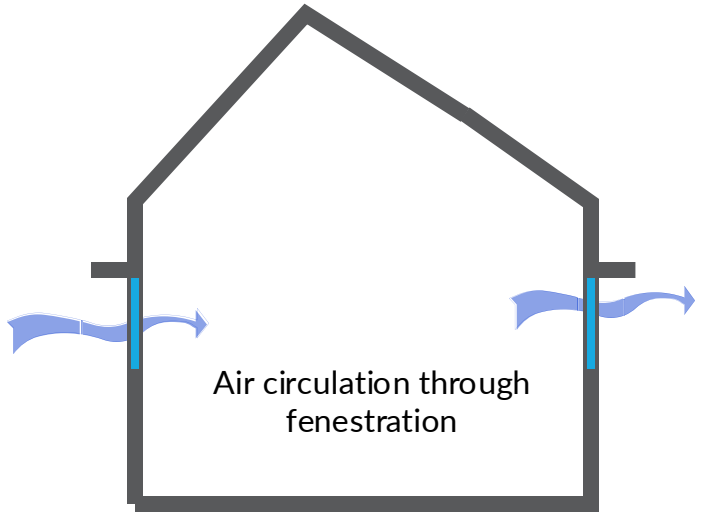
Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

CONVECTION

Heat transfer by fluid movement



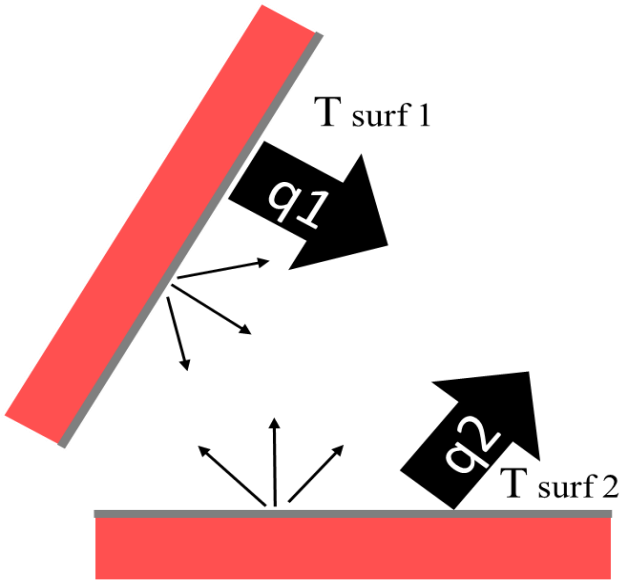


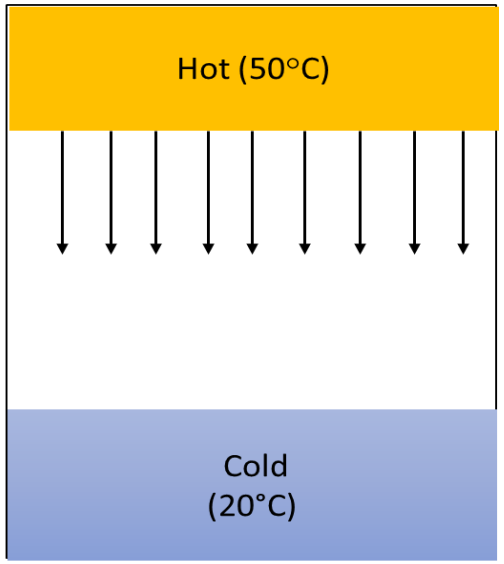


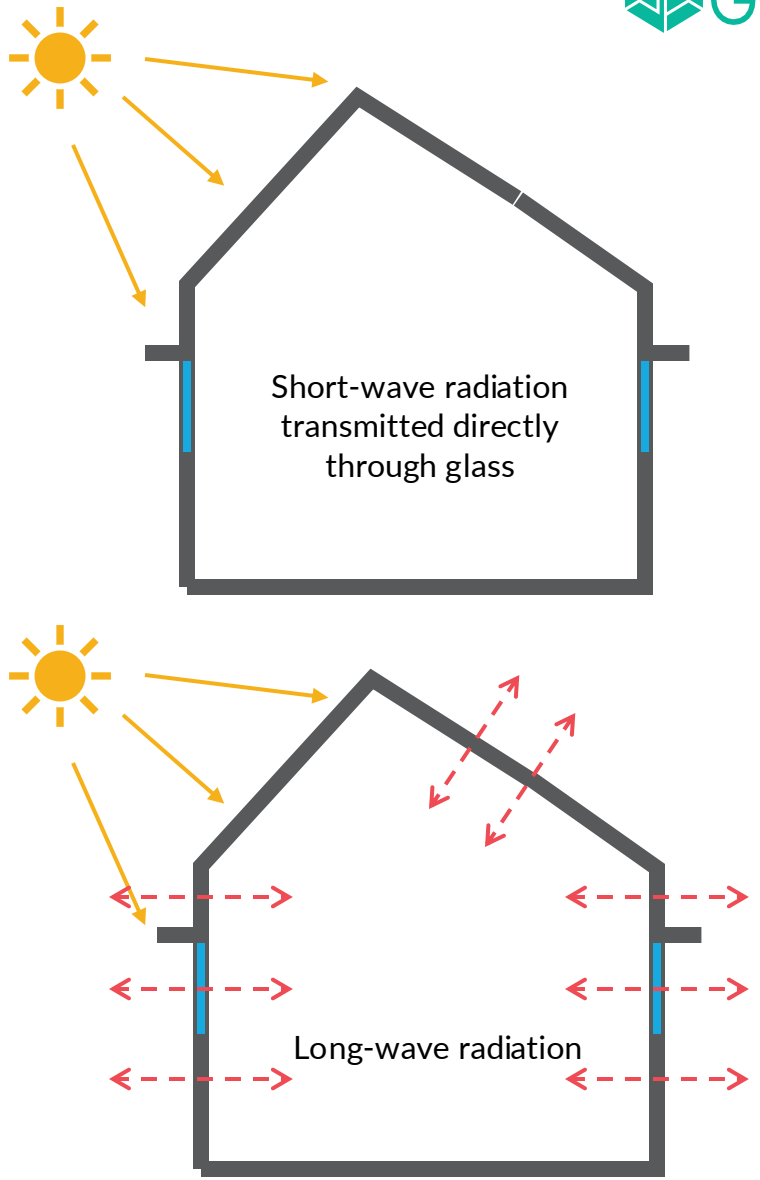
Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

RADIATION

Heat transfer via electromagnetic waves







Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

Building Materials

Thermal Properties



Image source: https://www.bricknbolt.com/blogs-and-articles/construction-guide/building-material-density-importance-construction

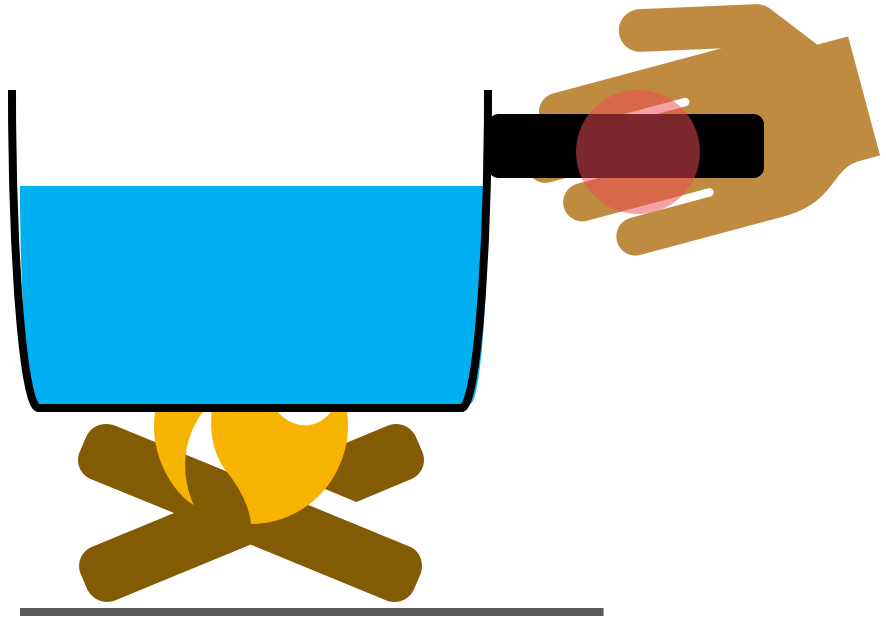
THERMAL CONDUCTION

Understanding parameters

Thermal Conduction (K-value)
Low K-value = **good insulation**

Thermal Resistance (R-value)
High R-value = **good resistance**

Thermal Transmittance (U-value)
Low U-value = **low heat transfer**



THERMAL PROPERTIES

Walls and roofs

- Reflectance and emissivity, combined as Solar Reflective Index (SRI)
- Thermal conductivity and transmittance (ability to conduct heat)
- Thermal mass (ability to absorb and store heat)

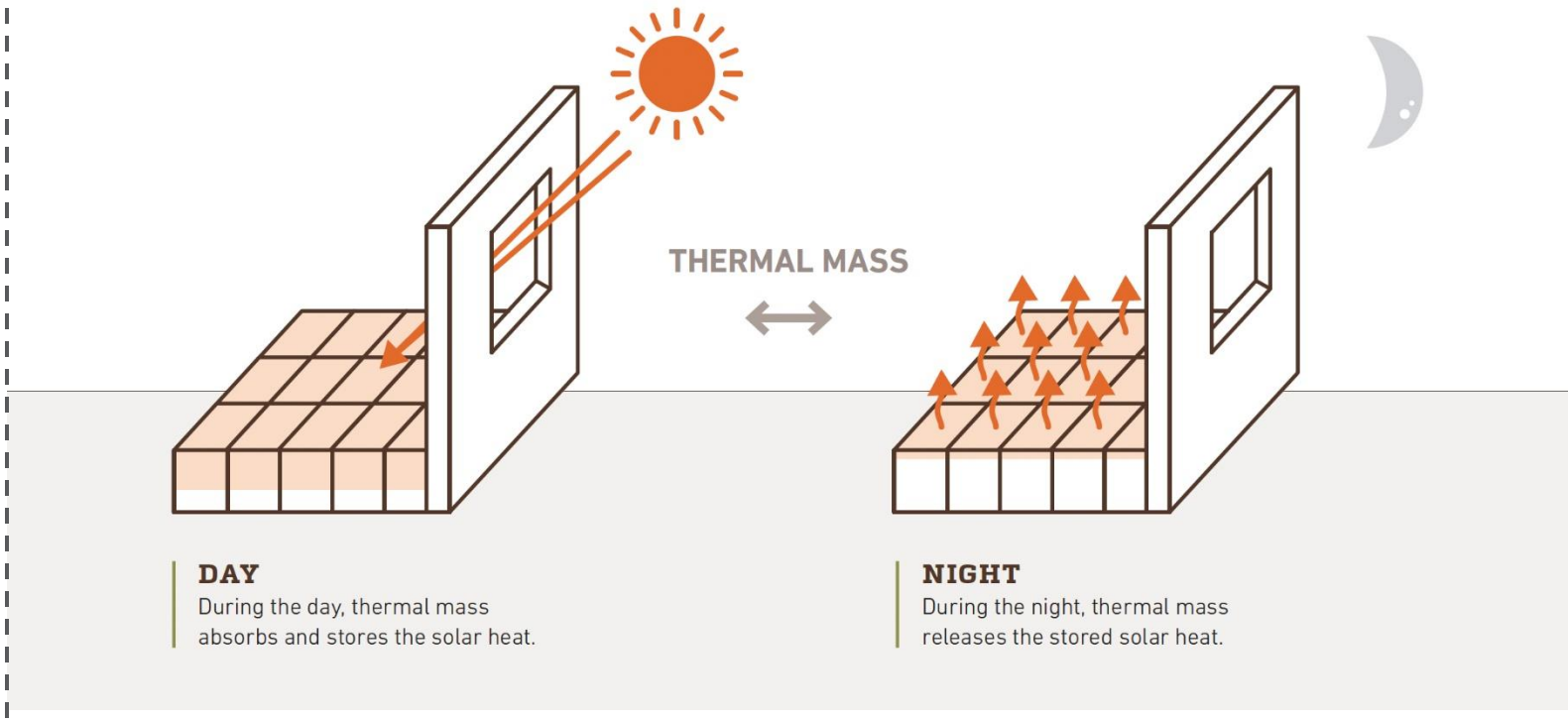
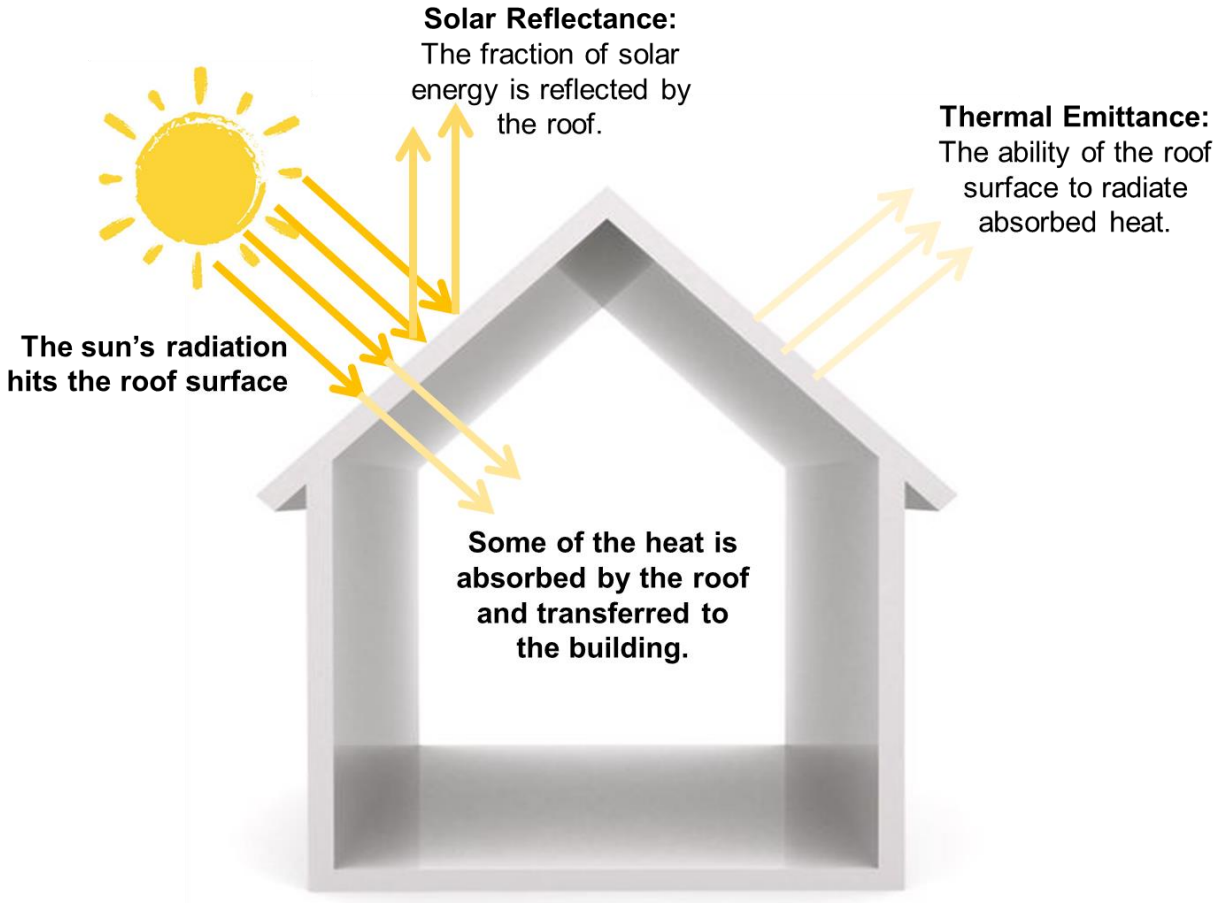


Image source: https://www.echelonmasonry.com/2018/06/29/capitalizing-on-thermal-mass-to-improve-efficiency-in-construction/

SOLAR REFLECTIVE INDEX

SRI: Combination of solar reflectance and thermal emittance

- Calculated value that combines solar reflectance and thermal emittance into one number
- SRI can be used as an indicator of how hot the material is likely to become when solar radiation is incident on the surface
- SRI values for most materials fall between 0 and 100, although values outside of this range is possible
- High SRI roof and wall finishes are beneficial in warm and hot climates

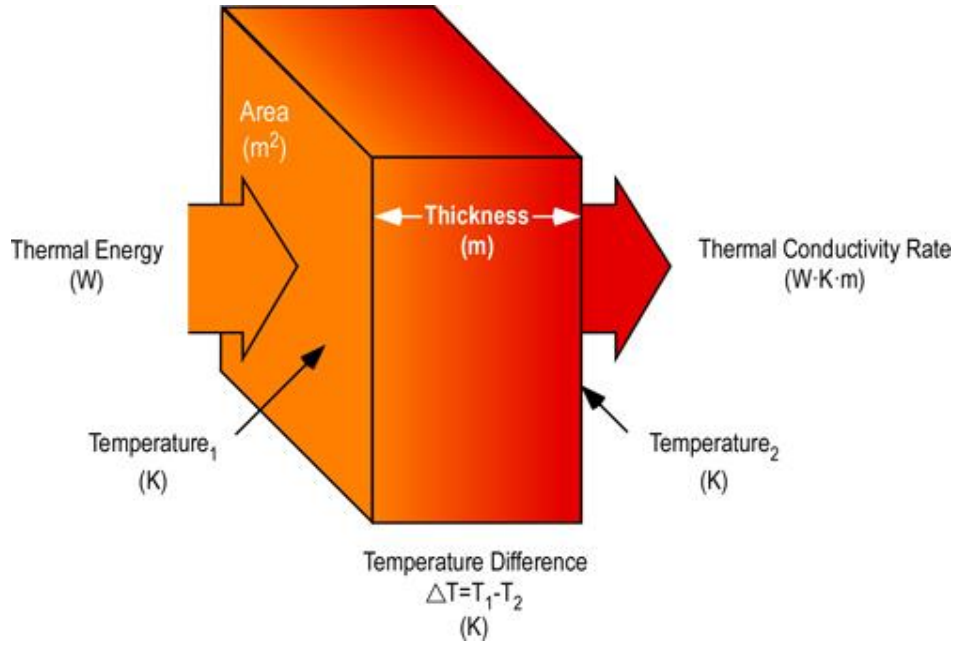


Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

THERMAL CONDUCTIVITY

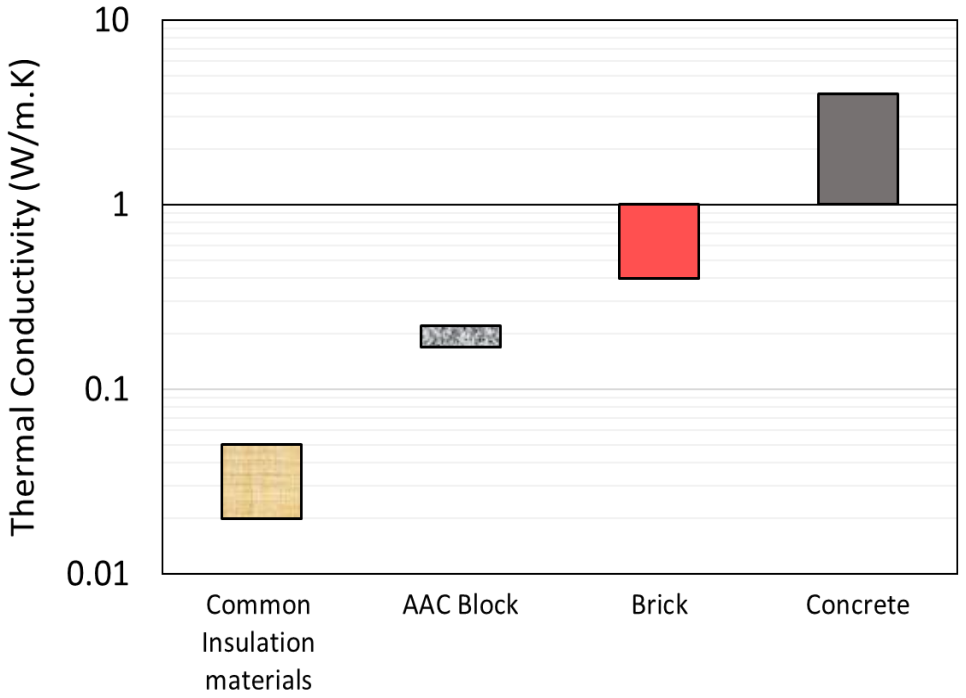
K-value

Measured in watts per meter-degree kelvin (W/m.K)



Heat transferred in unit time, through unit area (1m^2) of homogenous material, of unit thickness (1m) of the material, with the two surfaces of the material differing by one unit of temperature (1°K)

Thermal conductivity of common building materials



Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

THERMAL TRANSMITTANCE

U-value

Heat transmission, in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on either side

The unit of U-value is $W/m^2.K$

$$U = \frac{1}{R_{si} + R_{se} + \frac{t_1}{k_1} + \frac{t_2}{k_2} + \cdots + \frac{t_n}{k_n}}$$

R_{si} is the interior surface film thermal resistance, $m^2.K/W$

R_{se} is the exterior surface film thermal resistance, $m^2.K/W$

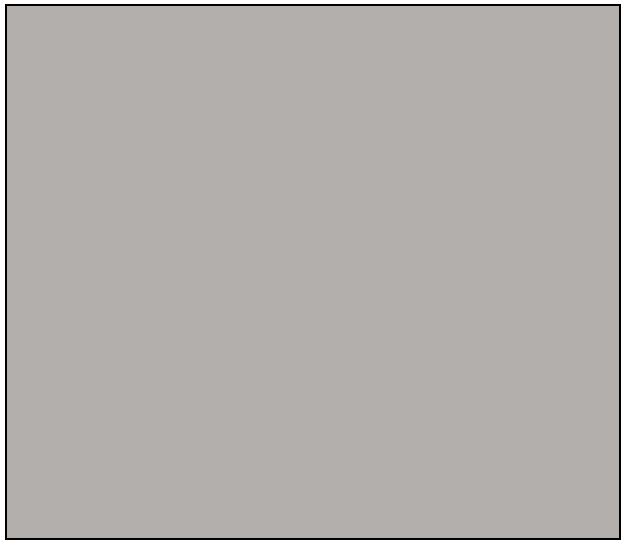
t is the thickness of material (in meters)

k is the thermal conductivity of material, W/(m.K)

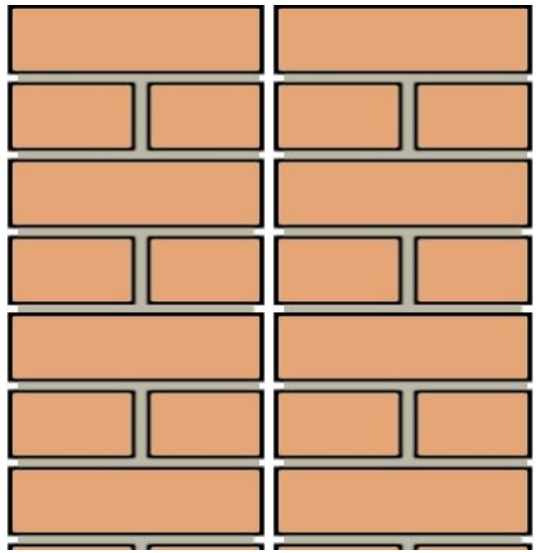
Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

MATERIAL THICKNESS

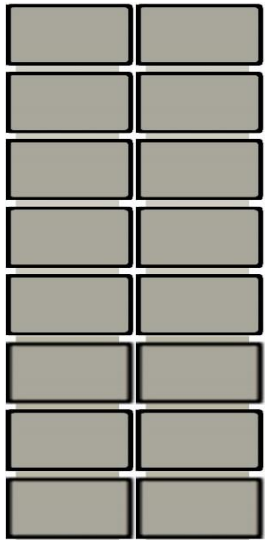
For U-value of 0.40 W/m^2.K



RCC
3.7m thick



Brick
1.8m thick



AAC
0.42m thick



XPS
0.08m thick

Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

MATERIAL THICKNESS

For different wall assemblies



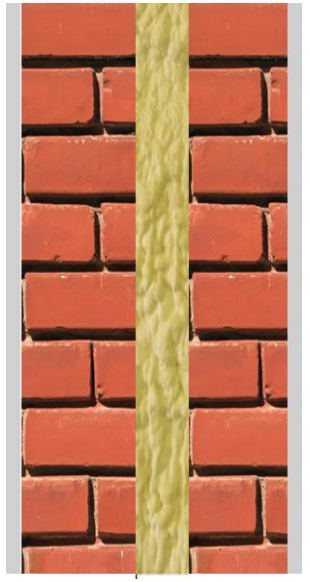
Hollow Brick Wall

Total thickness: 230mm
U-value: 1.85 W/m^2.K



Autoclaved Aerated Concrete (AAC) Wall

Total thickness: 230mm
U-value: 0.96 W/m^2.K



Cavity Wall with Insulation

Total thickness: 255mm
(with 25mm mineral wool insulation)
U-value: 0.74 W/m^2.K

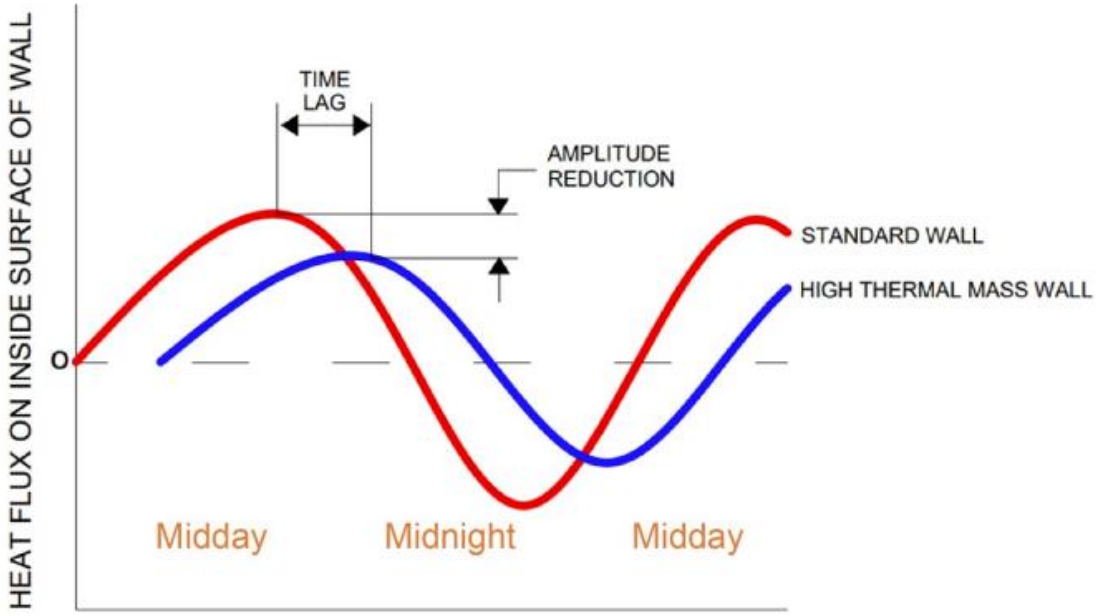
Source: UNEP, Compendium of Passive Cooling Strategies in Cambodia (draft)

THERMAL MASS

Heat capacity of a material

- Thermal mass is the property of a **building's mass** that enables it to store heat, providing 'inertia' against temperature fluctuations
- Scientifically, thermal mass is **equivalent to heat capacity** – the amount of heat to be supplied to a given mass of a material to produce a unit change in its temperature
- The unit of measurement is joule per kelvin (J/°K)
- The use of materials with high thermal mass is most advantageous where there is a big difference in outdoor temperatures from day to night

Depending on the climate, building usage and comfort requirement, a higher OR lower thermal mass should be preferred



Impact of thermal mass on heat exchange

Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

Image source: https://decarbhealthcare.com/guidebook/542

THERMAL BRIDGES

Pathways for heat or cold transmission

Description:

- Pathways for heat or cold to cross from inside to outside
- Reduce insulation effectiveness and can cause condensation

Minimization techniques:

- Using external insulation
- Installing thermal breaks in metal frames
- Fixing prefab insulated panels over frames
- Using less conductive framing materials (e.g., timber, UPVC)



Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

SOLAR RADIATION

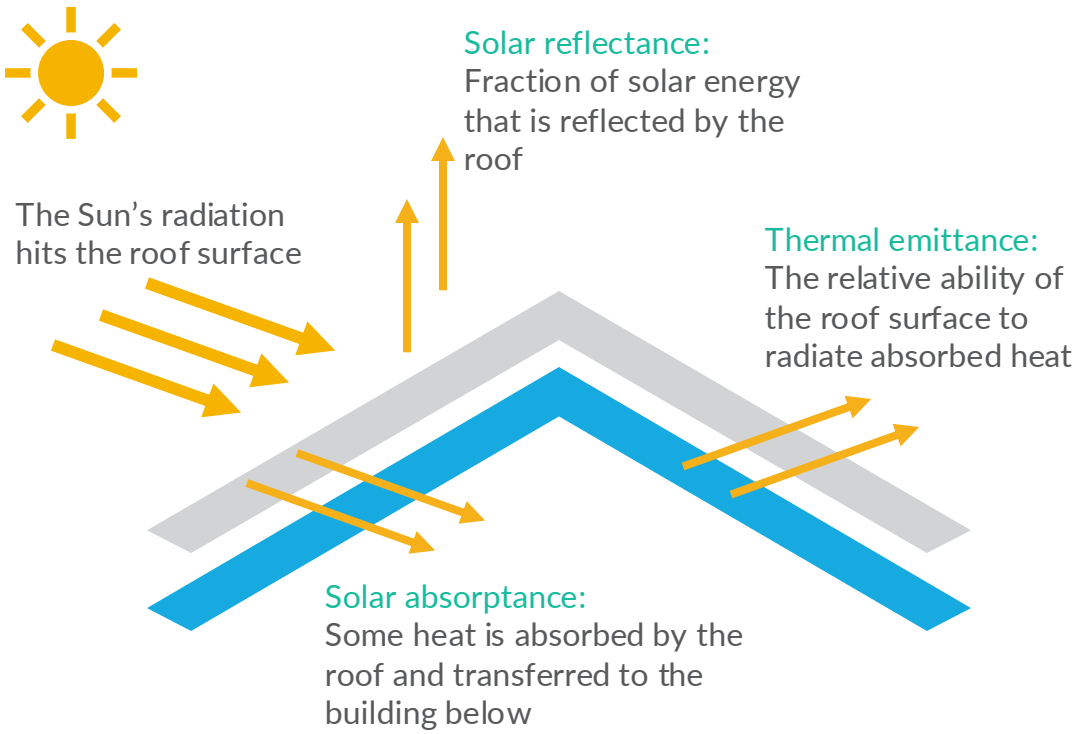
Components of solar radiation

- **Solar reflectance**: Energy reflected back to the atmosphere
- **Solar absorptance**: Energy absorbed by the roof and transferred to the building's interior
- **Solar emittance**: Absorbed solar energy radiated back to the atmosphere

Standard white surface (reflectance 0.80, emittance 0.90): SRI = 100

Standard black surface (reflectance 0.05, emittance 0.90): SRI = 0

Roofs attract solar radiation almost throughout the day and need to be protected more than the walls



Source: ECBC User Guide, July 2009

Fenestration

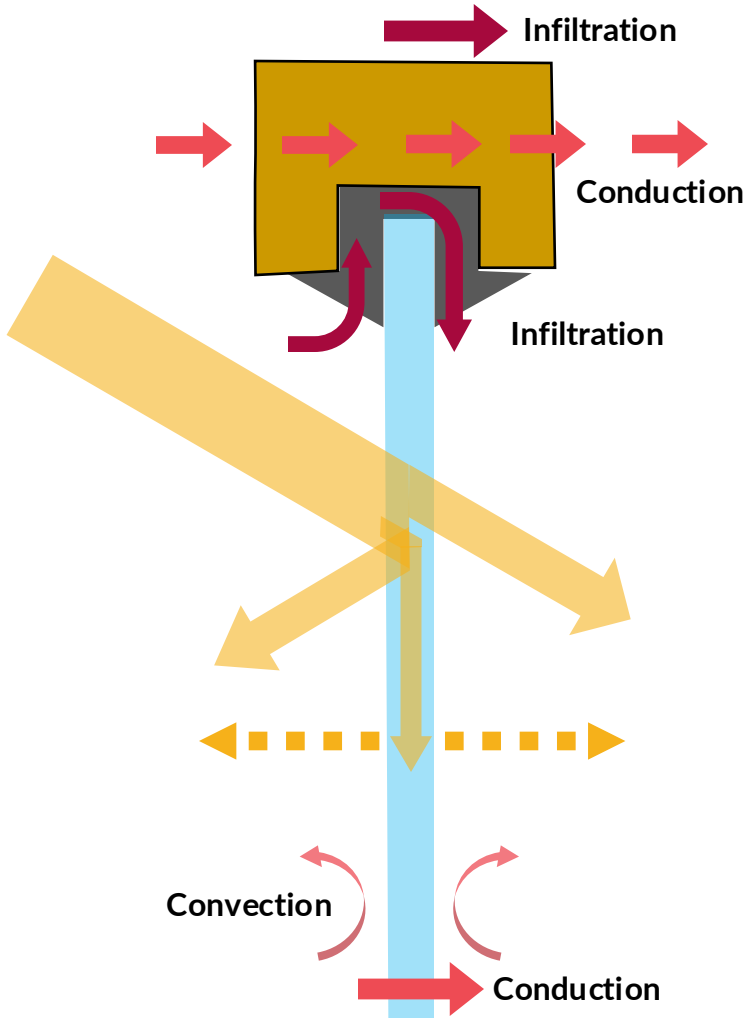
Thermal Properties



FENESTRATION

Heat transfer

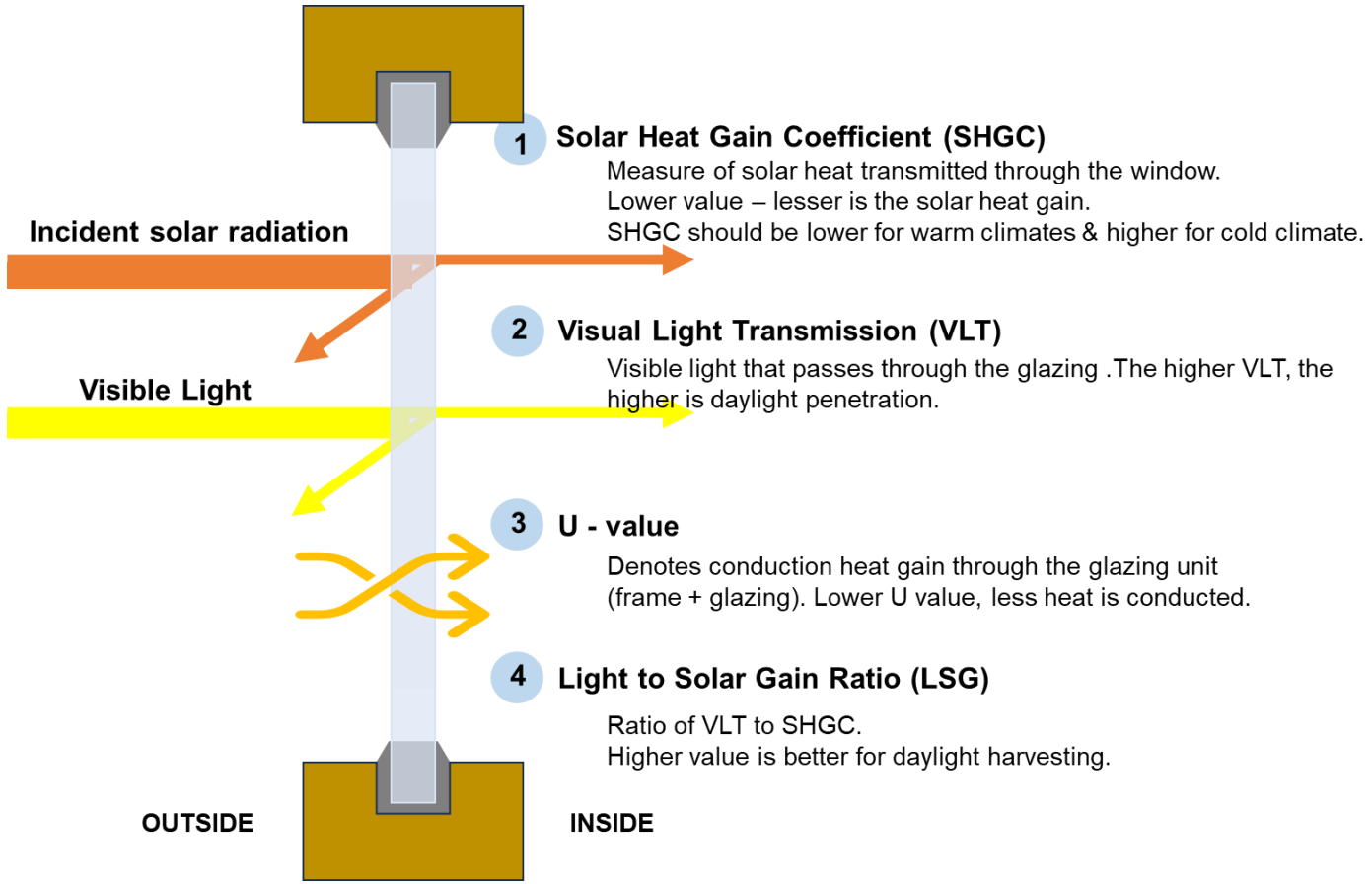
- In a building, fenestration comprises both opaque and solid elements (such as wood, aluminum, etc.) and non-opaque or transparent elements (i.e., glass). Between the two, a significant amount of heat transfer occurs through the glass
- In addition to conduction, heat transfer occurs through infiltration, i.e., unintentional air entering a space through the cracks and gaps in the fenestration elements. This is part of the air exchange process



Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

GLAZING

Key parameters



1 Solar Heat Gain Coefficient (SHGC)

Measure of solar heat transmitted through the window.
Lower value – lesser is the solar heat gain.
SHGC should be lower for warm climates & higher for cold climate.

2 Visual Light Transmission (VLT)

Visible light that passes through the glazing .The higher VLT, the higher is daylight penetration.

3 U - value

Denotes conduction heat gain through the glazing unit (frame + glazing). Lower U value, less heat is conducted.

4 Light to Solar Gain Ratio (LSG)

Ratio of VLT to SHGC.
Higher value is better for daylight harvesting.



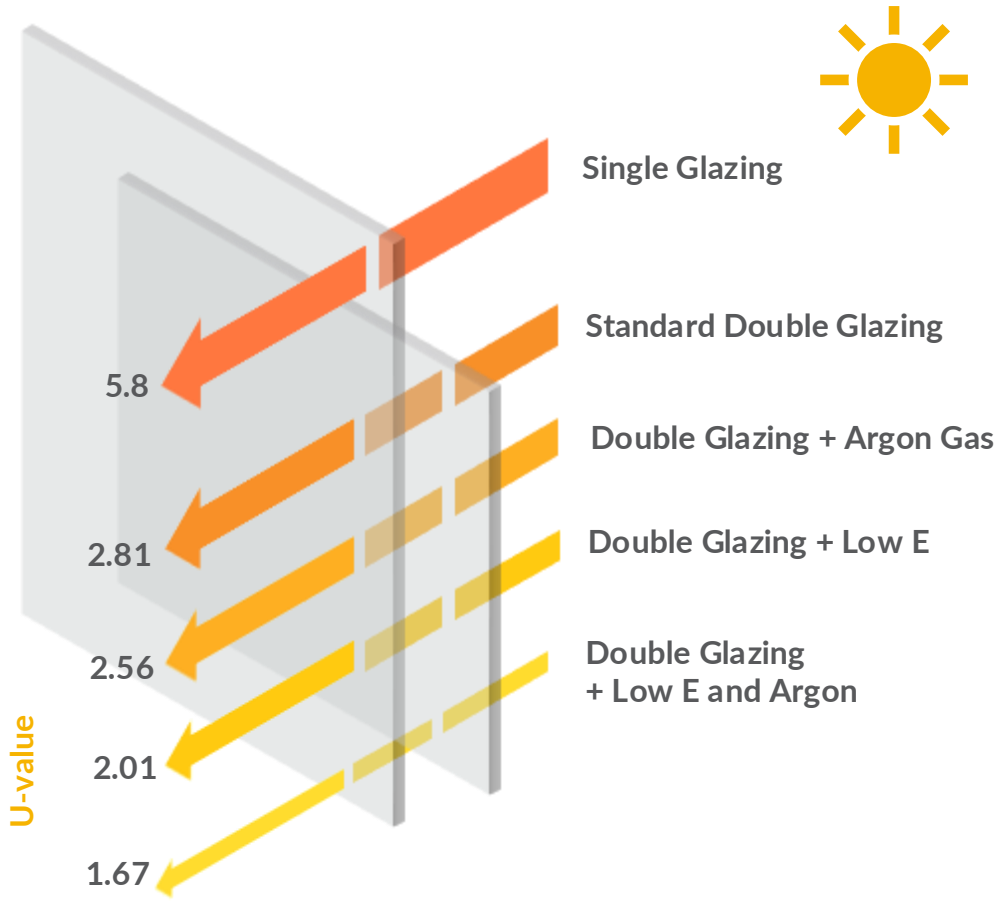
Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

GLAZING

U-value

- In the United States, values are normally given for NFRC / ASHRAE winter conditions of 0°F (-18°C) outdoor temperature, and for 70°F (21°C) indoor temperature, with 15 mph of wind speed, and no solar load
- U-values are often quoted for windows and doors
- In the case of a window, for example, the U-value may be expressed for the glass alone or for the entire window assembly, which includes the effect of the frame and the spacer materials

Heat Transfer – Fenestration U-value

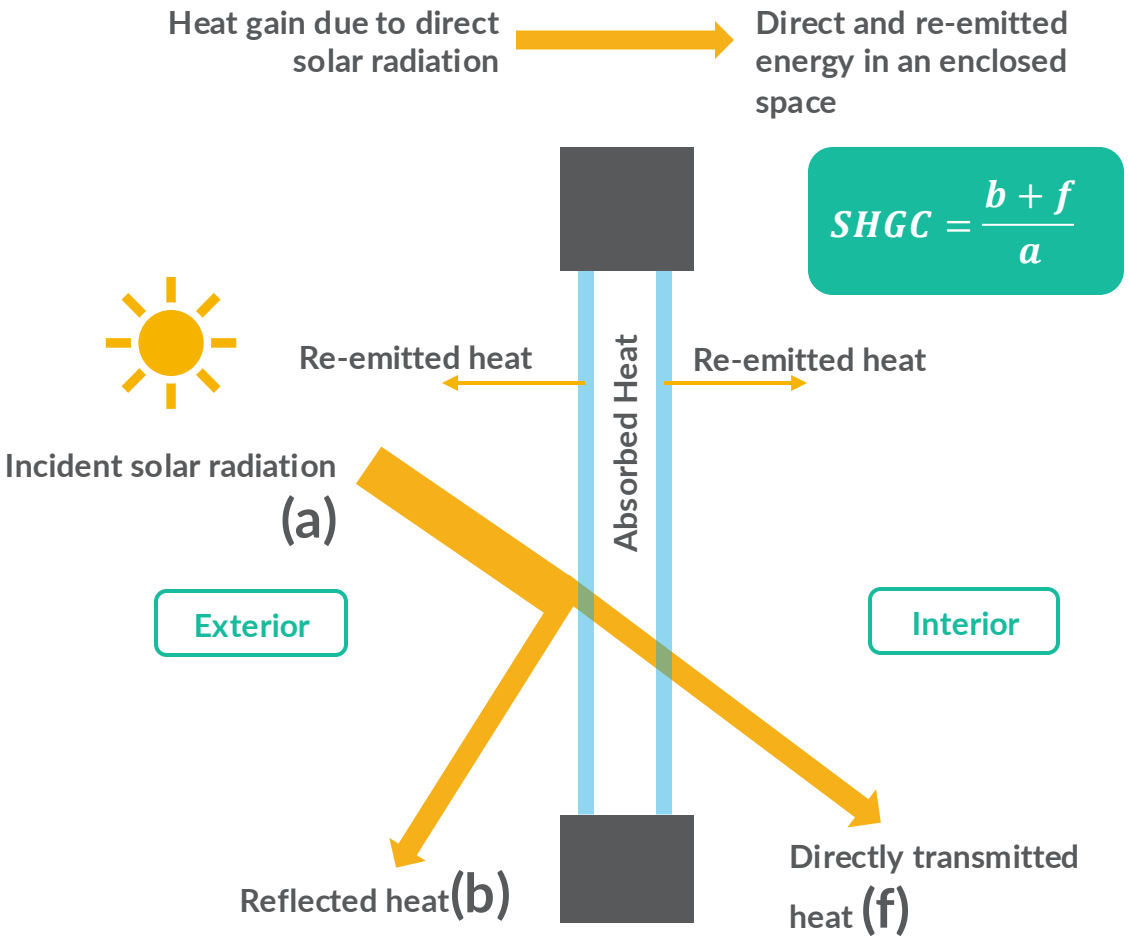


Source: USAID ECO-III Tip Sheets

SOLAR HEAT GAIN COEFFICIENT

SHGC – unshaded

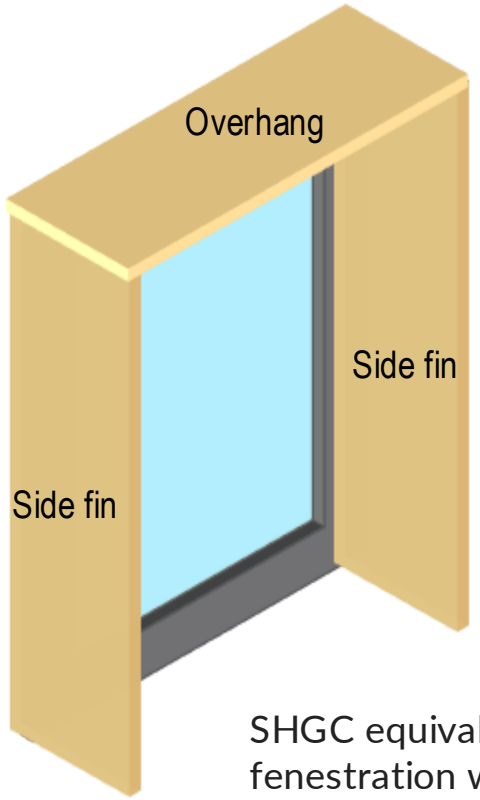
- SHGC is the ratio of solar heat gain that passes through fenestration to the total incident solar radiation that falls on the fenestration
- Lower SHGC means lesser heat transfers into the building through the window
- In hot climates, SHGC is more significant than U-value



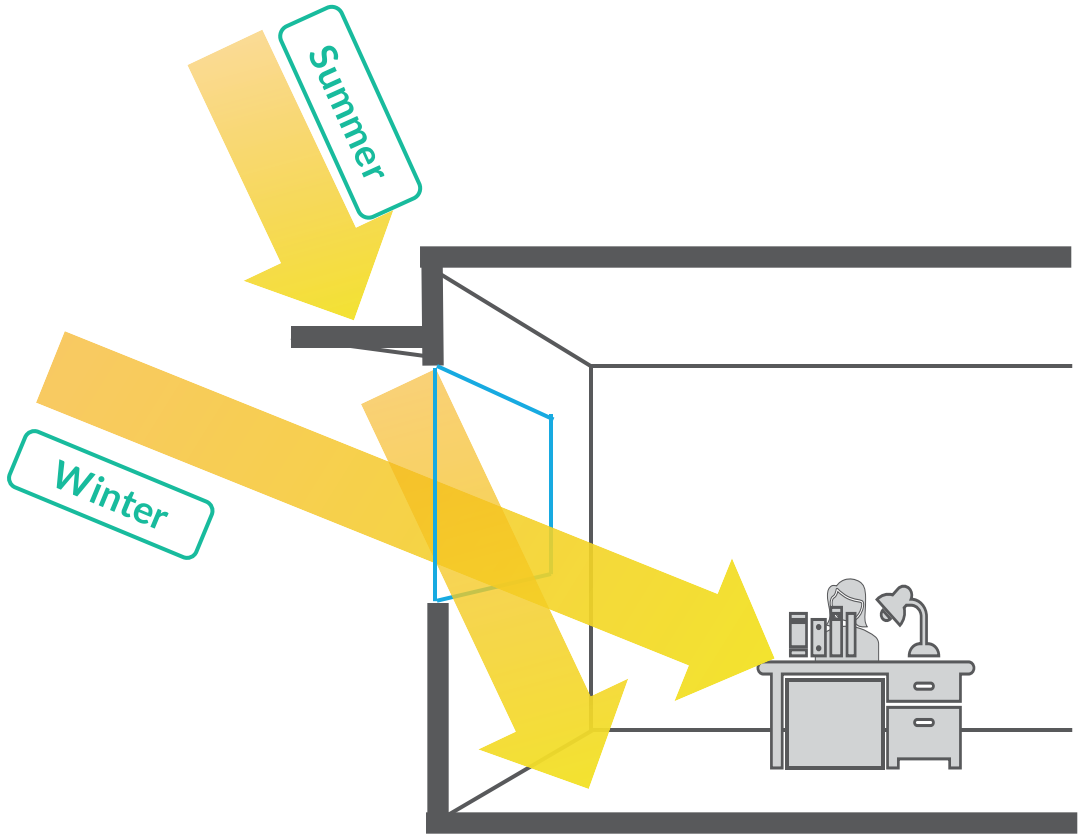
Source: USAID ECO-III Tip Sheets

EFFECT OF SHADING

SHGC equivalent



SHGC equivalent is the SHGC of a fenestration with a permanent external shading projection (overhang and side fins)



External shading devices impact the SHGC of a fenestration by impacting the solar radiation incident on the window. The impact of the shading device on the unshaded SHGC results in SHGC equivalent

Source: Building Energy Efficiency in Nepal (BEEN) Project, 2024

EXTERAL SHADING VS. INTERNAL SHADING

SHGC equivalent

- Internal shading does not prevent heat from entering the building
- With internal curtains the effective SHGC is around **0.75** (with 6 mm clear glass)
- In case of external shading the heat get reflected from outside the window
- With good external shading the effective SHGC is around **0.18** (with 6 mm clear glass)

Up to four times reduction in window solar gains with external shading as compared to internal shading

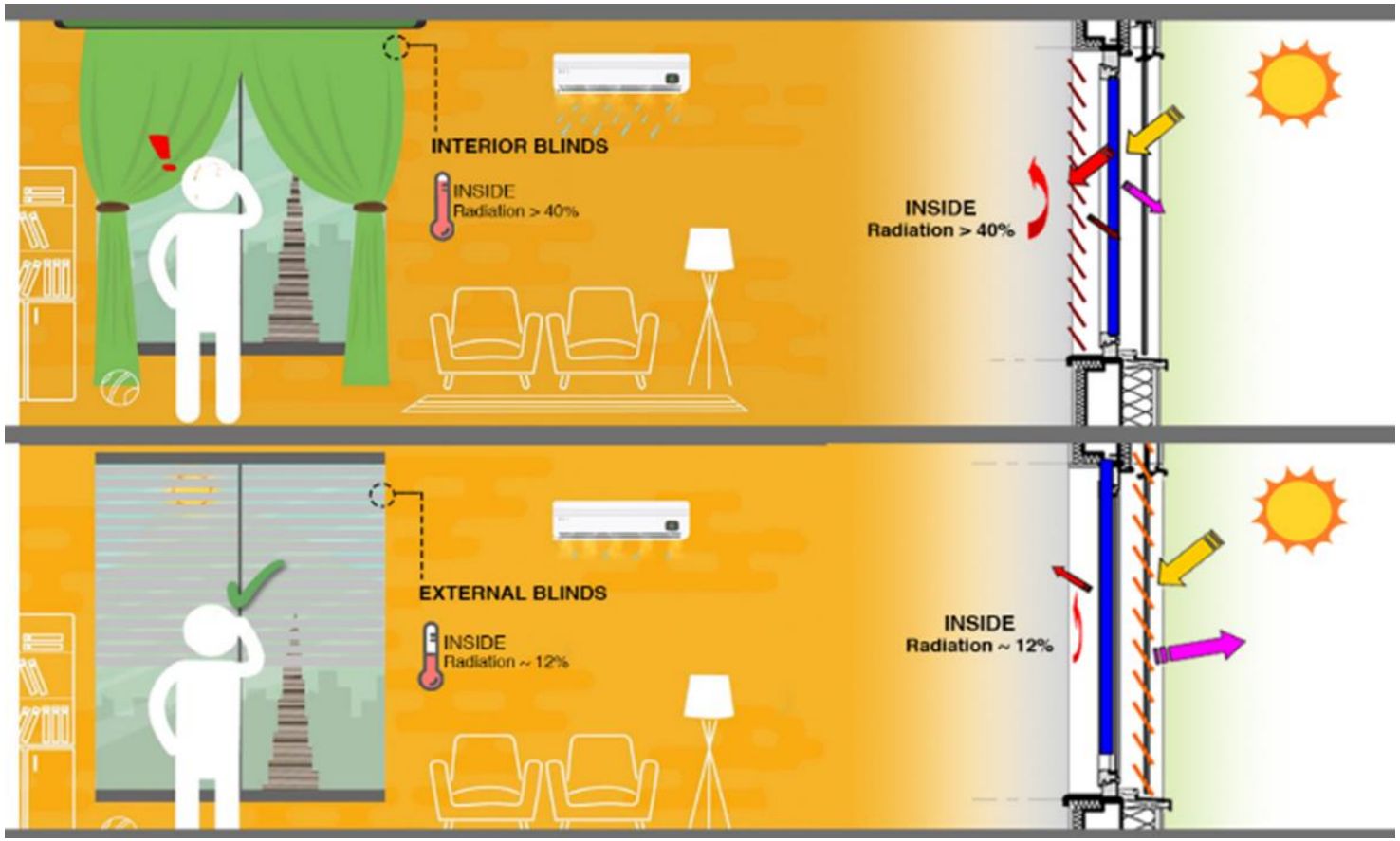


Illustration of external vs. internal shading

Source: Ministry of Power, Government of India, 2022b

GLAZING

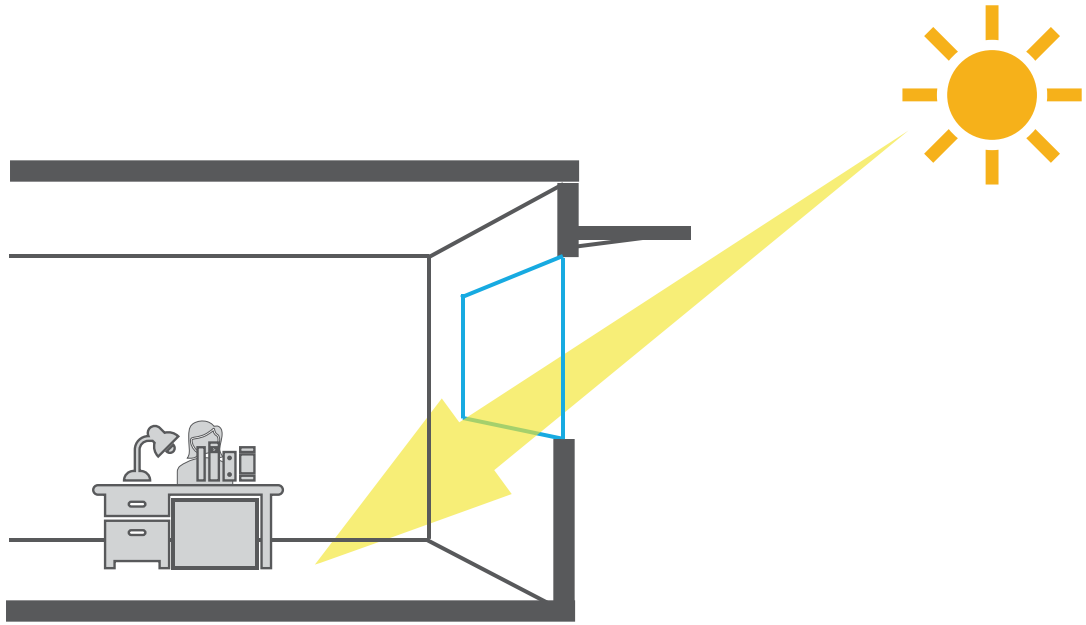
Visible light transmittance (VLT)

VLT is the fraction of visible light transmitted through the glazing

- Affects daylight and visibility
- Varies between 0 and 1

Typically, the lower the SHGC, the lower the VLT

- Higher insulating property glass will reduce daylight



Source: USAID ECO-III Tip Sheets

GLAZING

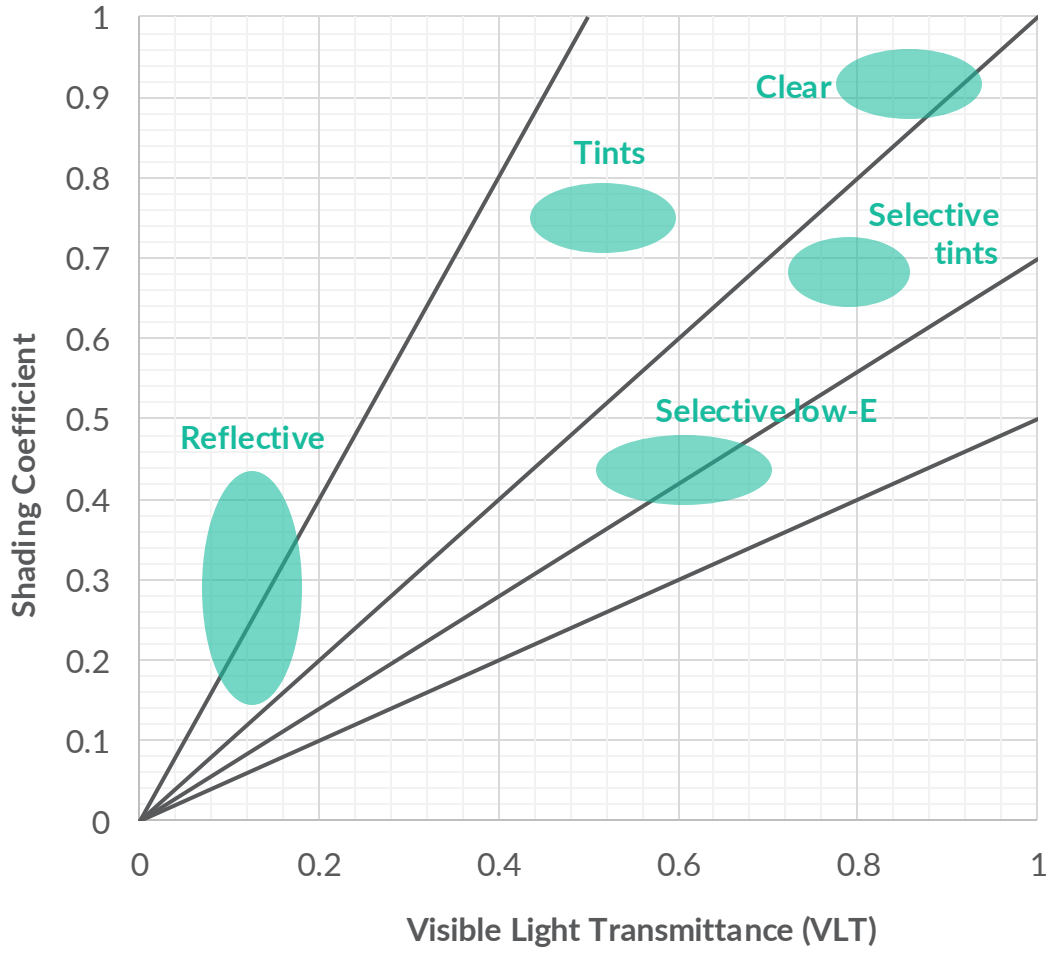
Minimum illuminance level required

- ASHRAE provides recommendations for minimum illuminance levels in different areas through its standards, particularly **ASHRAE 90.1** and **IES Lighting Handbook** (in collaboration with the Illuminating Engineering Society)
- These standards are widely referenced in building codes for energy efficiency and lighting quality
- The table shows some typical illuminance levels suggested by ASHRAE and IES for various types of spaces (measured in lux)

Area	Minimum illuminance levels
General Office Areas	300–500 lux
Conference Rooms	300–500 lux
Reception Areas	300 lux
Classrooms	300–500 lux
Laboratories	500 lux
Lecture Halls and Auditoriums	200–300 lux
Warehousing and Storage Areas	100–300 lux
Restaurants (Dining Areas)	100–300 lux

RELATION OF SHADING COEFFICIENT AND VLT

- The graph depicts that, for clear glass, the VLT is very high, and the shading coefficient is also high, leading to heat and glare
- As selective metallic oxides are applied on clear glass (either as soft or hard coat), the glass performance improves
- Depending on the need, a balance between VLT and shading coefficient must be managed
- **For larger floor plates, VLT is not very significant, as daylight cannot penetrate more than 6–7m from perimeter**
- **For such large buildings, shading coefficient plays a major role in reducing heat gains through glazing**



Source: USAID ECO-III Tip Sheets

Building Heat Transfer Values

RTTV and OTTV



ROOF THERMAL TRANSFER VALUE

RTTV: Metric for heat transfer

- **Roof thermal transfer value (RTTV)** is a metric used to quantify heat transfer through a building's roof structure. It is commonly used in tropical and subtropical climates, where the roof is a primary source of heat gain in buildings
- RTTV is measured in **W/m²** and helps evaluate the roof's thermal performance, contributing to the building's overall energy efficiency
- **RTTV considers:**
  - **Direct solar radiation:** Heat absorbed by the roof due to sunlight
  - **Thermal conductivity:** The ability of the roof materials to conduct heat
  - **Surface temperature differentials:** The temperature difference between the inside and outside surfaces of the roof

$$RTTV = (a \times (1 - SKR) \times U_r) + (b \times SKR \times U_s) + (c \times SKR \times SC \times CF)$$

- RTTV: roof thermal transfer value (W/m²)
- SKR: skylight ratio of roof (skylight area/gross area of roof)
- U_r: Thermal transmittance of opaque roof (W/m².K)
- U_s: Thermal transmittance of skylight (W/m².K)
- SC: Shading coefficient of skylight
- CF: Solar correction factor for roof (based on the orientation and slope)
- a, b, c = multiplying factors determined based on the specific country/location



Source: Building and Construction Authority, Government of Singapore

ROOF THERMAL TRANSFER VALUE

RTTV: Sample calculation

For example, one building located in Singapore with the total roof (flat roof) area of 250m², containing 50m² of skylight. The technical specification of the roof construction materials are as follows:

- A_r=200m², U_r=0.5 W/m²·K
- A_s=50 m², U_s=3 W/m²·K
- SC=0.5,
- CF= 1 (flat roof)
- SKR= 0.2

Calculation of RTTV:

$$RTTV=(a\times(1- SKR)\times U_r)+(b\times SKR\times U_s)+(c\times SKR\times SC\times CF)$$

Multiplier factors values for Singapore:
a = 12.5
b = 4.8
c = 485

Breaking it down:

Opaque roof contribution: 12.5×0.8×0.5 = 5 W

Skylight conduction: 4.8×0.2×3 = 2.88 W

Skylight solar heat gain: 485×0.2×0.5×1 = 48.5 W

$$RTTV = 5 + 2.88 + 48.5 = 56.38\ W/m^2$$

The RTTV value of this roof is **56.4 W/m²**. This value should be below the prescribed limits mentioned in the national building energy efficiency code

Source: Building and Construction Authority, Government of Singapore

OVERALL THERMAL TRANSFER VALUE

OTTV: Metric for heat transfer

- **Overall thermal transfer value (OTTV)** is a widely-used metric to assess the thermal performance of the building envelope, particularly in tropical and subtropical climates. It measures the average rate of heat transfer into a building through its external walls, windows, and other opaque and transparent façades
- OTTV is expressed in **W/m²** and evaluates the thermal efficiency of external walls and fenestration systems in terms of heat gain
- **Key components of OTTV:**
  - **Wall heat conduction:** Heat transfer through the opaque portion of walls
  - **Glass heat conduction:** Heat transfer through windows and glazing systems
  - **Solar heat gain through windows:** Heat from solar radiation entering through glazed surfaces

$$\text{OTTV} = \boldsymbol{a}(\mathbf{1} - \boldsymbol{WWR})\boldsymbol{U_w} + \boldsymbol{b}(\boldsymbol{WWR})\boldsymbol{U_f} + \boldsymbol{c}\,(\boldsymbol{WWR})(\boldsymbol{CF})(\boldsymbol{SC})$$

- OTTV: Overall thermal transfer value (W/m²)
- WWR: Window-to-wall ratio (fenestration area / gross area of external wall)
- U_w: Thermal transmittance of opaque roof (W/m².K)
- U_f: Thermal transmittance of fenestration (W/m².K)
- SC: Shading coefficient of fenestration
- CF: Solar correction factor for fenestration (based on the orientation and slope)
- a, b, c = multiplying factors determined based on the specific country/location

Source: Building and Construction Authority, Government of Singapore

OVERALL THERMAL TRANSFER VALUE

OTTV: Sample calculation

For example, taking a building with the following specifications:

- **Wall (opaque)**
  - Area of wall (A_w) = 50m²
  - Thermal transmittance of wall material (U_w) = 1.5W/m²·K
- **Window (glazing)**
  - Area of window (A_f) = 10m² (On north façade)
  - Thermal transmittance of glazing (U_f) = 5.0W/m²·K
  - Shading coefficient (SC) = 0.8
  - Window-to-wall ratio (WWR) = 0.2
  - CF = 0.8
- **Multiplier factors values for Singapore:**

  a = 12
  b = 3.4
  c = 211

$$\text{OTTV} = a(1 - WWR)U_w + b(WWR)U_f + c\,(WWR)(CF)(SC)$$

Wall heat transfer:
12 x 0.8 x 1.5 = **14.4 W/m²**

Glazing heat transfer:
3.4 x 0.2 x 5 = **3.4 W/m²**

Solar heat gain through windows:
211 x 0.2 x 0.8 x 0.8 = **27 W/m²**

OTTV = 25 + 16.67 + 0.53 = **44.8 W/m²**

Source: Building and Construction Authority, Government of Singapore

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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on the basis of a decision by the German Bundestag



GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

2.2 Solar Passive Design

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

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IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

01 Understanding the Climate

02 Building Massing and Orientation

03 Optimizing Building Envelope – Windows for Better Daylight and Minimum Heat Gain

04 Optimizing Building Envelope – Windows for Better Natural Ventilation

05 Solar Shading

06 Optimizing Building Envelope – Walls and Roofs

07 Building Envelope Features for Different Climates

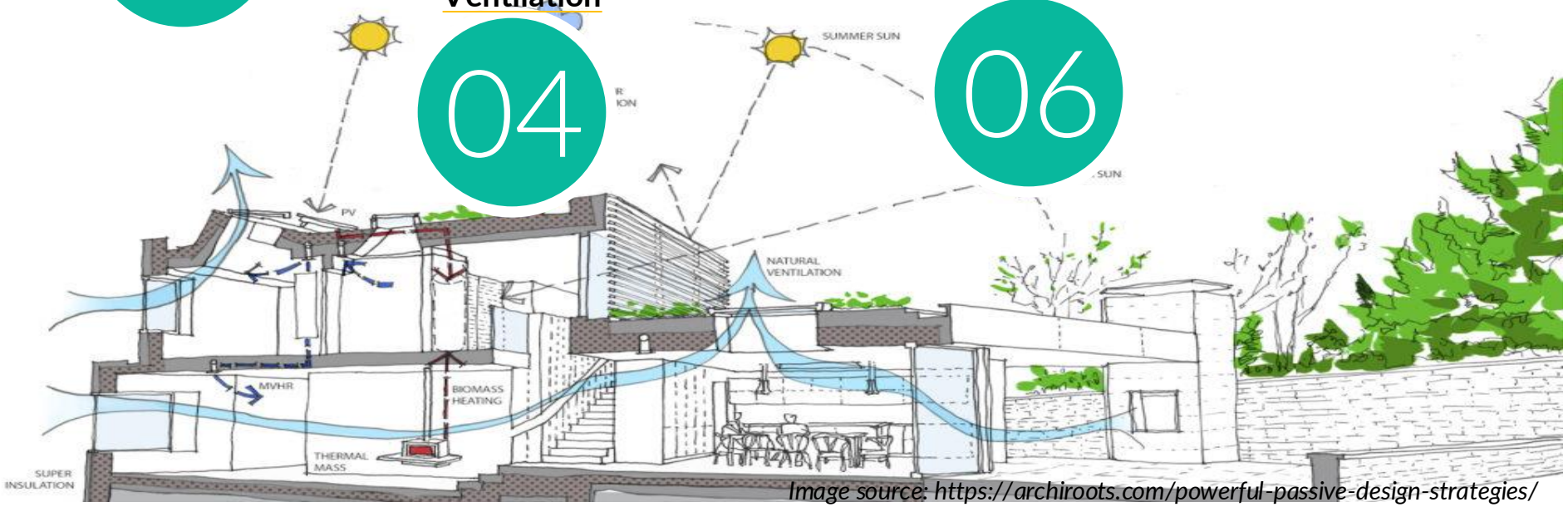


Image source: https://archiroots.com/powerful-passive-design-strategies/

Understanding the Climate

Temperature, Humidity, Wind and Solar Radiation



Image source: https://elemental.green/passive-solar-home-design-

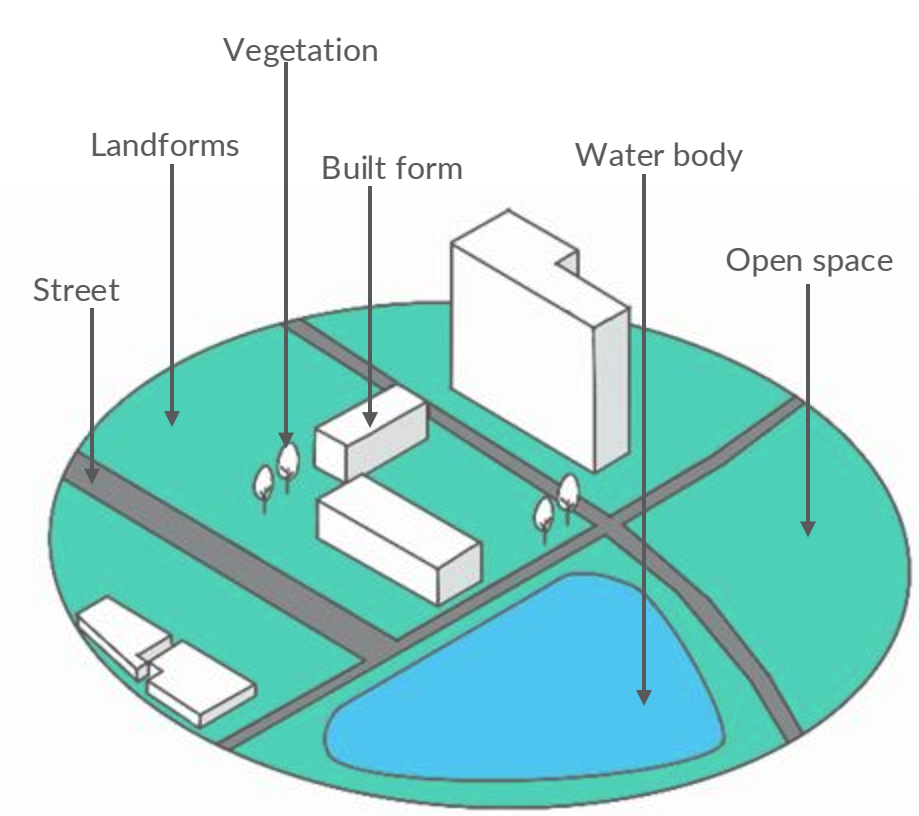
ROLE OF MICROCLIMATE

Determines the overall layout and comfort in buildings

Microclimate of a building affects energy transfer through building and how people respond to it

Local conditions that contribute to microclimate

- Temperature
- Air
- Humidity
- Radiation



Factors affecting microclimate of a site



Image source: SM Solutions

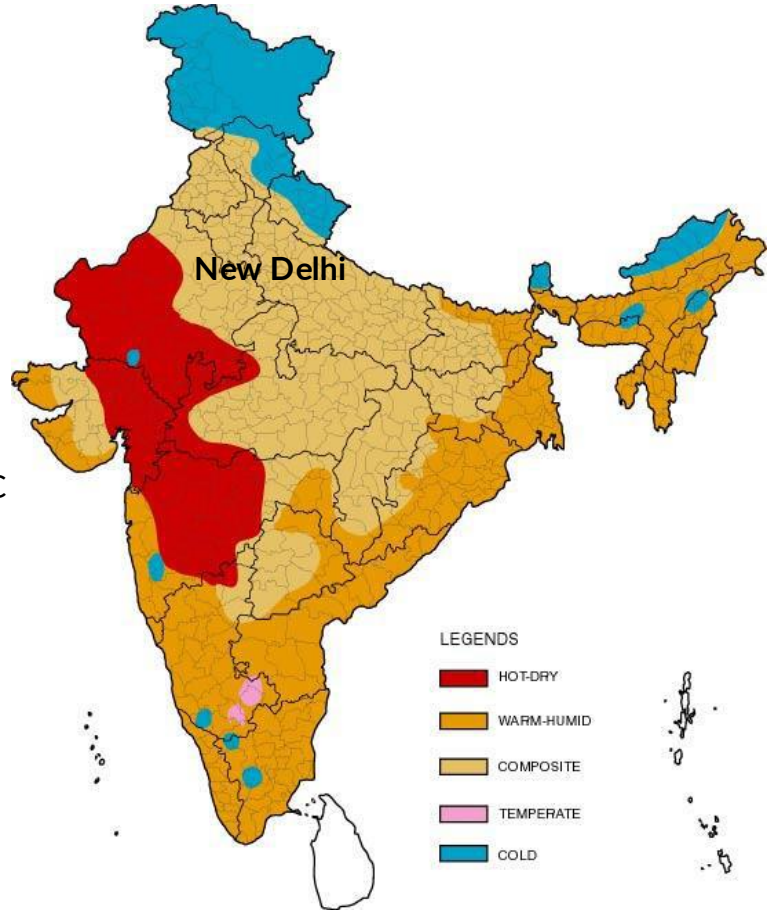
Open courtyards with combination of pervious and impervious materials add character to the building

CLIMATE ANALYSIS

Example: New Delhi, India

- To conduct a climate analysis, representative climate data of the location for the past 10–15 years is needed
- Several tools can assist in climate analysis. These tools use hourly weather data files as input
- The latest available weather files should be used for climate analysis
- One potential source for weather files is https://climate.onebuilding.org/default.html

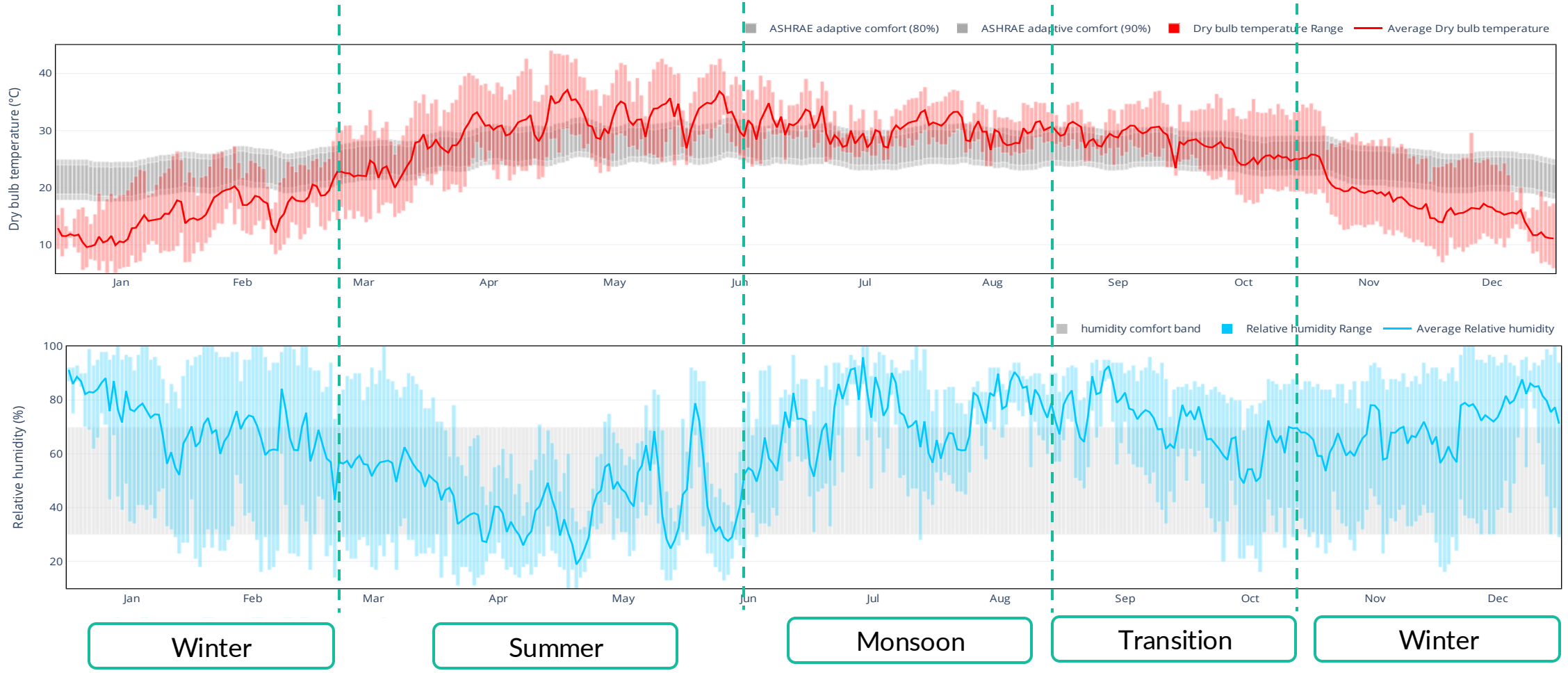
- Location: New Delhi, India
- Latitude: 28.6139° N
- Longitude: 77.2088° E
- Altitude: 216 m
- Climatic zone: Composite
- Climate summary:
  - Average yearly temperature: 24.8 °C
  - Hottest temperature (99%): 40.8 °C
  - Coldest temperature (1%): 7.1 °C
  - Annual cumulative horizontal solar radiation: 1909.09 kWh/m^2



Source: Bureau of Indian Standards, Government of India, 2016b

TEMPERATURE AND RELATIVE HUMIDITY

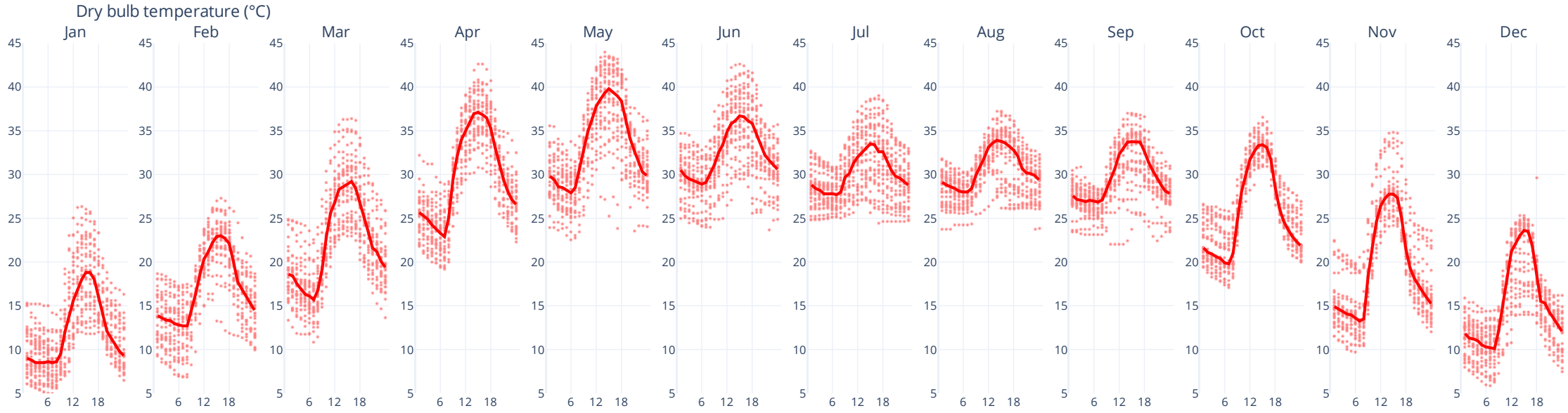
New Delhi, India: Seasonal variations



Source: https://clima.cbe.berkeley.edu/

CLIMATE ANALYSIS

New Delhi, India: Air temperature – hourly diurnal

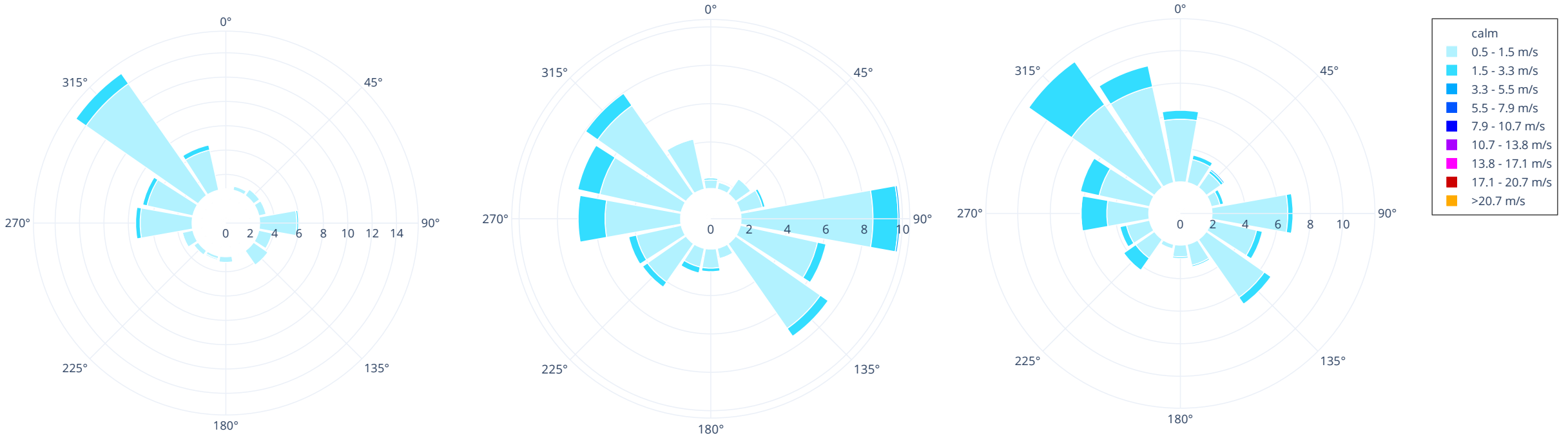


Overview of month-wise hourly average temperature variations to understand the need for cooling and heating

Source: https://clima.cbe.berkeley.edu/

WIND SPEED AND DIRECTION

New Delhi, India



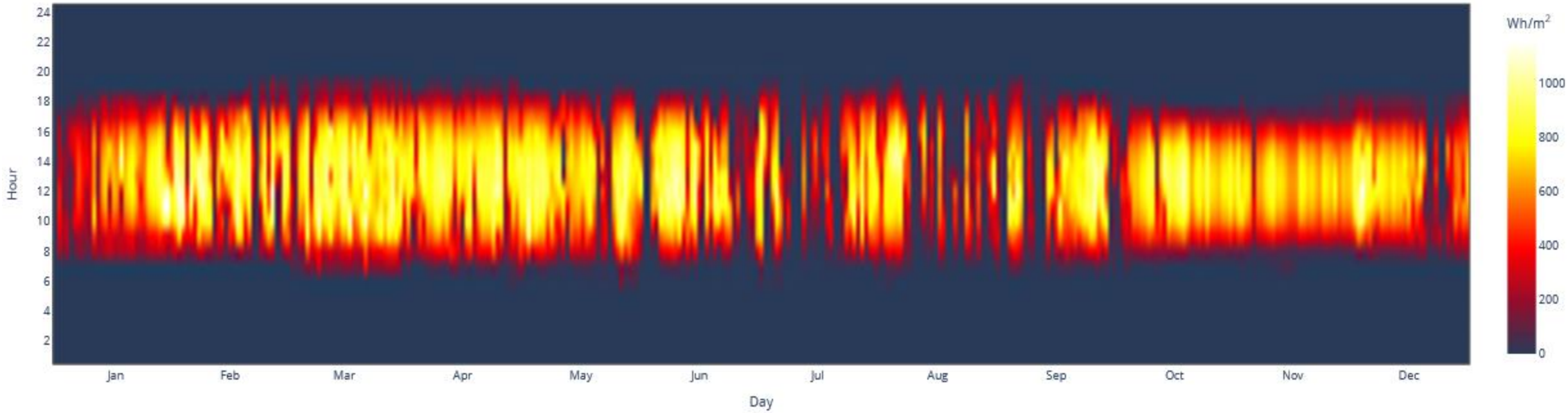
Winter | Monsoon | Summer

Overview of wind velocity and direction of wind for different seasons to draw inferences for building orientation and placement of openings for maximizing or minimizing natural ventilation

Source: https://clima.cbe.berkeley.edu/

SOLAR RADIATION

New Delhi, India

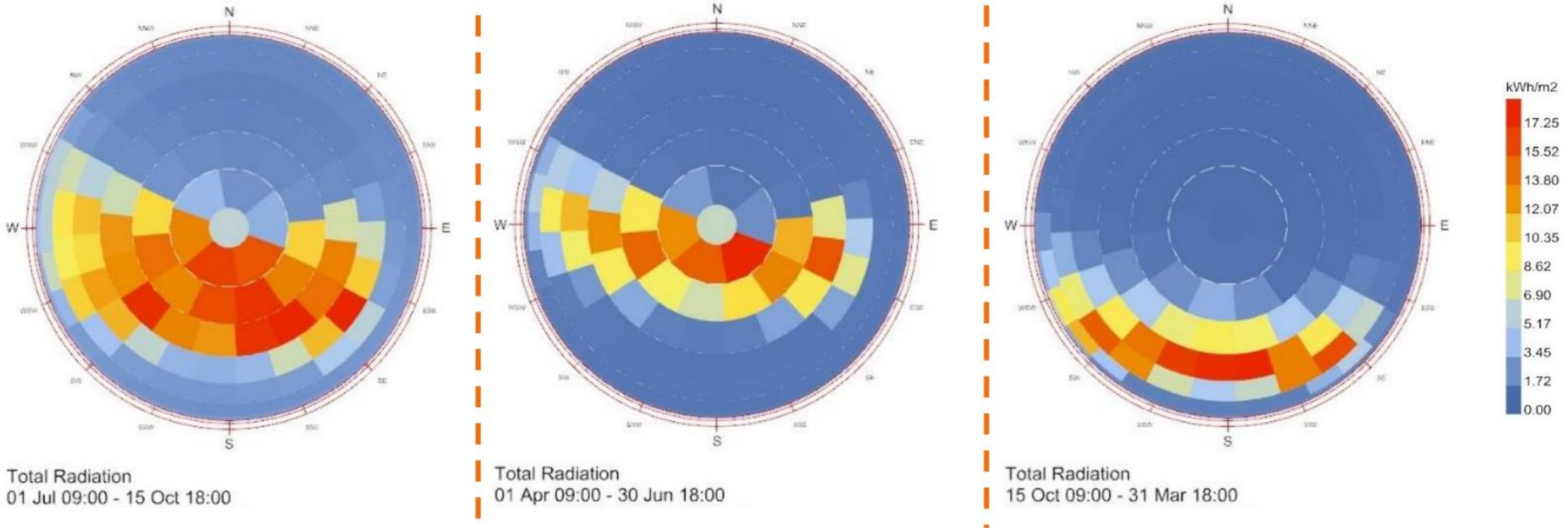


Overview of annual solar radiation for different months helps plan for solar protection or higher solar exposure, and estimates the energy generation potential from solar energy

Source: https://clima.cbe.berkeley.edu/

SOLAR RADIATION

New Delhi, India



Overview of solar radiation on different façades in different seasons, to plan for solar protection strategies

Source: CEPT University, 2022

CLIMATE ANALYSES

New Delhi, India: Inferences from temperature, humidity and wind analyses

Temperature and humidity analysis:

- **Hot and dry summer** season with **temperatures reaching up to 44°C**
- It is followed by the monsoon season with **temperatures ranging from 25°C to 37°C, with average humidity above 70%**
- Winter season last for four months, when **temperatures go below 10°C**
- During the **transition months**, there is **higher diurnal variation** in the outdoor dry bulb temperature. By introducing night purging, the overall cooling demand can be reduced or eliminated
- However, during the winter months, night purging can lead to higher heat loss from the spaces

Wind analysis:

- The wind speed in New Delhi is predominantly from the north-west and northern winds with an average wind velocity of 5.85 m/s. In passive strategies like mix mode and night purging, with the consideration of temperature of wind, openings on the north-west façade can be optimized

CLIMATE ANALYSES

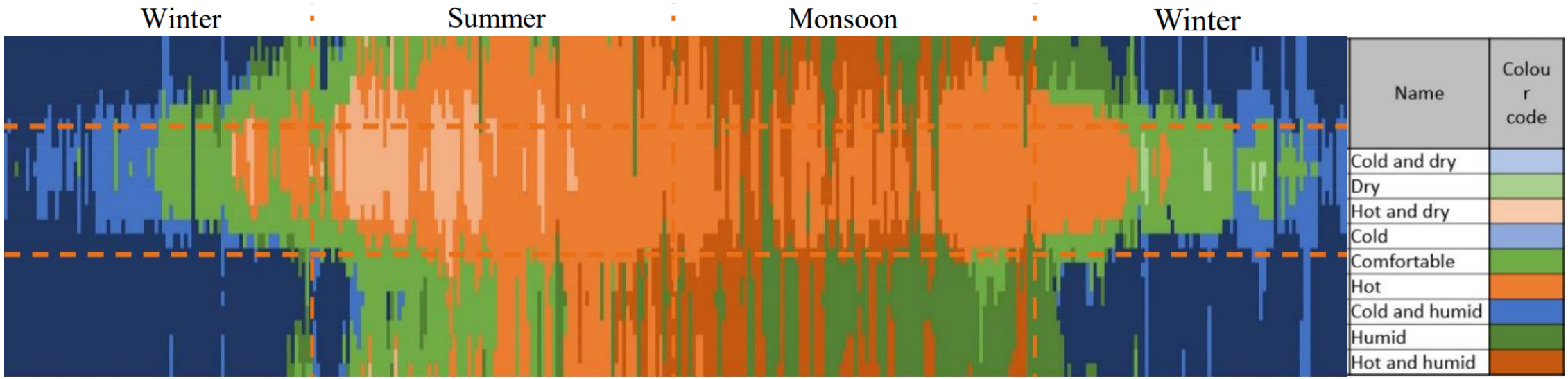
New Delhi, India: Inferences from solar radiation analysis

Solar radiation analysis:

- The average global horizontal radiation is 217.21 Wh/m² and maximum global horizontal radiation is 987 Wh/m². This shows a **high potential for the installation of solar photovoltaic panels for electricity generation** throughout the year
- During summer, **maximum radiation is received on the west;** this will require a strategy of shading from the lower altitude sun
- In the winter months the south façade will receive higher solar radiation, this can be favorable to cut down the heating load during these months
- By providing overhangs on the south façade windows, we can cut down the higher altitude sun in the summer months and take advantage of the lower altitude sun in the winter months

CLIMATE ANALYSES

New Delhi, India: Thermal comfort analysis



- Based on outdoor dry bulb temperature and relative humidity, 8,760 hours of the year can be divided into nine thermal conditions
- Here, the comfortable condition is at **21.5°C–28.5°C** and **30%–70% relative humidity**
- The graph above indicates that during summer months, the daytime is hot and dry, while during monsoon months, it is warm and humid

Source: CEPT University, 2022

CLIMATE ANALYSES

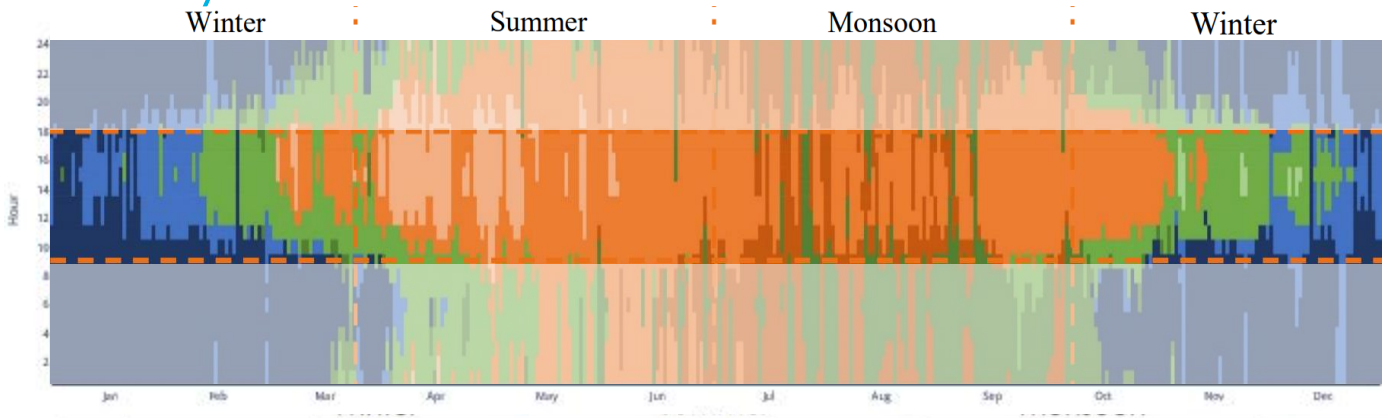
New Delhi, India: Thermal comfort analysis

Correlating the key inferences with the building during operating hours

(9am to 6pm for a typical office):

- Cooling required for 41% of the time
- Heating required for 11% of the time
- Natural ventilation meets the comfort requirement for 17% of the hours
- Cooling and dehumidification required for 11% of the time (mainly during the monsoon months)

*Based on outdoor conditions; with internal loads, these requirements will change



Operating hours (9am–6pm)

No.	Name	Colour code	Quality	Temperature range (°C)	RH range (%)	3650 operating Hours		Strategies Required
						Number of Hours	Hours in %	
1	Cold and dry		Low RH & Low DBT	0 - 21.5	0-30	0	0.0	Humidification & Heating
2	Dry		Low RH & Moderate DBT	21.5 -28.5	0-30	18	0.5	Humidification
3	Hot and dry		Low RH & High DBT	28.5 - 44	0-30	266	7.3	Humidification and Cooling
4	Cold		Moderate RH & Low DBT	0 - 21.5	30-70	393	10.8	Heating
5	Comfortable		Moderate RH & Moderate DBT	21.5 -28.5	30-70	620	17.0	Natural Ventilation
6	Hot		Moderate RH & High DBT	28.5 - 44	30-70	1528	41.9	Cooling
7	Cold and humid		High RH & Low DBT	0 - 21.5	70-100	413	11.3	Dehumidification & Heating
8	Humid		High RH & Moderate DBT	21.5 -28.5	70-100	151	4.1	Dehumidification
9	Hot and humid		High RH & High DBT	28.5 - 44	70-100	261	7.2	Dehumidification & Cooling

Source: CEPT University, 2022

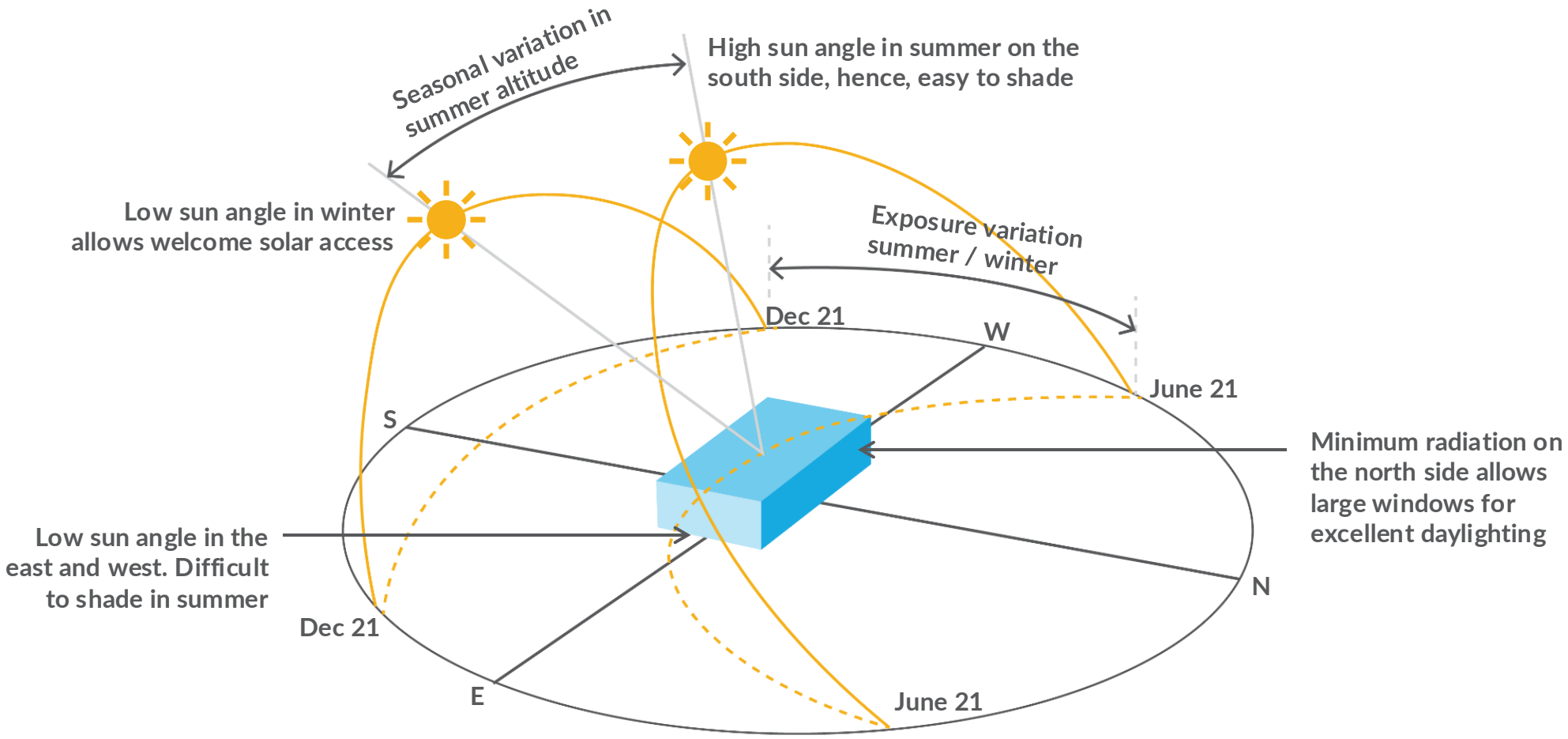
SUN PATH ANALYSIS

For orientation and massing

Understanding of **the sun's movement** around the building

Which **façades** will be exposed to the sun?

Shadows of the adjoining buildings and the proposed building itself



CLIMATE

Example: Phnom Penh, Cambodia

- Location: Phnom Penh, Cambodia
- Latitude: 13.41100°N
- Longitude: 103.8130°E
- Altitude: 12.2m
- Climatic zone: Hot and humid



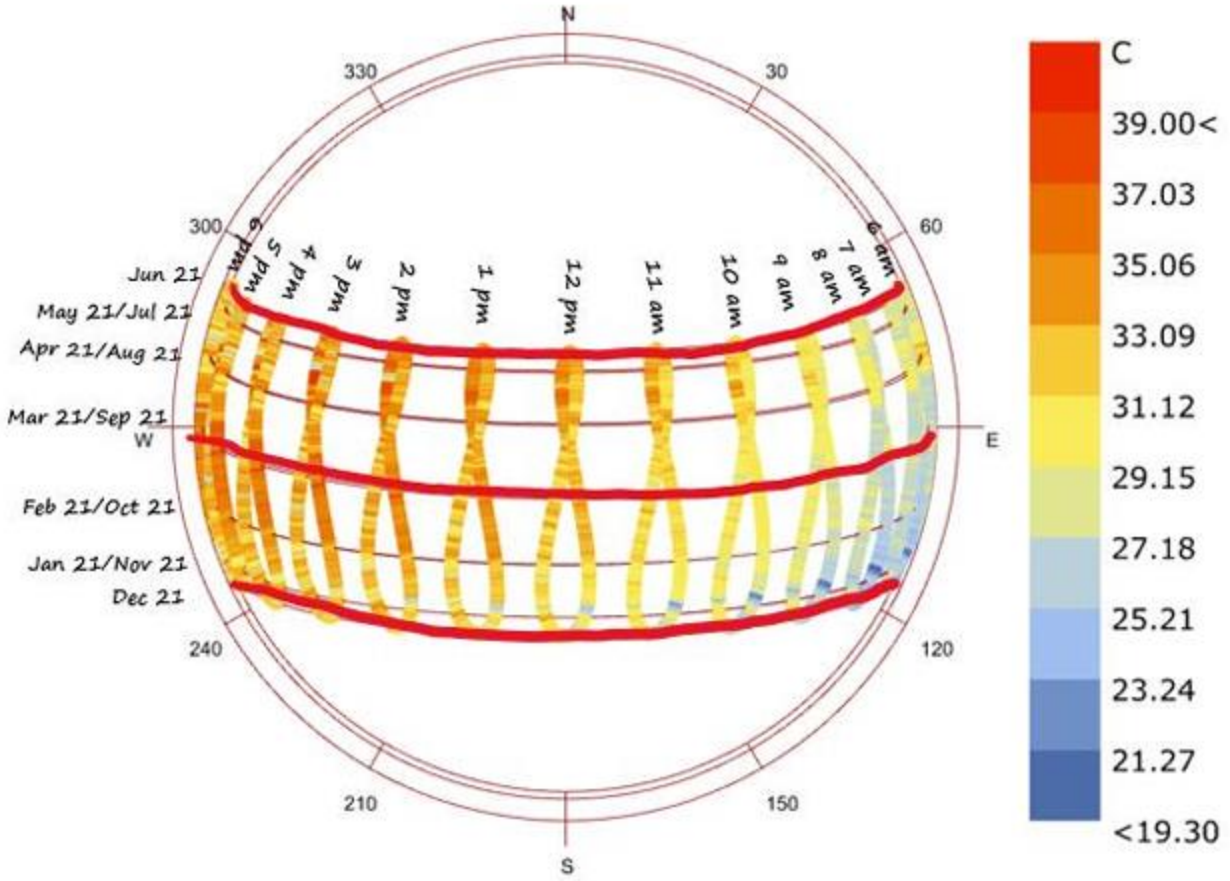
Phnom Penh

Sources: UNEP; ESCAP; Cool Coalition; Ministry of Environment, Government of Cambodia

SUN PATH AND SOLAR RADIATION

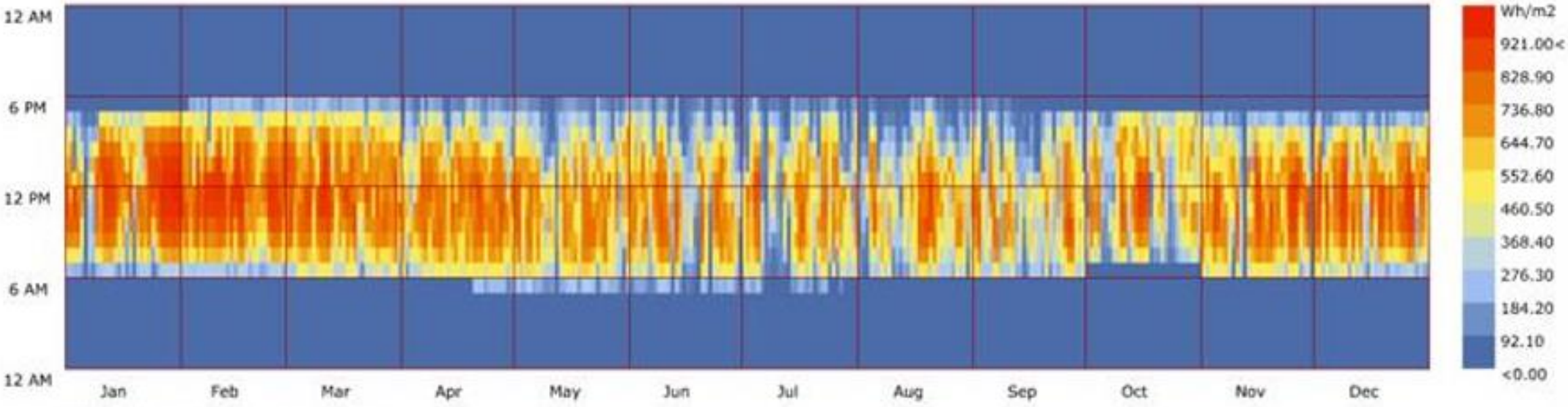
Phnom Penh, Cambodia

- Maximum daily direct solar radiation: 921 Wh/m²
- Maximum daily diffused solar radiation: 386 Wh/m²
- Diffused solar radiation higher during the months of June to September, coinciding with a higher level of humidity and cloudiness
- Solar intensity is notably high from 11:00 am to 6:00 pm from February to October, and from 1:00 pm to 6:00 pm from November to January



DIRECT SOLAR RADIATION

Phnom Penh, Cambodia



Direct Normal Radiation (Wh/m2) - Hourly
Phnom.Penh.Intl.AP_PP_KHM
1 JAN 1:00 - 31 DEC 24:00

PRECIPITATION

Phnom Penh, Cambodia

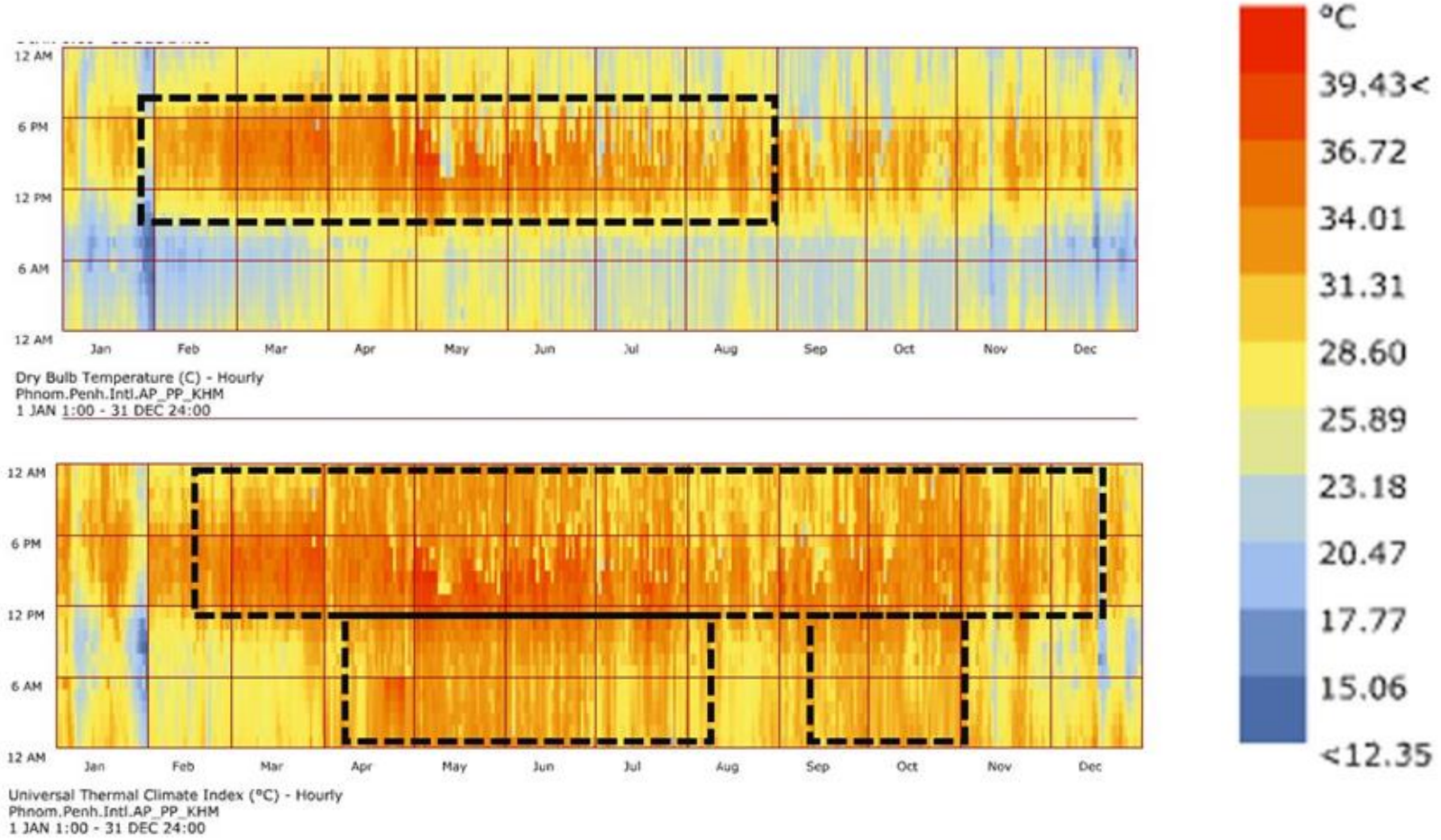
- Average annual precipitation of about **1,432 mm** (56.4 inches)
- **February is the driest** month, with an average precipitation of 9 mm (0.4 inches) recorded over 1.87 days. Conversely, **September** experiences the highest amount of precipitation, with an average of 255 mm (10.0 inches) recorded over 26.07 days

	January	February	March	April	May	June	July	August	September	October	November	December
Precipitation / Rainfall	17	9	41	86	163	157	159	185	255	246	86	28
mm (in)	(0)	(0)	(1)	(3)	(6)	(6)	(6)	(7)	(10)	(9)	(3)	(1)
Humidity(%)	60%	57%	60%	66%	75%	77%	77%	78%	82%	83%	76%	66%
Rainy days (d)	2	1	5	11	17	17	18	19	20	18	9	4

CLIMATE ANALYSIS

Phnom Penh, Cambodia: Temperature variation

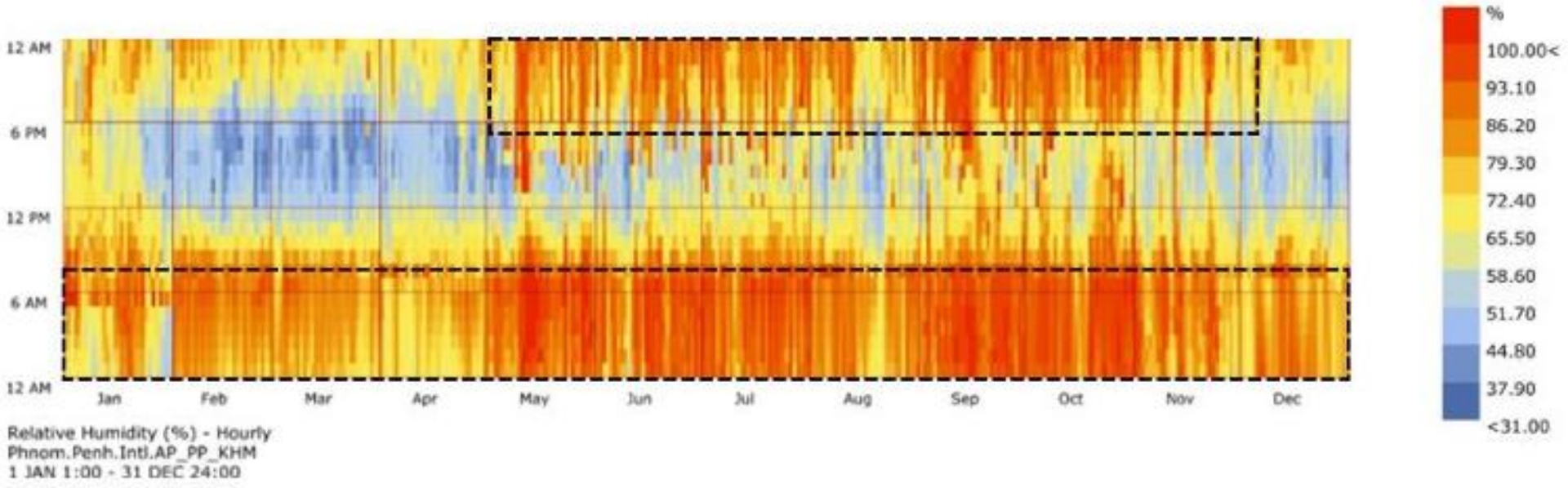
- High dry bulb temperatures exceeding 31°C from February to August
- Universal Thermal Climate Index (**UTCI**), which factors in parameters such as humidity and wind speed, shows that the felt temperature **surpasses 31°C** throughout the day from April to July, September and October



CLIMATE ANALYSIS

Phnom Penh, Cambodia: Relative humidity

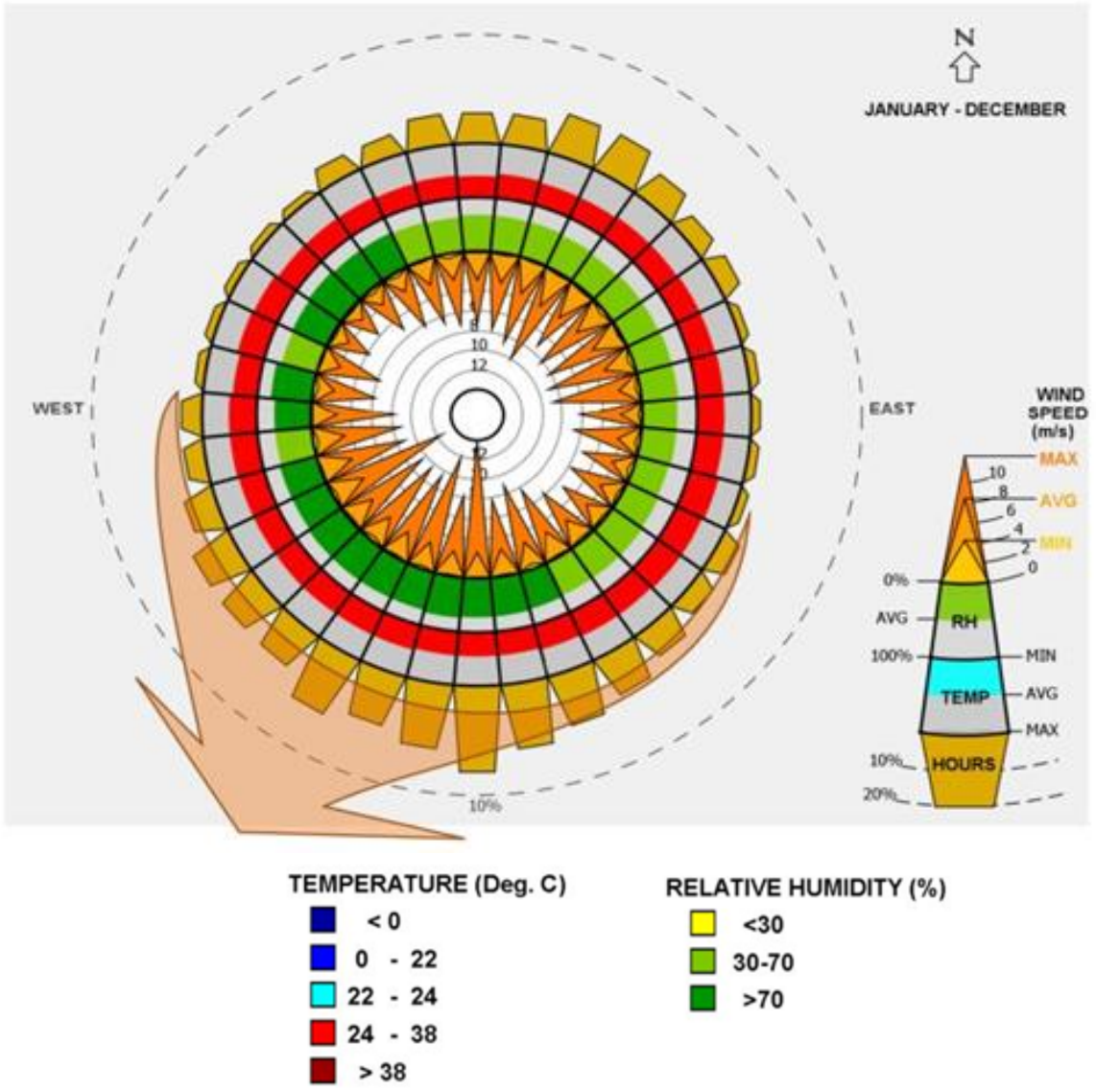
- High levels of relative humidity (RH) throughout the year
- During nighttime, the RH remains consistently above 70%. From 6:00 pm to 12:00 am, elevated RH levels persist between May and November
- On average, humidity remains high from May to November. However, from November to April, the RH ranges between 40% and 70% during the day



CLIMATE ANALYSIS

Phnom Penh, Cambodia: Wind analysis

- Generally, wind peaks in the southwest, south and southeast directions from February to September
- From October to January, the wind direction shifts toward the north and northeast
- Relative humidity exceeds 70%
- Average temperature of the wind throughout the year in Phnom Penh ranges from 24°C to 38°C



Building Massing and Orientation

Harnessing Daylight and Natural Ventilation

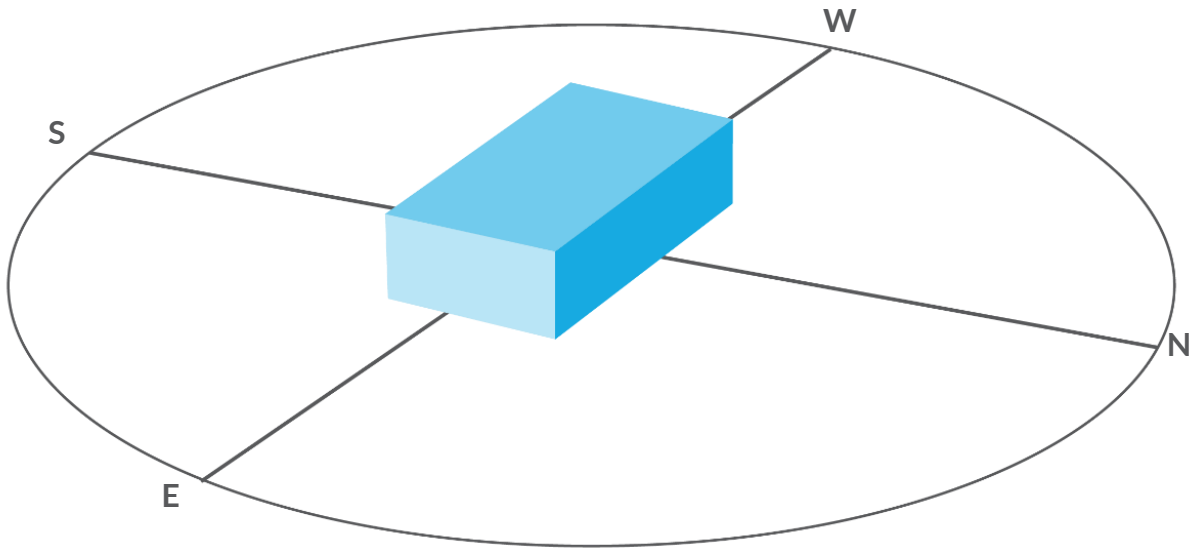


MASSING AND ORIENTATION

For harnessing daylight and natural ventilation

- **Orientation** is the positioning of a building in relation to seasonal variations in the sun's path, as well as prevailing wind patterns
- **Massing** is the overall shape and size of the building

Climate-appropriate building massing and orientation helps harness daylight, solar and wind energy for comfort, and reduce the building's energy dependence



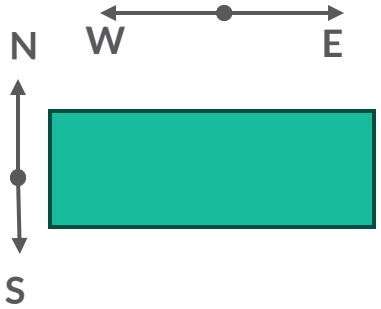
BUILDING ORIENTATION

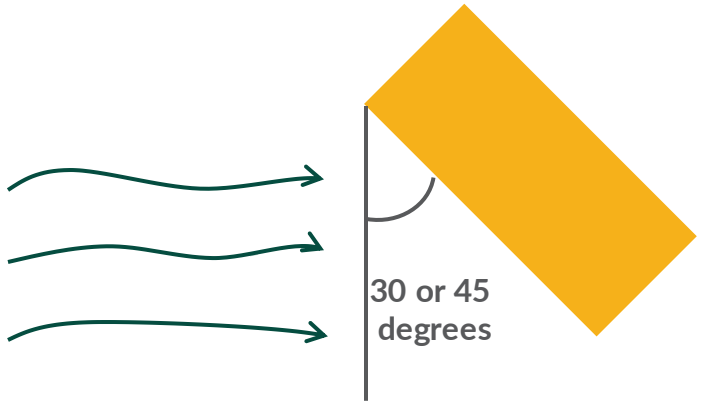
To harness daylight and natural ventilation

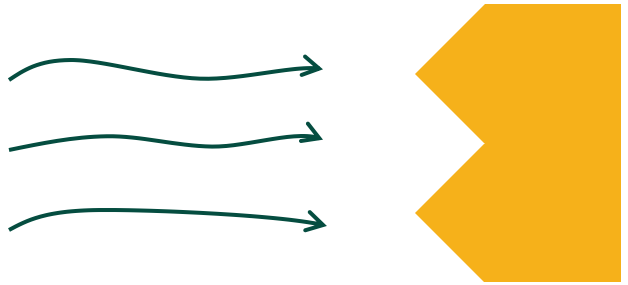
- Requirements to manage solar gains and utilize wind flows may lead to conflicting results
- Designers must **strike a balance** between orientation with respect to the sun and wind flow
- Critical façades and windows should be well-shaded to avoid solar radiation

Longer façades, fenestration and habitable spaces are ideally located in the north and south directions – less solar radiation BUT great for daylight access

East and west façades are kept small







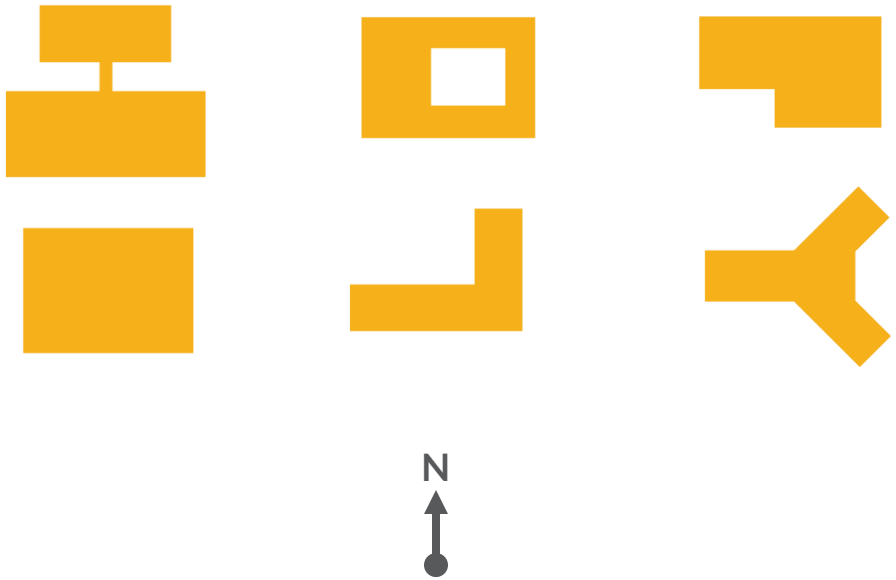
In India, the preferred orientation is toward the north and south directions, with respect to the sun's path

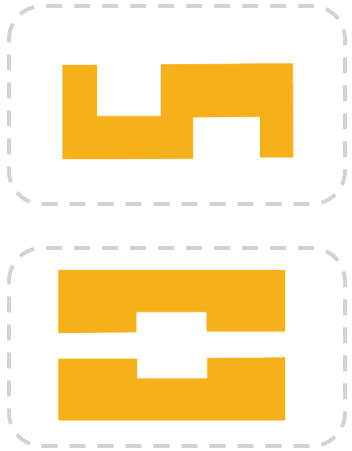
For proper utilization of the wind, the longer façade of the buildings needs to be oriented at an angle (usually ±45 degrees) to the prevailing wind direction

BUILDING FLOOR PLATES

For harnessing daylight and natural ventilation

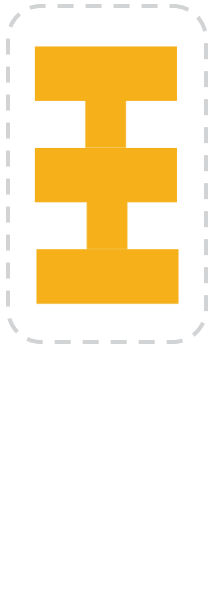
Different types of building floor plates for good daylight and natural ventilation





North-south orientation can be used in creative ways to generate a variety of built and open spaces

North-south orientation can also be used in case of unfavourable orientation of the land



PASSIVE DESIGN STRATEGIES

Massing strategies

- **Mutual shading** of built forms
- Compact forms are ideal for extreme climates
  - Low surface area to volume **(S/V) ratio**
  - Low perimeter to area **(P/A) ratio**
  - **Compact forms** gain less heat during daytime and lose less heat at nighttime

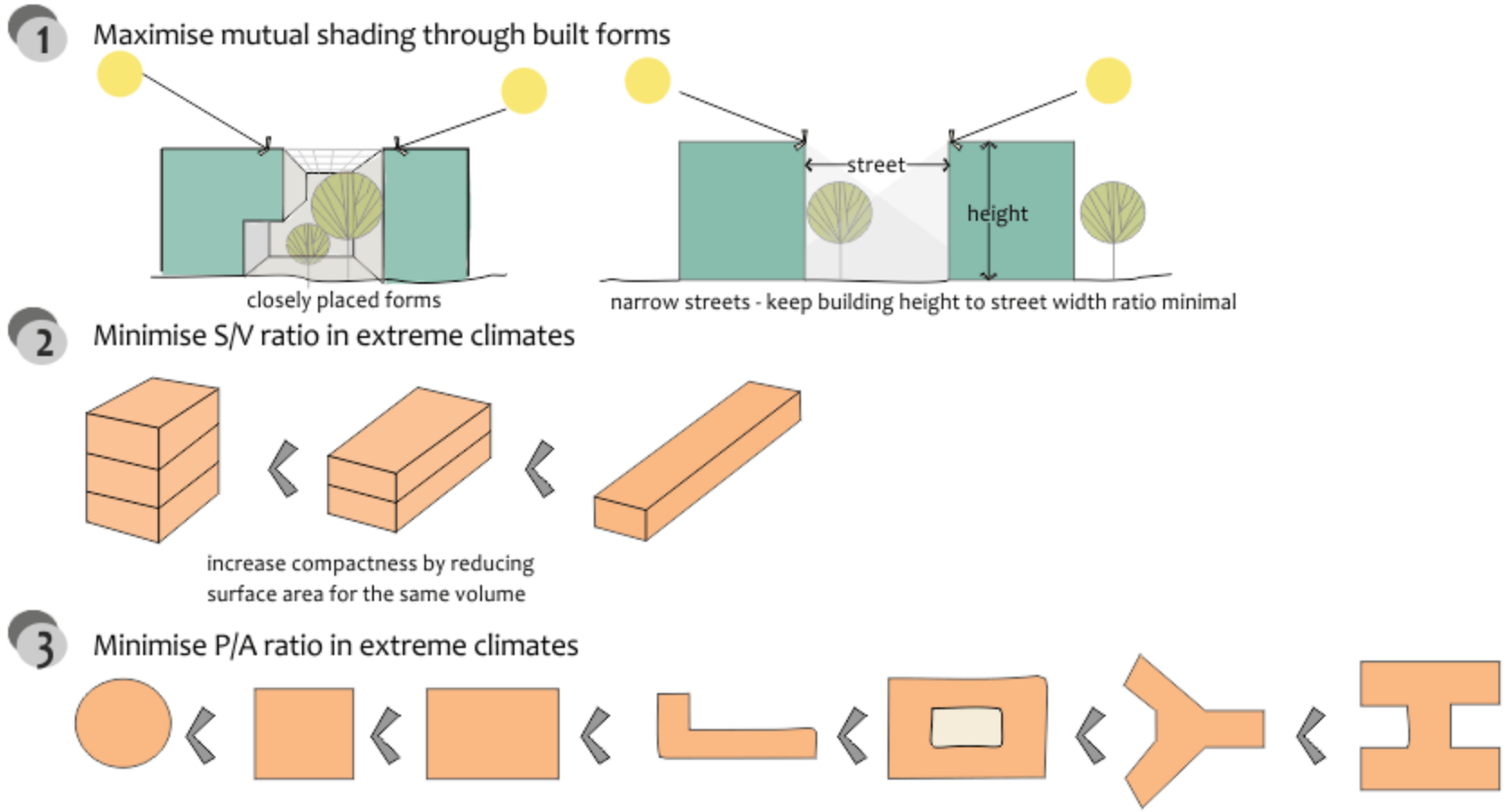


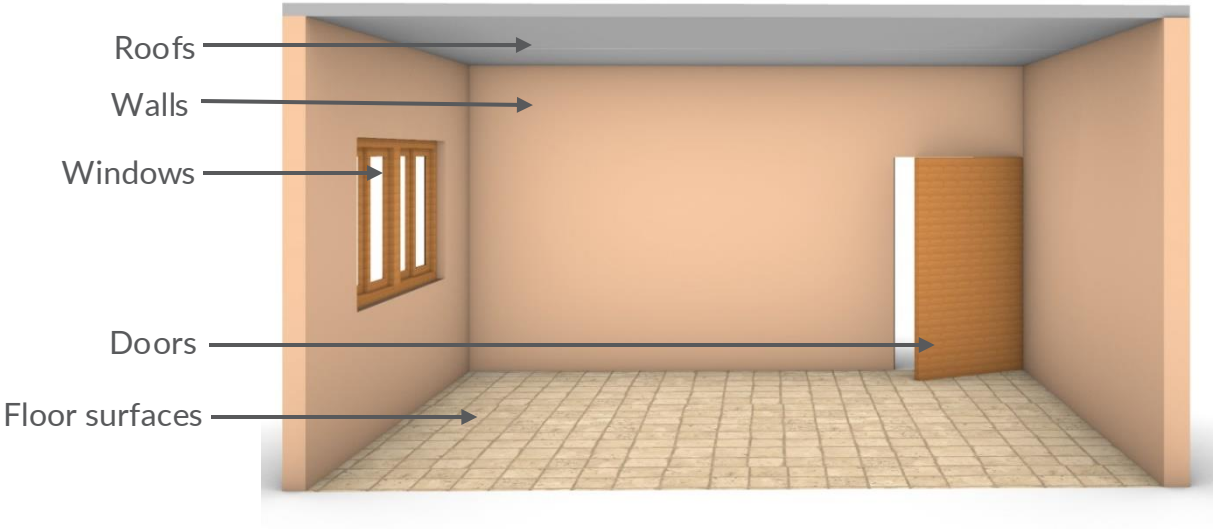
Image source: https://nzeb.in/knowledge-centre/passive-design/form-orientation/

ENVELOPE DESIGN

Significance

- **Envelope design is a major factor in determining the amount of energy a building will use in its operation**
- The overall environmental life cycle impacts, and energy costs associated with the production and transportation of different envelope materials, vary greatly
- The building envelope or 'skin' consists of structural materials and finishes that enclose space, separating inside from outside

Elements of building envelope

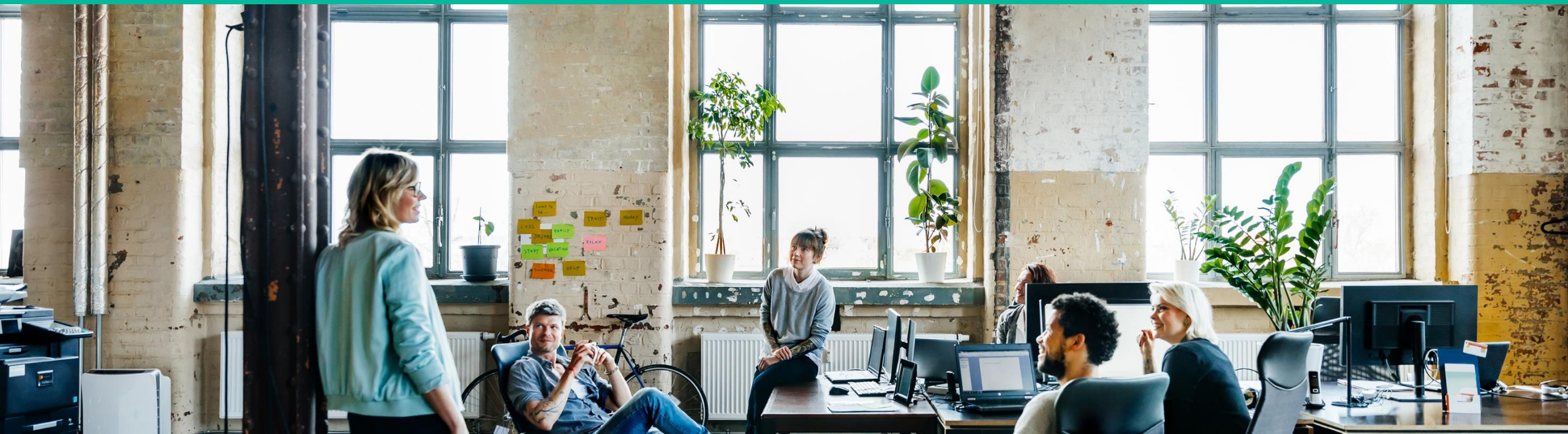


Source: ASHRAE Journal

Building envelope design is the key to energy efficient building

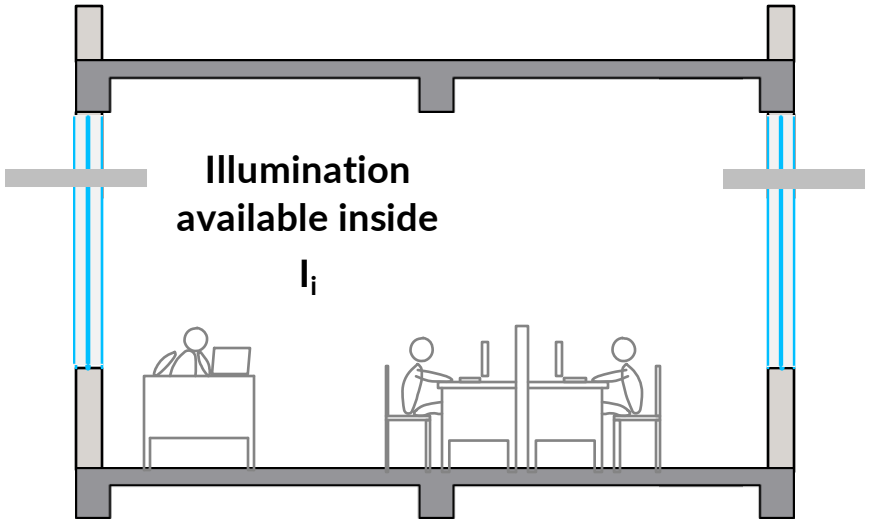
Optimizing Building Envelope

Windows for Better Daylight and Minimum Heat Gain



DAYLIGHT FACTOR AND DAYLIGHT AUTONOMY

Key performance indices for daylight



Daylight Factor = I_i / I_o

Daylight Autonomy:
Percentage of time-in-use that daylight levels exceed a specified target illuminance or lighting set-point

TIME-IN-USE:
Time when building is being used
e.g., 9 am to 6 pm

TARGET ILLUMINANCE / LIGHTING SET-POINT:
Recommended illuminance (lux) levels
e.g., lighting set-point for standard offices is 300 lux–500 lux

Daylight Autonomy:
Percentage of time that an occupant can work through the use of just daylight without supplemental electric lighting

WINDOWS

Sizing and placement

Building spaces can be zoned to place areas requiring more daylight near the perimeter

Areas requiring less daylight placed in the center of the floor plate



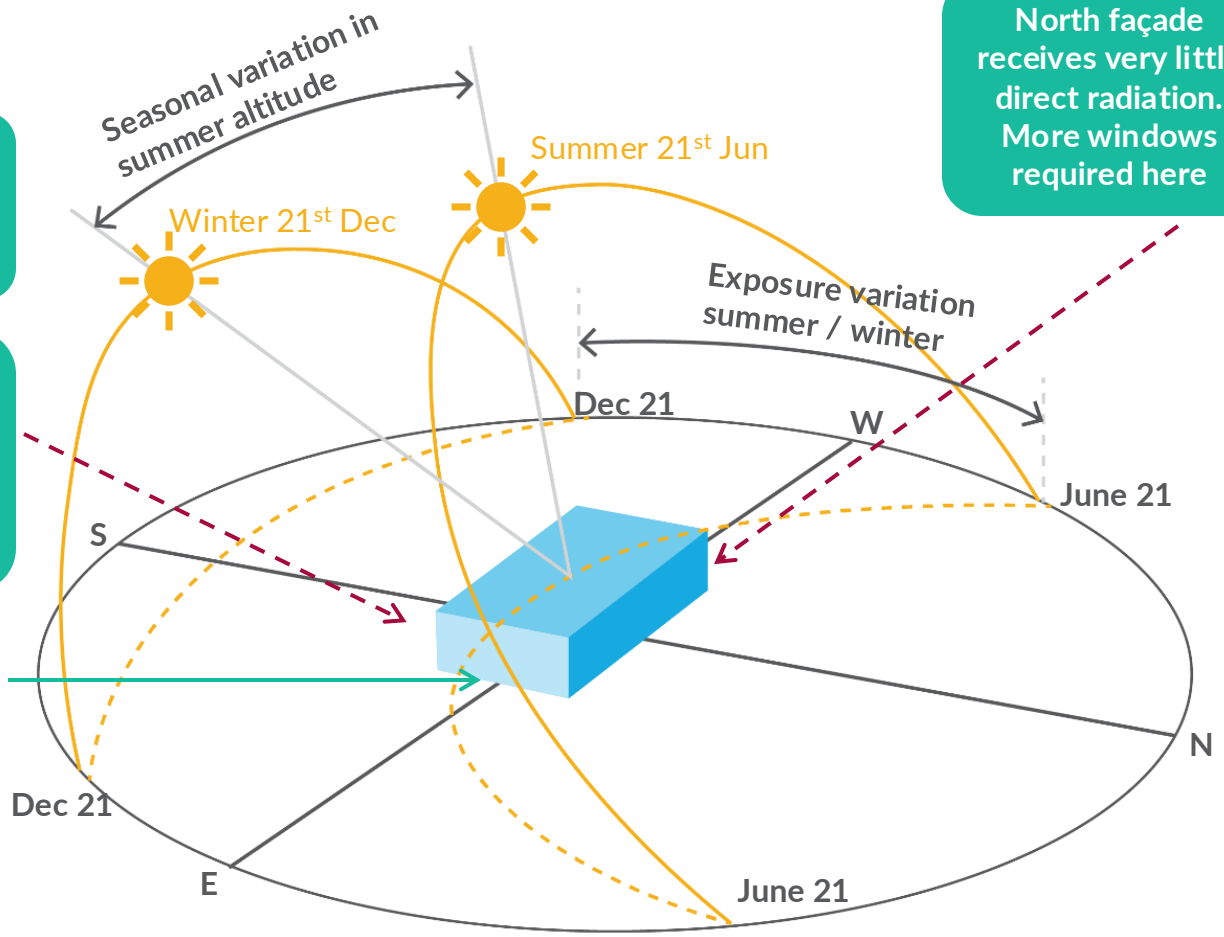
Shallow floor plates provide daylight access to greater floor area

Keep window-to-wall ratio around 20%–30%

South façade is highly exposed in winter, but less in summer. Windows can be easily shaded here

East and west façades receive high amount of radiation. Difficult to shade. Hence, less windows required here

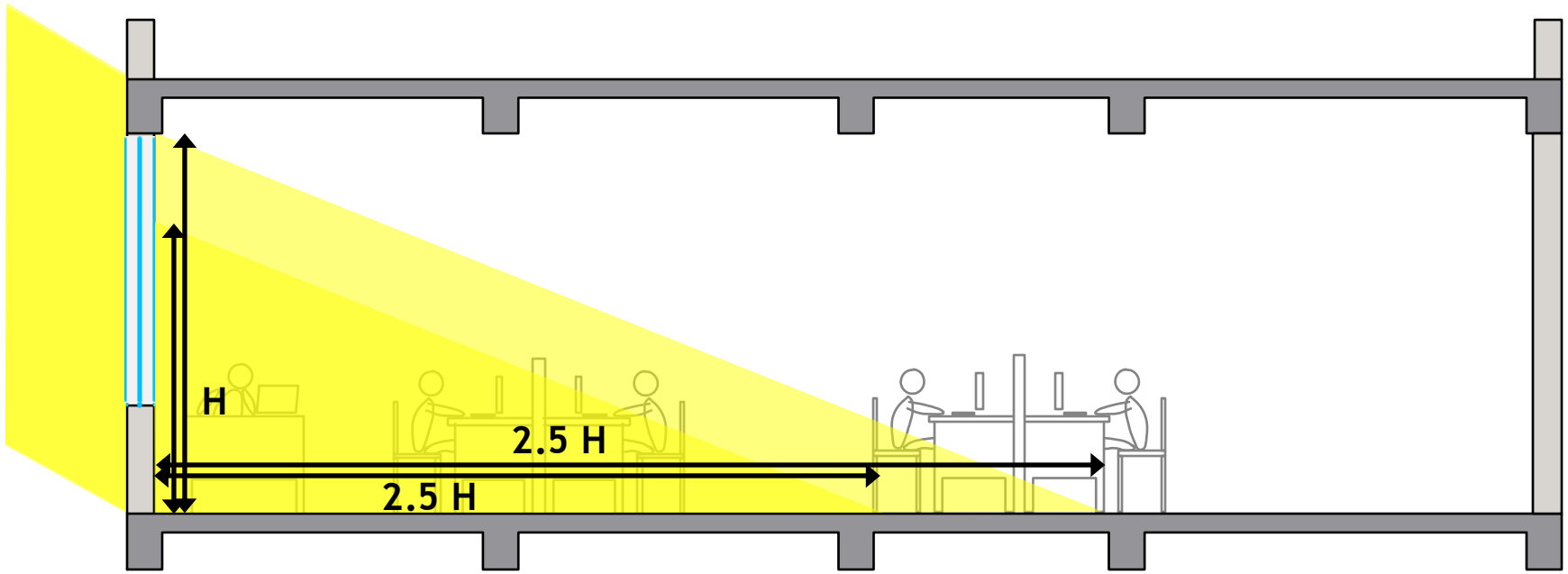
North façade receives very little direct radiation. More windows required here



WINDOWS

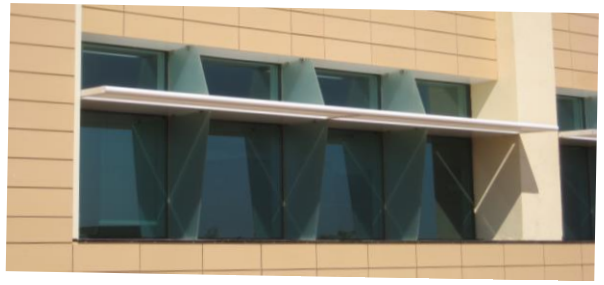
Sizing and placement

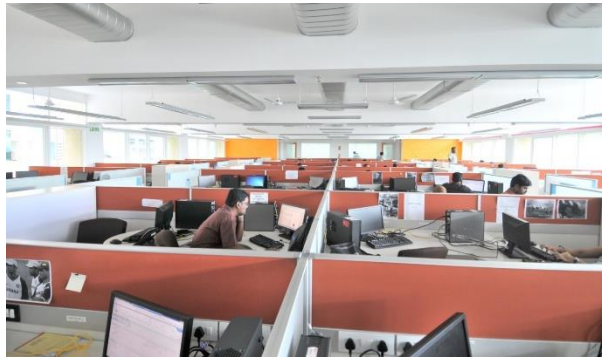
- Daylight penetrates into a room roughly 2.5 times the height of the top of the window from the ground
- The higher the window, the deeper the daylight penetration in the room
- Usually, daylight penetration in the room is 6m–8m from the fenestration



BETTER DAYLIGHT ACCESS

Desirable features



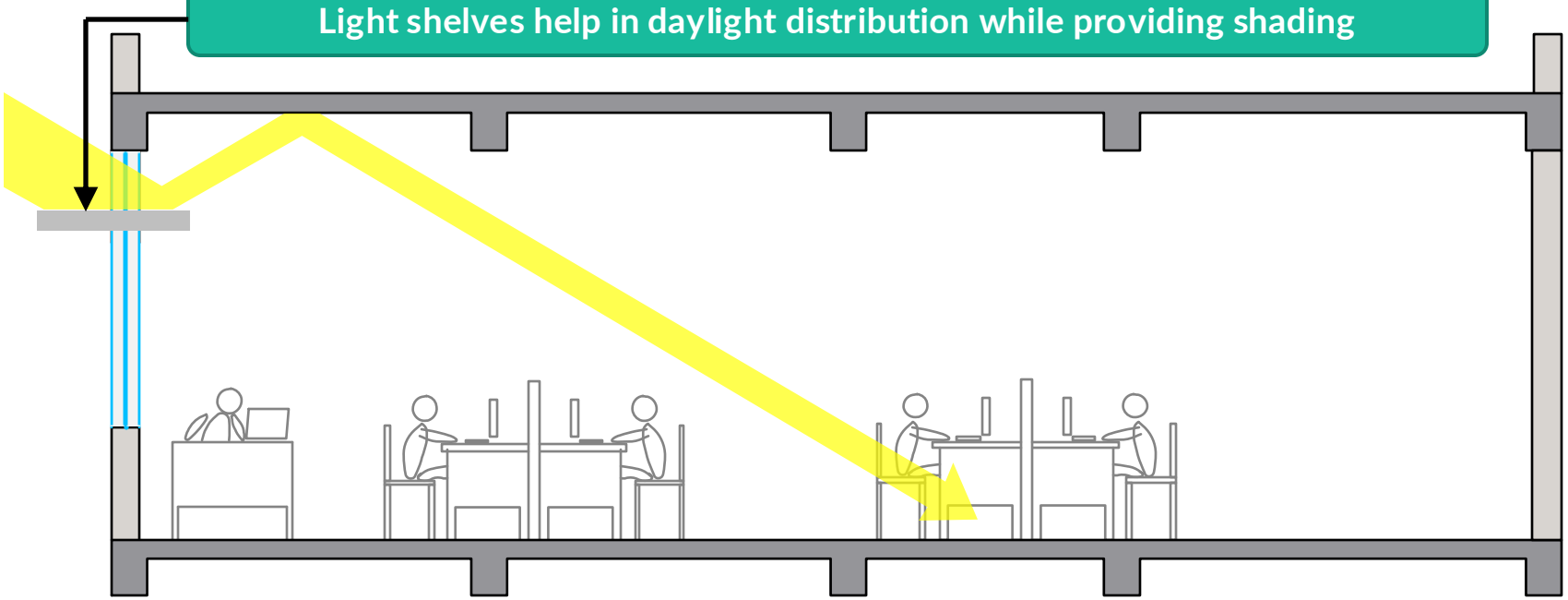


Infosys, Hyderabad Campus

Lighter colors on interior surfaces:

- **Reflect light better**
- **Help in daylight distribution**
- **Reduce glare**

Light shelves help in daylight distribution while providing shading



GLASS PROPERTIES

VLT, SHGC and U-value

VLT is the ratio of visible light that passes through a glazing unit to the total visible light incident on it

Use high VLT glass for better daylight

SHGC is the ratio of solar (radiant) heat gain that passes through the fenestration to the total incident solar radiation that falls on it

SHGC is a dimensionless number between 0 and 1. Use low-SHGC for minimum heat gain

U-value is the overall heat transfer coefficient that indicates the heat transfer from the glass through conduction

Use glass with low U-value for minimal heat gain

FACTORS INFLUENCING VLT:

- Color of glass
- Tints and coatings on the glazing
- Number of glass panes

FACTORS INFLUENCING SHGC:

- Solar protection or shading
- Type of glass and number of panes
- Tints and coatings on the glazing
- Gas fill between glazing layers

FACTORS INFLUENCING U-VALUE:

- Size of the air gap between glass panes
- Coatings on the glazing
- Gas fill between glass panes
- Frame construction

Source: ASHRAE Journal

Optimizing Building Envelope

For Better Ventilation



NATURAL VENTILATION

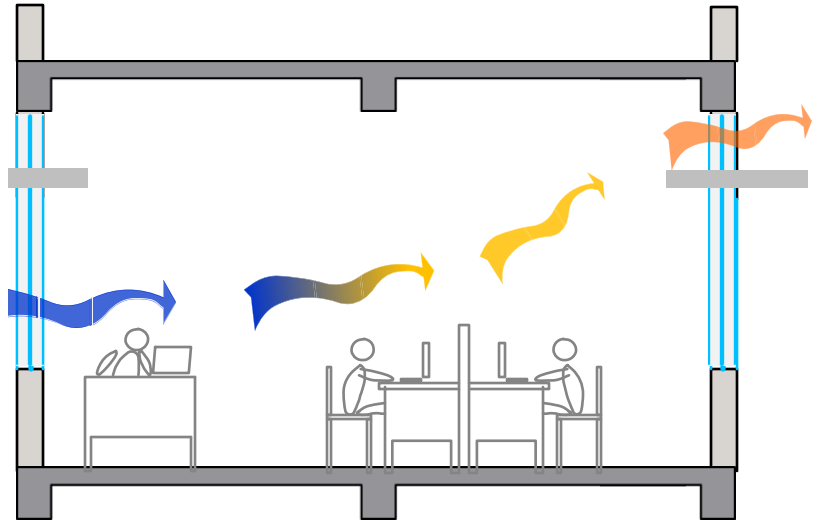
Implications

Natural ventilation (NV) is the process of supplying and removing air through an indoor space without using mechanical systems:

- NV provides acceptable indoor air quality
- NV provides thermal comfort by providing a heat transport mechanism
  - Cooling of indoor air by replacing or diluting it with outdoor air as long as outdoor temperatures are lower than indoor temperatures
  - Cooling of the building structure i.e., thermal mass of building
  - Direct cooling effect over the human body through convection and evaporation

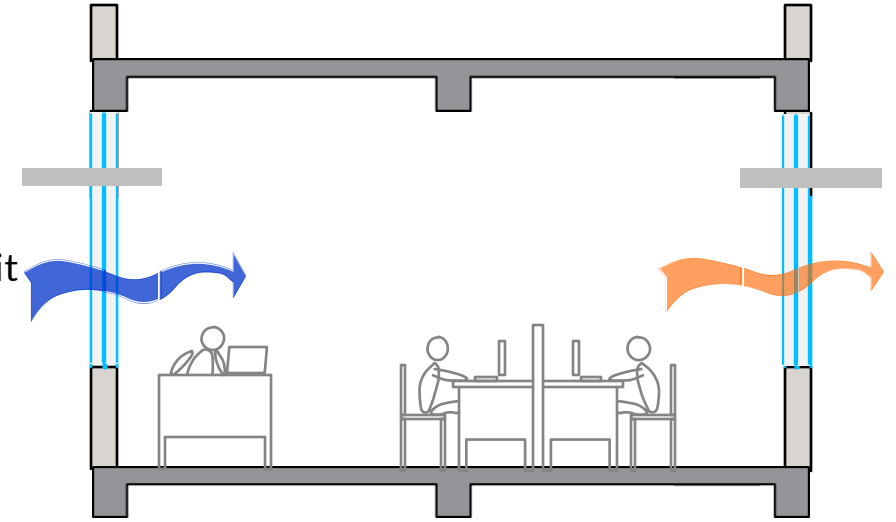
Buoyancy-driven natural ventilation:

- The natural movement of air through a building resulting from differences in vertical pressure developed by temperature differences in the air
- This occurs in a building by warm air escaping from openings at a substantial height on the building envelope, which draws in colder, denser outside air through the lower openings of the building



Wind-driven natural ventilation:

- Relies on wind pressure to drive air movement
- When wind hits the windward façade, it creates a positive pressure on the façade. Similarly, as it flows away from the leeward façade, a region of lower pressure will be created. This pressure difference will force air movement

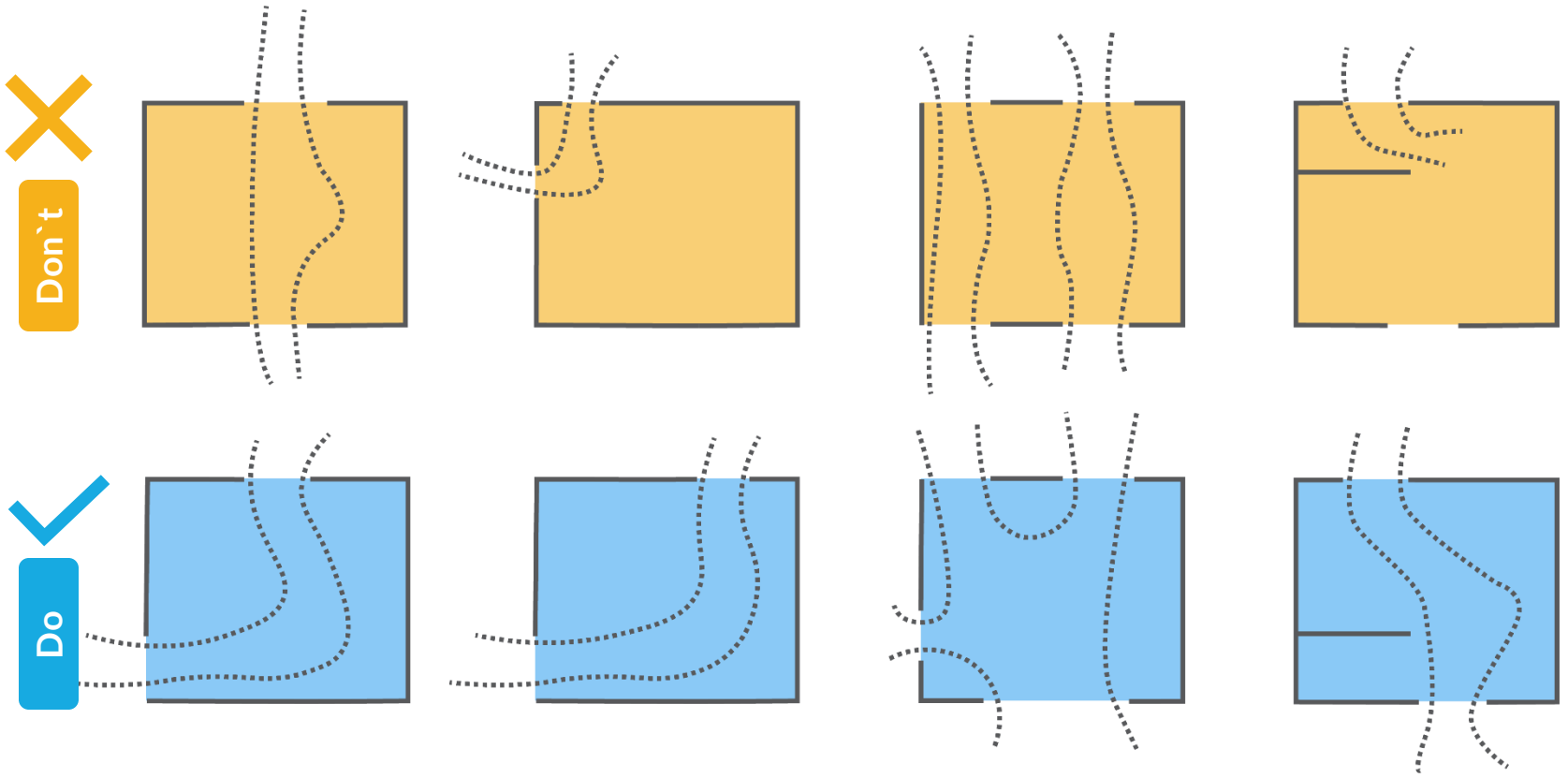


CROSS VENTILATION

Do’s and don'ts

Windows located diagonally opposite to each other with the windward window near to the upstream, offers better performance than other window arrangements

The placement of window openings can alter air movement inside spaces

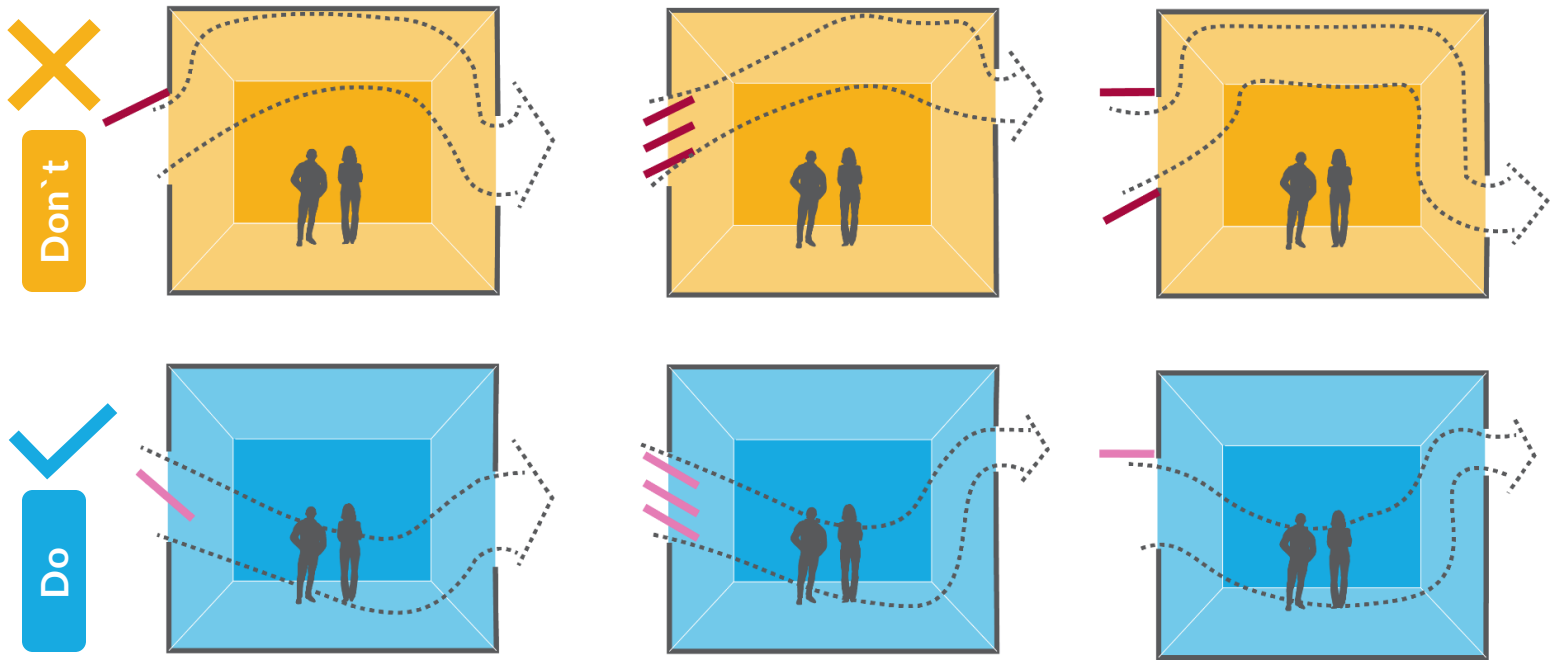


CROSS VENTILATION

Do's and don'ts

- The provision of horizontal sashes at an angle of 45° in the appropriate direction helps in promoting indoor air movement
- Sashes projecting outward are more effective than inward

Position of overhangs and louvers can be used to direct the air inside at the required level and area

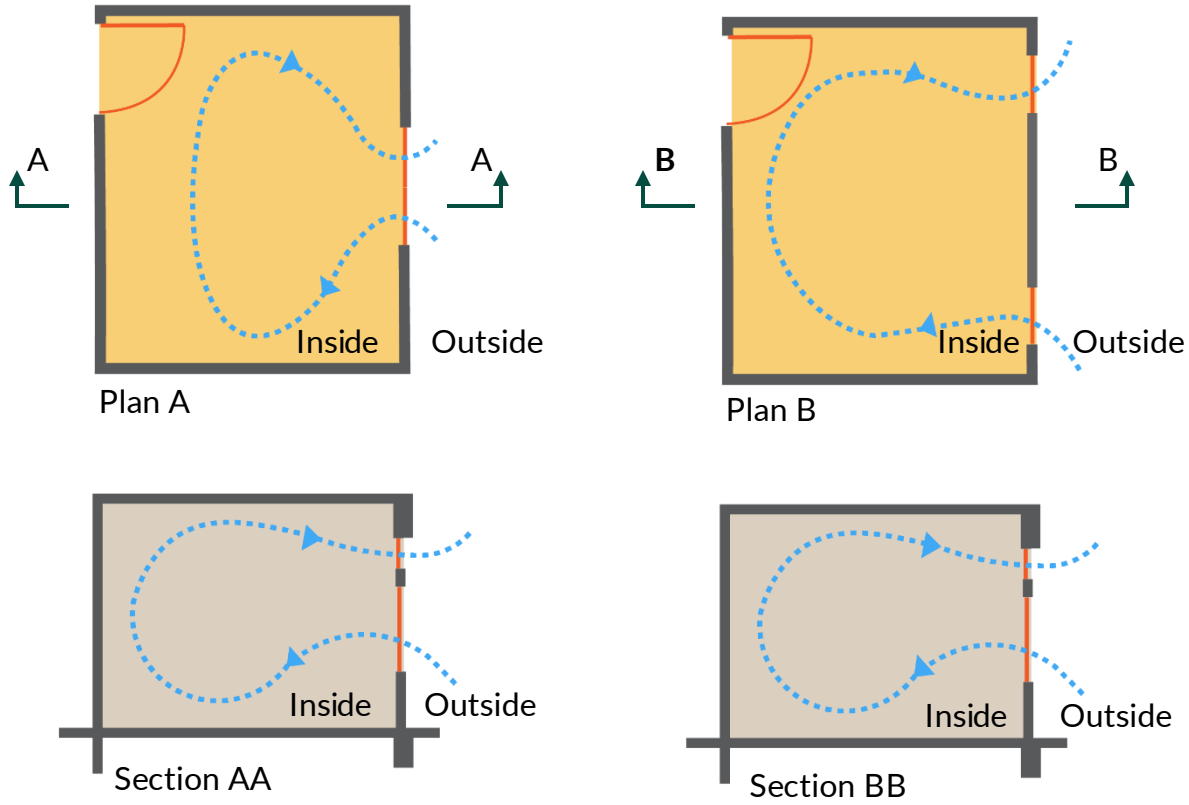


ONE-SIDED VENTILATION

Do’s and don’ts

Single-sided ventilation is the scenario in which only a single façade of the building is exposed to wind and openable windows are located on a single wall. In such cases, it is preferred to provide at least two windows on the façade

Provision of two windows on the same façade

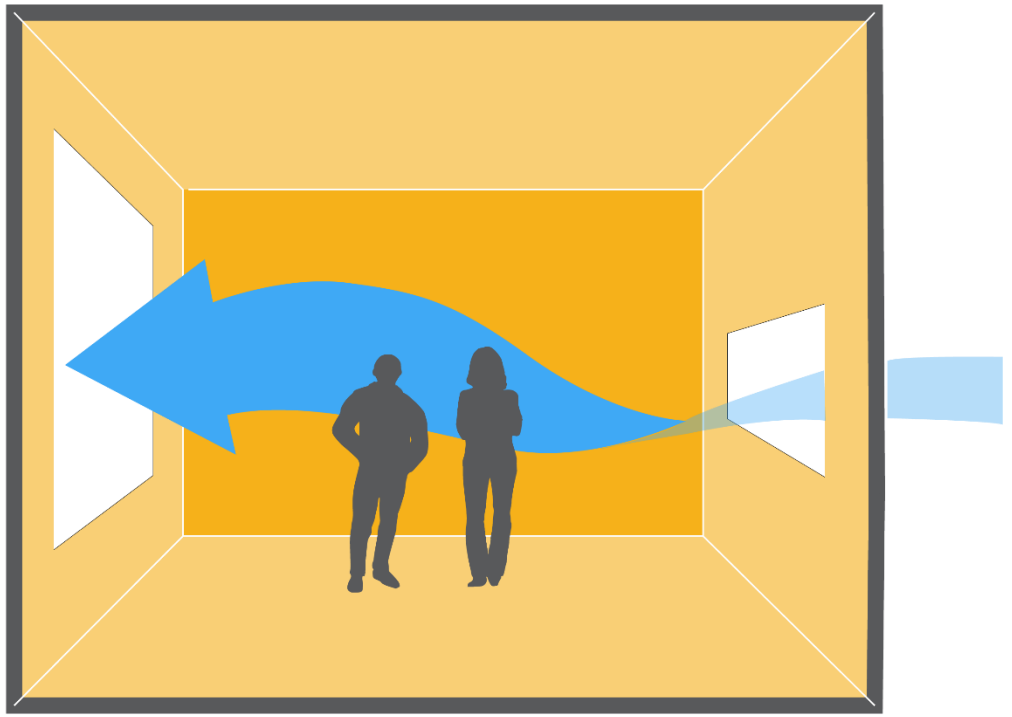


WINDOW SIZING

In naturally-ventilated buildings

- Window size can affect both the amount of air and its speed
- For an adequate amount of air, one rule of thumb states that the area of operable windows or louvers should be 20% or more of the floor area, with the area of inlet openings roughly matching the area of outlets
- To increase cooling effectiveness, a smaller inlet can be paired with a larger outlet opening. With this configuration, inlet air can have a higher velocity

Usually a ratio of 1:2.5 or 1:3 between windward side and leeward side is preferred in tropical areas



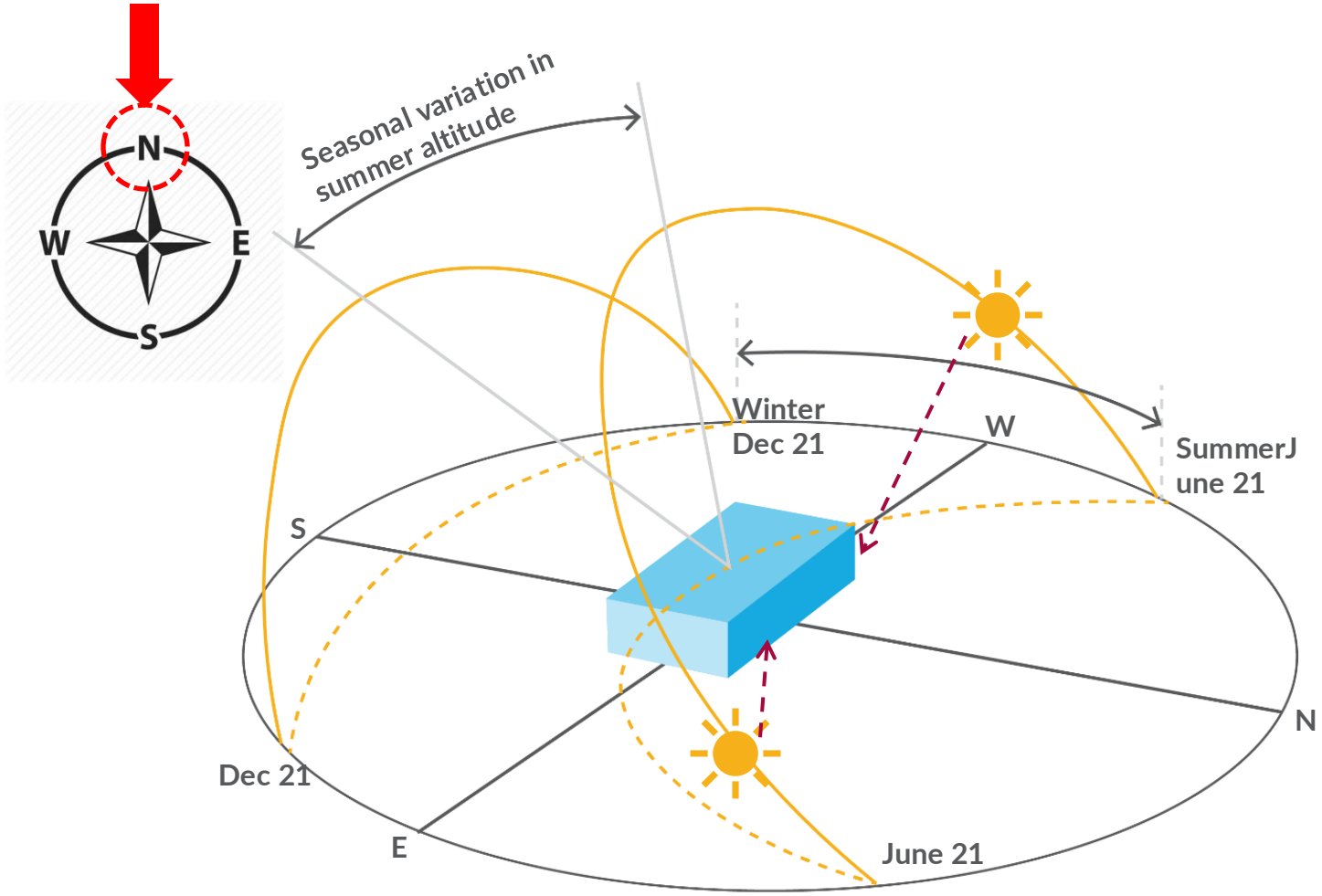
Solar Shading



SOLAR SHADING

North façade

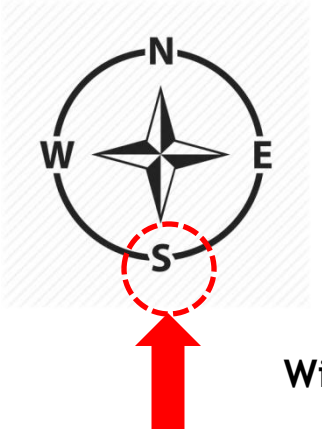
- In the northern hemisphere, north-facing windows receive direct sunlight in summer mornings and evenings
- Vertical fins can shade adequately

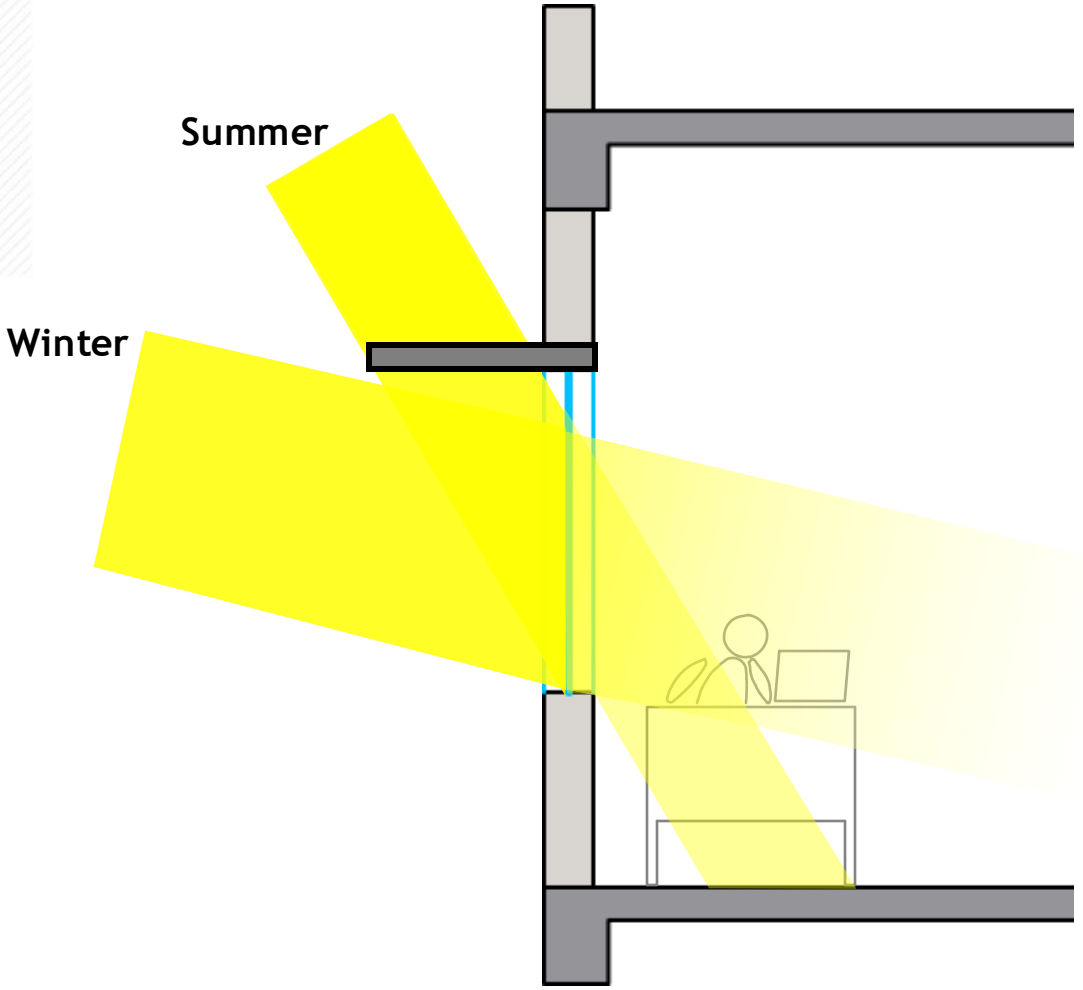


SOLAR SHADING

South façade

In the northern hemisphere, horizontal overhangs can effectively cut direct solar radiation on the south façade in summer



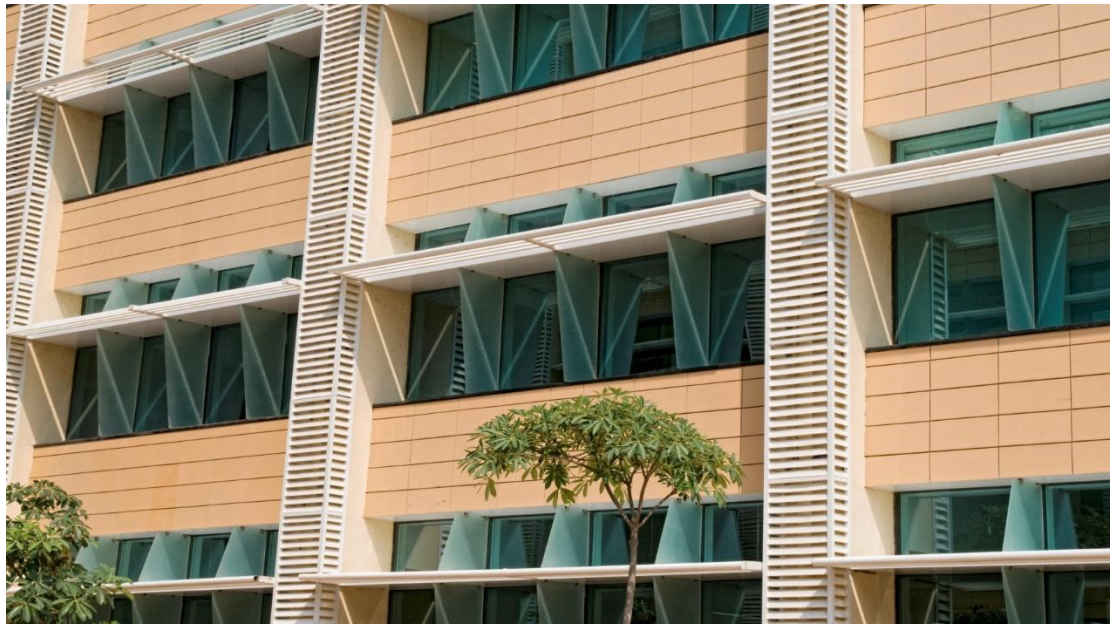


SOLAR SHADING

Case examples: South façade



Institute of Rural Research and Development, Gurugram, India

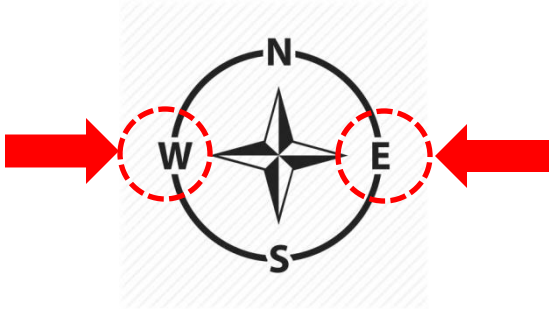


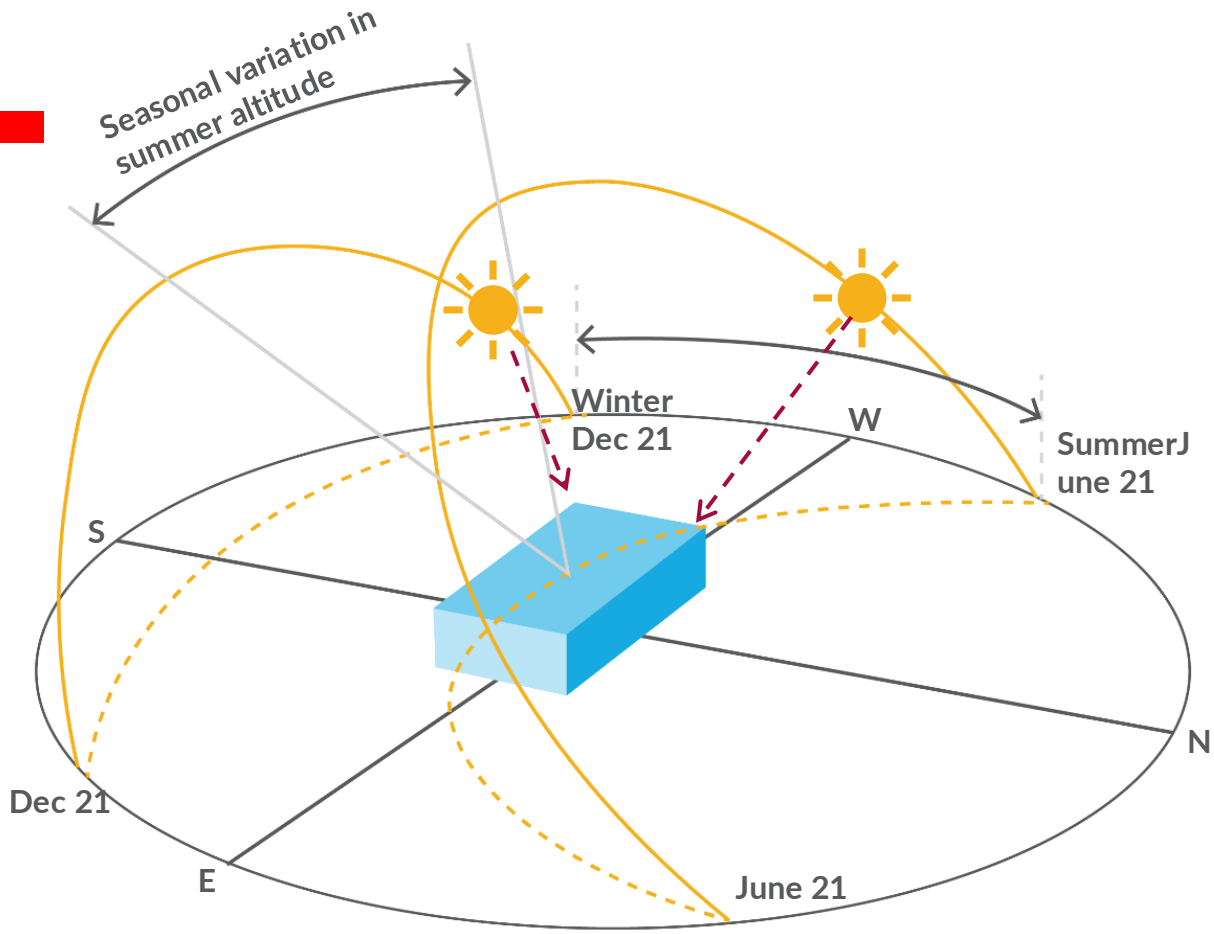
Infosys, Hyderabad, India

SOLAR SHADING

East and west façades

- Low sun on east and west façades
- Solar azimuth angle also changes
- **Dynamic shading** most effective on east and west façades





EXTERNAL MOVABLE SHADING

Case examples: East and west façades



Rolex Learning Centre, Lausanne



Safal Profitaire, Ahmedabad

EXTERNAL MOVABLE SHADING

Reduces solar heat gains by 60%–80%

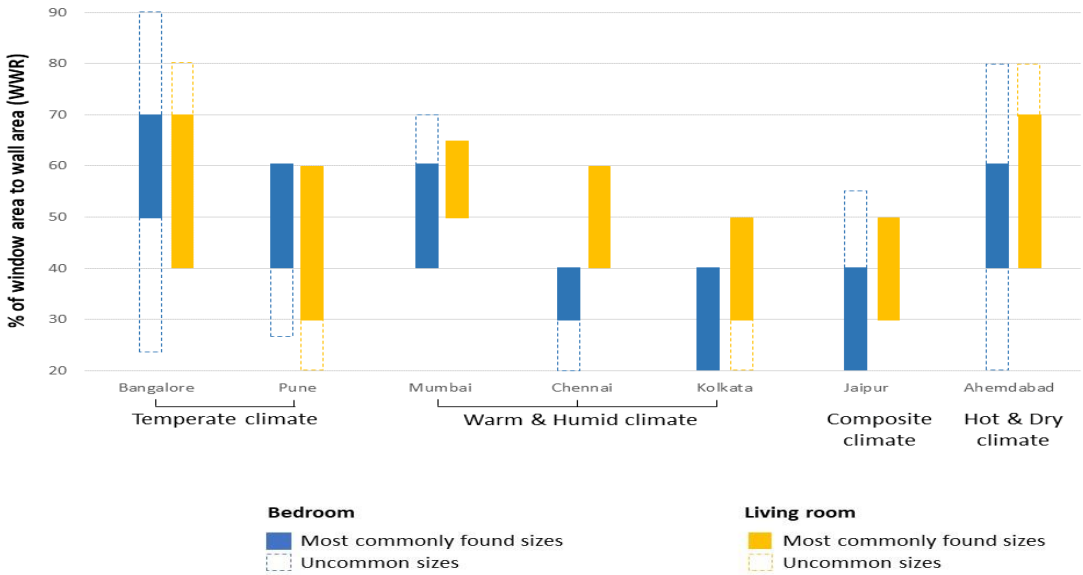
- Performance monitoring of **two identical flats** on the 10th and 11th floor in Gurugram
- One flat with **external movable shading** and the other with **internal curtains**
- Monitored for both **naturally-ventilated (NV) and air-conditioned (AC)** cases

NV

A difference of **~3.5°C** was observed in peak inside operative temperature in naturally-ventilated case

AC

A difference of **~32%** was observed in cumulative cooling demand (thermal) in air-conditioned case

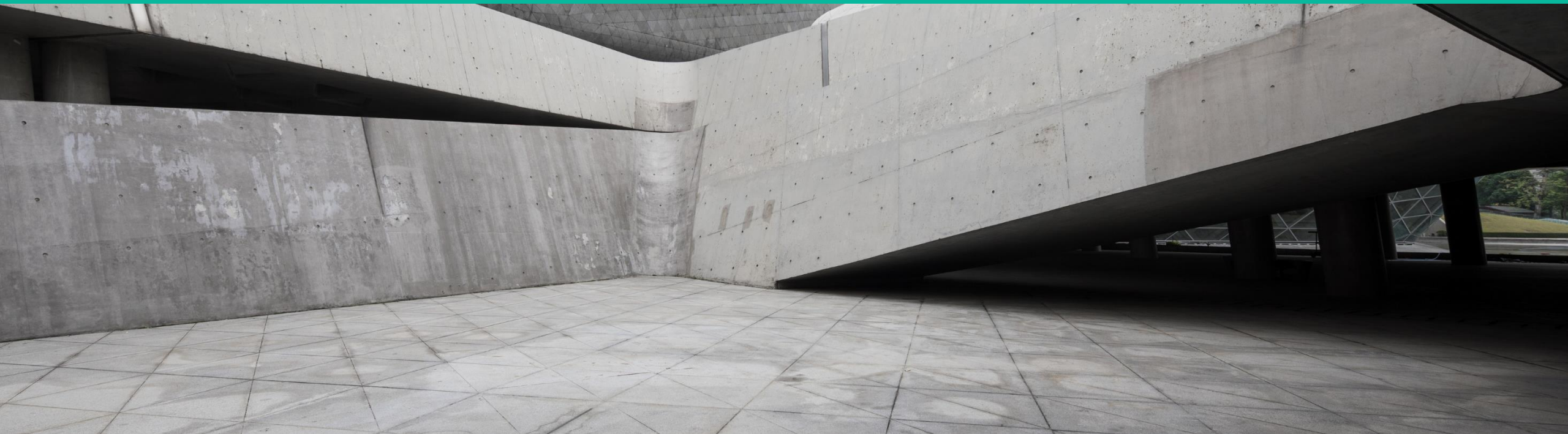


- Trends **of increasing window areas** in residential buildings
- Window-to-wall ratio of 50 buildings spread over 7 cities measured
- Low-income, middle-income and high-income housing covered in study
- **High-income houses showed the largest window sizes across all cities and climate zones**

Source: Ministry of Power, Government of India, 2022b

Optimizing Building Envelope

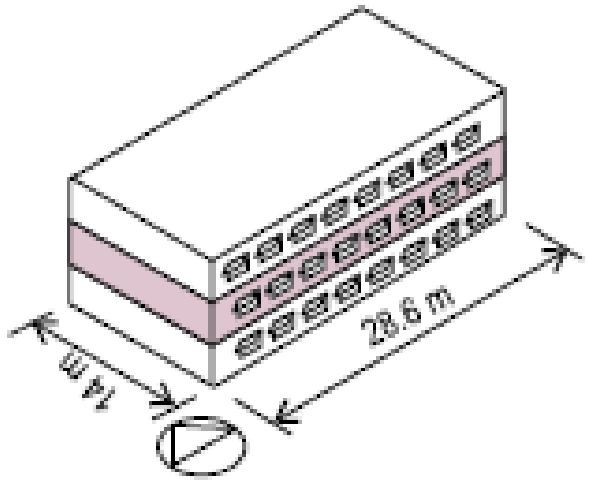
Walls and Roofs



WALLS AND ROOFS

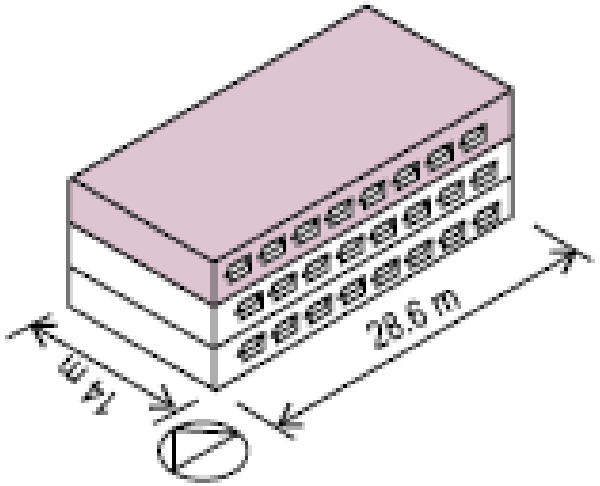
Reducing solar heat gains

- Walls with **high thermal mass and low U-value**
- Use of insulation
  - **Roofs** - All climates
  - **Walls** – All climates, excluding warm-humid climates



Level: Intermediate floor 6 inch RCC slab with plaster (U-value: 3.8 W/m^2.K)

In case of an intermediate floor, heat gain from window is highest

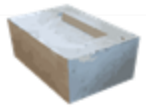
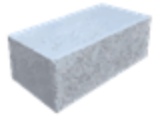


Roof: 150mm RCC slab with plaster (U-value: 3.8 W/m^2.K)

In case of top floor, heat gain from roof is highest

WALLING MATERIALS

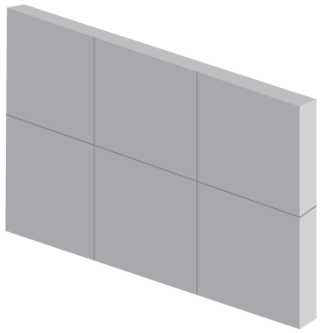
Comparative thermal properties and embodied carbon

	Type	U-Value (W/m.K)	Thermal Mass	Embodied Energy
	Solid Fired Clay Brick	Medium (0.4–1.0)	Medium to High	1,616 MJ/m^2
	Hollow Clay Fired Block	High (0.3)	Low to Medium	814 MJ/m^2
	Compressed Stabilized Earth Brick	Medium (0.6–1.0)	High	203 MJ/m^2
	Fly Ash Brick	Medium (0.4–0.9)	Medium to High	466 MJ/m^2
	Concrete Block	Poor (1.0–1.5)	High	407 MJ/m^2
	Autoclaved Aerated Concrete Block	High (0.2)	Low to Medium	317 MJ/m^2

Sources: Bureau of Energy Efficiency, Government of India, 2024; EDGE

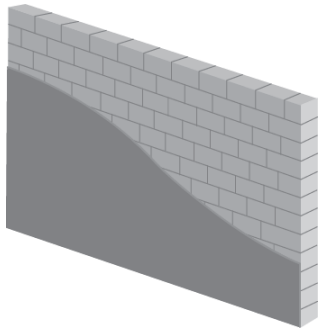
TYPES OF WALLING ASSEMBLIES

U-values



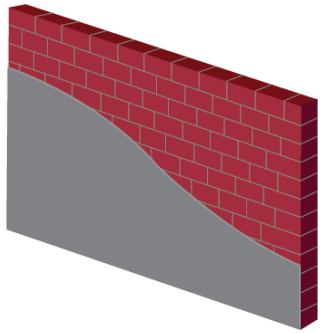
150 mm RCC (no plaster)

U-value
3.77 W/m^2.K



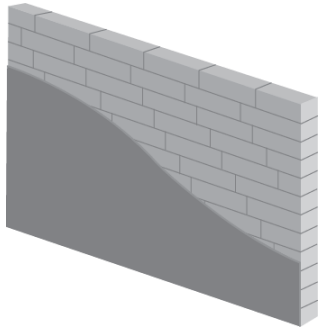
200 mm solid concrete block with 15 mm plaster on both sides

U-value
2.8 W/m^2.K



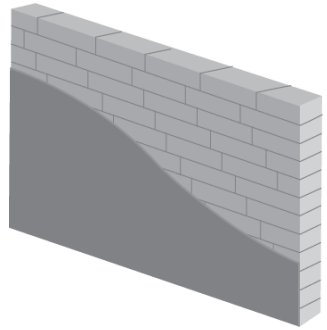
230 mm brick with 15 mm plaster on both sides

U-value
1.72–2.24 W/m^2.K



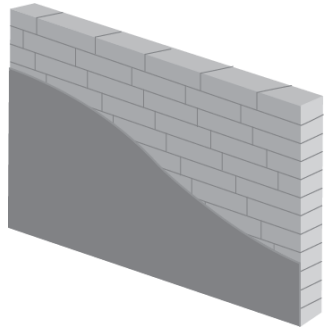
200 mm autoclaved aerated concrete with 15 mm plaster on both sides

U-value
0.77 W/m^2.K



300 mm autoclaved aerated concrete with 15 mm plaster on both sides

U-value
0.54 W/m^2.K



230 mm thick cavity wall of bricks (115 mm outer wall, 75 mm inner wall with 40 mm cavity)

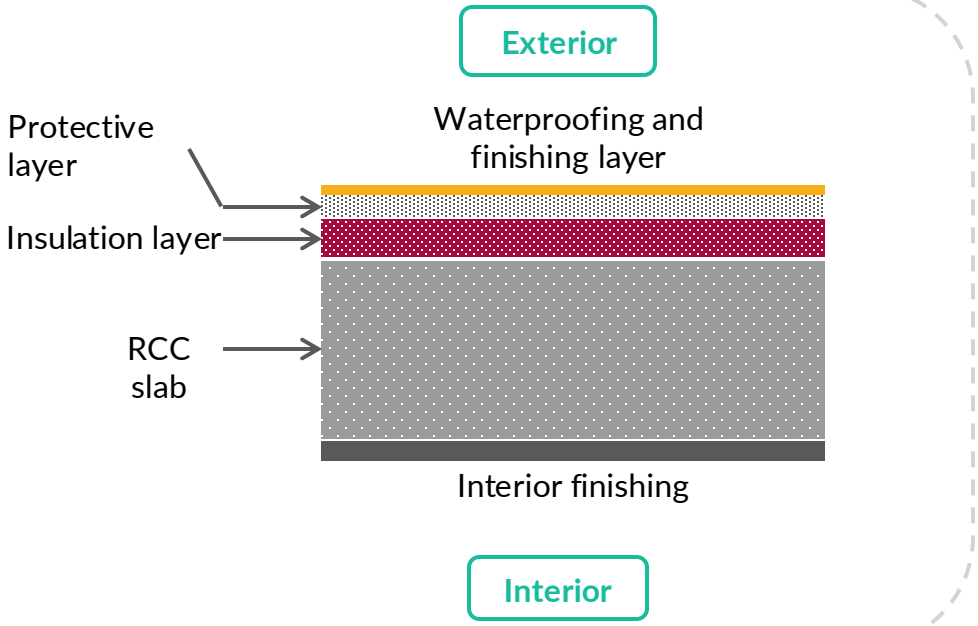
U-value
0.62 W/m^2.K

Source: Bureau of Energy Efficiency, Government of India, 2024

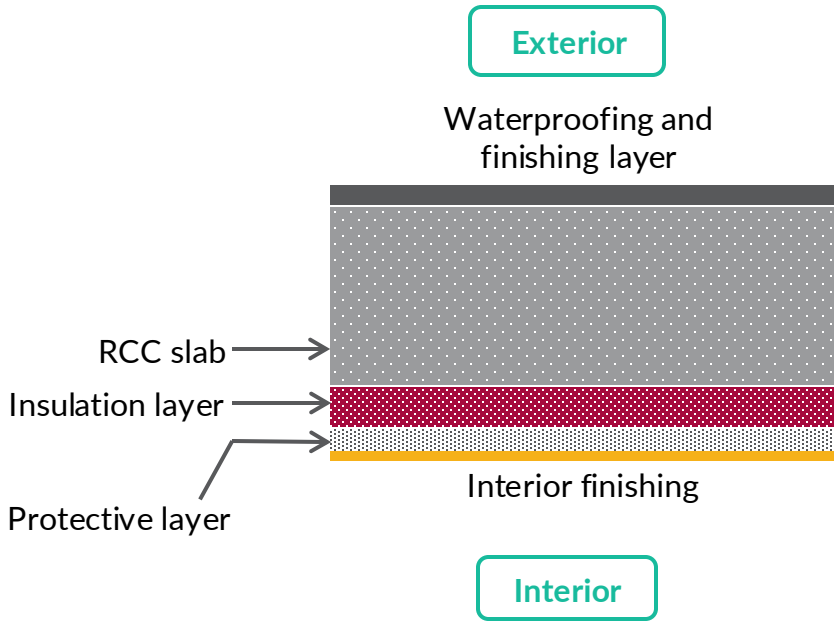
ROOF INSULATION

Methods of application

Thermal conductivity of common insulation materials usually range from 0.03–0.05 W/m.K which is 1/10th to 1/20th that of fired clay brick



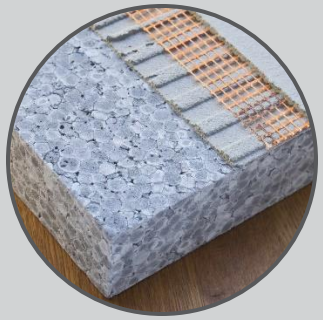
Roof with over-deck insulation



Roof with under-deck insulation

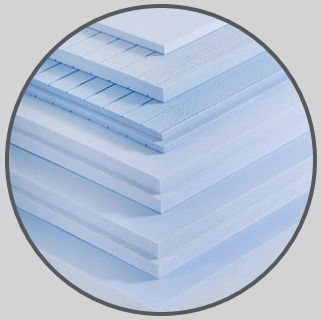
BUILDING INSULATION

Rigid insulation materials



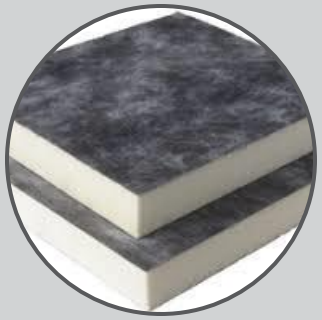
Expanded Polystyrene (EPS)

- Composed of small beads of polystyrene that are fused together
- Colorless and transparent thermoplastic material



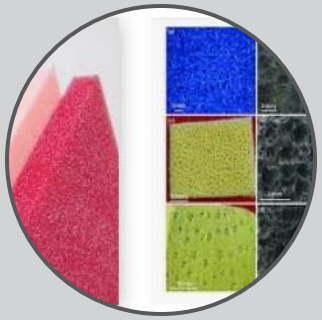
Extruded Polystyrene (XPS)

- Made of polystyrene, in which molten polystyrene is pressed out of a form into sheets



Polyisocyanurate (PIR)

- Thermosetting type of plastic, closed-cell foam that contains in its cells a hydro-chlorofluorocarbon-free gas of low conductivity
- Available as liquid, sprayed foam and rigid foam board



Polyurethane (PUR)

- Foam insulation material that contains in its cells a gas of low conductivity

INSULATION MATERIALS

Fibrous insulation materials



Glass Wool

- Made from extremely fine fibers of glass
- Arranged into a texture similar to wool by using a binder
- Small air pockets between the glass, which ensures high thermal insulation
- Available in three different forms – blanket (batts and rolls), loose-fill and rigid boards



Mineral Wool

- Rock wool, a synthetic material consisting of natural minerals like basalt or diabase
- Slag wool, a synthetic material from blast furnace slag (the scum that forms on the surface of molten metal)

INSULATION MATERIALS

Natural organic materials



Hemp Insulation

- Made from hemp wool
- Hemp wool is strong and woody fibers that are derived from the hemp plant



Cellulose Insulation

- Plant fiber used in wall and roof for insulation purposes
- Modern cellulose insulation is made from either ground recycled paper or recycled denim



Straw Insulation

- Straw bales are made from agro-waste. Once the edible part of the grain has been harvested (such as wheat or rice), the remaining waste is compressed to make insulation panels

COOL ROOF

Reflective external roof surfaces

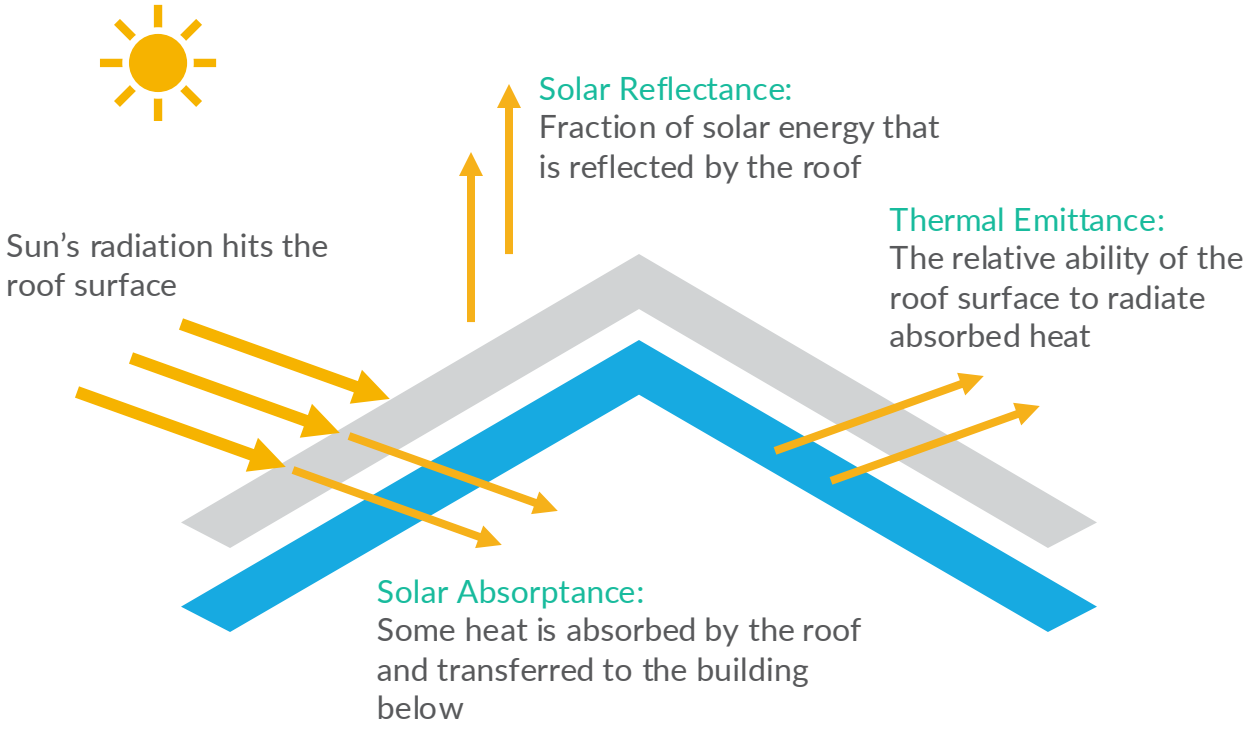
- High Solar Reflectance Index finishes on roofs
- Use of **insulation in all climates** (preferably over-deck)

Cool roofs reflect sunlight back to the atmosphere to a greater extent than regular roof surfaces

When solar radiation falls on a roof, the roof surface performs three functions:

- Reflects a part of the incident solar radiation back into the atmosphere
- Conducts a part of the heat through itself into the buildings
- Transfers a part of the heat to the ambient air (external and internal)

Cool roofs emit a part of the absorbed heat to internal surfaces and the rest back to the sky



COOL ROOF

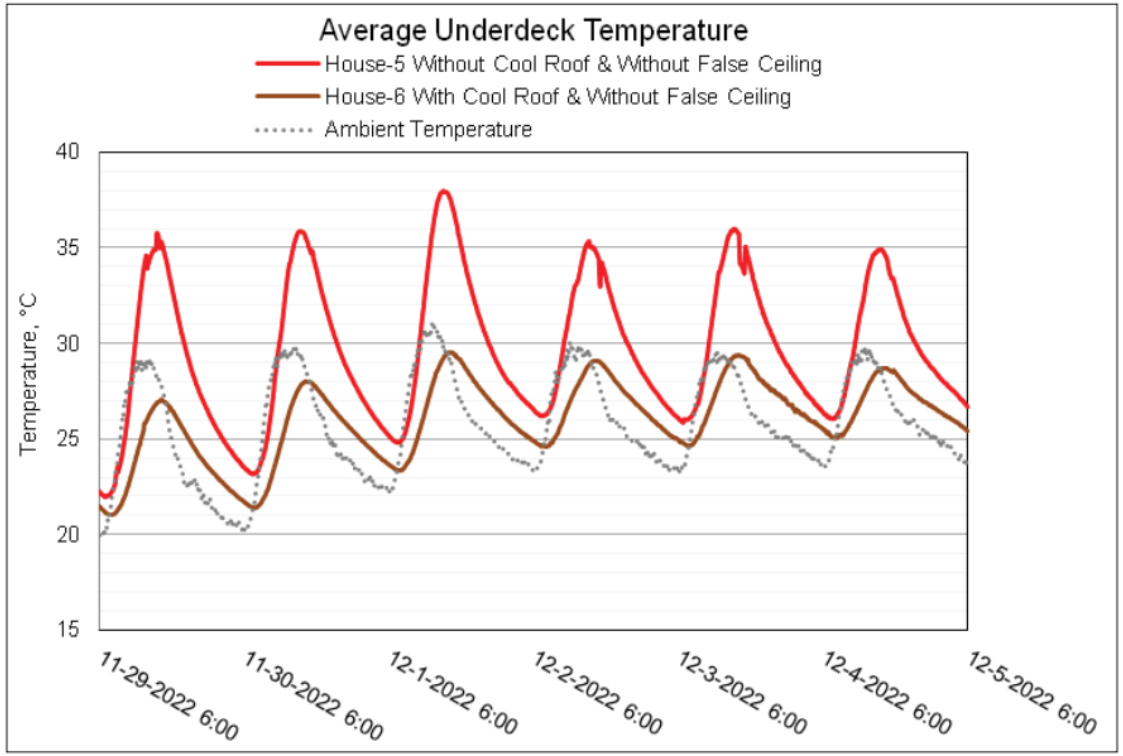
Case study: Affordable Housing Project, Andhra Pradesh, India

Comparative performance monitoring to monitor the impact of cool roofs in Andhra Pradesh. Total 12 houses in 3 locations were monitored – half of the houses with cool roof and other half without the cool roof





Reduction of around 6°C–9°C in under-deck temperatures was found with cool roof application (without any false ceiling)



Building Envelope Features

Recommendations for Different Climates



HOT AND DRY CLIMATE

Key recommendations

OBJECTIVES	PHYSICAL MANIFESTATION
1) Resist heat gain	
• Decrease exposed surface area	• Orientation and shape of building
• Increase thermal resistance	• Insulation of building envelope
• Increase thermal capacity (time lag)	• Massive structure
• Increase buffer spaces	• Air locks, lobbies, balconies, verandas
• Decrease air exchange rate (ventilation during daytime)	• Weather stripping and scheduling air changes
• Increase shading	• External surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	• Pale color, glazed china mosaic tiles, etc.
2) Promote heat loss	
• Ventilation of appliances	• Provide windows and exhausts
• Increase air exchange rate (ventilation during nighttime)	• Courtyards, wind towers, arrangement of openings
• Increase humidity level	• Trees, water ponds, evaporative cooling

Source: Nayak and Prajapati, 2006

WARM AND HUMID CLIMATE

Key recommendations

OBJECTIVES	PHYSICAL MANIFESTATION
1) Resist heat gain	
• Decrease exposed surface area	• Orientation and shape of building
• Increase thermal resistance	• Roof and wall insulation. Reflective surface of roof
• Increase buffer spaces	• Balconies and verandas
• Increase shading	• Walls and glass surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	• Pale color, glazed china mosaic tiles, etc.
2) Promote heat loss	
• Ventilation of appliances	• Provide windows and exhausts
• Increase air exchange rate (ventilation throughout the day)	• Ventilated roof construction, courtyards, wind towers, and arrangement of openings

Source: Nayak and Prajapati, 2006

TEMPERATE CLIMATE

Key recommendations

OBJECTIVES	PHYSICAL MANIFESTATION
1) Resist heat gain	
• Decrease exposed surface area	• Orientation and shape of building
• Increase thermal resistance	• Roof insulation and east and west wall insulation
• Increase shading	• East and west walls and glass surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	• Pale color, glazed china mosaic tiles, etc.
2) Promote heat loss	
• Ventilation of appliances	• Provide windows and exhausts
• Increase air exchange rate (ventilation)	• Courtyards and arrangement of openings

Source: Nayak and Prajapati, 2006

COMPOSITE CLIMATE

Key recommendations

OBJECTIVES	PHYSICAL MANIFESTATION
1) Resist heat gain in summer and resist heat loss in winter	
• Decrease exposed surface area	• Orientation and shape of building. Use of trees as wind barriers
• Increase thermal resistance	• Roof and wall insulation
• Increase thermal capacity (time lag)	• Thicker walls
• Increase buffer spaces	• Air locks and balconies
• Decrease air exchange rate	• Weather stripping
• Increase shading	• Walls and glass surfaces protected by overhangs, fins and trees
• Increase surface reflectivity	• Pale color, glazed china mosaic tiles, etc.
2) Promote heat loss in summer and monsoon	
• Ventilation of appliances	• Provide exhausts
• Increase air exchange rate (ventilation)	• Courtyards, wind towers, arrangement of openings
• Increase humidity level in dry summer	• Trees and water ponds for evaporative cooling

Source: Nayak and Prajapati, 2006

COLD CLIMATE

Key recommendations

OBJECTIVES	PHYSICAL MANIFESTATION
1) Resist heat gain in summer and heat loss in winter	
• Decreased exposed surface area	• Orientation and shape of building. Use of trees as wind barriers
• Increase thermal resistance	• Roof insulation, wall insulation and double glazing
• Increase thermal capacity (time lag)	• Thicker walls
• Increase buffer spaces	• Air locks and lobbies
• Decrease air exchange rate	• Weather stripping
• Increase air absorptivity	• Darker colors
2) Promote heat loss in summer and monsoon	
• Reduce shading	• Walls and glass
• Utilize heat from appliances	
• Trapping heat	• Sun walls, green houses, Trombe walls, etc.

Source: Nayak and Prajapati, 2006

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

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Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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on the basis of a decision by the German Bundestag



GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

2.3 Adaptive Thermal Comfort Design Strategies

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

01 Understand human comfort perceptions

02 Factors affecting human thermal comfort

03 Understand dynamics of heat generation and dissipation from human body

04 The importance of optimal air movement in rooms

05 ASHRAE Standards for adaptive thermal comfort

06 Models for adaptive thermal comfort

07 Potential solutions



Image source: https://www.firstinarchitecture.co.uk/internal-environment-thermal-air-sound-and-light/

Human Comfort in Buildings

Indoor Environment



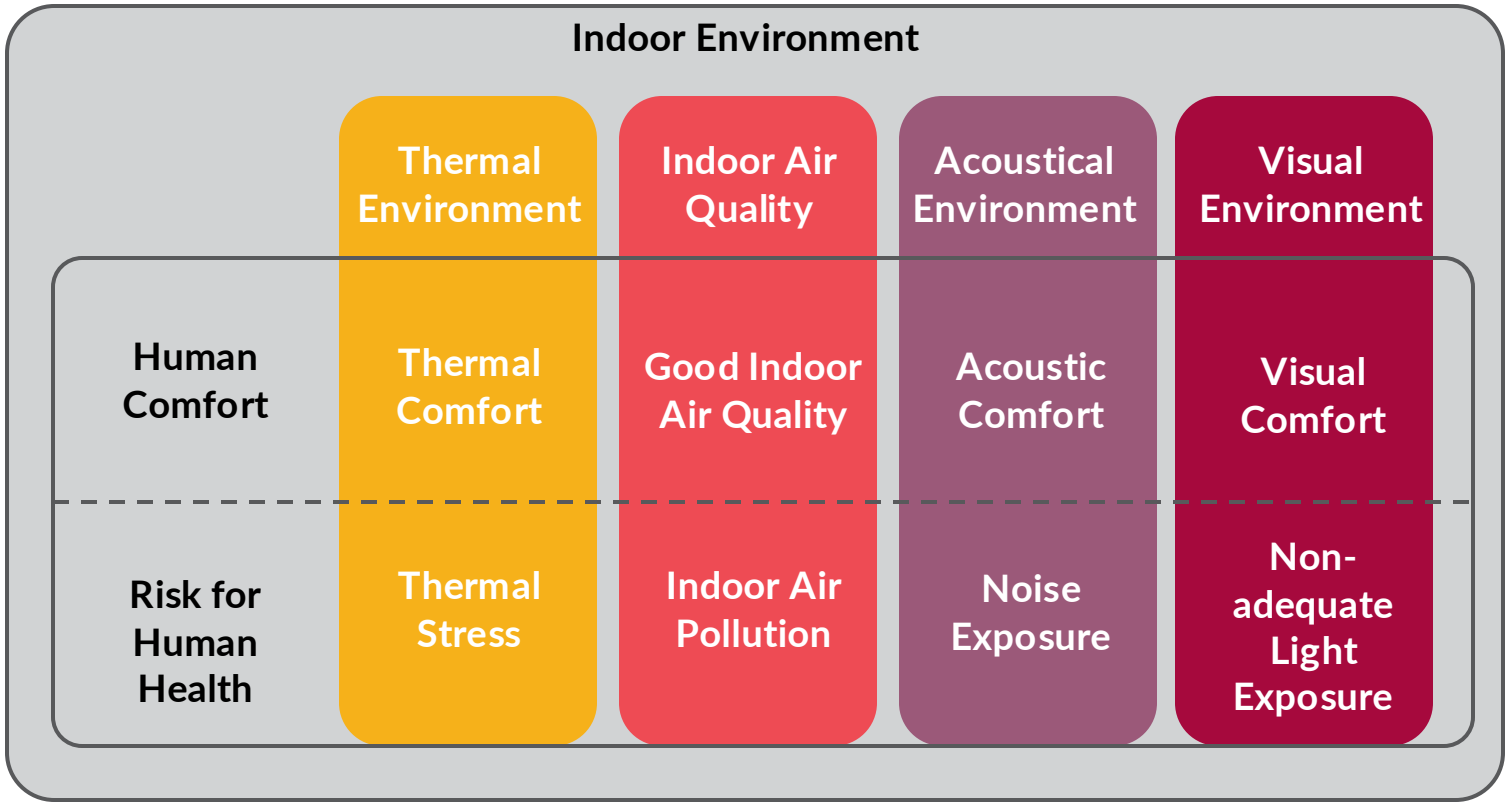
INDOOR ENVIRONMENT QUALITY

For human comfort

Human comfort within buildings can be categorized into four comfort parameters:

i. Thermal
ii. Visual
iii. Acoustical
iv. Indoor air quality

Each parameter can gradually impact **human health**, if not maintained to prescribed limits



Source: Fantozzi and Rocca, 2020

VISUAL COMFORT

Indoor environment

Sharp contrast or major change in light levels can **cause stress and fatigue**, as the human eye then has to constantly adjust to varying lighting levels

Both **too much and too little light** can be a cause of visual discomfort

Factors determining healthy visual environment include:

- Access to the outside view
- Adequate daylight without glare
- Uniformly distributed light within the space
- Adequate task lighting



Source: Franco, 2019

ACOUSTICAL COMFORT

Indoor environment

Four types of noise, emanating from the following sources, are usually experienced in buildings:

i. Exterior
ii. Interior
iii. Impact
iv. Equipment

These noises are transmitted through the building fabric.

The nature of the sounds and its perception by the human ear depends on its **reverberation and absorption within the building**



Source: Leardi, 2021

AIR QUALITY

Indoor environment

Health effects of poor indoor air quality:

i. Respiratory problems
ii. Headaches and fatigue
iii. Allergic reactions
iv. Long-term health risks

Common indoor air pollutants

i. Dust and particulate matter
ii. Mold and mildew
iii. Carbon monoxide
iv. Volatile organic compounds (VOCs)
v. Radon



Thermal Comfort

Adaptive Thermal Comfort



THERMAL COMFORT

And discomfort!!!



One person's comfort is another's discomfort

- The complaint of a person suffering warm, humid room condition may be legitimate
- But often, it is people in centrally air-conditioned rooms who complain of poor or excessive cooling



Cases of partially-sealed air supply duct outlets, installation of pedestal fans in air-conditioned spaces, and installation of split air conditioners in centrally air-conditioned rooms

Image source: SM Solutions

THERMAL COMFORT

Definition and influencing factors

Thermal comfort:

A state of mind that expresses satisfaction with the thermal surroundings

Influencing factors

- Activity (Metabolic Rate)
- Clothing
- Air Temperature
- Mean Radiant Temperature
- Air Movement
- Humidity

Depends on person specific activities

Depends on climatic conditions, building and HVAC design





Source: American Society of Heating, Refrigerating and Air-Conditioning Engineers

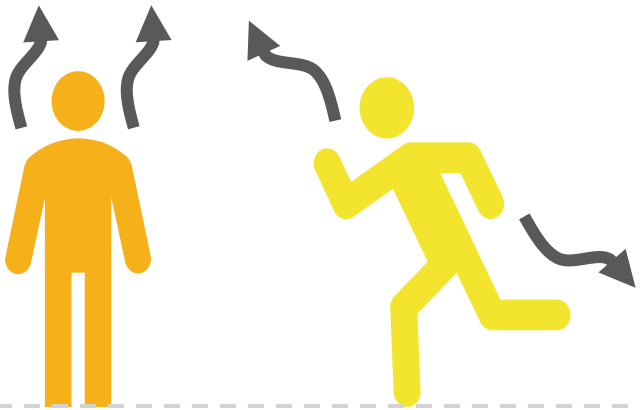
Image source: https://www.freepik.com/free-photo/1

THERMAL COMFORT

Facts

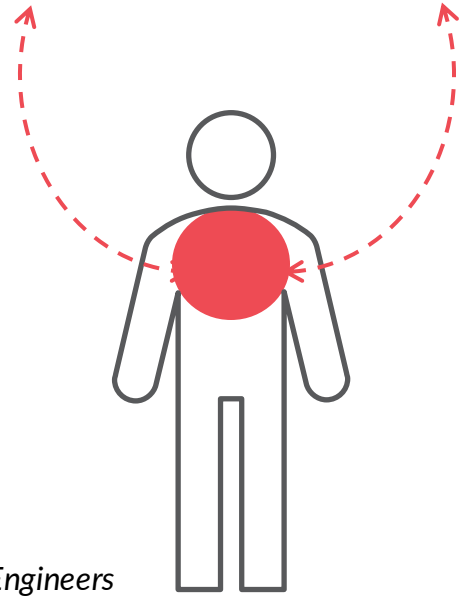
Static position
~105W

Physical activity
~400W

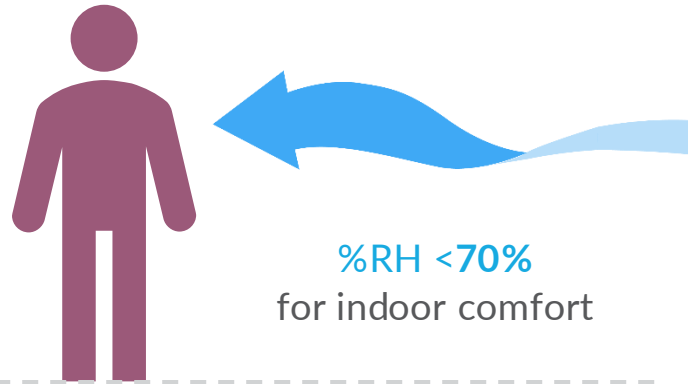


We feel comfortable when metabolic heat generated by the human body is dissipated at the same rate as it is produced

The human body needs to be maintained at **36°C ± 0.5°C** regardless of prevailing ambient conditions



Acceptable air velocity range
0.15m/s–0.50m/s
(at 23°C–26°C)



%RH <**70%**
for indoor comfort

Air movement is essential for comfort as it enhances heat transfer between air and the human body and accelerates cooling of the human body

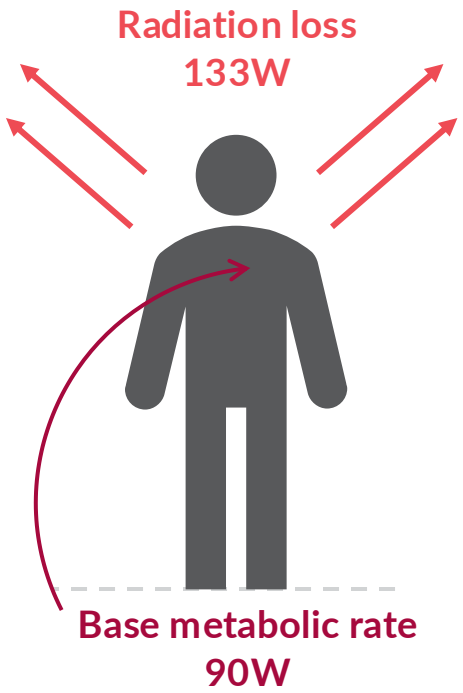
Source: American Society of Heating, Refrigerating and Air-Conditioning Engineers

COOLING OF HUMAN BODY

Radiation heat transfer dominates

An adult male (bare body) loses most of the heat through radiation (133W)

Since the base metabolic rate is 90W, without clothing, the person will feel cold

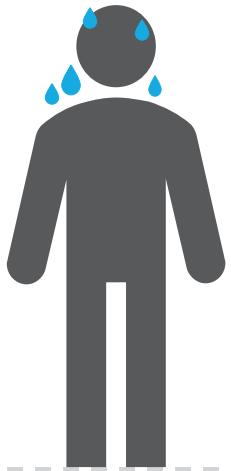


Perspiration
17 watts

Conduction
11 watts

Radiation
133 watts

Convection
(variable)



Skin
temperature
34°C

Ambient temperature
23°C

Basal production rate
≈ 90 watts

Source: BEEP Training Modules on Radiant Cooling

HUMAN COMFORT

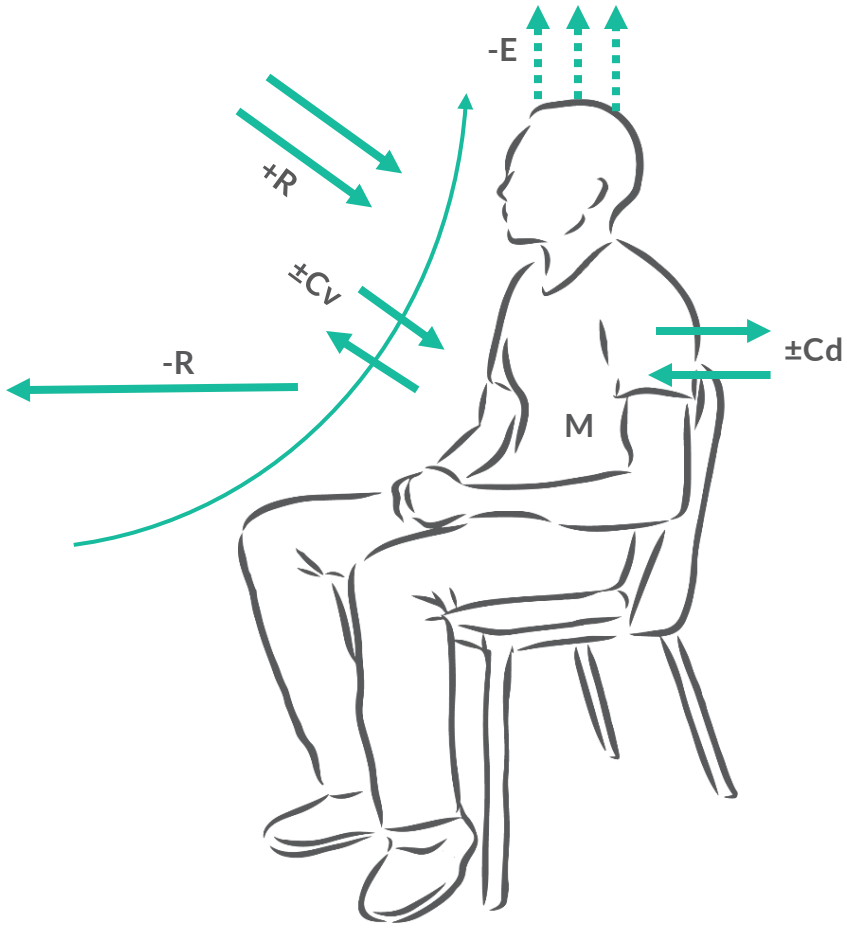
Human body heat balance

The body's heat balance can be expressed as:

M ± R ± Cv ± Cd - E = ΔS (W)

M = metabolic rate
R = net radiation
Cv = convection
Cd = conduction
E = evaporation heat loss
ΔS = change in heat stored

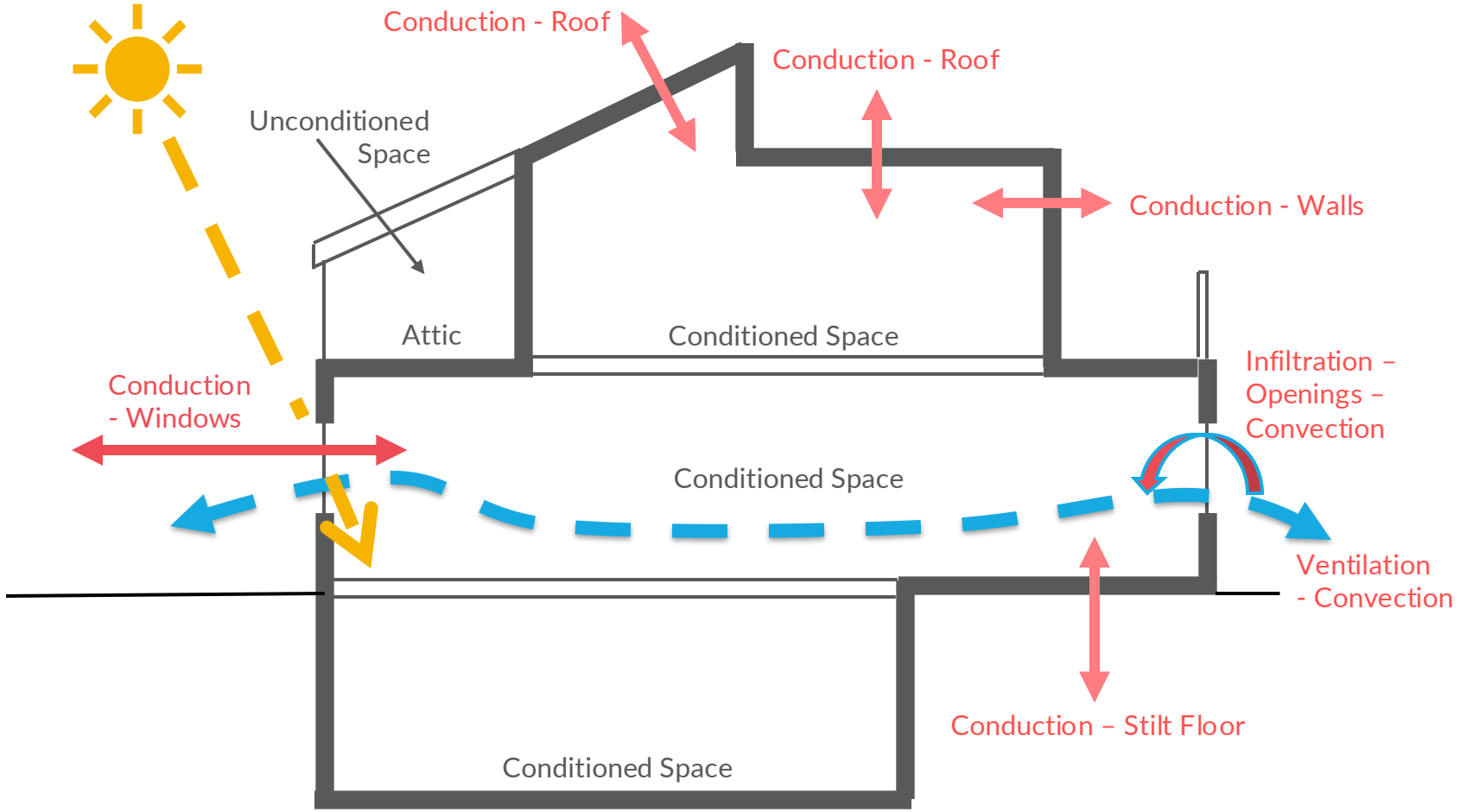
- If ΔS is positive, the body temperature increases; if negative, it decreases
- The heat dissipation rate depends on environmental factors, but the body is not purely passive, it is *homoeothermic*



BUILDING ENVELOPE

Its role in heat transfer

Building envelope design is the key to energy efficient building



THERMAL COMFORT

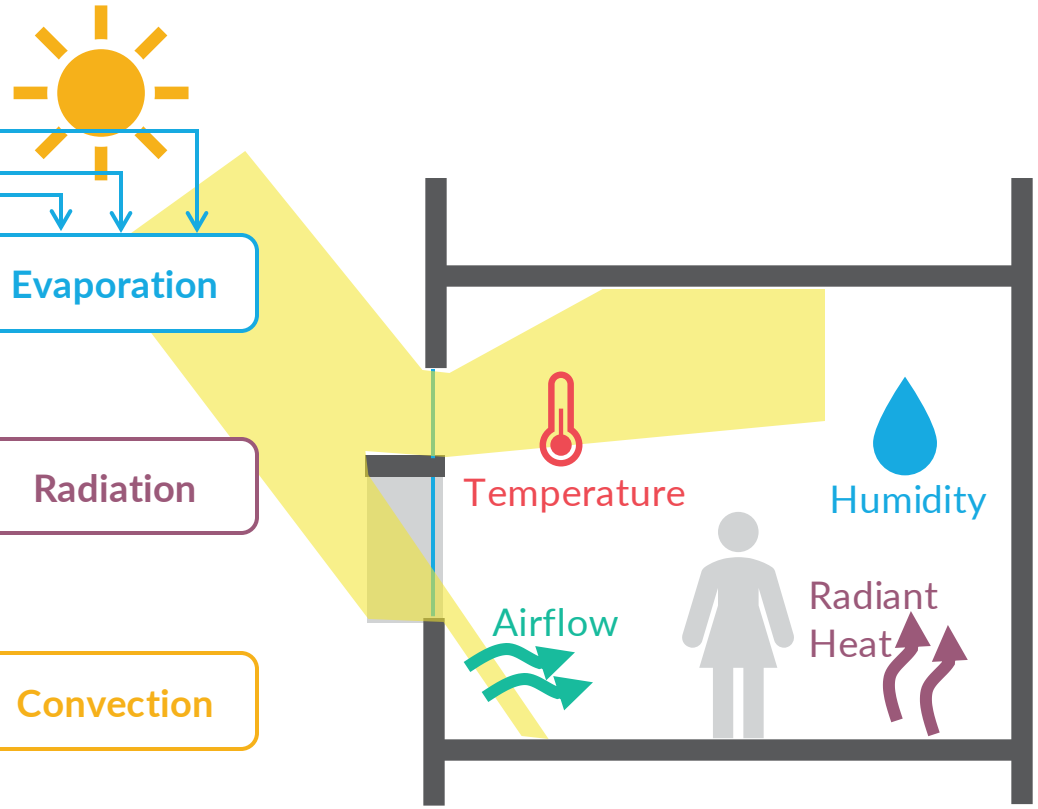
Important parameters

Air Temperature:
The temperature of the air surrounding the body

Mean Radiant Temperature (MRT):
Weighted average of the temperatures of all the surfaces in direct line of sight of the body

Air Movement:
Average speed of the air to which the body is exposed

Humidity:
Amount of water vapor in the room
(the amount of moisture that air can hold is a function of the temperature)



Source: BEEP Training Modules on Radiant Cooling

Thermal Comfort

Adaptive Thermal Comfort Band



ASHRAE STANDARDS

Building energy efficiency, adaptive comfort and ventilation

Internationally-accepted standards are:

- **American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1:** Energy efficiency of the system
  - Heating, ventilation and air conditioning (HVAC)
  - Lighting
  - Equipment
  - Hot water
- **ASHRAE Standard 55:** Adaptive comfort
- **ASHRAE Standard 62.1:** Ventilation system including fresh air

ADAPTIVE COMFORT

Thermal preference

Thermal preference

Physiological response to Immediate indoor parameters

- Air Temperature
- Air Movement
- Relative Humidity
- Radiation
- Activity Level
- Clothing Insulation

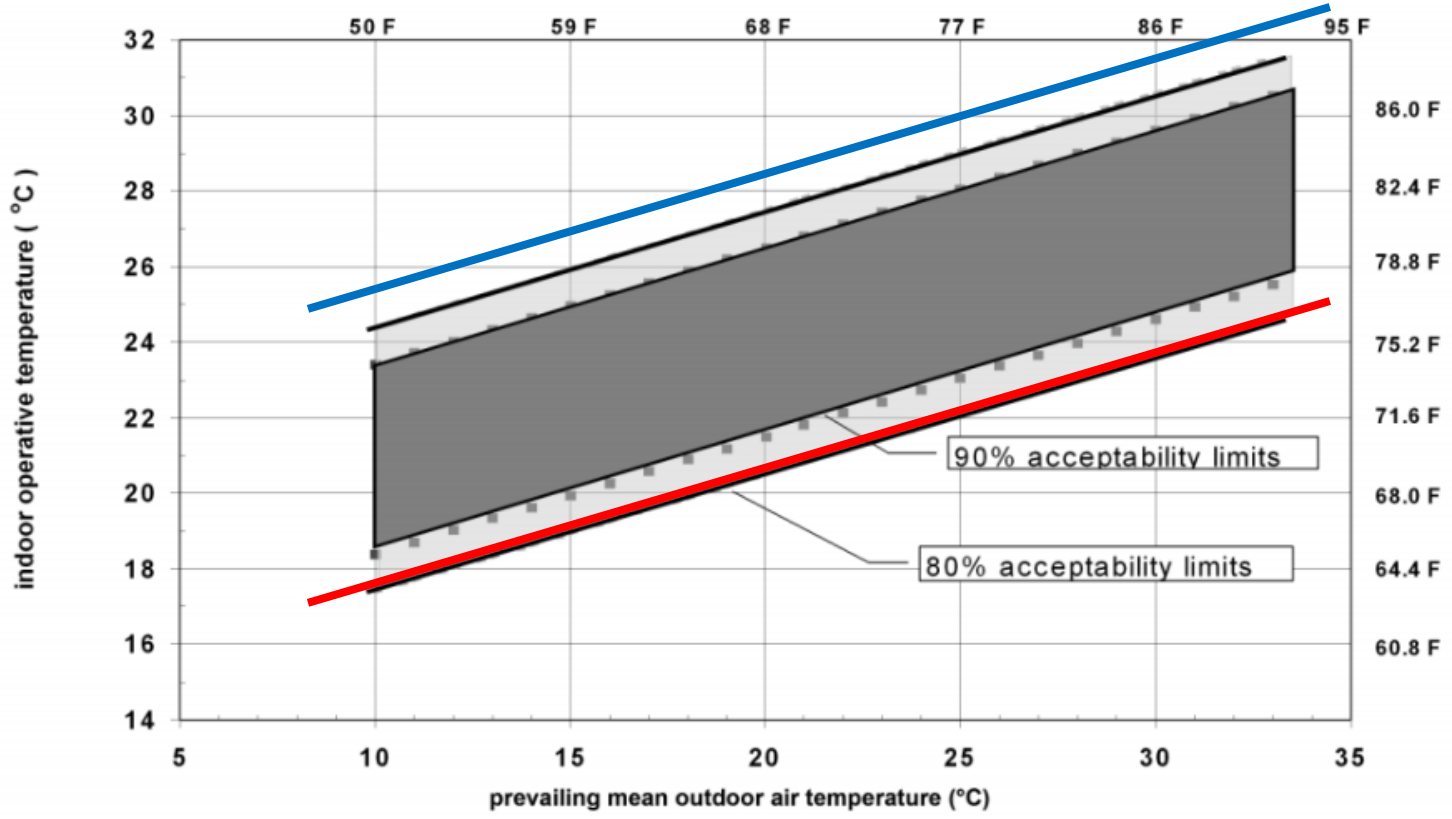
Climato-cultural determinants or recent past experiences & voluntary / adaptive adjustment

- altering activity,
- posture,
- clothing,
- opening or closing windows

ADAPTIVE COMFORT MODEL

ASHRAE

The acceptable indoor operative temperatures (t_o) can be determined from the graph



OR

using the equations

Upper 80% acceptability limit (°C)
= 0.31 $t_{pma(out)}$ + 21.3

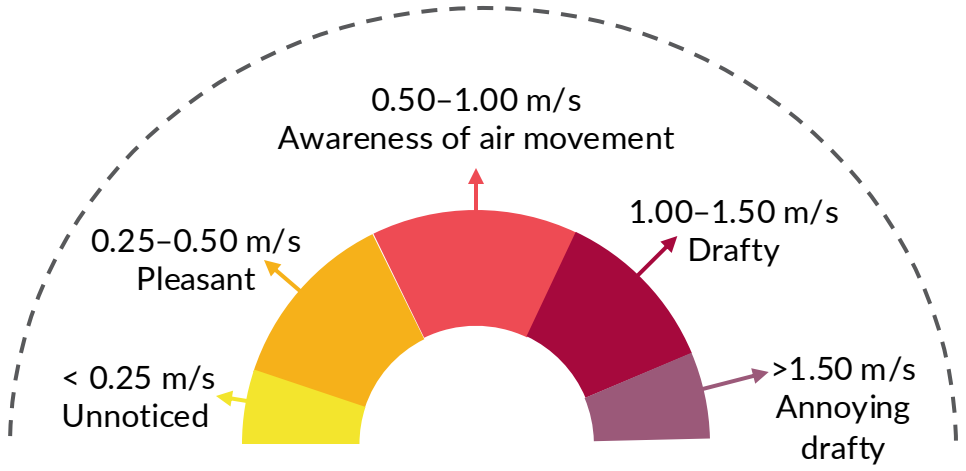
Lower 80% acceptability limit (°C)
= 0.31 $t_{pma(out)}$ + 14.3

$t_{pma(out)}$ is the arithmetic average of the mean daily outdoor temperatures over no fewer than 7 and no more than 30 sequential days prior to the day in question

AIR MOVEMENT

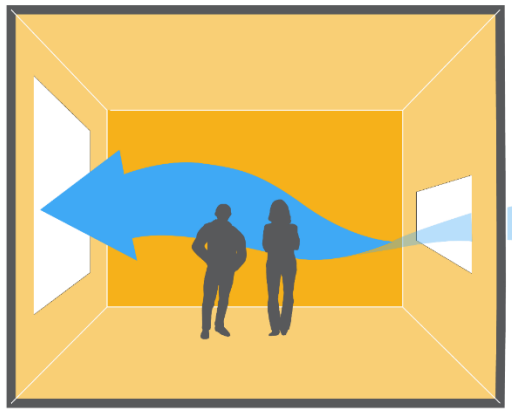
Essential for thermal comfort

It is common experience that air movement, be it natural breeze, or forced draft from a fan, has a cooling effect that depends on the velocity of that air movement

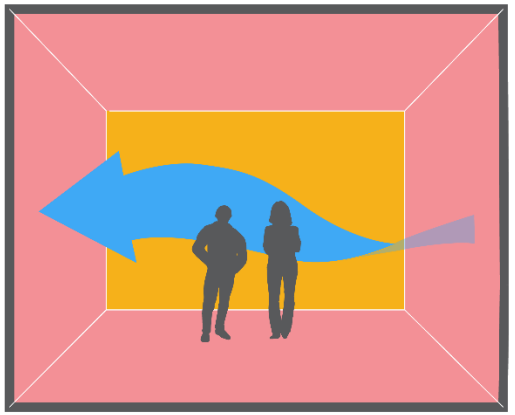


Average subjective reactions to various velocities under everyday conditions

Human responses to varied velocities depend on the temperature of the air



Under warm conditions, 1 m/s is pleasant and indoor air velocities up to 1.5 m/s are acceptable



In a heated room, stagnant air (velocities < 0.1 m/s) may be judged as 'stuffy'

ADAPTIVE THERMAL COMFORT

Works better with occupant participation and control

- Behavioral adaptation refers to any conscious or unconscious actions by a person to alter their body's thermal balance, e.g., choice of clothes, activity levels, using fans / heaters, and adjustment of diffusers or thermostats
- Behavioral adjustments offer the best opportunity for people to participate in maintaining their own thermal comfort with optimal energy consumption
- Providing ample opportunities for people to control the indoor climate is an essential strategy in the design of naturally-ventilated buildings. However, in most buildings, occupants have limited understanding and control



Case example: Integrating smart ceiling fans and communicating thermostats to provide energy efficient comfort

Source: Brager and de Dear, 2000

Image source: https://cbe.berkeley.edu/research/epic-integrating-smart-ceiling-fans-study/

ADAPTIVE COMFORT MODEL

Limitations of ASHRAE Standard 55

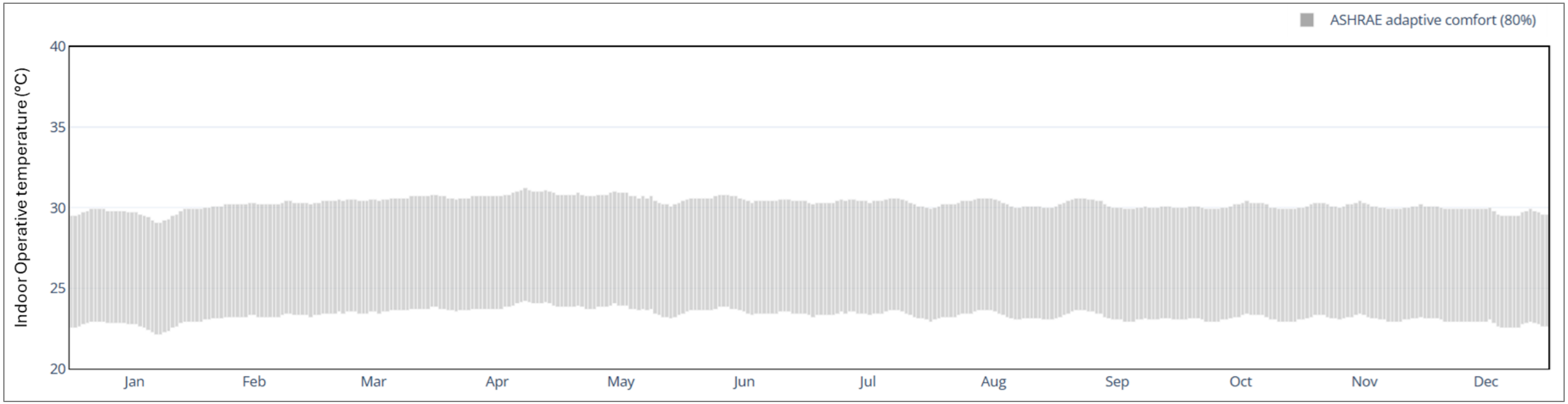
- Those advocating more flexible thermal comfort standard have long argued that the primary limitation of ASHRAE Standard 55 is its one-size-fits-all approach
- In ASHRAE 55, clothing and activity are the only modifications one can make to reflect seasonal differences in occupant requirements
- Using ASHRAE Standard 55 to determine acceptable indoor temperature ranges requires assumptions about the average metabolic rate and clothing worn by people
- In contrast, an adaptive model relates acceptable indoor temperature range to the mean monthly outdoor temperature, defined as the arithmetic average of mean monthly minimum and maximum air temperature

Source: Brager and de Dear, 2000

ADAPTIVE COMFORT MODEL

For Phnom Penh, Cambodia

Phnom Penh, Cambodia – ASHRAE Standard 55 – Comfort Band (80%)

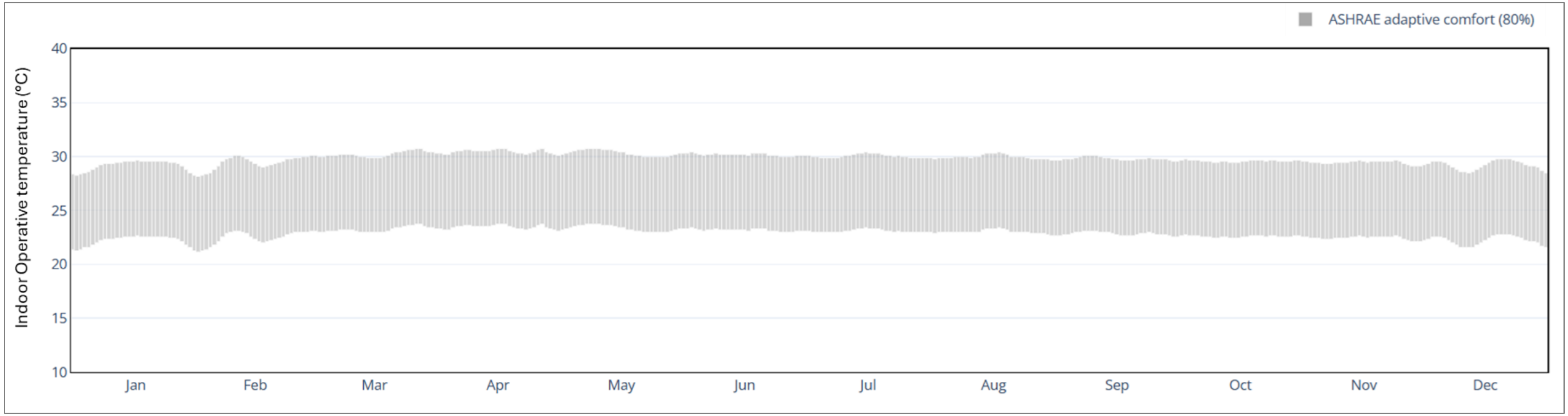


Source: Betti et al., 2023

ADAPTIVE COMFORT MODEL

For Battambang, Cambodia

Battambang, Cambodia – ASHRAE Standard 55 – Comfort Band (80%)



Source: Betti et al., 2023

INDIA'S IMAC

India's model for adaptive comfort

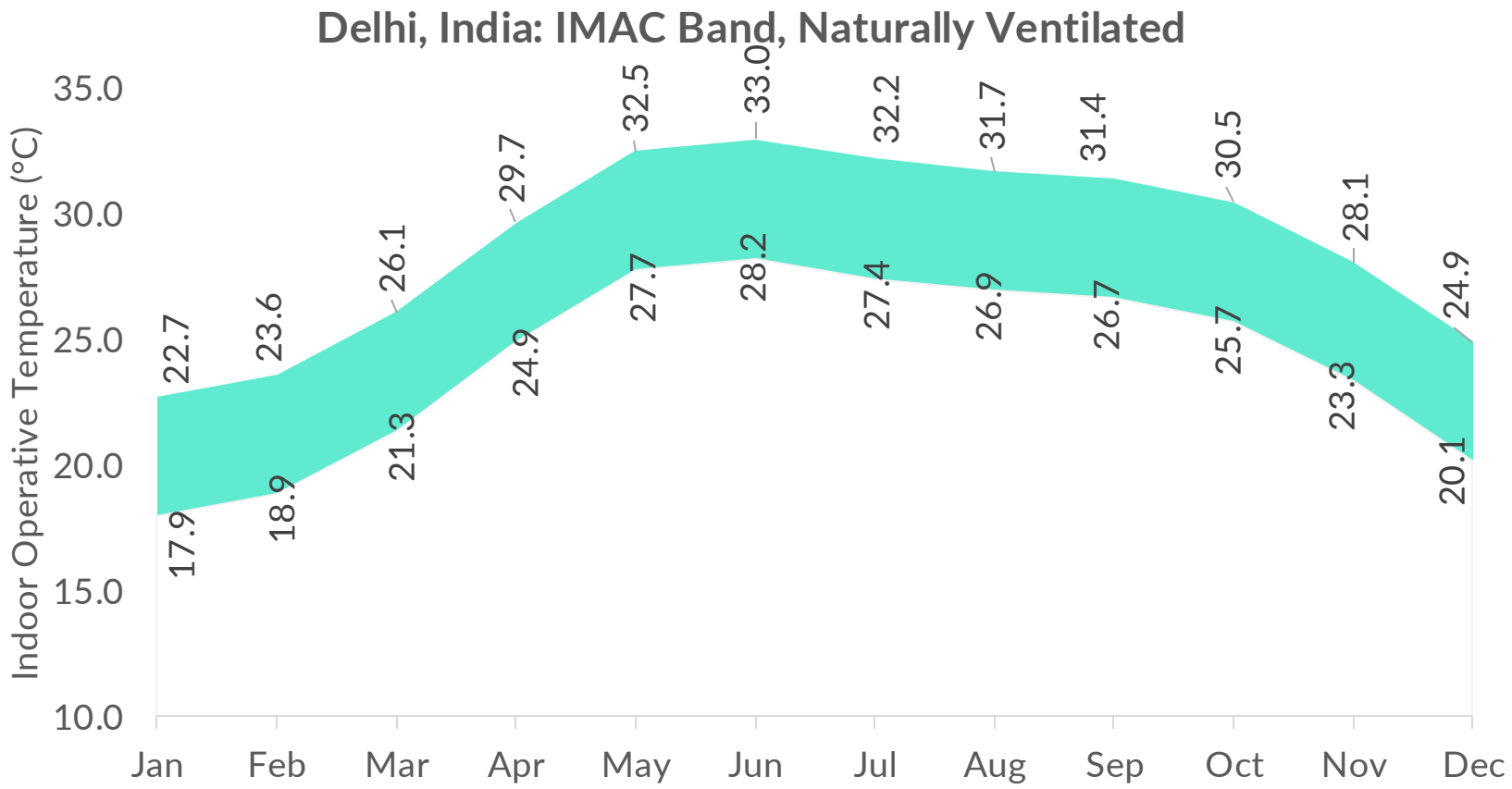
The India Model for Adaptive Comfort (IMAC) predicts the thermal comfort range in India for different months of the year, based on field studies in five cities. Some insights from the IMAC model are:

- A single adaptive model is proposed for 'naturally ventilated' and 'air conditioned' modes of operation
- Indian office occupants are more adaptive than predicted by ASHRAE-55 and EN15251 models
- International comfort standards are not appropriate for Indian office buildings
- Occupants in 'mixed-mode' offices are more adaptive than those in air-conditioned offices, and less adaptive than those in naturally-ventilated offices
- Use of fans and windows and appropriate clothing are significant adaptive measures in naturally-ventilated offices

Source: Manu et al., 2016

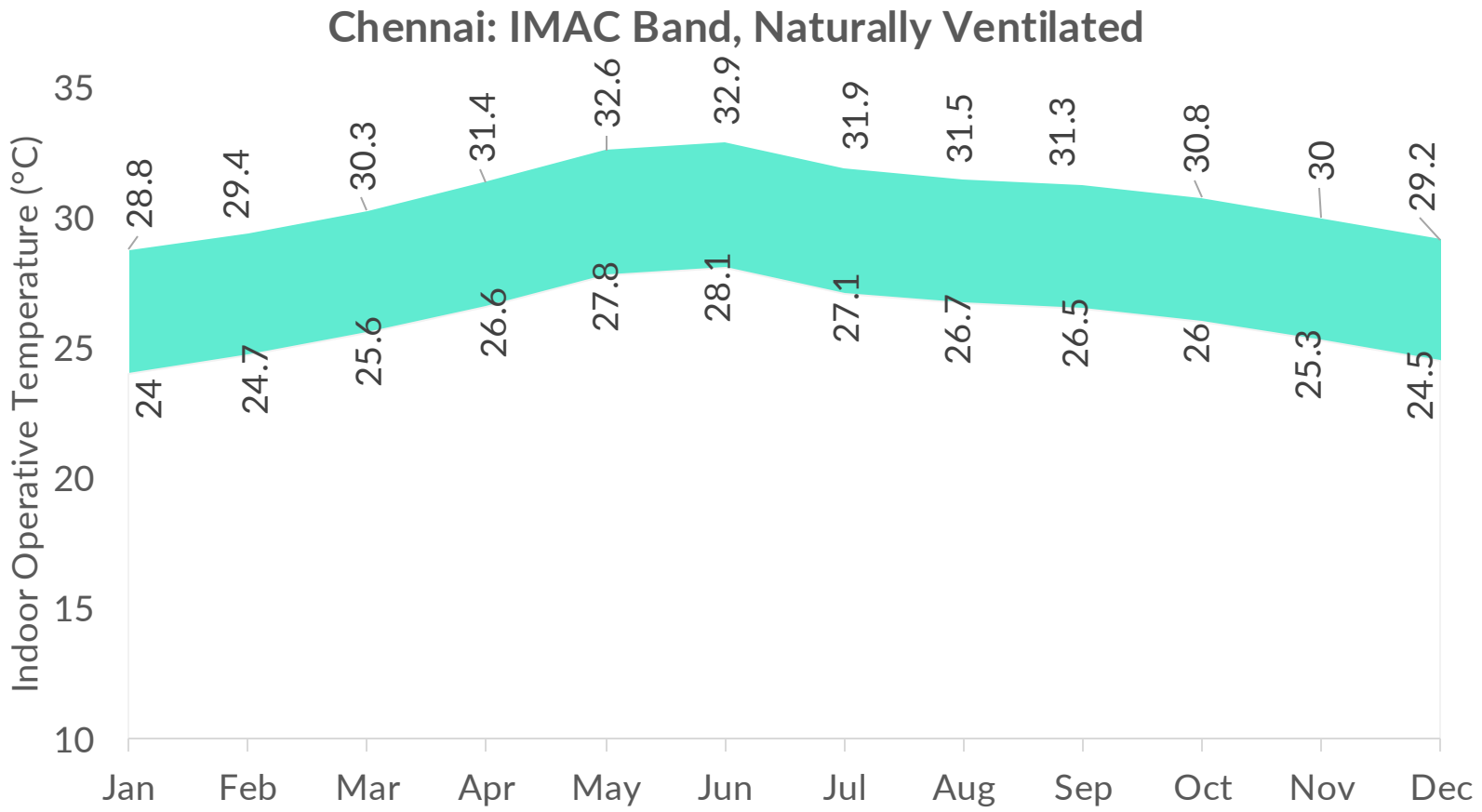
INDIA'S IMAC

Composite climate



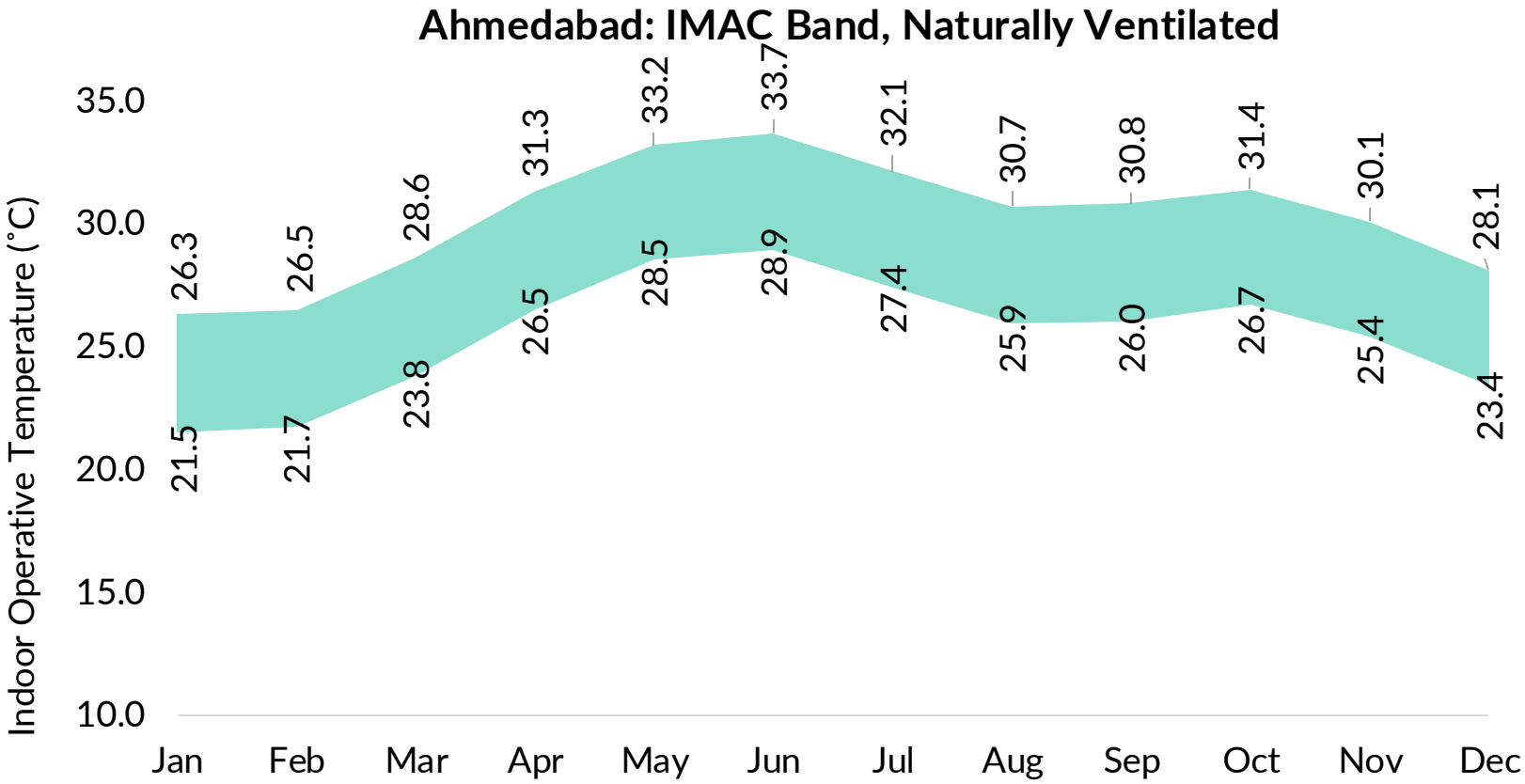
INDIA'S IMAC

Warm and humid climate



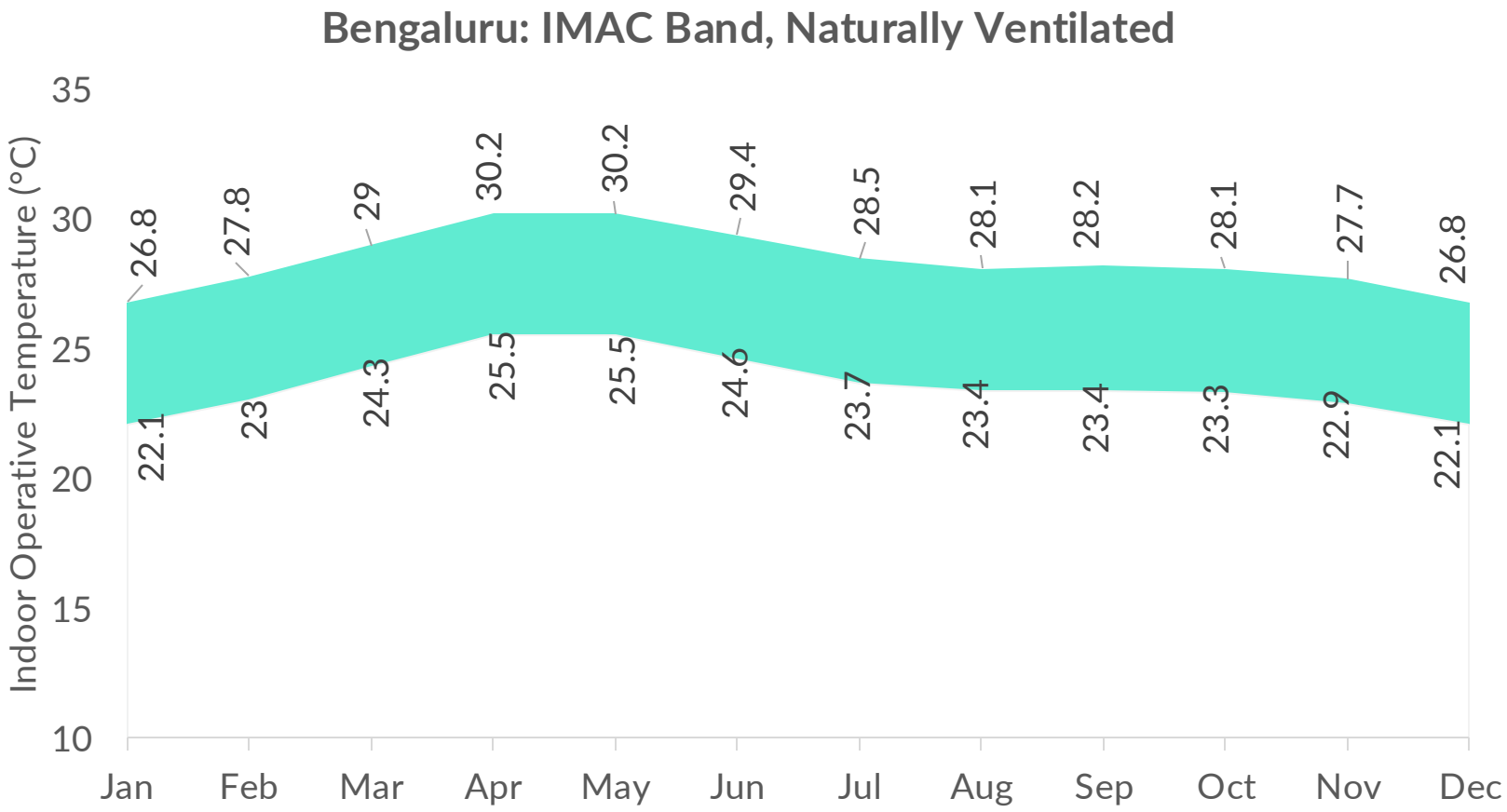
INDIA'S IMAC

Hot and dry climate



INDIA'S IMAC

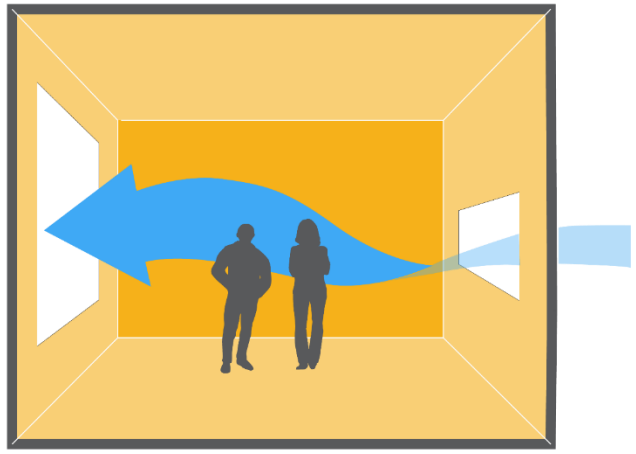
Temperate climate



TROPICAL SUMMER INDEX

For estimating room comfort temperatures with varying ambient temperatures

Naturally-ventilated Building

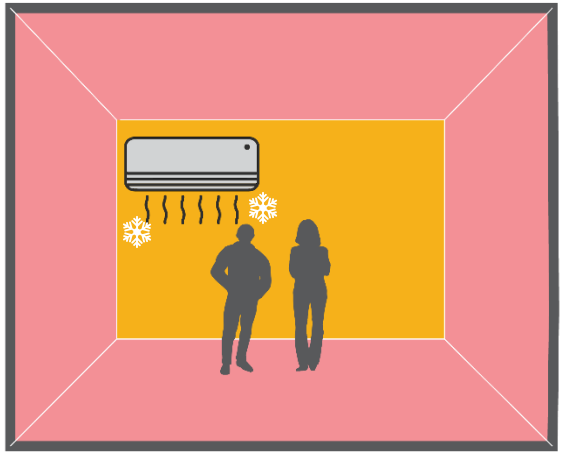


Indoor Operative Temperature, °C
= (0.54 x Outdoor Temperature) + 12.83

- Indoor temperature is neutral and outdoor temperature is 30 days outdoor mean air temperature
- 90% acceptability range for India-specific adaptive models is ± 2.38°C

e.g., **(0.54 x 33) + 12.83 = 30.68 °C**

Air-conditioned Building



Indoor Operative Temperature, °C
= (0.078 x Outdoor Temperature) + 23.25

- 90% acceptability range for India-specific adaptive models is ± 1.5 °C

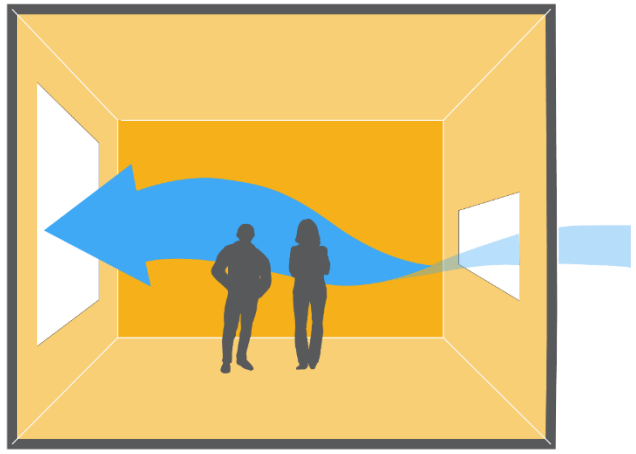
e.g., **(0.078 x 33) + 23.25 = 25.8 °C**

Source: Bureau of Indian Standards, Government of India, 2016b

COMFORT PERCEPTIONS

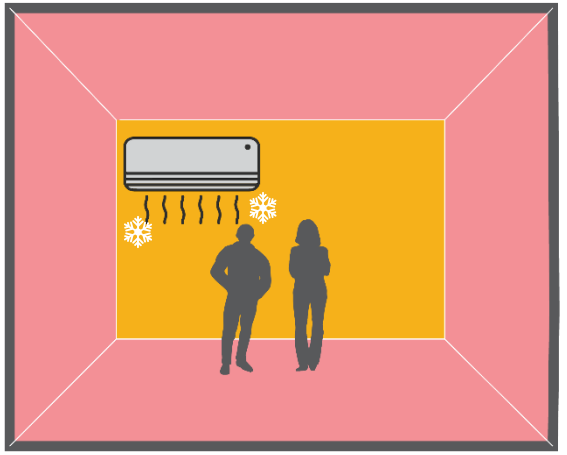
Human conditioning

Naturally-ventilated Building



Naturally-ventilated buildings, where occupants can open windows, create indoor conditions that are inherently more variable than buildings with centralized HVAC systems

Air-conditioned Building



Research has demonstrated that occupants of buildings with centralized HVAC systems become finely tuned to the very narrow range of indoor temperatures presented by the prevailing HVAC practice

Considerable research is now focusing on three primary modes of adaptation

Physiological **Behavioral** **Psychological**

Source: Bureau of Indian Standards, Government of India, 2016b

Adaptive Thermal Comfort

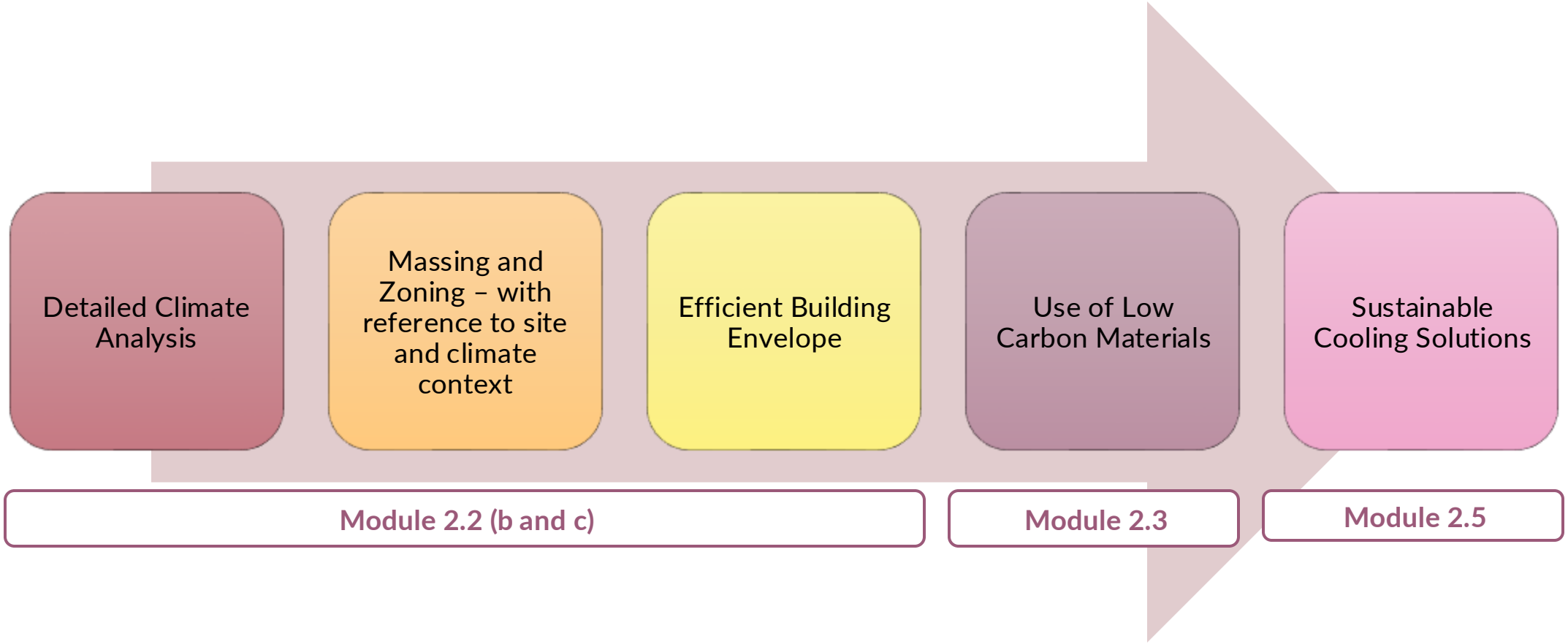
Potential Solutions



Image source: https://nzeb.in/a-paradigm-for-thermal-comfort-for-nzebs-in-tropics/

CLIMATE RESPONSIVE BUILDING DESIGN

Potential solutions are covered in subsequent sub-modules 2.2(b), 2.2(c), 2.3 and 2.5



Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy | PROJECT

2.4 Sustainable Cooling Solutions

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

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on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

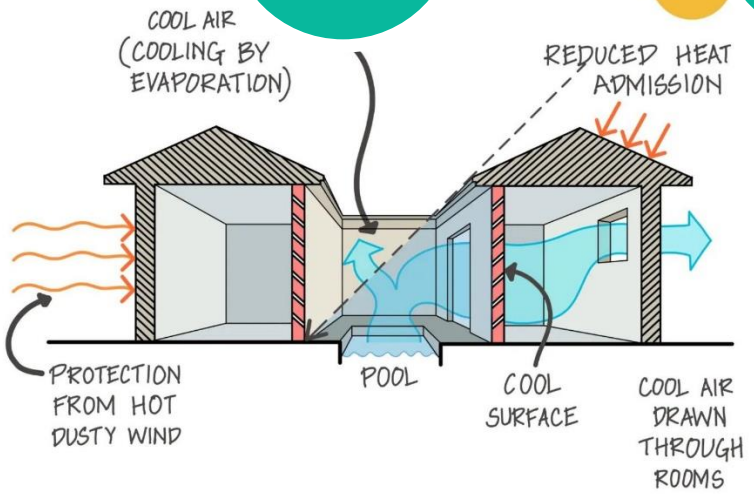
01 Sustainable Cooling and its Need

02 Approach

03 Technologies

04 Refrigerants

05 Services, Policies and Financial Solutions



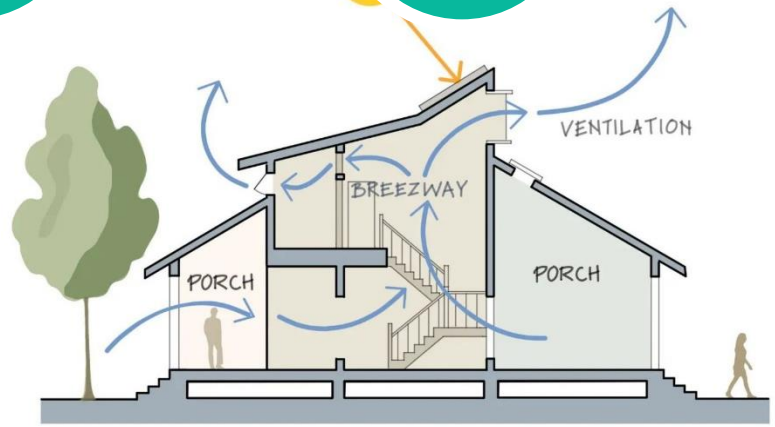


Image source: https://www.arch2o.com/passive-cooling-systems/

Sustainable Cooling

Needs and Relevance

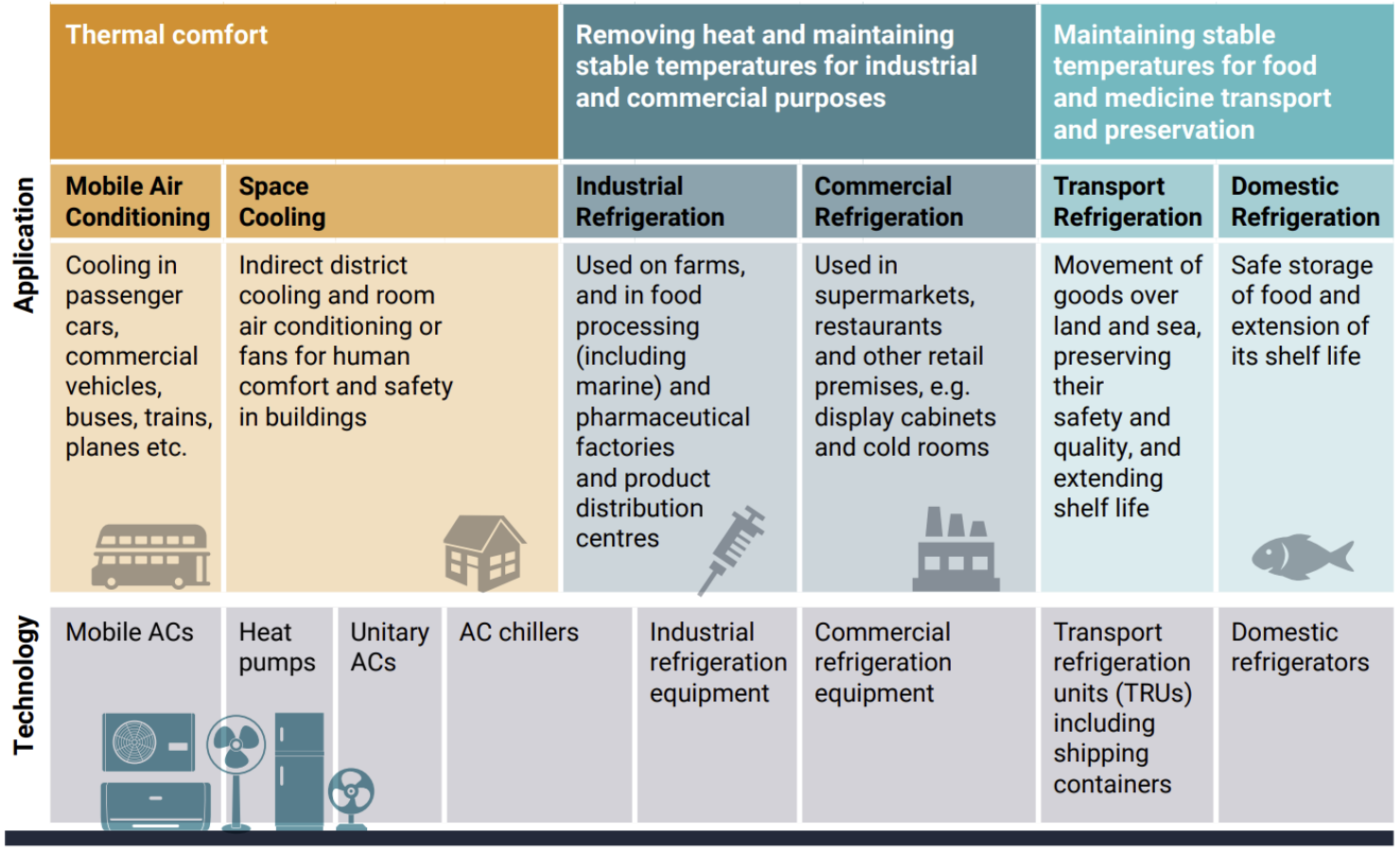


Image source: https://www.ecohome.net/guides/1451/stay-cool-the-old-fashioned-way/

FUNDAMENTAL COOLING NEEDS

Basic applications

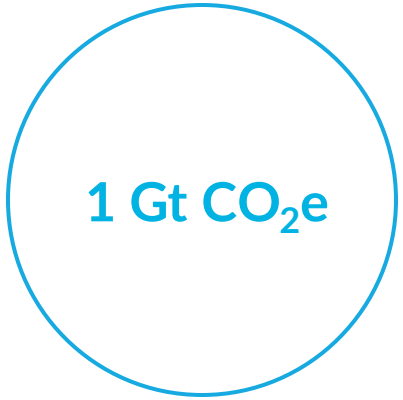
- **Comfort and safety:** For human thermal comfort and associated well-being; for productivity and linked incomes; and safety and health in extreme weather conditions
- **Food and nutrition:** For the agriculture sector to have access to cooling for food and nutrition security, rural incomes, and the agriculture cold chain
- **Health and care:** For safe medical clinics and the secure transport and storage of vaccines and medical products



Source: Sustainable Energy for All, 2019

SPACE COOLING

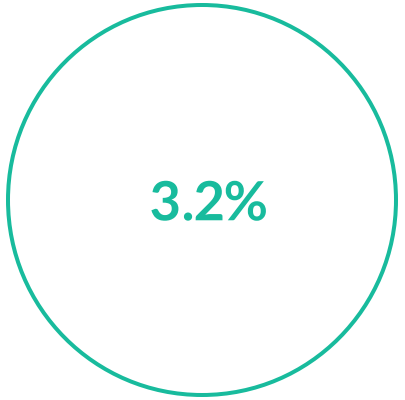
Emissions impact



Global CO_2 emissions from electricity use for space cooling (2022)[1]



Global non-CO_2 GHG emissions associated with the leakage of refrigerants used in space cooling (2022)[2]



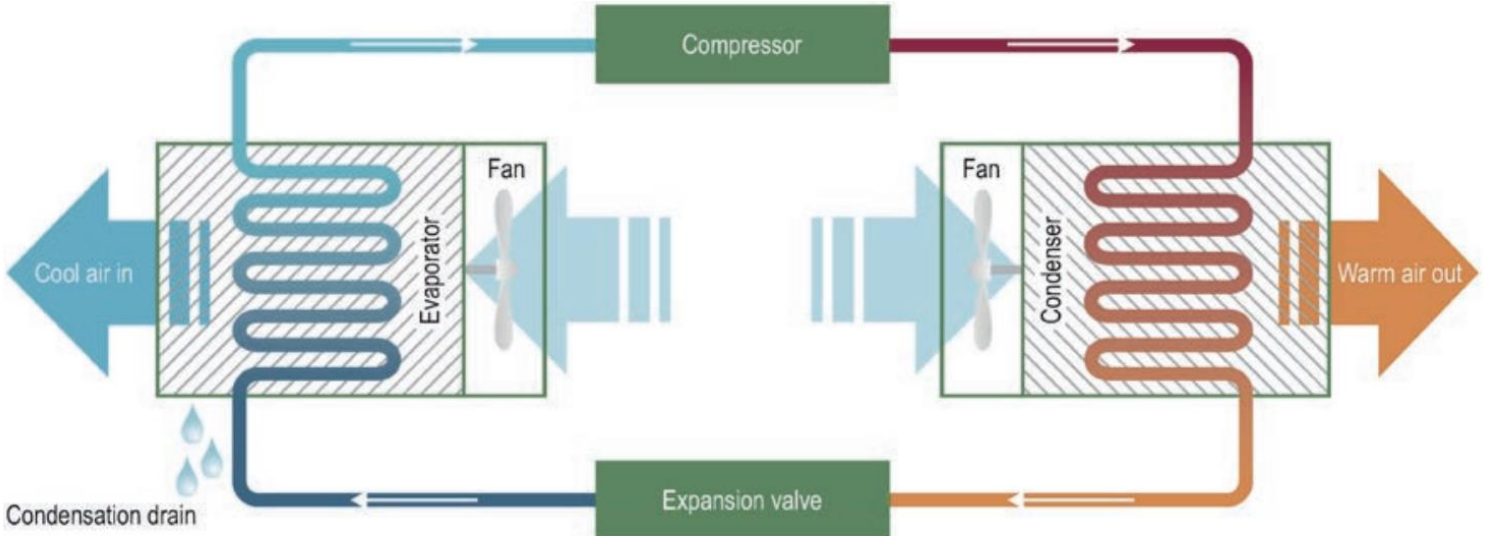
Percentage of total global GHG emissions[2]

Sources:
[1] *International Energy Agency*
[2] *Ritchie, 2024*

CONVENTIONAL AIR CONDITIONING

Emissions impact

- Conventional air conditioning is mainly based on **vapor compression refrigeration cycle technology**. This technology exploits a basic law of physics: when a liquid converts to a gas (in a process called phase conversion), it absorbs heat; and when it condenses again (to a liquid), it releases heat
- Air conditioning equipment uses phase conversion by forcing either natural or special chemical compounds, known as refrigerants, to evaporate and condense repeatedly in a closed loop of coils
- **Most refrigerants in use today are synthetic chemical compounds, with significant global warming potential**



Source: International Energy Agency, 2018

CONVENTIONAL AIR CONDITIONING

Major contributor to global warming

- **Air conditioning is energy intensive.** It is largely dependent on grid electricity, predominantly fueled by fossil fuels, indirectly driving greenhouse gas emissions
- **Uses refrigerants with overwhelmingly high global warming potential**, responsible for direct greenhouse gas emissions
- **Contributes to urban heat islands** by rejecting waste heat into the outdoors, thus warming the urban environment



Source: United Nations Environment Programme, 2021a

SUSTAINABLE COOLING

Implication

- **Sustainable or 'clean' cooling** means cooling that uses climate-friendly refrigerants and without other environmental damage including climate impact, in line with the objectives of the Paris Agreement on Climate Change and the Montreal Protocol
- Clean cooling must be accessible and affordable to help deliver societal, economic and health goals

Cooling needs, solution approach and solution pillars



Source: United Nations Environment Programme and International Energy Agency, 2020
Image source: https://www.seforall.org/chilling-prospects-2020/sustainable-cooling-solutions

SUSTAINABLE COOLING

The need

- Heat waves and related droughts have devastated lives and livelihoods across the globe in recent years. Many of the world's most vulnerable people have limited or no access to modern cooling technologies like air conditioners
- Cooling is increasingly being understood as a critical infrastructure service, akin to energy, water and others. Without adequate cooling, achieving global Sustainable Development Goals (SDGs) will be increasingly challenging
- It is urgent to meet people's needs for cooling and heat adaptation while also achieving GHG mitigation and development goals, conserving natural resources and improving the local environment. This requires a rapid transition to sustainable cooling

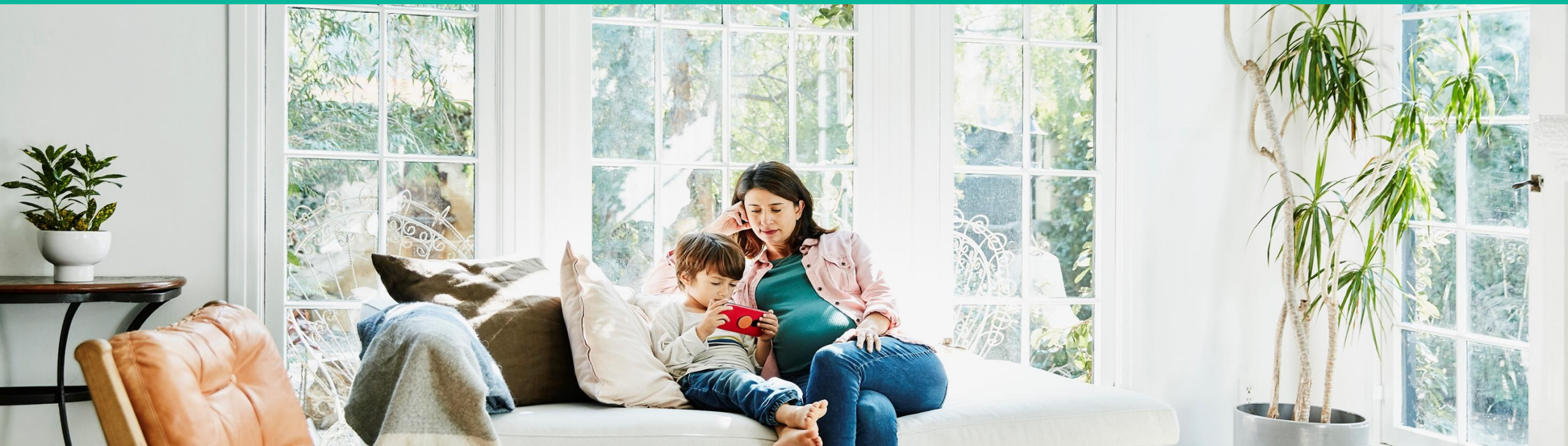
Cooling needs, solution approach and solution pillars



Source: United Nations Environment Programme and International Energy Agency, 2020
Image source: https://www.seforall.org/chilling-prospects-2020/sustainable-cooling-solutions

Sustainable Cooling

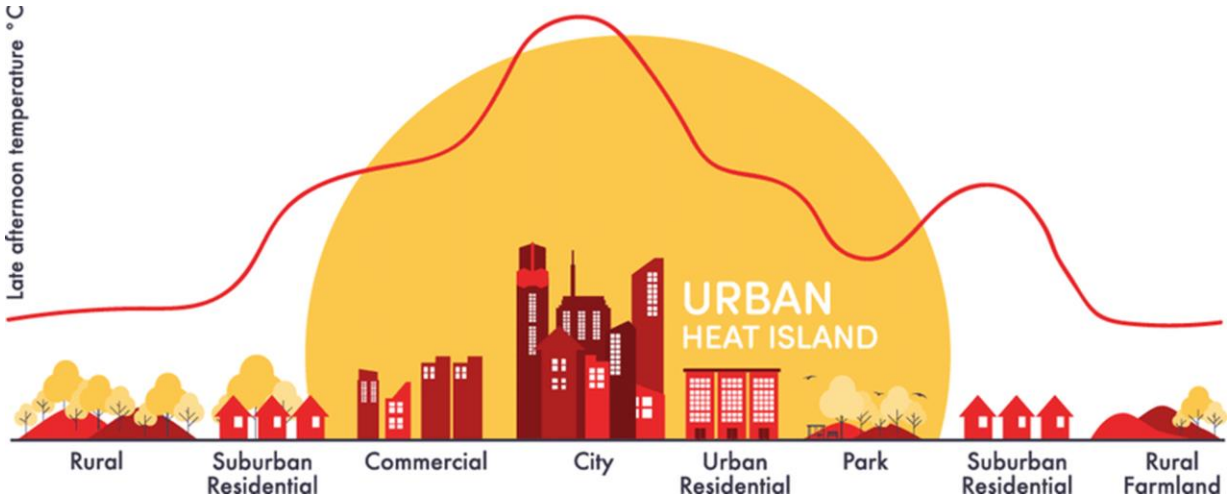
Approach



URBAN HEAT ISLAND

Heating up cities

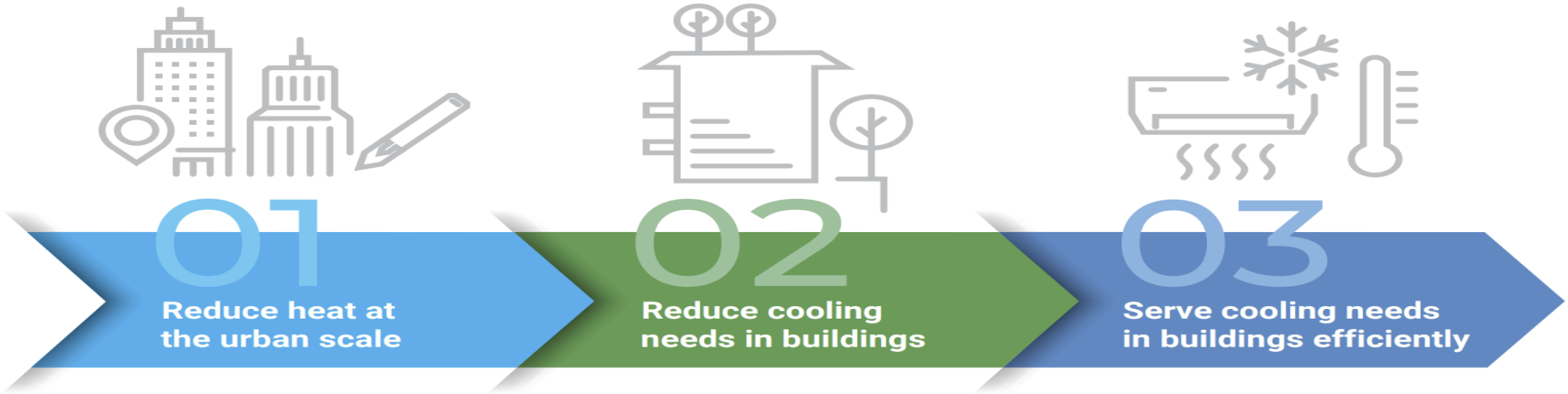
- An urban heat island (UHI) is **a metropolitan area that is significantly warmer than its surroundings**
- Many US cities have air temperatures up to 5.6°C warmer than the surrounding natural land cover
- This temperature difference is usually larger at night than during the day, and larger in winter than in summer, and is most apparent when winds are weak
- The main causes are changes in the land surface by urban development along with waste heat generated by energy use
- With the growth in urban centers, greater areas of land tend to change, which then undergo a corresponding increase in average temperature



Source: University Corporation for Atmospheric Research

SUSTAINABLE COOLING

Holistic approach



Efficient planning and design at the scale of the city or urban district, with an emphasis on heat minimizing urban form and design, nature-based solutions, and cool surfaces designed to reduce the urban heat island effect, in turn also reducing cooling loads in buildings.

Enhancing the thermal performance of buildings and minimizing cooling loads using passive building design practices, with an emphasis on leading-by-example city-owned buildings, and raising the floor with building energy codes and standards.

Efficient and best-fit cooling technologies and operations to deliver the required amount of cooling with the least amount of energy, emissions and anthropogenic heat.

Source: UNEP et al. 2021

Source: United Nations Environment Programme, 2023

SUSTAINABLE COOLING

Holistic approach for urban areas

Urban form and planning

Land use and building design controls adjusted to maximize effectiveness and ensure that the density and form of new development is appropriate for future climate conditions. They include:

- Leveraging cooling benefits of green open spaces and water bodies
- Promoting wind flow
- Reducing waste heat

Nature-based solutions

Integrating vegetation and water bodies in the urban fabric can reduce local and ambient temperature

Cool surfaces

Reflective urban surfaces, such as for buildings and pavements, can make cities cooler

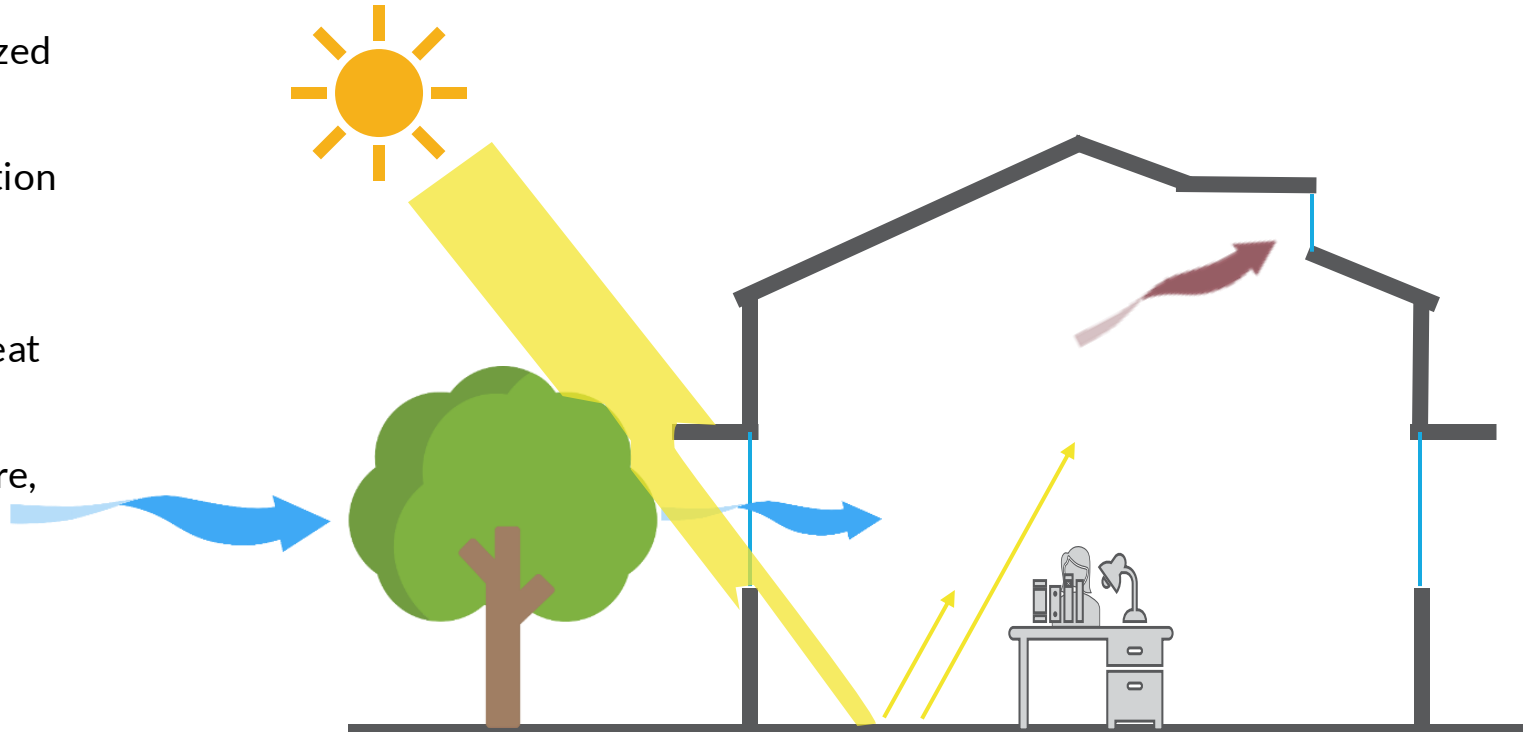
Source: United Nations Environment Programme, 2021a

SUSTAINABLE COOLING

Holistic approach to reduction of cooling demand in buildings

Cooling loads of buildings can be minimized through **passive design strategies:**

- Climate-appropriate building orientation
- Appropriate materials and design features in the building envelope like insulation and shading to minimize heat gain due to thermal transmittance
- Natural ventilation where temperature, humidity and air quality allow
- Thermal mass to stabilize interior temperatures



Source: United Nations Environment Programme, 2021a

SUSTAINABLE COOLING

Serving cooling needs efficiently in buildings

Selecting optimal cooling technology

A wide range of cooling technologies is available for buildings of different scales, climates etc. These can be made sustainable by:

- Improving minimum energy performance standards (MEPS)
- System design improvements to further improve energy efficiency
- Using low-GWP refrigerants

Efficient operations

Optimizing cooling operations by ensuring that cooling is delivered only where and when it is needed, and system performance is monitored and maintained, can be achieved by:

- Use of controls and sensors
- Load shifting
- User adaptations and behavior changes
- Good operations and maintenance and servicing practices
- Capacity building of service sector

Source: United Nations Environment Programme, 2021a

Sustainable Cooling

Technologies



Image source: https://fridgesworld.co.uk/blogs/news/sustainable-cooling-solutions-chillpro-s-commitment-to-eco-friendly-refrigeration-and-display-

SPACE COOLING

Generic technologies

Refrigerant-based cooling

- Residential buildings: Room air conditioner (RAC)
- Commercial buildings: Room air conditioner (RAC), chiller system, packaged direct expansion (DX) and variable refrigerant flow (VRF) system

Non-refrigerant-based cooling

- Fans and air coolers
- Significantly pervasive in the residential sector
- These do not provide the full utility that refrigerant-based vapor-compression cooling provides across all climatic conditions today

Not-in-kind cooling

- Non–vapor compression cooling technologies, most of which use no or low-GWP refrigerants

Sources: Ministry of Environment, Forest and Climate Change, Government of India, 2019; Khosla et al., 2022

REFRIGERANT-BASED COOLING

Overview

	**Room Air Conditioner**	Non-ducted unitary systems, including mini or single split (fixed-speed and inverter types) and window/through-the-wall (fixed-speed type) configurations
	**Chiller System**	Chiller systems (central chilled-water air conditioning systems) are the preferred choice for large commercial buildings. Other than the chiller itself, which is the largest energy-consuming component, the system comprises various auxiliaries, including chilled water pumps, condenser water pumps, cooling tower fans, air handling units and fan coil units
	**Variable Refrigerant Flow (VRF) System**	Typically used in medium-size commercial buildings and high-income group residential units that have varying exposure and cooling loads. The outdoor units are connected to multiple types and numbers of indoor units, such as wall mounted, ceiling mounted cassette, ducted and DX AHUs
	**Packaged DX**	Ducted and packaged systems, including rooftop and indoor packaged units in commercial air conditioning segment (also known as unitary and light commercial systems), typically cater to small-to-medium commercial buildings to avoid the complexities associated with chiller systems

Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019

REFRIGERANT-BASED COOLING

Efficiency improvements

Multi-stage and Variable-speed Drives/Controls

- Modulating motor speed on compressors, the air conditioning system can more closely match the part-load cooling demand and improve seasonal efficiency by reducing losses when the system's full capacity is not required
- Variable-speed controls operate fan motors at their most efficient setting to meet the airflow needs of the system

Advanced Compressors

- Air conditioning compressor efficiency and performance has steadily improved
- Larger systems use multiple compressors to stage capacity and improve part-load performance
- Magnetic and oil-free compressor technologies can deliver significant energy savings

Improved Heat Exchangers

- Manufacturers have increased the size of heat exchangers (metal tube-and-fin) to improve system efficiency
- Advanced heat exchanger designs, such as microchannel heat exchangers and other small diameter designs, have further improved system efficiency, and reduced refrigerant charge, fan energy consumption and physical size

Electronic Expansion Valves

- Thermostatic expansion valves (TXV) improve upon earlier static capillary tube and fixed orifice expansion devices by modulating refrigerant flow based on refrigerant superheat temperature at the evaporator exit
- Newer electronic expansion valves (EEV) provide increased modulation capabilities to match more closely the needs of variable-capacity air conditioning systems

Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019

REFRIGERANT-BASED COOLING

Efficiency improvements (continued)

High Efficiency Fans

- Many systems have incorporated more aerodynamic component designs (e.g., fan blades, condensing unit housing), high efficiency motors and variable-speed controls
- Manufacturers have applied these innovations to axial and centrifugal fans for both heat exchange and distribution of conditioned air throughout buildings

High Efficiency Motors

- Improved motor designs have a significant impact on overall air conditioning system efficiency
- Electrically commutated motors (ECM) have higher efficiencies than permanent split capacitor (PSC) motors for air conditioning fans and operate at a wider range of conditions using electronic controls

Advanced Controls

- Different occupancy sensing strategies can automatically alter thermostat setpoints when building occupants are away to reduce energy consumption
- Economizer controls enable air conditioning systems to use cooling energy from ventilation air or chilled-water cooling

Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019

ACCEPTABLE REFRIGERANTS

As per the Montreal Protocol

For new medium-temperature retail standalone units

- R-448A
- R-449A
- R-449B

For new residential and light commercial air conditioning and heat pumps

- R-32
- R-452B
- R-454A
- R-454B
- R-454C
- R-457A

Source: CAREL Industries

NON-REFRIGERANT BASED COOLING

Overview



Fan

Includes ceiling, pedestal, table and wall-mounted fans. They are widely used in the tropics, in the residential and small to mid-commercial segment. Despite a rise in the penetration of room air conditioner in households, a significant portion of the population will still not be able to afford air conditioning in the next two decades and will continue to rely on natural ventilation and fan-assisted ventilation for thermal comfort



Air Cooler and Evaporative Cooler

These require a climate that is hot and dry. Water is evaporated on cooling pads and ventilated into the building by fans. Evaporating water absorbs a significant amount of heat, cooling the air in the same way that perspiration enables humans and animals to cool themselves. It is an important cooling appliance for users, especially across households and medium-size commercial buildings in hot and dry and composite climates

Sources: Ministry of Environment, Forest and Climate Change, Government of India, 2019; International Energy Agency, 2018

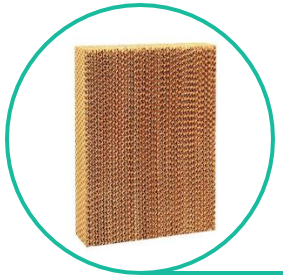
NON-REFRIGERANT BASED COOLING

Advancements



BLDC Fan

Typically, ceiling fans contain single phase induction motors, consume 70–80W and deliver air at 230–250 m^3/minute. Fans with brushless DC (BLDC) motors combined with better blade design have led to more efficient fans, which consume 30–35W and deliver air at 220–230 m^3/minute



Cooling Pad in Air Cooler

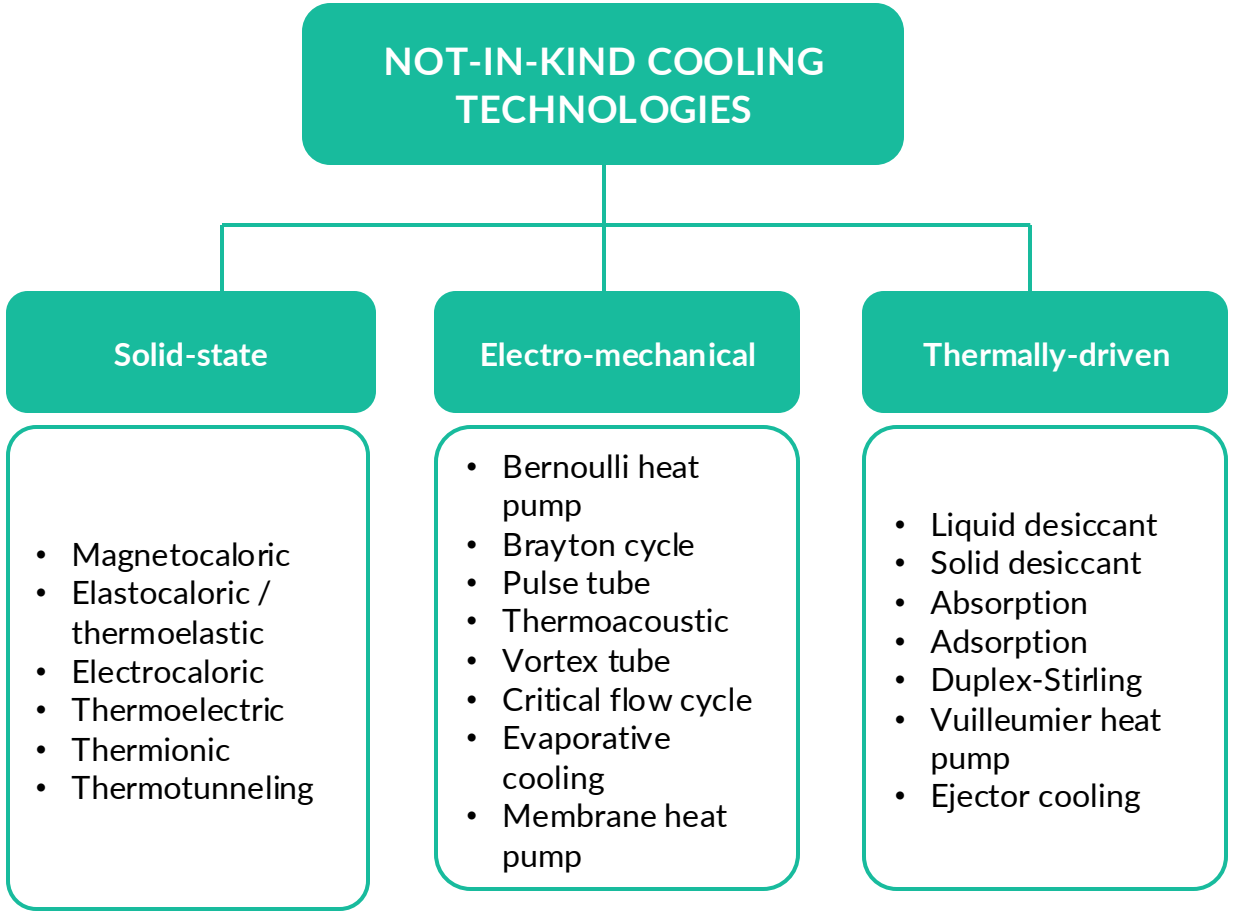
The patterns used on cooling pads have a significant bearing on the water absorption and evaporation process. Aspen (wood wool) pads are 75% efficient and honeycomb are roughly 85% efficient. The cooling pad area is also important – steel body coolers have a larger cooling pad area compared to fiber body ones, and are more efficient

Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019

NOT-IN-KIND TECHNOLOGIES

Overview

- Not-in-kind cooling technologies are non–vapor compression cooling technologies, most of them use no or low-GWP refrigerants
- Most of these technologies are still in low technological readiness levels
- More research is required to improve the performance of technologies of low to moderate maturity
- Supportive deployment-oriented policies are necessary to increase the installation of cooling technologies with moderate or high technical maturity, e.g., evaporative cooling, absorption cooling, etc.



Source: Khosla et al., 2022

NOT-IN-KIND TECHNOLOGIES

Evaporative cooling

Evaporative cooling operates on thermal energy and water is used as a refrigerant. Water is evaporated in non-saturated air to produce a drop in dry bulb temperature and an associated rise in moisture content. It only works efficiently when the air to be cooled is relatively dry. There can be considerable water consumption

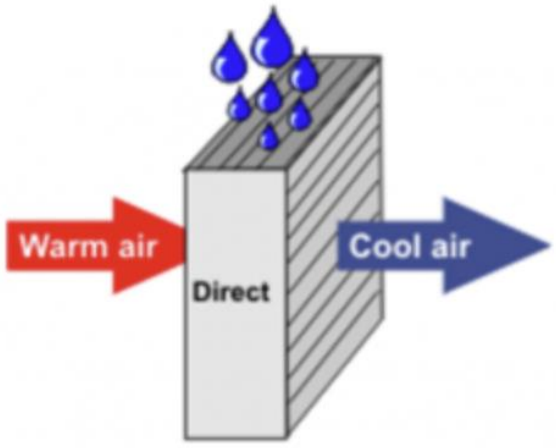
Direct evaporative cooling	The ventilation supply air is passed directly through a water spray before entering the space to be cooled
Indirect evaporative cooling	The ventilation supply air is passed through an evaporative heat exchanger, to be indirectly cooled. Unlike direct evaporative cooling, cooling of the supply air takes place without it absorbing extra moisture. However, the cooling efficiency is reduced
Indirect-direct evaporative cooling	Here, direct cooling follows indirect cooling. The intention is to maximize cooling potential while minimizing the increase in moisture absorption of the supply air

Source: International Energy Agency, 2000

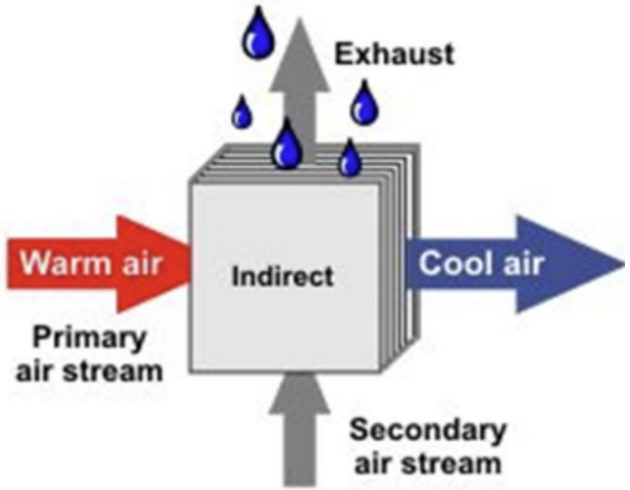
NOT-IN-KIND TECHNOLOGIES

Evaporative cooling

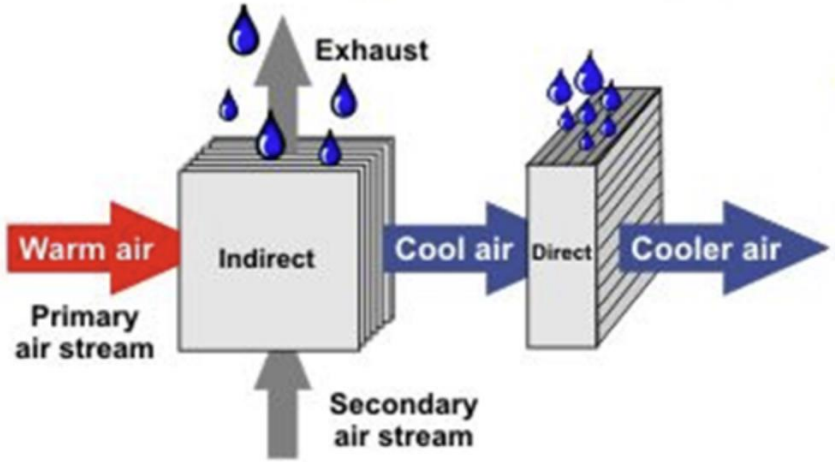
Direct evaporative cooling



Indirect evaporative cooling



Indirect-direct evaporative cooling



Source: Fairconditioning

NOT-IN-KIND TECHNOLOGIES

Evaporative cooling: Major applications

- Comfort cooling of commercial and institutional buildings
- Data center cooling
- Environmental control for processed food industry
- Provision of treated fresh air required in pharma and healthcare industry
- Animal house ventilation
- Industrial buildings, shop floors, warehouses etc.

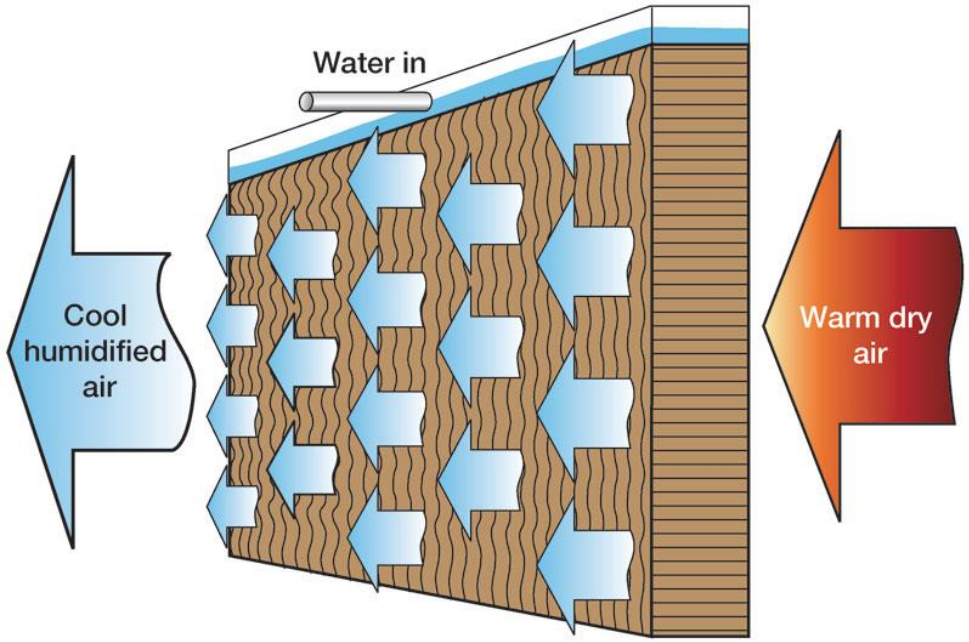


Image source: https://www.condairgroup.com/Energy-optimization/cool-humidification-evaporative-cooling-humidifier

NOT-IN-KIND TECHNOLOGIES

Case example: Evaporative cooling

Central University of Rajasthan, India

- Indirect-direct evaporative cooling system is used
- Indoor temperatures were between 31°C and 34°C when the ambient was approximately 44°C
- Energy consumption in the hostel building was reduced to one-third of a similar building with no major energy conservation measures and using conventional air conditioning systems
- The Energy Performance Index was 60–65 kWh/m^2/year (2012)



Source: United States Agency for International Development, 2014

NOT-IN-KIND TECHNOLOGIES

Case examples: Evaporative cooling





Industrial building, Jaipur, India



School (Classrooms), Jaipur, India



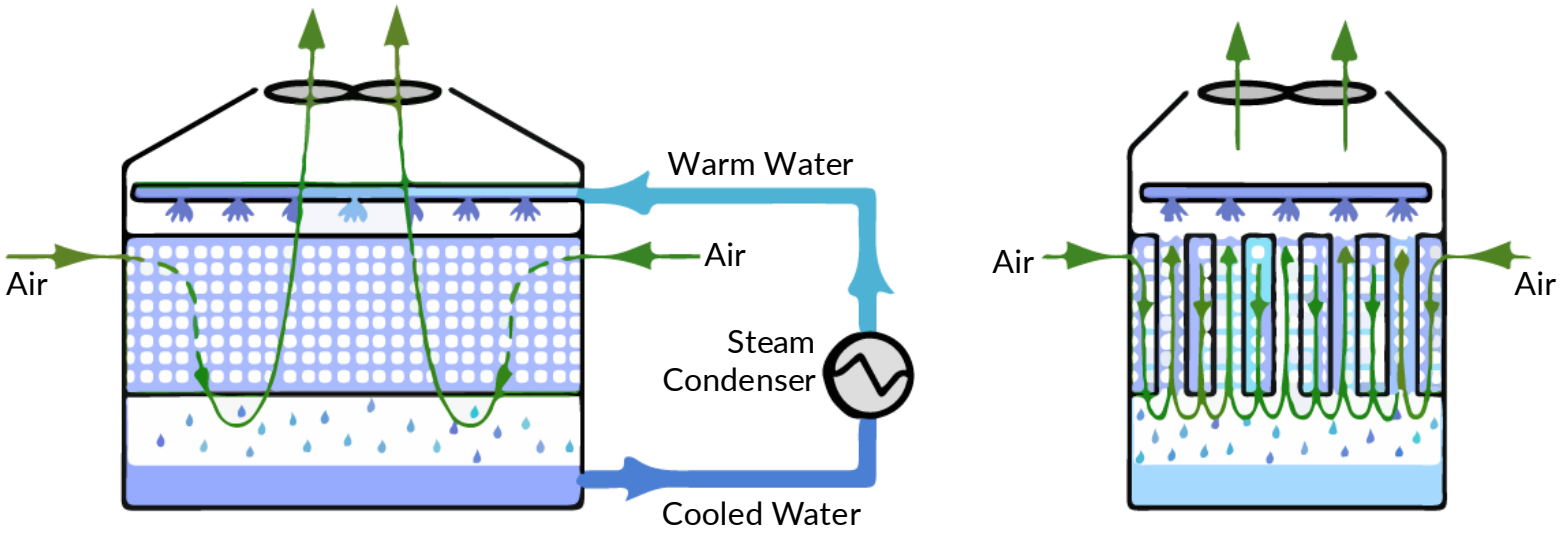
Hostel, Lucknow, India

Source: Evapoler

NOT-IN-KIND TECHNOLOGIES

Dew-point evaporative technology

- Evaporative cooling in its most common forms can cool air up to the ambient wet bulb temperatures
- Dew-point evaporative cooling, using a novel heat exchanger and flow path arrangement, has been seen to deliver un-humidified air below wet bulb temperatures consuming less water than direct evaporative cooling



Advanced dew-point cooling tower concept

Source: Glanville, 2011

Image source: https://www.researchgate.net/figure/Advanced-Dew-Point-Cooling-Tower-Concept_fig1_269692837

NOT-IN-KIND TECHNOLOGIES

Structure cooling

- In a structure cooling system, the heat accumulated in the building structure is removed by water flowing through pipes embedded in the building structure, mostly the slabs
- Structure cooling uses water supplied at 20°C–27°C to the piping network embedded in the building slabs to remove the heat
- The objective is to prevent the build-up of heat in the building thermal mass during harsh summers in tropical climates, keeping it at temperatures lower than the body temperature of the occupants. The skin will lose heat to the cooler surroundings by radiation
- Cooling tower, storage water or geothermal sink may be used as the cold-water source



Image source: https://www.attainablehome.com/what-is-radiant-floor-cooling-does-it-work/

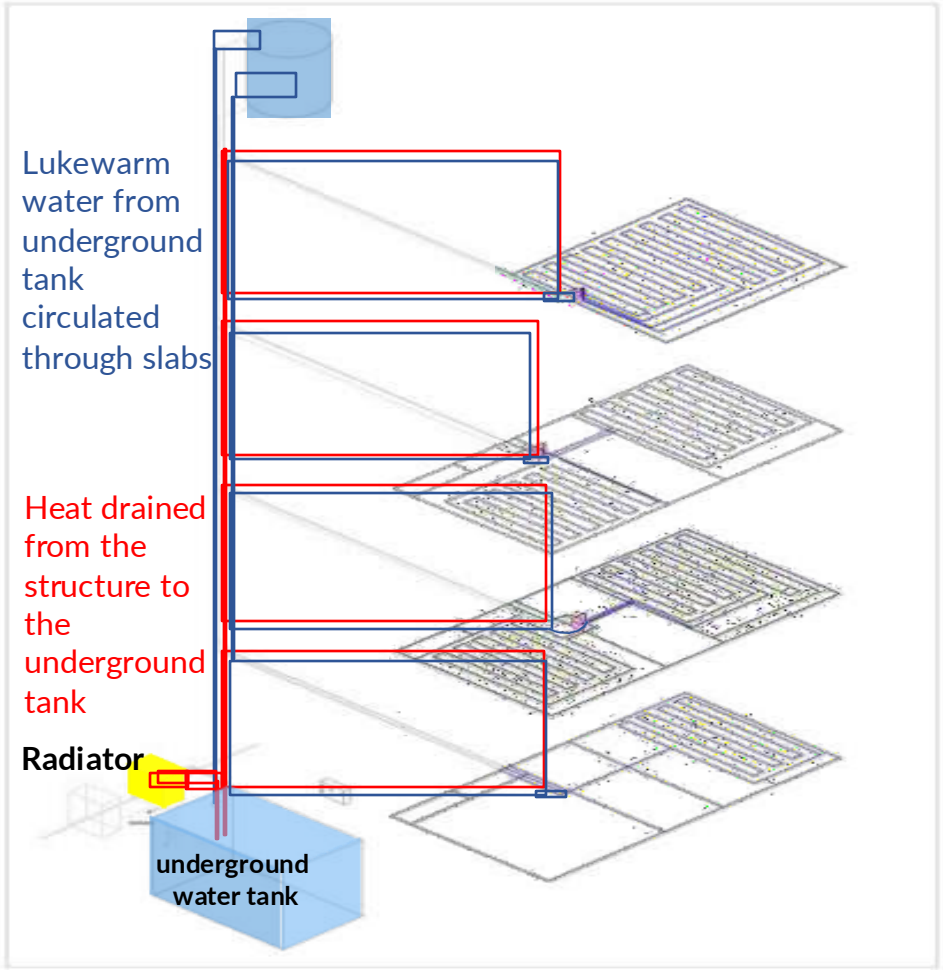
Sources: Yehuda, 2019; Solar Impulse Foundation

NOT-IN-KIND TECHNOLOGIES

Case example: Structure cooling

Greenspace Realtors' Office, Nashik, India

- The system laid 21mm diameter plastic pipes in a grid on the slabs of all floors
- The system is designed to remove 763 W/m^2 of heat from the slabs
- The water absorbs the heat from the roof and flows through a radiator, where most of the heat is released
- Lukewarm water is stored in the tank and recycled through the radiator at night, when the cool night air absorbs the residual heat. The cycle starts again the next morning
- Energy for the pump and the fan is supplied by a solar PV system



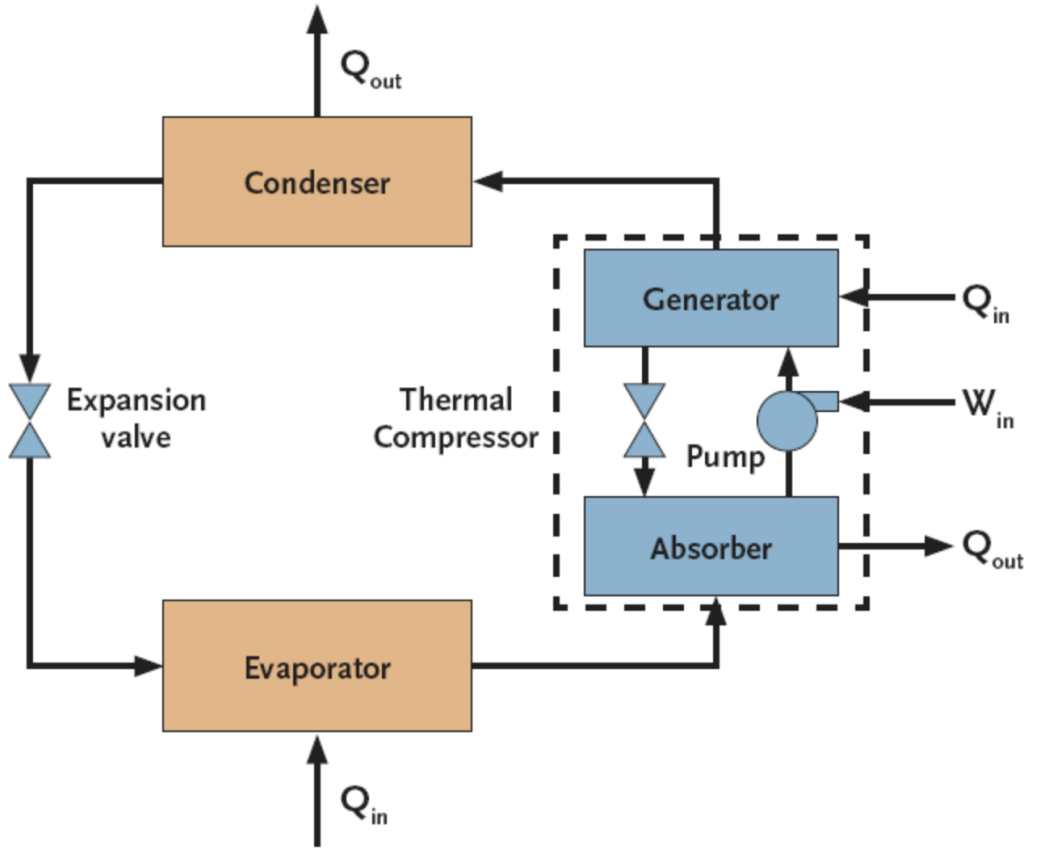
Structure cooling system installed in a office building at Nashik

Source: Yehuda, 2019

NOT-IN-KIND TECHNOLOGIES

Vapor absorption system

- Vapor absorption system produces chilled water for cooling using a heat source rather than electrical input as in the more familiar vapor compression cycle
- The vapor absorption cycle is similar to the vapor compression cycle in that it uses a circulating refrigerant, an evaporator, a condenser and an expansion device
- The difference is that the compressor of the vapor compression cycle is replaced by a chemical absorption process and generator, with a pump to provide the circulation and pressure change



Basic absorption cycle

Sources: Welch, T. 2009; Bhatia, A.

NOT-IN-KIND TECHNOLOGIES

Comparison between vapor absorption system and vapor compression system

Vapor Compression	Vapor Absorption
• Uses a compressor to create the pressure rise between evaporator and condenser, which requires energy in the form of electrical energy • Generally, uses refrigerants, like HFCs, with high environmental impact, ozone depletion or global warming potential • Coefficient of performance (COP) of conventional compression chiller is sensitive to load variations and does not reduce significantly at part loads • Has higher COP, but operating costs are higher • Can be noisy and requires more maintenance	• Uses heat to operate the cycle. This opens up options for its application and use, including solar energy and waste heat • Absorption cycle uses a liquid pump to create the pressure rise between evaporator and condenser • Uses different refrigerants that have no associated environment hazard, ozone depletion or global warming potential, e.g. lithium bromide absorption system uses distilled water as the refrigerant • COP of absorption chiller is not sensitive to load variations and does not reduce significantly at part loads • Has lower COP, but operating costs can be substantially reduced because they are powered by low-grade waste heat • Contains very few moving parts, has less noise and vibration, is compact for large capacities, and requires minimal maintenance

Source: Bhatia, A.

NOT-IN-KIND TECHNOLOGIES

Case example: Vapor absorption cooling

Solar Energy Centre, Gurgaon, India

- Example of solar thermal cogeneration
- 100kW cooling capacity standalone system is integrated with a triple-effect vapor absorption chiller (VAC) and solar parabolic concentrators. The VAC can use steam, hot water, gas, kerosene or oil to run continuously
- The integrated system is estimated to be 20% more efficient than VACs with no solar component. COP is 1.7, which is highest among the vapor absorption technology coupled with eco-friendly energy resource



Source: United States Agency for International Development, 2014

NOT-IN-KIND TECHNOLOGIES

Case example: Vapor absorption cooling

GAIL Jubilee Tower, Noida, India

- Example of cogeneration facility to generate power and cooling
- **440 TR (220 TR X 2) of vapor absorption cooling**
- Heat source is hot water from waste heat of 1.6 MW (800 kW X 2 cumulative capacity) engines exhaust, with optional direct gas firing, if required

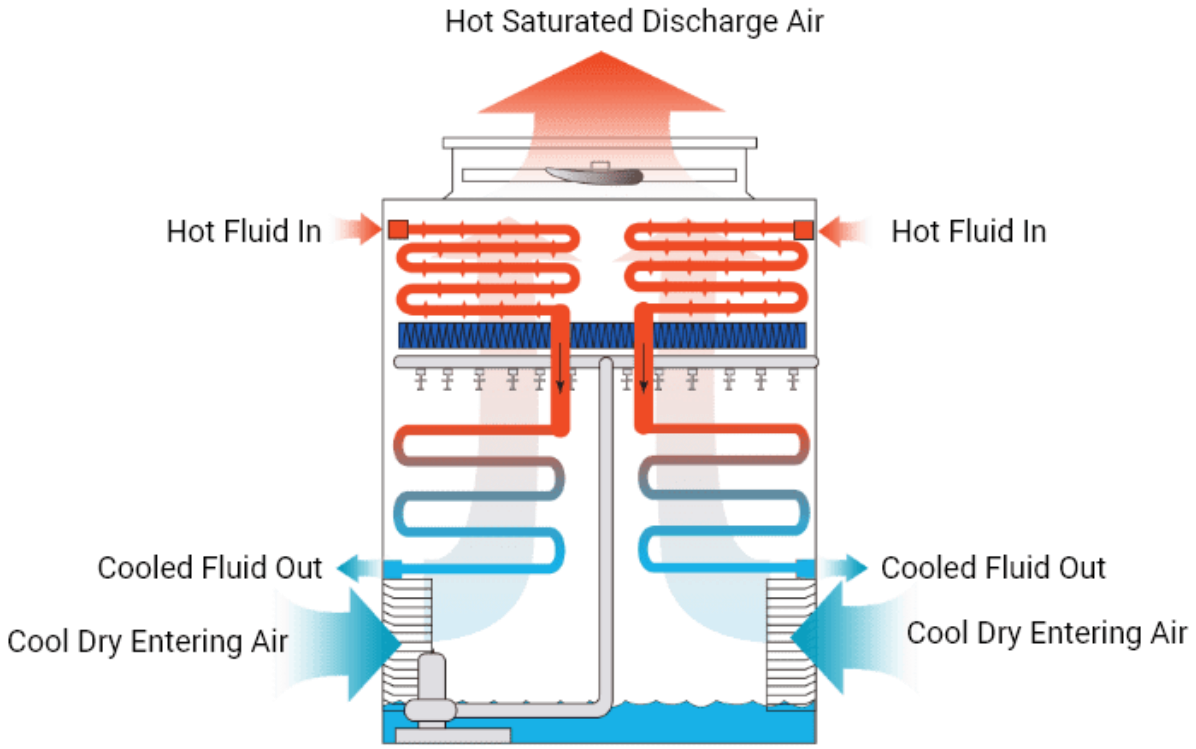


Source: Net Zero Energy Buildings

HYBRID SYSTEMS

Integrating not-in-kind technologies with vapor compression systems and other technologies

- The not-in-kind options can be integrated with conventional vapor compression systems to derive benefits of multiple technologies
- Heat/energy recovery technologies such as energy recovery ventilators (residential) or heat pipes, run-around coils or enthalpy wheels (commercial), when included in a cooling system, can help recover energy that would otherwise be wasted

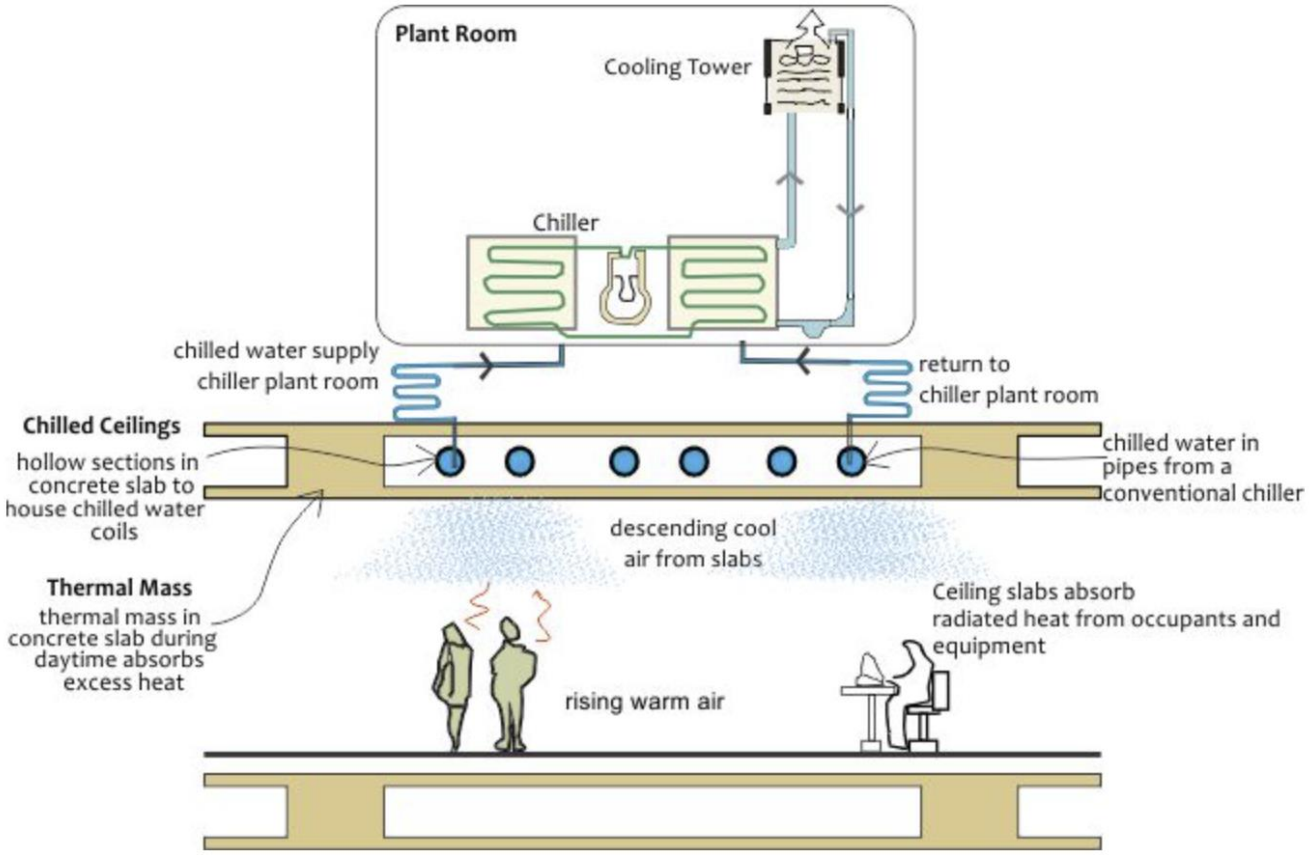


Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019
Image source: https://www.flycoolingtower.com/products/hybrid-wet-dry-cooling-tower/index.html

HYBRID SYSTEMS

Radiant cooling

- Heat transfer to the space being cooled in conventional chiller-based air conditioning happens through convection. In a radiant cooling system, heat transfer happens through radiation
- Radiant cooling systems consist of coils, which carry chilled water generated either through conventional electric chiller (vapor compression) systems or low-energy chilled water generation systems like absorption chillers or desiccant chillers. Chilled water in the coils cools down the slabs or panels, which in turn act as heat sinks for sensible heat loads of internal spaces
- Condensation in humid conditions is a risk in these systems. An ancillary dedicated outdoor air system (DOAS) is required to avoid condensation



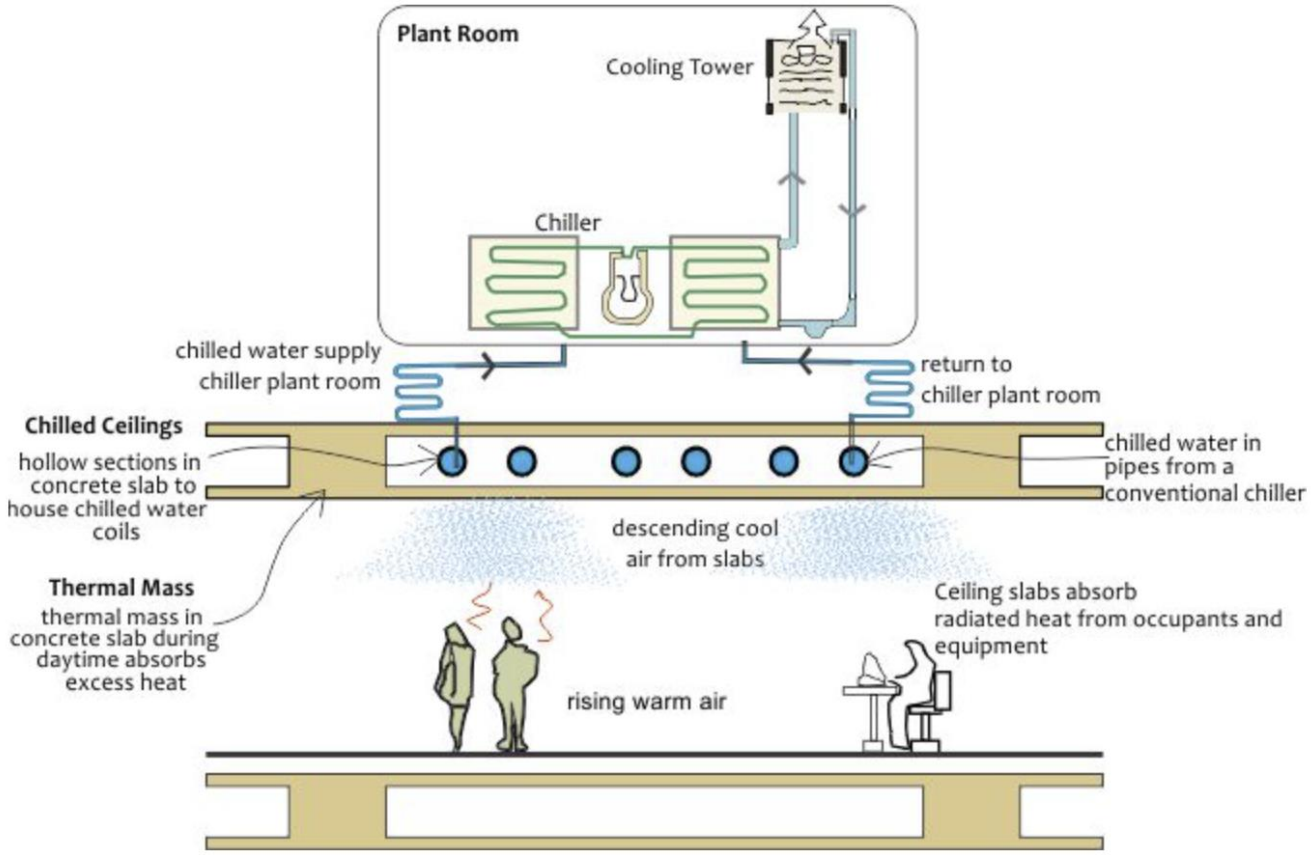
Source: United States Agency for International Development, 2014

Image source: https://pillarplus.com/radiant-cooling-system/

HYBRID SYSTEMS

Radiant cooling: Types

- **Chilled slabs:** Deliver cooling through the building structure, usually slab. Generally, cheaper than panel systems and offer the advantage of the thermal mass
- **Ceiling panels:** Deliver cooling through specialized panels. Offer faster temperature control and flexibility



Source: United States Agency for International Development. 2014

Image source: https://nzeb.in/knowledge-centre/hvac-2/radiant-cooling-systems/

HYBRID SYSTEMS

Case example: Radiant cooling

Infosys Software Development Building (SDB-1), Hyderabad, India

- The two symmetric halves of the buildings are cooled with different technologies. Conventional cooling system in one half, radiant cooling system in the other
- The radiant system is designed for a cooling output of 75 W/m^2
- Chilled water design temperatures for supply are 14°C and for return, 17°C
- Cooling tower approach temperature is 2°C
- Low-pressure piping and ducting distribution system is installed
- A DOAS with energy recovery system is installed to provide dehumidified air to offices



Cooling energy use for conventional system (2011–2012)

38.7 kWh/m^2

Cooling energy use for radiant system (2011–2012)

25.7 kWh/m^2

33% improvement in energy efficiency with radiant cooling system

Source: Net Zero Energy Buildings

HYBRID COOLING

Case example: Conventional air conditioning, fresh air dehumidification and evaporative cooling

Centre Point School, Nagpur, India

- Cooling mode switches between conventional chillers and evaporative cooling system, depending on the ambient temperature and humidity
- During operation of the conventional chillers, the treated fresh air (TFA) unit ensures adequate moisture removal from fresh air, permitting operation of the air conditioning at higher temperature setting
- During cool and dry ambient weather, chillers can be switched off, and chilled water is substituted by 'cold' cooling water from the cooling tower, thus, almost achieving 'free cooling', with minimal cooling tower fan power



Source: Centre Point School, Nagpur, India

HYBRID COOLING

Case example: Conventional air conditioning, fresh air dehumidification and evaporative cooling (continued)

Centre Point School, Nagpur, India

- Indirect adiabatic two-stage evaporative cooling, in addition to free cooling by direct use of outside cold air during favorable outdoor air temperatures to provide partial space cooling requirements
- During night, the strategy is to have the cool night air pass over the exposed interior surfaces to keep the surfaces cool at night
- All classrooms have three-speed fan coil units (with water coils) with controls for room temperature and humidity
- High efficiency, variable speed BLDC fans are used for room air circulation, for enhancement of thermal comfort, while operating chillers at higher chilled water temperatures





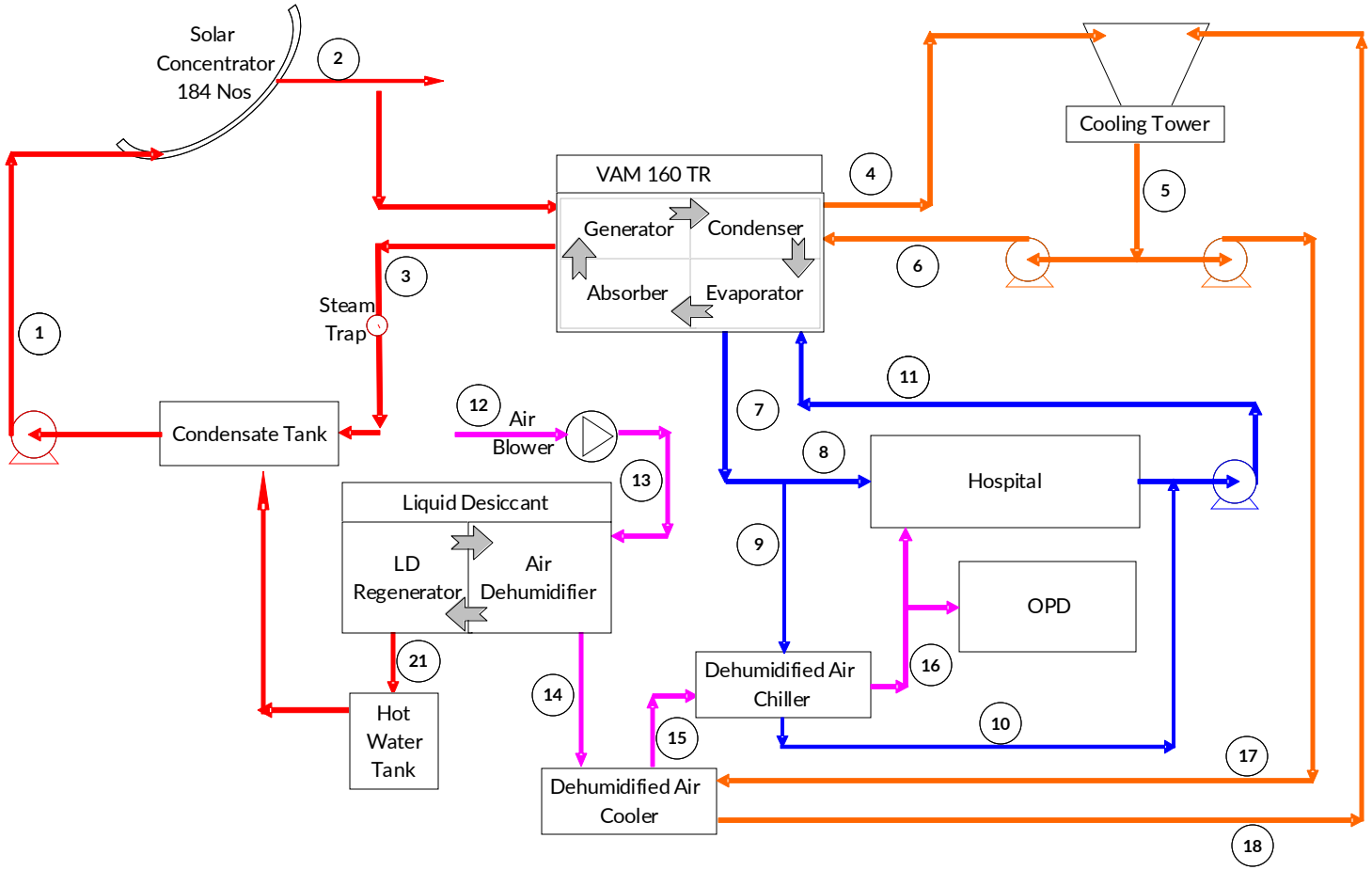
Source: Centre Point School, Nagpur, India

HYBRID COOLING

Case example: Vapor absorption cooling and liquid desiccant dehumidification

Chhatrapati Shivaji Maharaj Hospital, Thane, India

- The waiting area of the Out-Patients Department (OPD) has very high occupancy and is open from the sides
- A liquid desiccant dehumidification system (LDDS), along with a cooling tower, provides 'once-through' 100% fresh air at 26°C, at a dew point of 15°C, for adaptive cooling of the OPD waiting area, with chilled water generated by VAM



Source: Chhatrapati Shivaji Maharaj Hospital, Thane, India

HYBRID COOLING

Case example: Vapor absorption cooling and liquid desiccant dehumidification (continued)

Chhatrapati Shivaji Maharaj Hospital, Thane, India

- Scheffler solar thermal concentrators have been installed to provide steam and hot water for regeneration of liquid desiccant and heat source for the absorption chiller
- The solar-heated absorption chiller has a cooling capacity of 160 TR, which provides cooling to other areas of the hospital
- This system has substituted electrical chillers and LDO-fired boilers



Liquid desiccant dehumidification system



Scheffler solar thermal concentrators

Source: Chhatrapati Shivaji Maharaj Hospital, Thane, India

NOT-IN-KIND TECHNOLOGIES

Case example: Tri-generation with vapor absorption cooling system

Pushpanjali Crosslay Hospital, Ghaziabad, India

- Tri-generation systems are combined heat and power (CHP) systems integrated with a thermally-driven refrigeration system to provide cooling, as well as generate electrical power and heating
- The tri-generation system provides 1,000 TR cooling for air conditioning
- The system components to provide heating and cooling include a gas genset (1.7 MW), 600 TR capacity vapor absorption machines (VAM) with heat recovery, and electrical chillers of 400 TR capacity



Source: Net Zero Energy Buildings

ALTERNATIVE COOLING STRATEGIES

Thermal energy storage and tri-generation

Thermal energy storage

Thermal energy storage is a method of demand-side load management and must be integrated with cooling technologies. It can significantly reduce energy costs by allowing cooling equipment to be predominantly operated during off-peak hours (favorable electricity tariff periods). Ice banks, cryogenic liquids, phase change materials (PCMs) may be used as the storage medium

Tri-generation

Tri-generation can be used where there is a simultaneous demand for heat and power and uninterrupted availability of fuel. Advantages include: (i) onsite generation of electricity, heat and power; (ii) maximum total fuel efficiency; (iii) reduced fuel and energy costs; (iv) lower electrical demand during peak time; (v) elimination of HCFC/CFC refrigerants; and (vi) emissions reduction

Most vapor absorption cooling applications include tri-generation (heat, cooling and power) or co-generation (heat and power) systems

Source: Ministry of Environment, Forest and Climate Change, Government of India, 2019

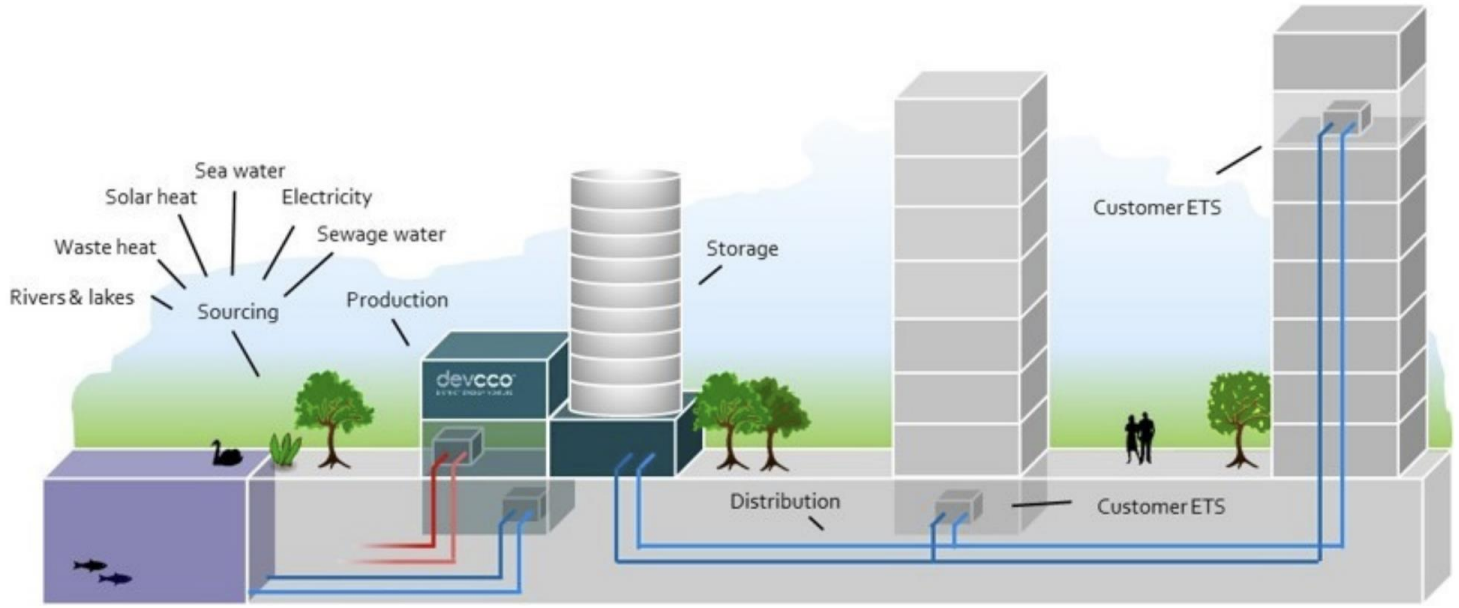
ALTERNATIVE COOLING STRATEGIES

District cooling

- District cooling systems provide cooling to an entire community from a network of centralized cooling devices. They supply chilled water produced in a central plant to buildings and industrial sites through a network of insulated pipes

Advantages

- Buildings do not require their own air conditioning systems, saving space and reducing the need to have surplus cooling capacity for peak loads
- Lower costs due to economies of scale, especially if it makes use of a low-cost source of energy, such as industrial waste, excess heat or geothermal energy



General scheme of a district cooling system

Sources: International Energy Agency, 2018; Calderoni et al., 2019

ALTERNATIVE COOLING STRATEGIES

District cooling

- The chilled water is typically produced using the same technology i.e., vapor compression system but generally at a much larger scale
- In some locations, the water may be chilled in part or in full using heat exchange with natural sources, such as groundwater, rivers and the sea, if environmental conditions and costs permit. Waste heat from industries, geothermal or even solar thermal sources, can also be used with absorption chillers
- District cooling systems often incorporate storage in the form of cold water, slurry or ice, to reserve cooling energy during low load periods to:
  - Reduce the need for extra capacity during peak loads
  - Minimize the partial load operation and maximize operation near full load to improve energy efficiency
  - Allow for flexibility to produce more cooling than required when electricity prices are low

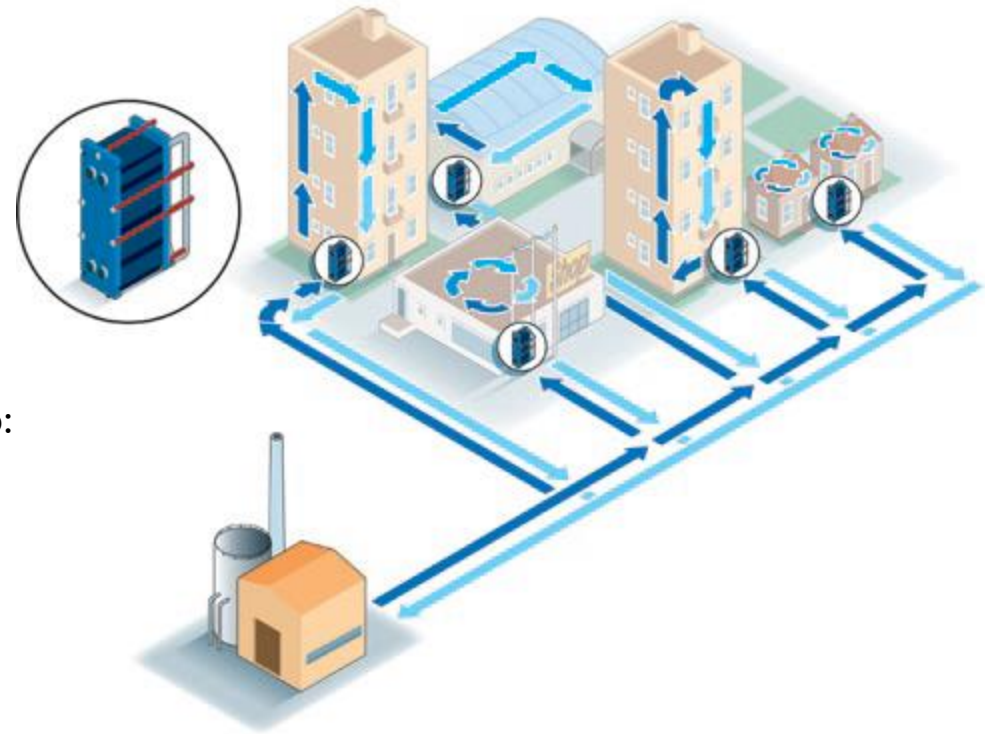


Image source: https://www.alfalaval.my/industries/hvac/district-cooling/what-is-district-cooling-system/

ALTERNATIVE COOLING STRATEGIES

Case example: District cooling

GIFT City, Gandhinagar, India

- Consists of office buildings, residential apartments, schools, a hospital, hotels, retail stores and recreational facilities
- When fully built, it will reduce the requirement for installed cooling capacity from 270,000 TR to 180,000 TR. It is expected to reduce the cooling power demand of the city, as compared to business as usual, by 105 MW of electricity
- The system will use low GWP refrigerant for cooling generation and include stratified thermal energy storage tanks that are used to meet the cooling loads during peak demand periods, reducing total power demand of the system



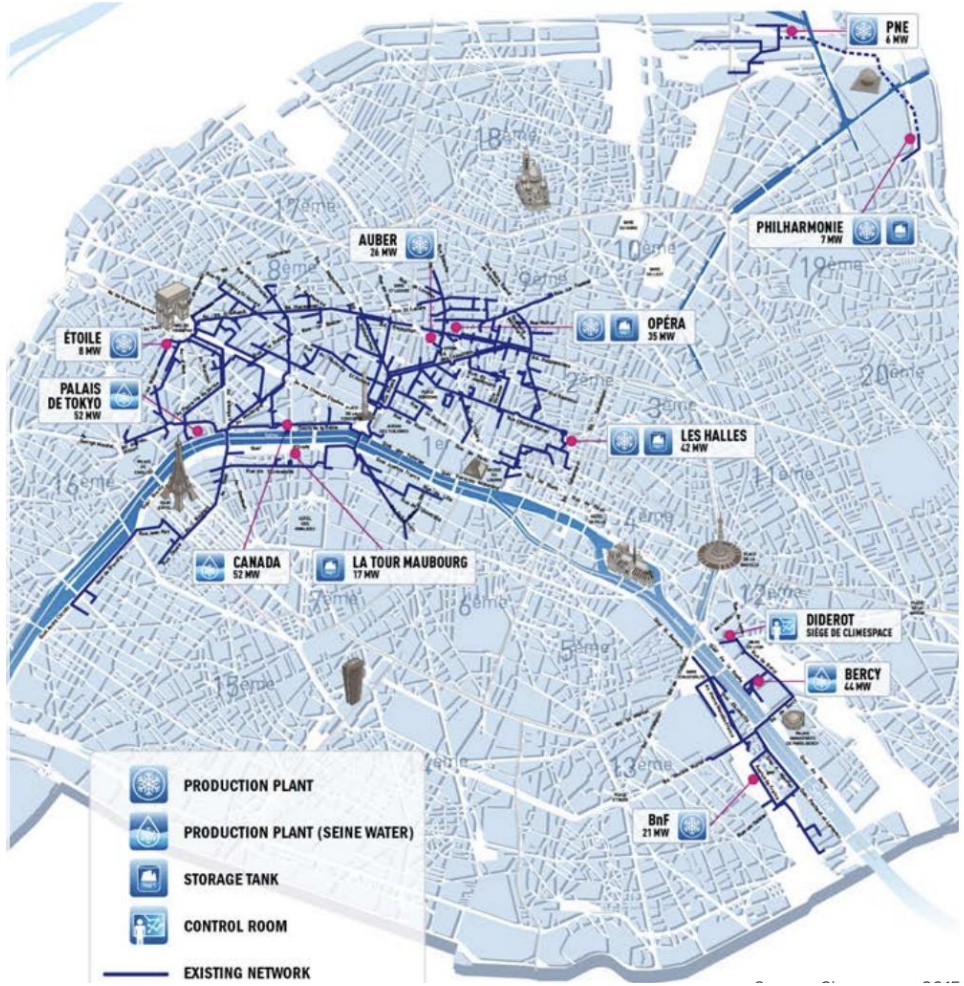
Sources: United Nations Environment Programme, 2021a; GIFT City

ALTERNATIVE COOLING STRATEGIES

Case example: District cooling

Paris, France

- It is the largest district cooling network in Europe, serving offices, banks, stores, hotels, museums and other buildings
- Leverages the Seine River as an available heat sink in 3 of its 10 production sites. When the water temperature is below 8°C, water from the Seine is distributed directly through these sites as free cooling
- During the night, when the demand for cooling is lower, it takes advantage of off-peak electricity and stores thermal energy as either chilled water or ice, which is then used during the hours of peak demand during the day. This storage has the potential to decrease peak power for cooling by 15%–50%
- Nearly 60% of the chilled water distribution system is routed through the city's sewage network



District cooling network in Paris

Sources: United Nations Environment Programme, 2017 and 2021a

Sustainable Cooling

Refrigerants



Image source: https://bootes.in/radiant-cooling/

REFRIGERANTS

The story so far .....

Early refrigeration technology	Refrigerants were flammable or toxic, confining their use mainly to industrial systems
Refrigerants for space cooling	Safer refrigerants, based on chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), were developed
Montreal Protocol 1987	This protocol mandated the phase out of CFCs and HCFCs due to their high ozone depletion potential (ODP). They were mainly replaced by hydrofluorocarbon (HFC)-based refrigerants with short-lived gases that have no ODP
Kigali Amendment to Montreal Protocol 2016	The GWP of HFCs is still high, ranging between 1,340 GWP_{100} for R134a and 3,940 GWP_{100} for R404a. The Kigali Amendment to the Montreal Protocol was initiated to phase down these high-GWP HFCs

Source: Khosla et al., 2022

REFRIGERANTS

Alternatives

Low-ODP and low-GWP refrigerants will need to balance the trade-offs between energy efficiency, safety, cost, availability, and environmental considerations of new refrigerants. Examples of alternative refrigerants are:

Hydrofluoroolefins (HFOs)

- HFOs have GWP_{100} values of less than 1
- But they typically still need to be mixed, e.g., with HFCs, to obtain a non-flammable blend or for direct substitution in existing equipment, which results in higher GWP

Natural refrigerants

- Use of natural refrigerants, such as ammonia and hydrocarbons, are commonplace in industrial systems where large equipment sizes are common, and flammability and toxicity can be more readily managed
- Their use in residential space cooling is debatable due to smaller sizes, life cycle emissions and need for increased safety measures

Source: Khosla et al., 2022

ALTERNATIVE REFRIGERANTS

Current space cooling applications

Vapor absorption systems	• Refrigerants used are ammonia (0 GWP_{100}) and water • Used for comfort cooling in commercial and industrial buildings and process cooling
HC 290 air conditioners	• Hydrocarbon-based cooling system • Refrigerant used is HC 290 (5 GWP_{100}), which is flammable • Available for residential and commercial air conditioning
Solar-assisted cooling	• Solar-assisted vapor absorption cooling • Refrigerants used are ammonia (0 GWP_{100}) and water • Applicable for cluster air conditioning

Source: iForest, 2021

ALTERNATIVE REFRIGERANTS

Challenges in adoption

Lack of awareness

Decision-making on residential air conditioner purchase are not based on the refrigerant gas. In the absence of substantive awareness efforts on natural refrigerants, HFC-based air conditioners continue to be the mainstream choice

High cost

Natural refrigerant systems are found to have a high initial cost, due to small manufacturing capacity for these technologies and scarcity of expertise both in terms of technical experts and servicing technicians

Difficulty with retrofitting

Large number of existing equipment like chillers, VRF and packaged DX may not be suitable for retrofitting with natural refrigerant-based systems

Safety and lack of standards

Concerns around safety of natural and low-GWP refrigerants remain. Standards for system design and refrigerants become imperative for safety

Source: iForest, 2021

Sustainable Cooling

Services, Policies and Financial Solutions



SUSTAINABLE COOLING

Services solutions

Preparational services

- Activities that support the preparation (e.g., theory and practical skills) to create or deploy more sustainable cooling solutions
- Includes fundamental education, skills development and project services

Operational services

- Activities to deliver and use more sustainable cooling
- Includes direct operation of cooling services, the management that supports cooling services, and the maintenance that ensures the cooling services and technologies are operating sustainably

Source: Sustainable Energy for All, 2020

SUSTAINABLE COOLING

Policy solutions

Regulatory policies

Legally binding or 'stick' measures:

- Building energy codes
- Planning and zoning codes
- Minimum energy performance standards (MEPS)
- Disclosures through labels and certificates
- Audits and evaluations
- Utility obligations
- Public procurement requirements
- Import and export controls

Information policies

Awareness generation measures:

- Disclosures through public databases
- Certification of education, product or service
- Labels for branding, endorsement and comparison
- Voluntary standards
- Awareness through information and behavior campaigns

Incentive policies

Motivational or 'carrot' measures:

- Non-financial incentives such as expedited approval and expanded scope allowance
- Policies to deliver financial solutions

Source: Sustainable Energy for All, 2020

SUSTAINABLE COOLING

Financial support

Finance solutions

- Loans
- Risk sharing
- Energy performance contracts or service agreements
- Bulk purchases
- Leasing
- On-bill or on-tax repayment
- Equity
- Bonds
- Sustainable or energy investment funds
- Crowdsourcing

Fiscal solutions

- Energy pricing and subsidies
- Energy or carbon tax on unsustainable systems
- Tax credits on more sustainable solutions
- Import and export duties (reduced for sustainable solutions)

Funding solutions

- Grants: Direct financial contribution
- Rebates: Direct financial contribution as a result of purchasing a product or service
- Subsidy: Direct financial contribution to reduce cost of product or service

Source: Sustainable Energy for All, 2020

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy | PROJECT

2.5 Operational Energy – Opportunities for Optimization

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

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WHAT WILL YOU LEARN?

01 Approach for Operational Energy Reduction

02 Operational Energy Reduction in HVAC

03 Operational Energy Reduction in Lighting

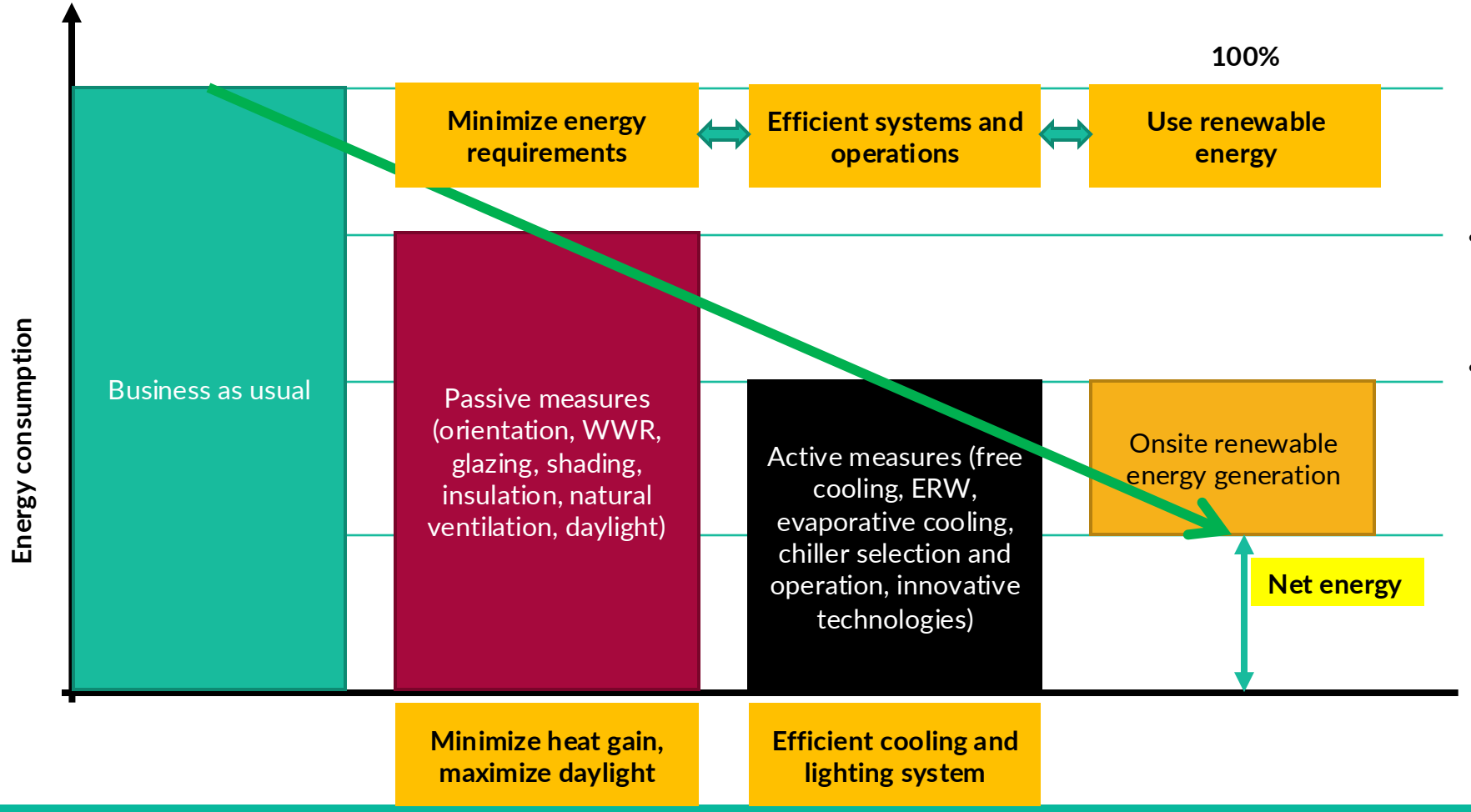
04 Operational Energy Reduction in Other Services

05 Integration of Renewable Energy



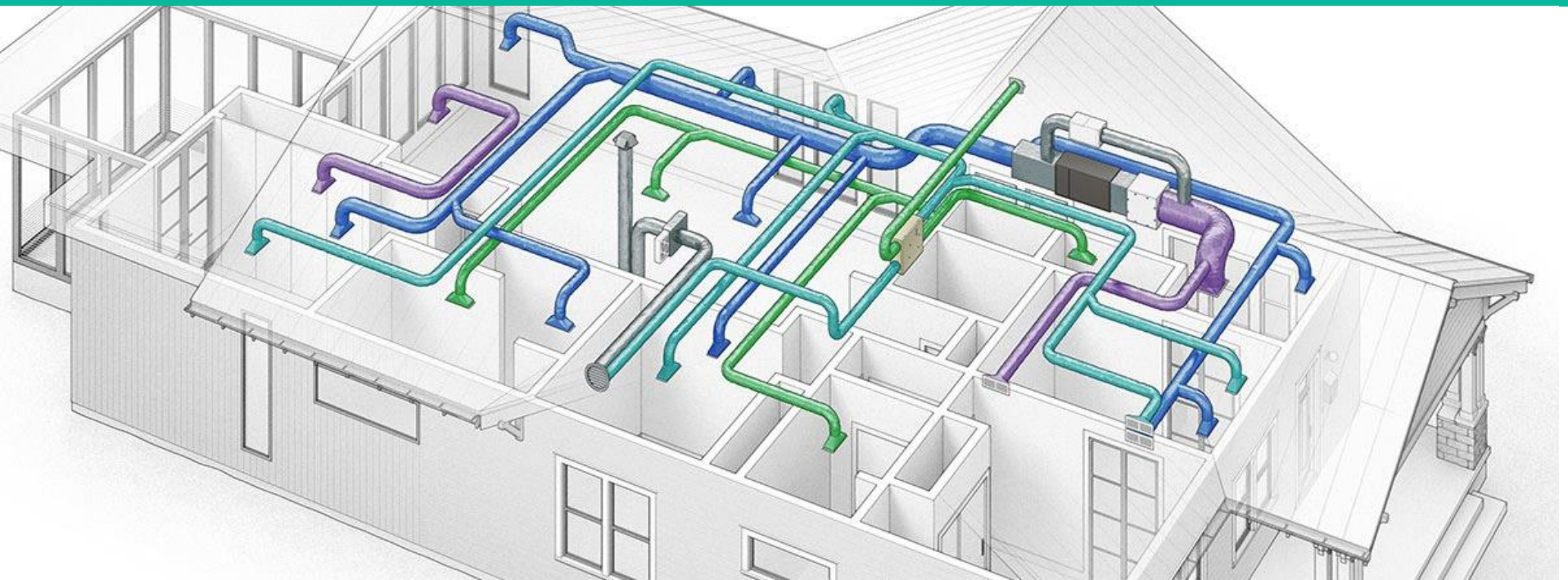
OPERATIONAL ENERGY REDUCTION

First step: Minimize energy requirement by adopting passive measures



- First, reduce energy requirement of the building using passive measures
- Integrated design process is imperative to achieve operational energy goals

Operational Energy Reduction in HVAC



SIZING THE HVAC SYSTEM

Factors for optimization

Depends on several factors:

- Ambient conditions (temperature, humidity, solar radiation, wind)
- Internal conditions (stringent setpoints, adaptive comfort)
- Building usage and internal loads (occupants, lighting loads, equipment loads)
- Building envelope (wall, window, roof) and its properties (passive measures that helps in load or required size reduction)

Do not consider only the worst possible scenario
Use calculation sheets and software tools to size the system optimally



Target kW/TR of cooling?

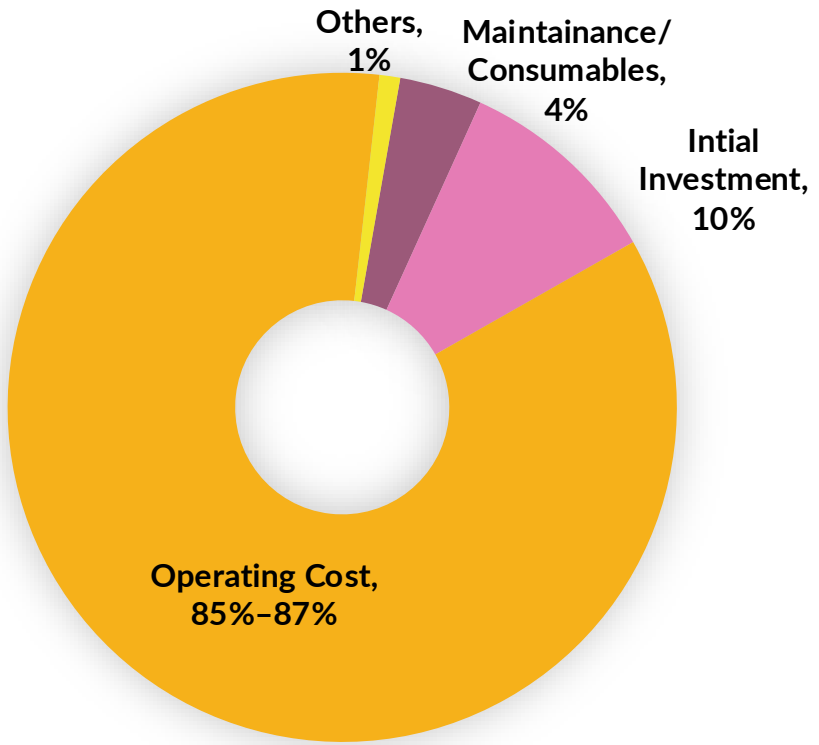
HVAC: LIFE CYCLE COSTING

Energy cost is the obvious focus area

Consider operational life of 15 years for equipment and systems

- The initial capex is about 10%
- Cost of operation and maintenance is 3%–5%
- **Operating cost (energy consumed) is 85%–87%**

Select systems and equipment with long-term perspective and not just initial cost

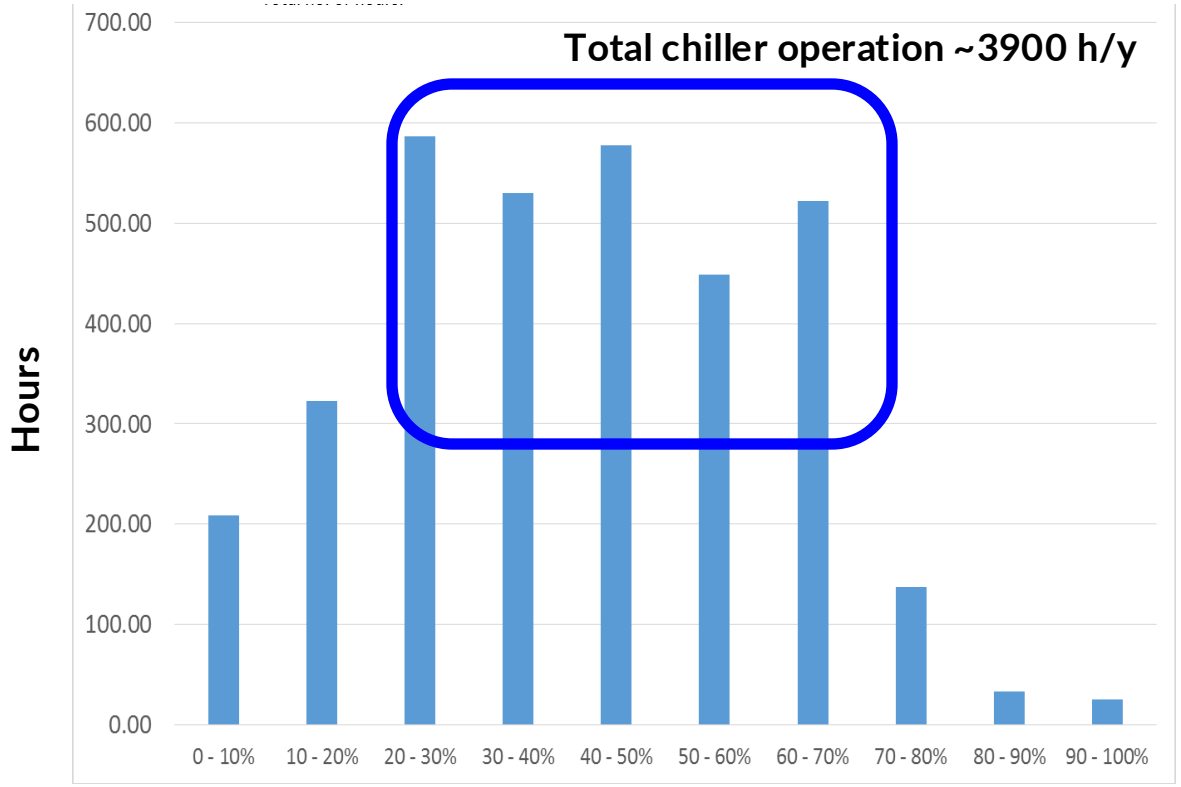


SELECT EFFICIENT SYSTEMS

Part-load performance is important

- Most equipment have a full-load minimum efficiency metric that is based on standard conditions at rated full-load
- When selecting system, it is important to check the part-load performance, which gives system efficiency at varying loads and operating conditions
- Some figures of merit for chillers are:
  - Integrated part-load value (IPLV)
  - Integrated energy efficiency ratio (IEER)
  - Seasonal energy efficiency ratio (SEER)
- Loads may vary significantly with climatic conditions and building utilization

Select a system that gives better part-load performance in the most frequently operating load band



Example: Load variations on a chiller

SYSTEM EFFICIENCY

Guidance on minimum efficiency levels

- The system efficiency levels are prescribed at both international and national levels, and are updated at regular intervals
- Internationally, the minimum equipment efficiency values defined in **ASHRAE Standard 90.1** are well recognized and widely used. Meeting the prescriptions of the latest edition can ensure that selected systems will require lower operational energy
- At national levels, the local codes or standards will **supersede**; for example, in **India**, the **Energy Conservation Building Code (ECBC)** is applicable to both commercial and residential buildings. The minimum equipment efficiency values are prescribed with reference to local conditions, available systems and future prescriptions on minimum performance levels

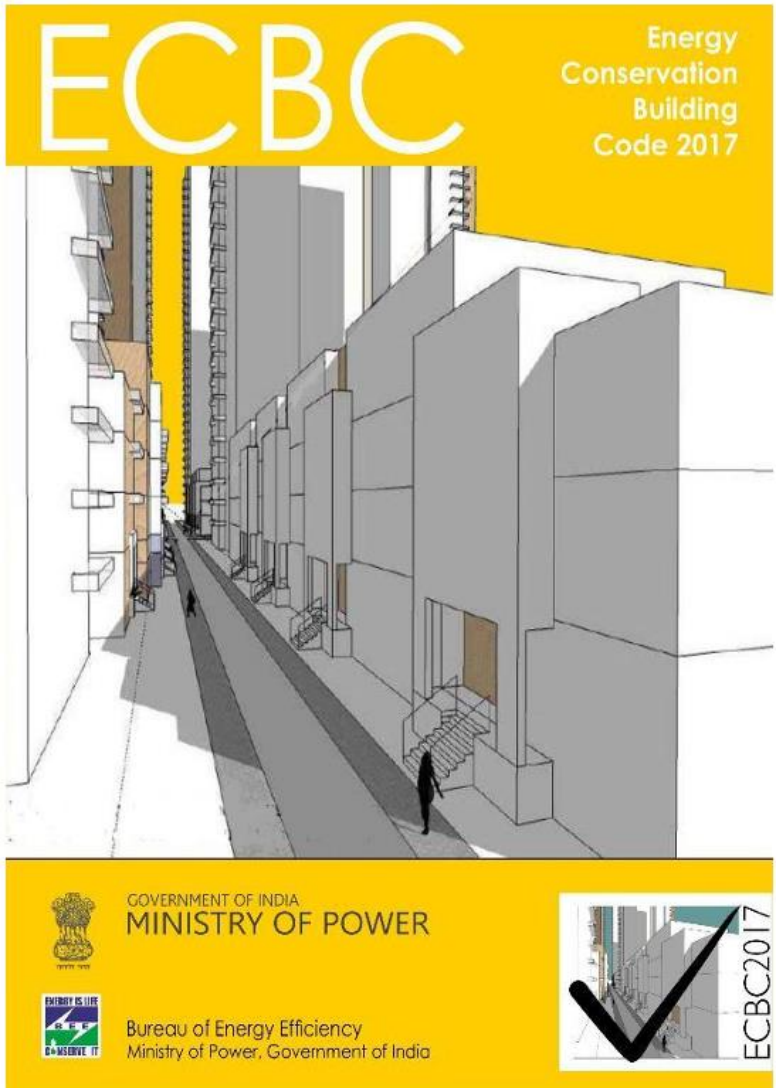


Image source: Bureau of Energy Efficiency, Government of India, 2017

UNITARY AIR CONDITIONERS

ECBC 2017 (India) prescriptions for COP of unitary air conditioners

Requirements for unitary, split, packaged air conditioners

Cooling Capacity		ECBC Buildings		ECBC+ Buildings		Super ECBC Buildings	
kW_r	TR	Water-cooled	Air-cooled	Water-cooled	Air-cooled	Water-cooled	Air-cooled
≤ 10.5	≤ 3	NA	BEE 3 Star	NA	BEE 4 Star	NA	BEE 4 Star
> 10.5	> 3	3.3 EER	2.8 EER	3.9 EER	3.4 EER	3.9 EER	3.4 EER

- The criteria given under 'ECBC Buildings' are mandatory in India as per ECBC 2017
- The criteria for 'ECBC+ Buildings' and 'Super ECBC Buildings' are optional; however, they give specifications for more efficient systems

Source: Bureau of Energy Efficiency, Government of India, 2017

AIR COOLED VRF AIR CONDITIONERS

ECBC 2017 (India) prescriptions for COP of VRF air conditioners

Mandatory requirements for air-cooled variable refrigerant flow (VRF) air conditioners under ECBC Buildings

		For Heating or cooling or both	
Type	*Size category (kWr)*	*EER (W/W)*	*IEER (W/W)*
VRF Air Conditioners, Air cooled	< 40	3.28	4.36
	>= 40 and < 70	3.26	4.34
	>= 70	3.02	4.07

Source: Bureau of Energy Efficiency, Government of India, 2017

CHILLER EFFICIENCIES

ECBC 2017 (India) prescriptions for COP of chillers

Mandatory requirements for chillers

Chiller	ECBC Buildings	ECBC+ Buildings	Super ECBC Buildings
All	BEE 1 star	BEE 3 star	BEE 5 star

Star rating levels for water-cooled chillers
(valid from January 1, 2024 to December 31, 2025)

kW of Cooling	ISEER				
	1 Star	2 Star	3 Star	4 Star	5 Star
<260	4.80	5.20	5.60	6.10	6.60
>=260 and <530	5.00	5.60	6.20	6.80	7.40
>=530 and <1,050	5.50	6.10	6.70	7.40	8.20
>=1,050 and <1,580	5.80	6.50	7.20	7.90	8.70
>=1,580	6.00	6.70	7.40	8.20	9.00

Star rating levels for air-cooled chillers
(valid from January 1, 2024 to December 31, 2025)

kW of Cooling	ISEER				
	1 Star	2 Star	3 Star	4 Star	5 Star
<260	3.00	3.30	3.60	4.00	4.40
>=260	3.10	3.50	3.90	4.30	4.70

Source: Bureau of Energy Efficiency, Government of India, 2017

COOLING TOWER

ECBC 2017 (India) prescriptions for cooling towers

Prescribed cooling tower pumping power for ECBC, ECBC+ and Super ECBC Buildings

Equipment type	*Rating Condition*	*Efficiency*
Open circuit cooling tower Fans	35°C entering water 29°C leaving water 24°C WB outdoor air	0.017 kW/kW$_r$ *0.31 kW/ L/s*

ECBC+ and Super ECBC Buildings have additional requirements for VFD installed in cooling tower fans

Source: Bureau of Energy Efficiency, Government of India, 2017

PUMPS IN HVAC SYSTEMS

ECBC 2017 (India) prescriptions for power of pumps

Prescribed installed pumping power

Equipment	ECBC Buildings	ECBC+ Buildings	Super ECBC Buildings
Chilled Water Pumps (Primary and Secondary)	18.2 W/kW_r with VFD on secondary pump	16.9 W/kW_r with VFD on secondary pump	14.9 W/kW_r with VFD on secondary pump
Condenser Water Pumps	17.7 W/kW_r	16.5 W/kW_r	14.6 W/kW_r
Pump Efficiency	Min. 70%	Min. 75%	Min. 85%

Source: Bureau of Energy Efficiency, Government of India, 2017

UTILITY PLANT ROOM

ECBC 2017 (India) prescriptions for central chilled water plant

In ECBC 2017, the efficiency of the entire plant room has been specified for all categories of the buildings

System Type	Peak Building Cooling Load (kW)	
	< 3,516 kW	≥ 3,516 kW
Central Chilled Water Plant (Water Cooled)	0.21 (kW/kW_r) 0.74 (kW/TR)	0.20 (kW/kW_r) 0.70 (kW/TR)
Minimum system efficiency based on total installed equipment power per unit cooling capacity		

Reference System Efficiency	ECBC	ECBC+	Super ECBC
HVAC Plant Room, kW/kW_r	0.26	0.23	0.20

Source: Bureau of Energy Efficiency, Government of India, 2017

AHU FAN EFFICIENCIES

ECBC 2017 (India) prescriptions on minimum AHU fan efficiencies

Prescribed minimum mechanical efficiency and motor efficiency for fans in ECBC Buildings

System type	*Fan Type*	*Mechanical Efficiency*	*Motor Efficiency (As per IS 12615)*
Air-handling unit	Supply, return and exhaust	60%	IE 2

Prescribed minimum mechanical efficiency and motor efficiency for fans in ECBC+ Buildings

System type	*Fan Type*	*Mechanical Efficiency*	*Motor Efficiency (As per IS 12615)*
Air-handling unit	Supply, return and exhaust	65%	IE 3

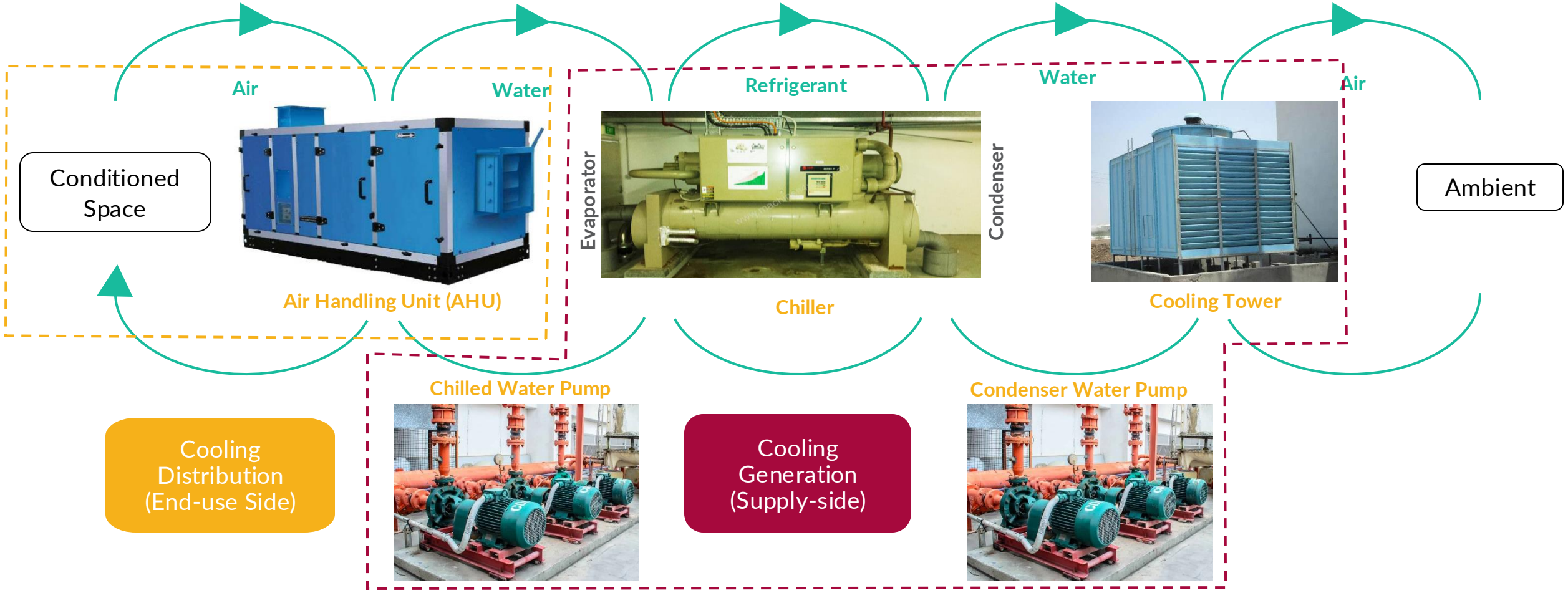
Prescribed minimum mechanical efficiency and motor efficiency for fans in Super ECBC (ECBC+) Buildings

System Type	*Fan Type*	*Mechanical Efficiency*	*Motor Efficiency (As per IS 12615)*
Air-handling unit	Supply, return and exhaust	70%	IE 4

Source: Bureau of Energy Efficiency, Government of India, 2017

TYPICAL COOLING SYSTEM (CENTRALIZED)

Two key segments



OPTIMIZING CENTRALIZED SYSTEM

Key strategies

Cooling Generation

- Increase the chilled water generation temperature
- Decrease the condenser water temperature
- Use VFD for chillers
- Pump selection

Cooling Distribution

- Minimize the air distribution path
- Enthalpy recovery
- Free cooling
- Use VFDs

Use building management systems (BMS) and building automation systems (BAS) to optimize operations

CHILLED WATER TEMPERATURE

Design option for operation at higher chilled water temperature

Design for higher chilled water temperature: Radiant cooling system

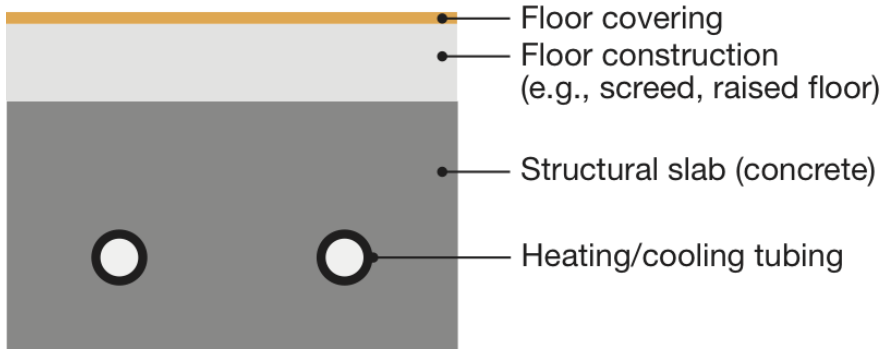
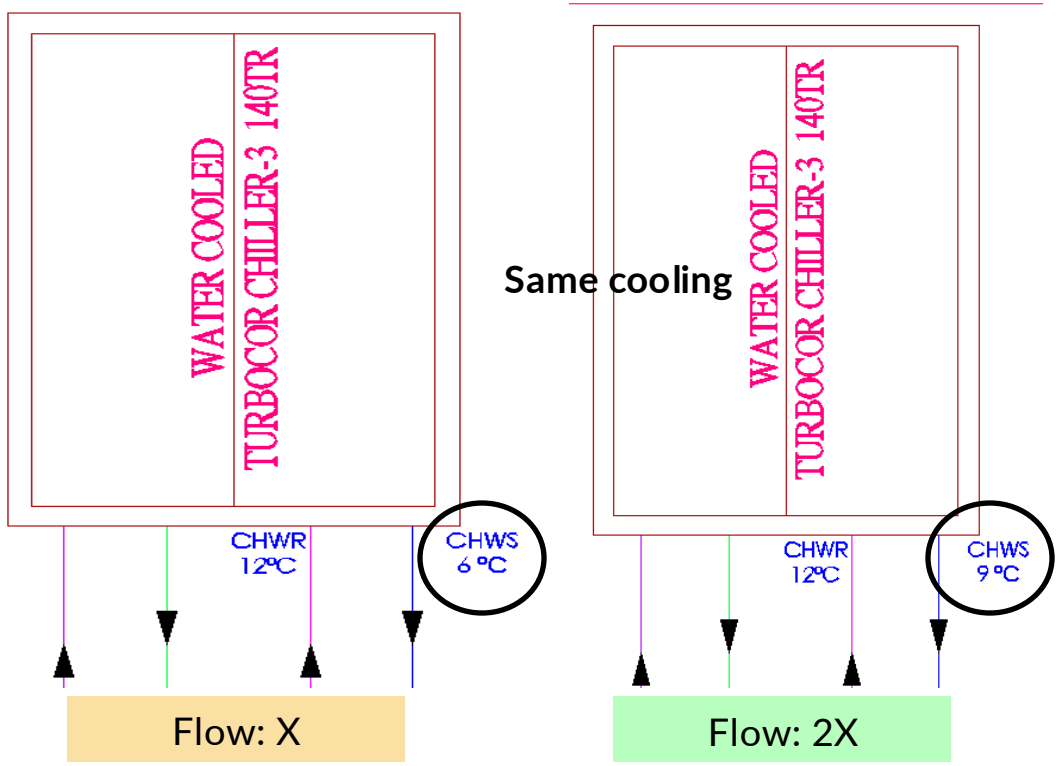




Image source: Infosys. India

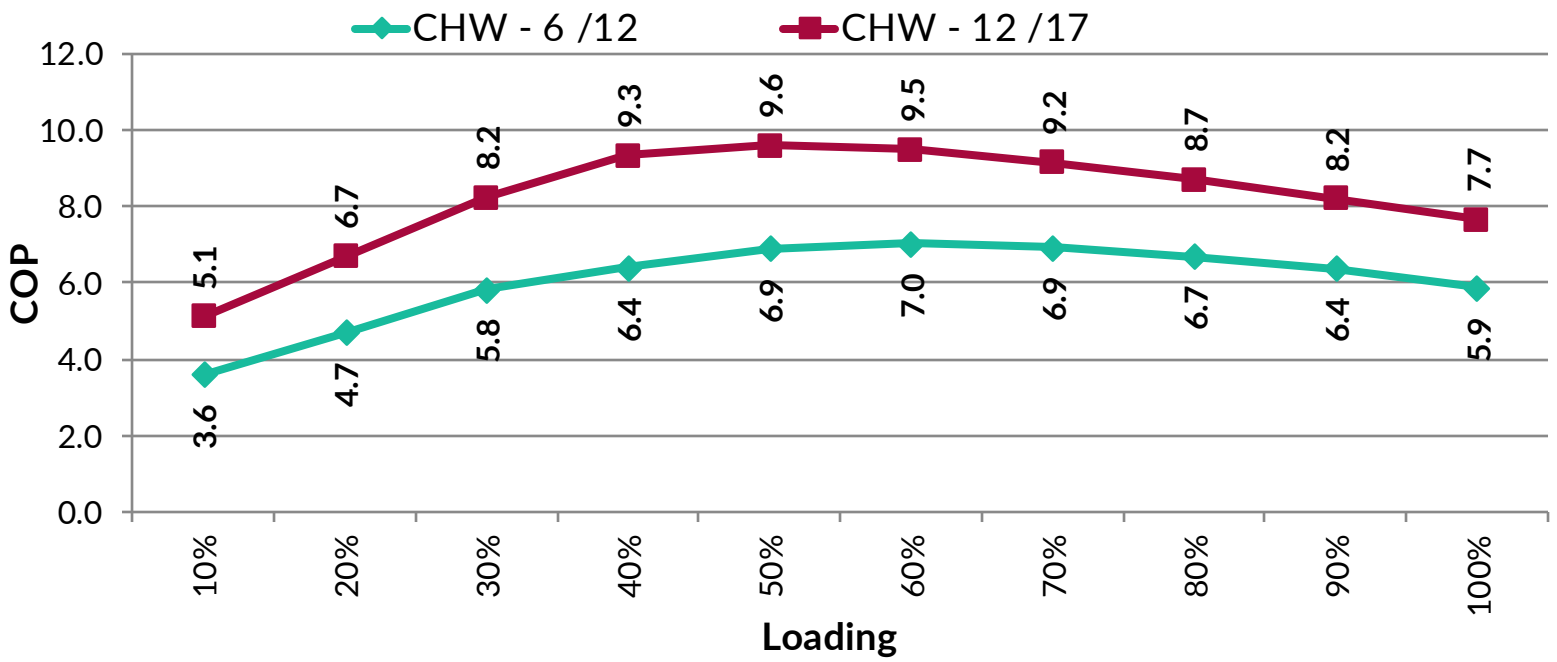
Operate at higher chilled water temperature



Limiting factor: Temperature required for **dehumidification**

CHILLED WATER TEMPERATURE

Impact of operation at higher chilled water temperature



Less power input for compressor; leading to increase in COP

30%–40%

COP

Note: At constant condenser cooling water inlet / outlet temperatures of 28°C / 34°C

Source: Ministry of Power, Government of India, 2022a

COOLING WATER TEMPERATURE

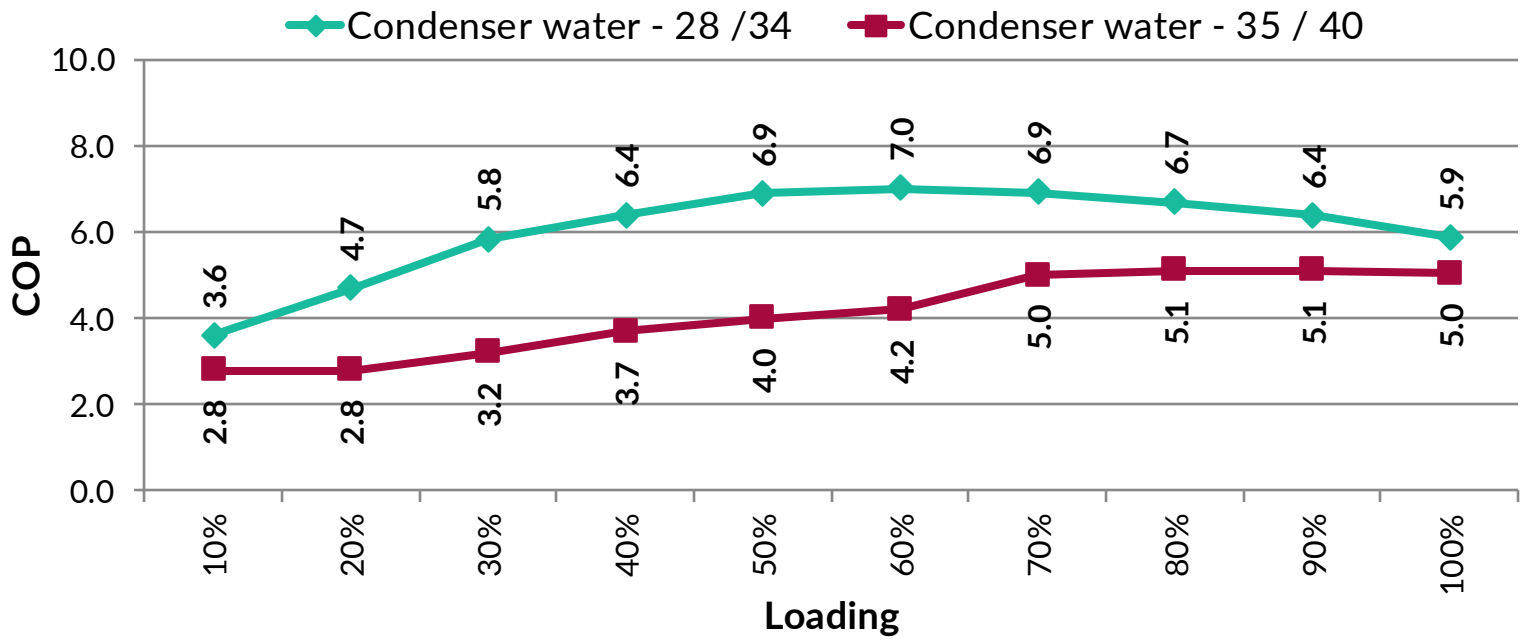
Options for lower condensing temperature

- Use water cooling or evaporative cooling of condensers instead of air-cooled condensers. This is desirable for reducing chiller power consumption
- Use cooling tower with low approach temperature (1°C–2°C) to improve heat transfer effectiveness in the condenser. This lowers the condensing temperature, thus, reduces the power input for the compressor and increases COP
- The limiting factor is water availability. Due to water scarcity, many urban local bodies in India do not permit the use of freshwater for HVAC cooling applications

Parameters	Unit	Water-cooled Chiller	Air-cooled Chiller	Evaporative Chiller
Refrigerant		R-134 a	R-134 a	R-134 a
Capacity	TR	100	100	100
Water Flow across Condenser	m^3/hr	60.5	NA	30.3
Condenser Pump Power	kW	5.51	NA	1.52
Condenser / CT Fan Power	kW	NA	15.12	NA
Compressor Power Consumption	kW	77.56	110.22	66.44
Specific Power Consumption	**kW/TR**	**0.78**	**1.10**	**0.66**
Evaporator Refrigerant Temp.	°C	2.0	2.0	2.0
Evaporator Refrigerant Pressure	bar	3.1	3.1	3.1
Condenser Refrigerant Pressure	bar	8.5	11.3	7.6
Condenser Refrigerant Temp.	°C	33.5	44.0	29.5
Make Up Water Requirement	m^3/hr	0.58	NA	0.52

DECREASING CONDENSER WATER TEMPERATURE

What's the impact?



Less power input for compressor; leading to increase in COP

20%–50%

COP

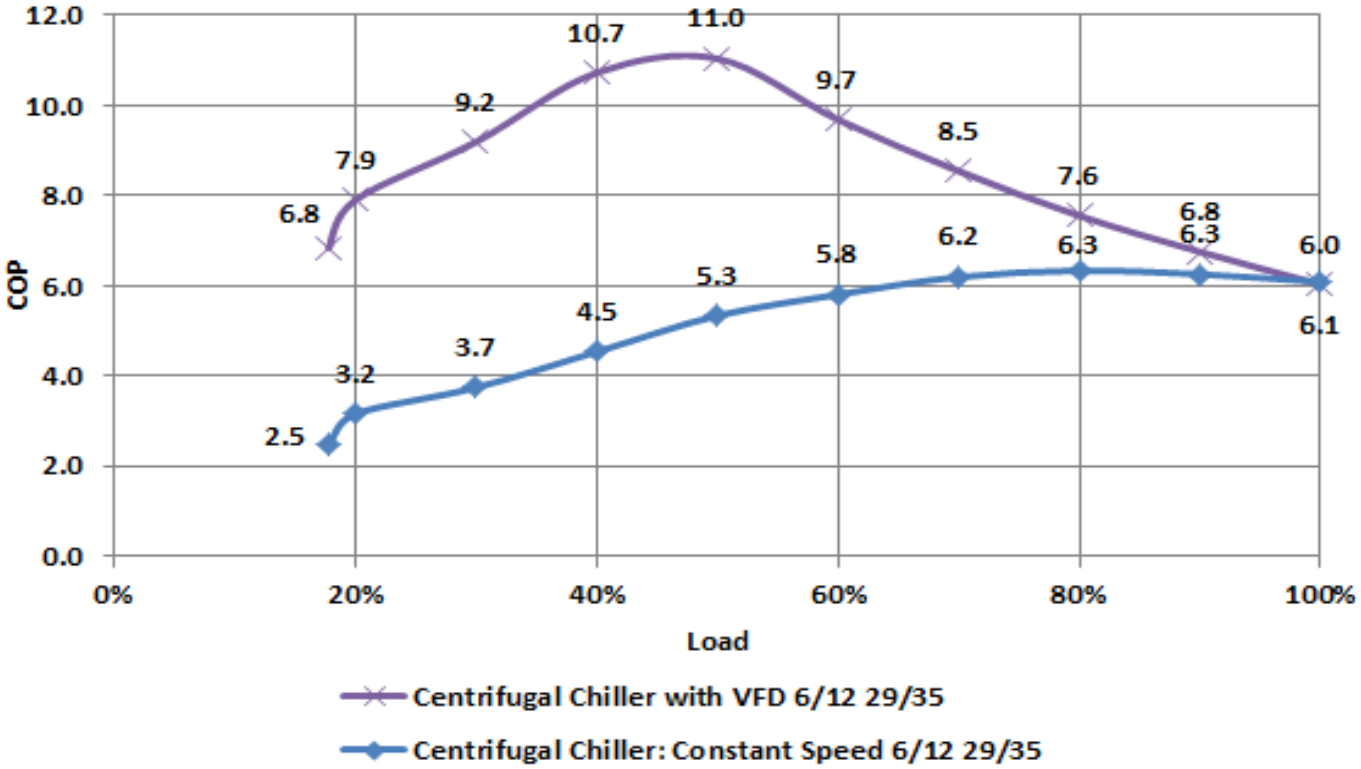
Note: At constant chilled water inlet / outlet temperatures of 12°C / 6°C

Source: Ministry of Power, Government of India, 2022a

VFD FOR CHILLERS

Energy efficient capacity control at partial loads

- Variable frequency drive (VFD) varies the electrical frequency to electric motor speed, eliminating the need for relatively inefficient methods of capacity control like cylinder unloading for reciprocating compressors, sliding valve control for screw compressors and inlet guide vane control for centrifugal compressors
- Elimination of energy losses from these inefficient capacity control devices, coupled with significant improvements in heat transfer effectiveness in evaporator and condenser, the chiller COP increases dramatically
- As the chillers operate on part-load most of the time, the energy consumption reduces significantly

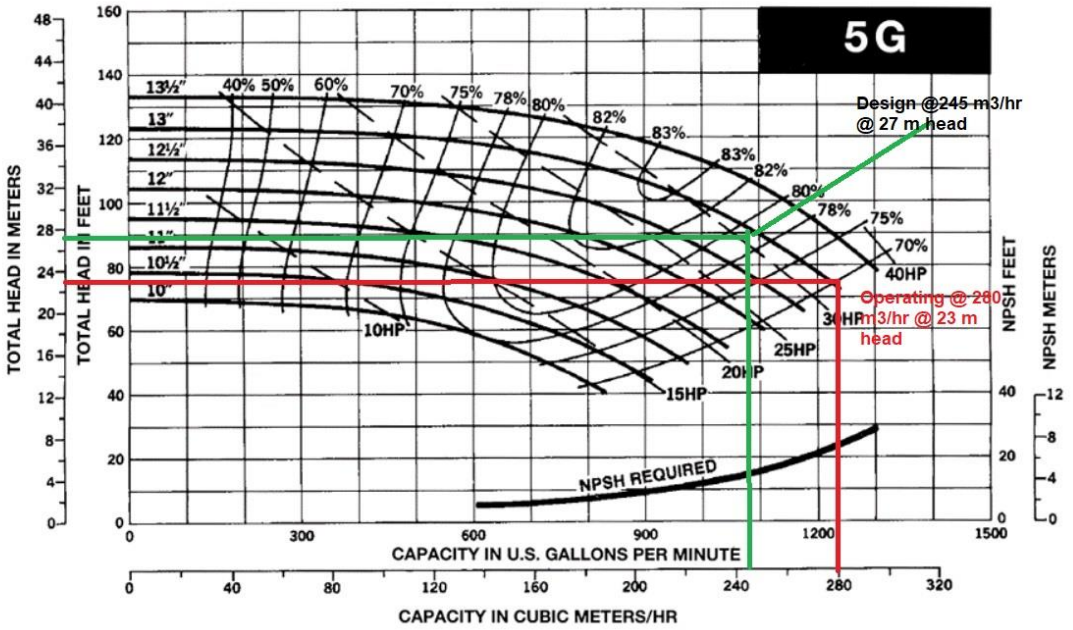


Source: Ministry of Power, Government of India, 2022a

PUMPS SELECTION

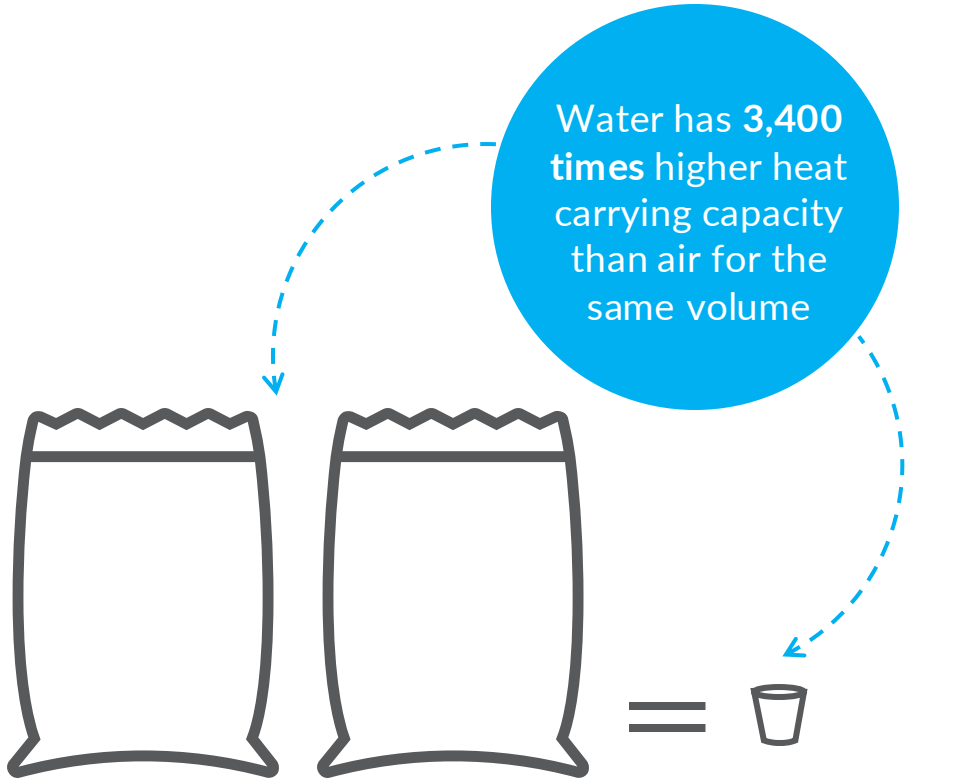
Selection of appropriately sized, efficient pumps

- In the HVAC system, flow through condenser and evaporator is important, and minimum flow must be maintained for smooth functioning of chillers
- The pressure drop across condenser and evaporator, associated friction drop on piping, and static lift determine the operating energy consumed by the pumps. These parameters should be calculated accurately before selection of pumps
- The head and flow for the pumps must be selected with minimum margins and maximum available pump efficiency to ensure efficient operation
- In case the selected head is more than the operating head, then the pump would tend to deliver more flow than the design value and would consume more power and operate at lower efficiency

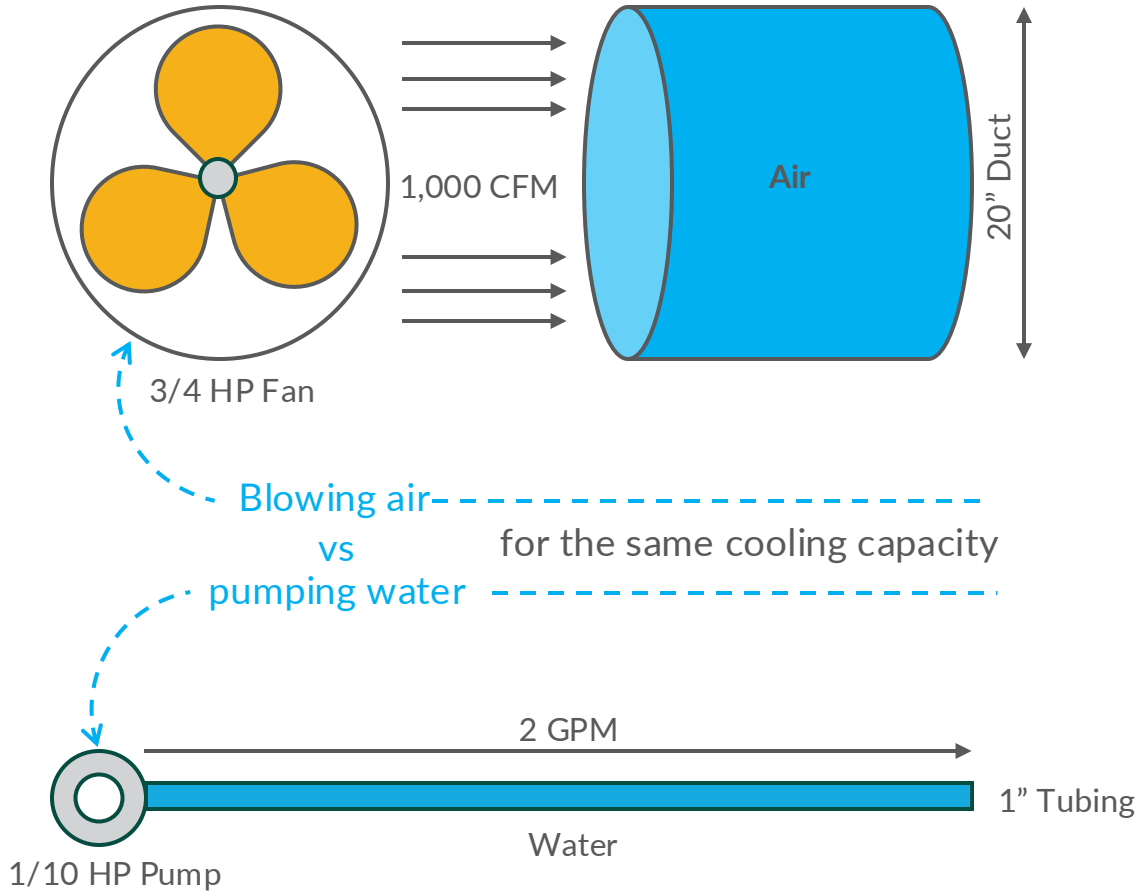


RADIANT COOLING

Leveraging the heat carrying capacity of water



The heat capacity of one cup of water is equal to the heat capacity of two bags of air

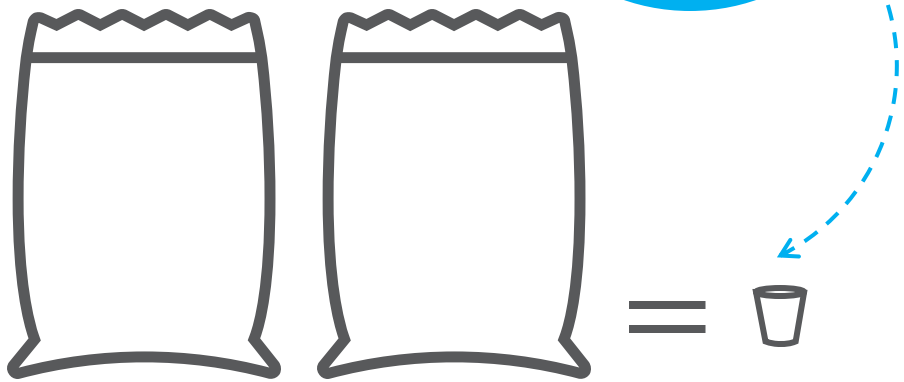


MINIMIZE COOL AIR DUCTING

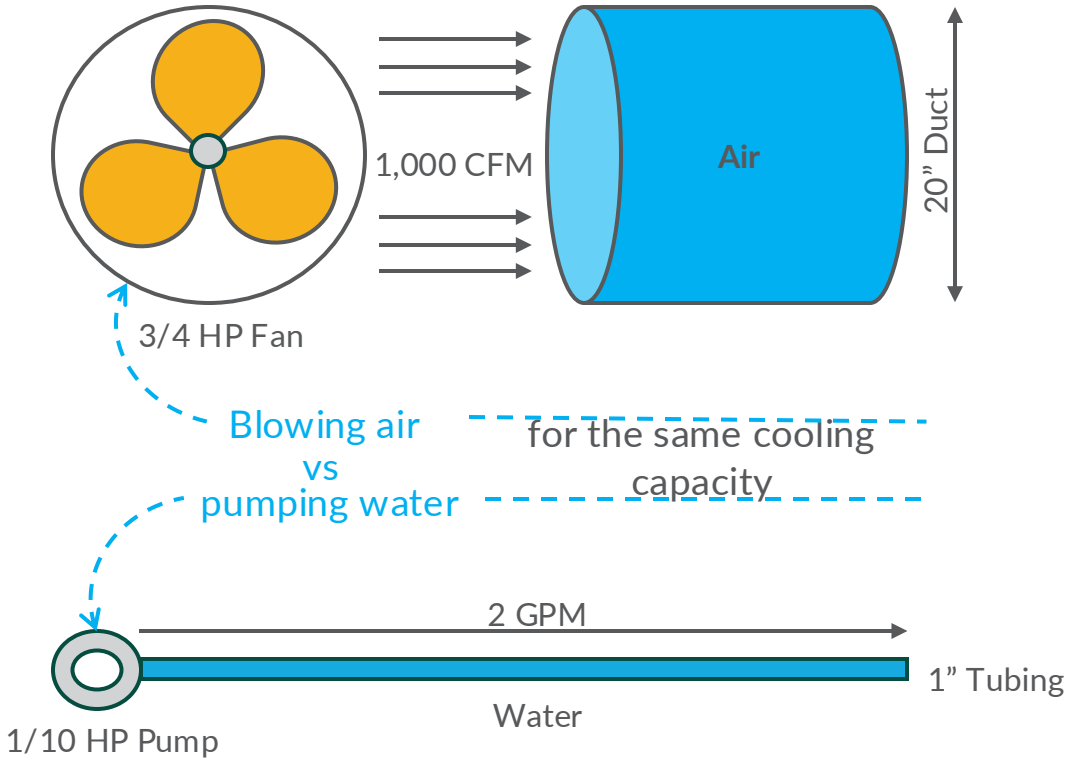
Chilled water is comparatively a better heat transfer medium than air

Use water to transport heat until the farthest end possible

Water has **3,400 times** higher heat carrying capacity than air for the same volume



The heat capacity of one cup of water is equal to the heat capacity of two bags of air



Pumping energy is 7.5 times lower

USE ENTHALPY RECOVERY AT AHU

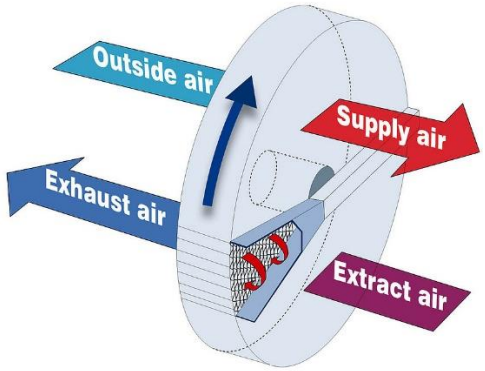
Cooling generated must be recovered to reduce losses

Enthalpy recovery wheel (ERW) recovers both sensible and latent heat

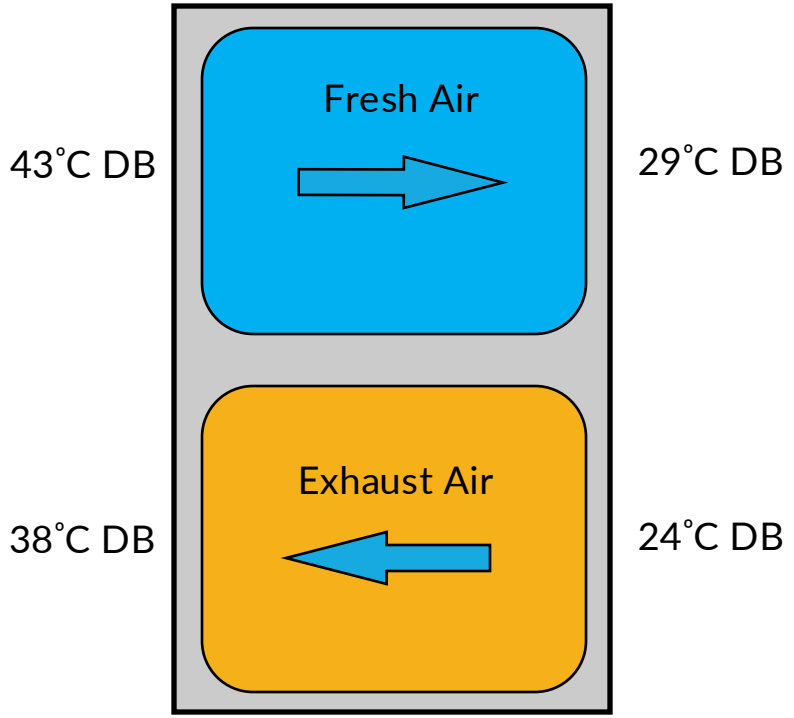


Typical AHU





Enthalpy Recovery Wheel



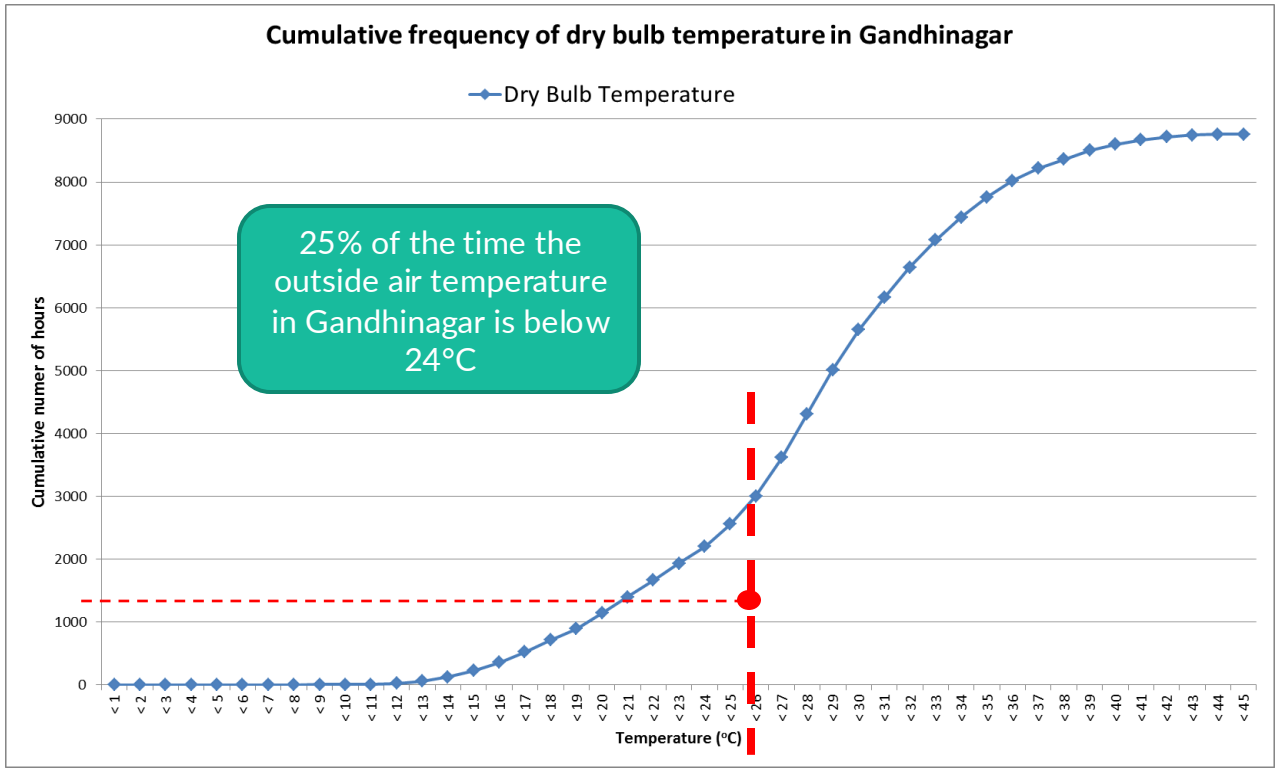
Example of heat recovery wheel: Effectiveness (74%)

The operational energy required for cooling / dehumidifying the fresh air is reduced by using ERW, which is indicated by its effectiveness

FREE COOLING

Provision in air handling unit (AHU)

- Free cooling uses ambient air whenever the temperature and humidity is suitable to cool the building
- Two separate openings are needed in the AHU: one for minimum fresh air and a larger opening for 100% fresh air (free cooling). There should be provision in the AHU to bypass the cooling coil when free cooling is availed
- For optimal utilization, the AHU switching between chiller-based cooling and free cooling should be automated with the use of enthalpy sensors

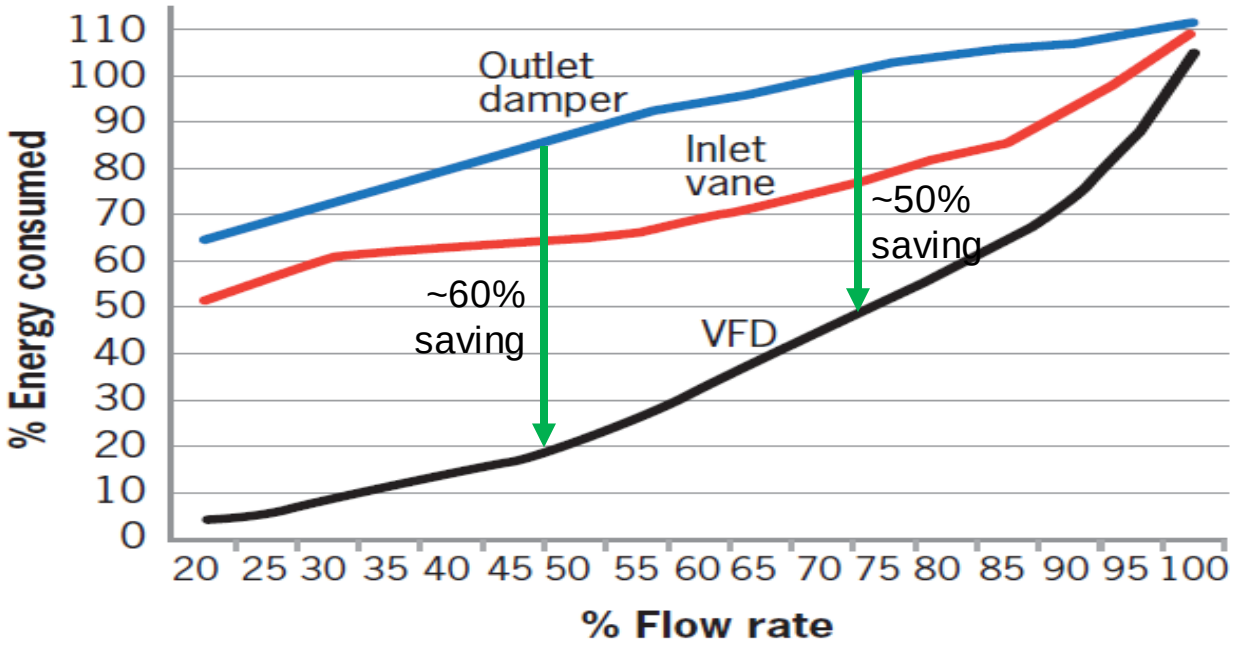


Example: Free cooling potential for Gandhinagar, India

VFD FOR FANS AND PUMPS

Optimize part-load operations

- As the cooling load varies, the water and air flow requirements also vary
- Conventional methods like damper throttling and inlet guide vanes are not efficient methods due to significant throttling losses
- Using VFDs for fans and pumps to meet the varying flow requirement at part loads, can save 50%–60% of energy



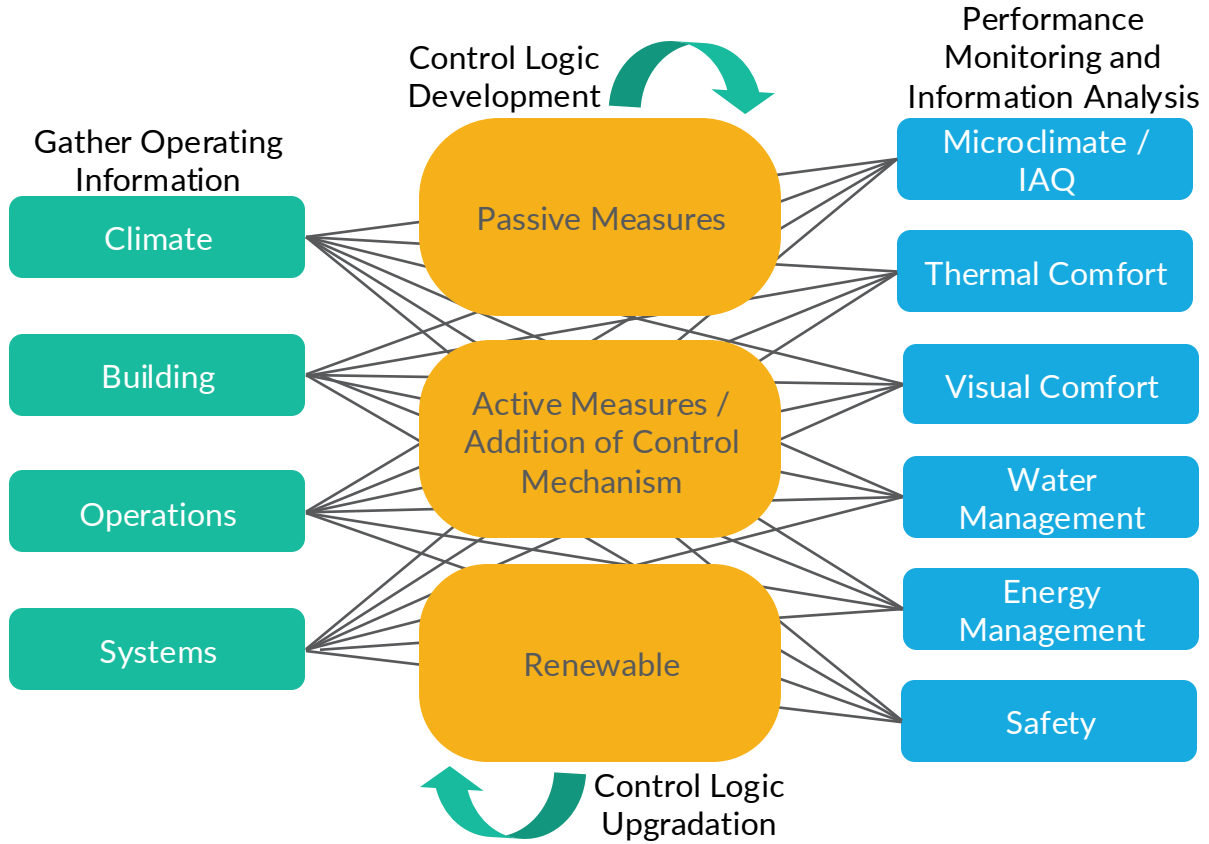
Energy savings with VFDs at lower flows in comparison to damper and IGV controls

Source: Ministry of Power, Government of India, 2022a

BMS CONTROL

For optimizing operational energy

- A building management system (BMS) is a useful tool for optimizing operational energy
- BMS algorithms can simultaneously consider the external factors (climate), and internal factors (operations, occupancy, micro-climate, indoor air quality, thermal and visual comfort), and optimize energy and water consumption
- Now, with artificial intelligence (AI) and machine learning (ML) algorithms, the BMS can automatically reset itself to the best combination
- BMS is useful as historical data and trends can easily be accessed for troubleshooting



Optimizing Other Services

Use of Star-rated Equipment and Appliances

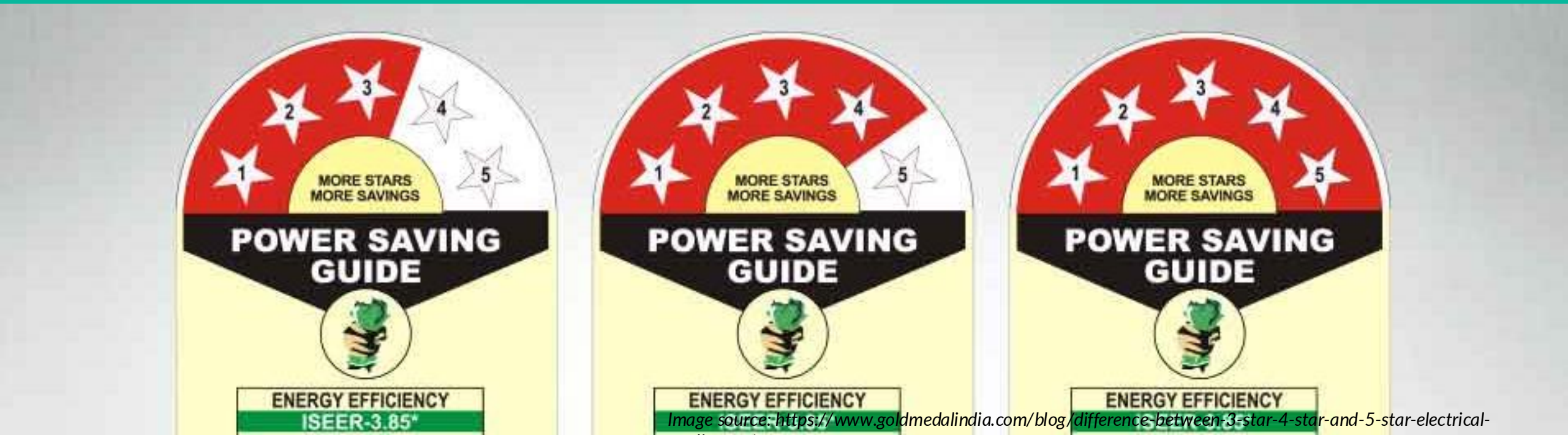


Image source: https://www.goldmedalindia.com/blog/difference-between-3-star-4-star-and-5-star-electrical-

STAR-RATED APPLIANCES

Residential apartment: Savings with energy efficient BLDC ceiling fans

Room Specifications	35W BLDC Fan		70W Capacitor Start Fan	
	Quantity	Operating Hours	Quantity	Operating Hours
Hall	1	12	1	12
BD 01	1	8	1	8
BD 02	1	8	1	8
Kitchen	0	0	0	0
Toilet 01	0	0	0	0
Toilet 02	0	0	0	0
Corridor	0	0	0	0
Installed Power	105W		210W	
Energy Consumed	980Wh		1960Wh	



Source: Bureau of Energy Efficiency, Government of India

STAR-RATED APPLIANCES

Water pumps and heaters: Energy saving potential

Head (m)	Discharge (liters per second)	Rating (kW)	Power Consumption of Unrated Pump Motor (kW)	Power Consumption of 5-star Pump Motor (kW)	Annual Energy Savings (kWh/year)
73	6.67	7.5	11	9	**1,600**
122	6.6	13	17.5	14.5	**2,400**



Capacity of Water Heater (liter)	Standing Losses in Unrated Conventional Water Heater (kW)	Standing Losses in 5-star Rated Water Heater (kW)	Energy Savings (kWh/year)
25	0.823	0.562	65
35	0.940	0.642	75



Source: Bureau of Energy Efficiency, Government of India

STAR-RATED APPLIANCES

Refrigerators

Type	Storage Volume (liter)	Annual Energy Consumption of an Unrated Refrigerator (kWh/year)	Annual Energy Consumption of a 5-star Rated Refrigerator (kWh/year)	Annual Energy Savings (kWh/year)
Frost Free	190	379	155	**224**
	250	400	164	**236**
	300	418	171	**247**
Direct Cool	190	339	138	**201**
	260	346	148	**198**
	310	379	154	**225**



Source: Bureau of Energy Efficiency, Government of India

OTHER SERVICES AND SYSTEMS

Elevators

- **Compliance:** Guideline VDI 4707: Class 1–5 for energy efficiency of lifts
- **Type of motor:** Use of IE3 motor and above
- Use of variable voltage variable frequency drives and regenerative drives
- **Lumen efficacy of lamps used in elevators:** Over 95 lumen/W



Source: Bureau of Energy Efficiency, Government of India, 2024

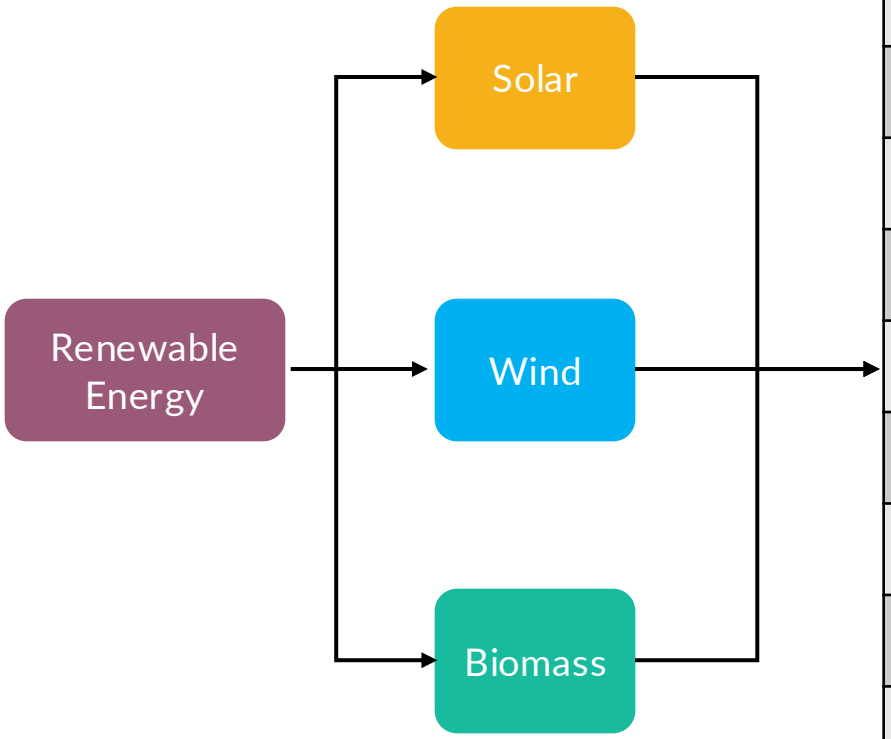
Integration of Renewable Energy



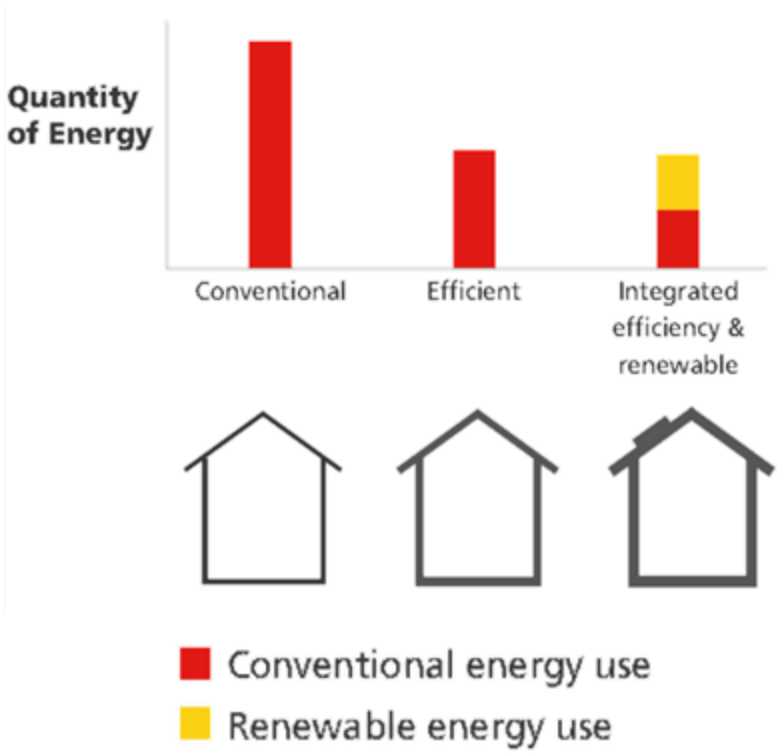
Image source: https://earth.org/the-present-and-future-of-renewable-energy-a-2023-

RENEWABLE ENERGY INTEGRATION

Renewable energy sources



Renewable Energy Technologies
Solar Rooftop (PV and Thermal)
Building Integrated PV Solutions
Hybrid Solar (PV and Thermal)
Small Wind Turbines
Small Wind + Solar Hybrid System
Biomass Energy – Bio Methanation
Heat Pump
Fuel Cells using RE Source as Input



Source: Swiss Agency for Development and Cooperation and International Institute for Energy Conservation, 2022

RENEWABLE ENERGY INTEGRATION

Photovoltaic (PV) system: Solar electrical power

PV systems fall into two main categories: Grid-connected and off-grid

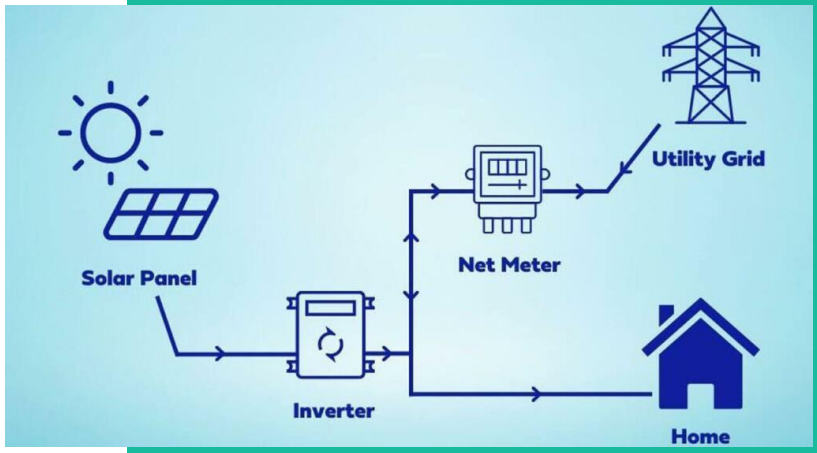
Grid-tied systems:

- The system is connected to the local electricity distribution grid; energy generated is sent to the utility grid
- A credit for the energy generated is provided
- Grid acts as an energy storage unit

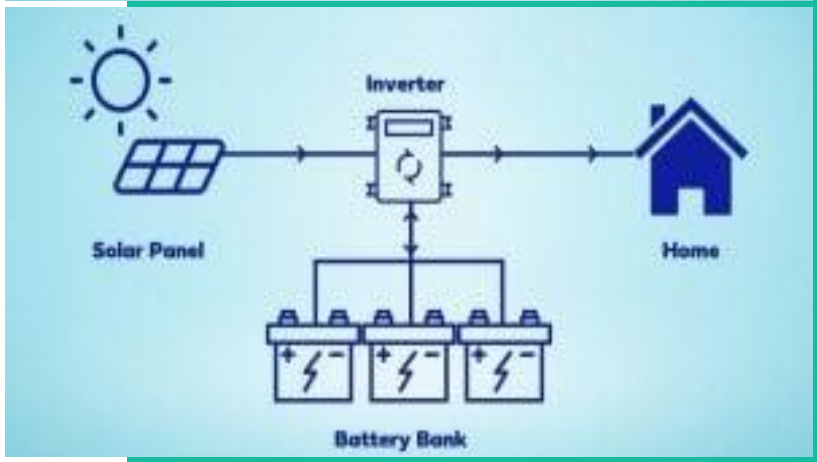
Off-grid systems:

- The system is independent of the local electricity distribution grid
- Energy generated is either consumed in real-time or stored in batteries

Grid-tied System



Off-grid System



Source: Swiss Agency for Development and Cooperation and International Institute for Energy Conservation, 2022

RENEWABLE ENERGY INTEGRATION

Photovoltaic (PV) system: Solar electrical power

- The rating of the solar panels is given in kilowatts peak (kWp)
- Standard test conditions (STC):
  - Irradiance of 1,000 W/m²
  - Module temperature at 25°C
  - Solar spectrum of AM 1.5
- As a rule of thumb, 1 kWp system in India generates around 4–5 kWh/day, and requires about 10 m² shadow free roof area

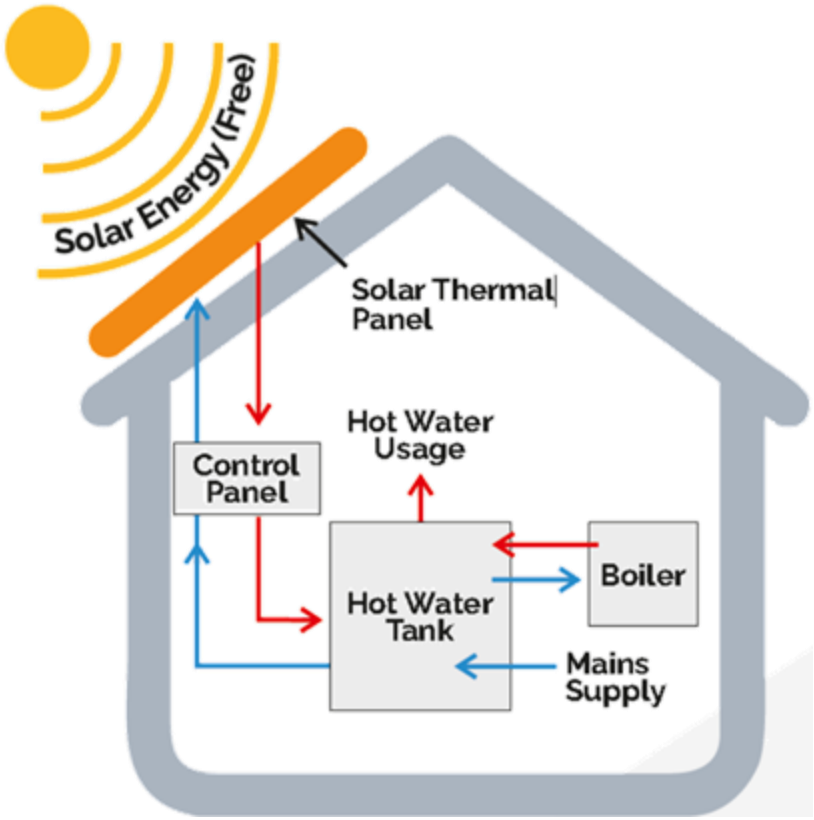


Source: Swiss Agency for Development and Cooperation and International Institute for Energy Conservation

RENEWABLE ENERGY INTEGRATION

Solar thermal system

- A solar thermal system works by harnessing the sun's energy and converting it into heat that is transferred into a home or business heating system as hot water or space heating
- There are two types of solar water heater systems:
  i. Flat Plate Collector
  ii. Evacuated Plate Collector
- A 100-liter capacity solar water heater (SWH) can replace an electric water heater for residential use and save 1,500 units of electricity
- A SWH of 100-liter capacity can prevent the emissions of 1.5 tons of carbon dioxide per year
- The use of 1,000 SWHs of 100-liter capacity each can contribute to a peak load saving of 1 MW
- A 100 LPD solar collector usually has dimensions of 1m x 2m (requiring 3m² rooftop area per collector)



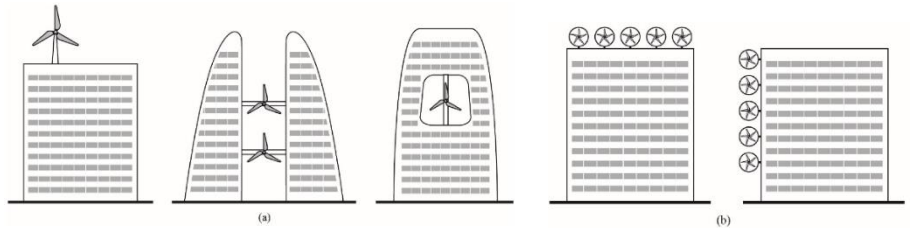
Source: Swiss Agency for Development and Cooperation and International Institute for Energy Conservation

RENEWABLE ENERGY INTEGRATION

Wind turbines

- Micro wind turbines, called ‘building-integrated wind turbines’ or ‘vertical axis wind turbines’ are suitable for building scale applications
- The main components of a wind turbine include blades, rotors, gearboxes and generators
- Vertical axis wind turbine generators (200W–10kW) can be used as standalone systems or as grid-connected systems, and both can be paired with other energy conversion systems, such as photovoltaics
- Wind turbines can generate energy throughout the day and the system does not require frequent cleaning
- The low cut in speed turbines start generating power at 2.5m/s–3m/s wind speed, without creating aerodynamic noise
- The wind turbine should be installed at the highest point of the site where no wind turbulence will be caused by any other building or site elements like trees



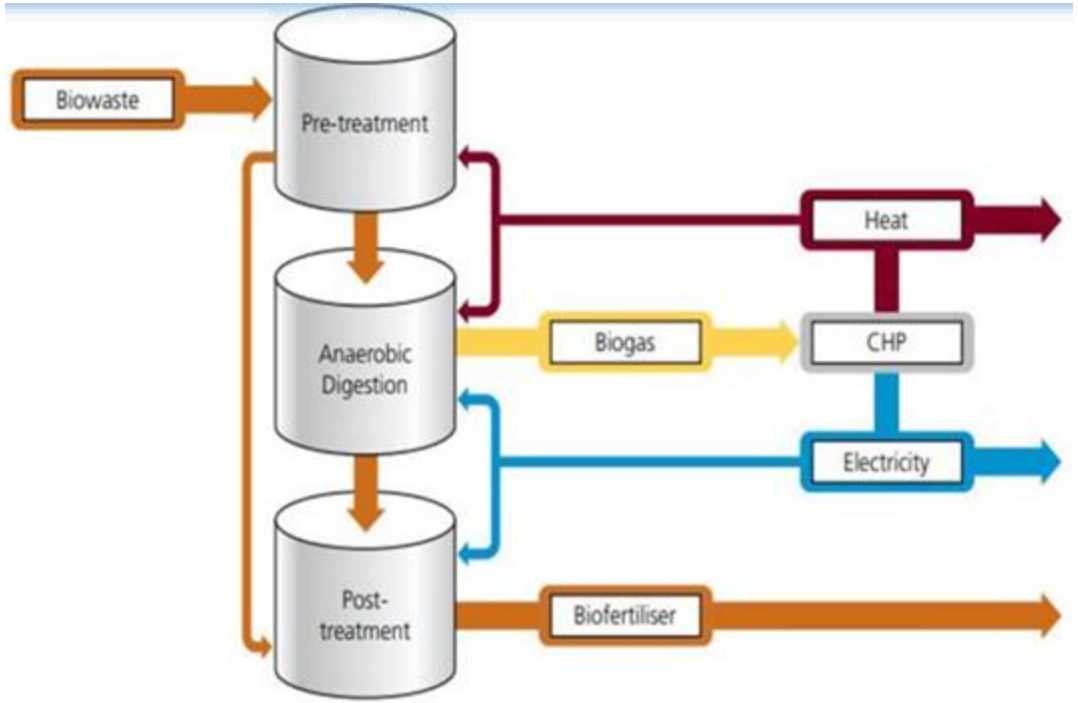


Source: Swiss Agency for Development and Cooperation and International Institute for Energy Conservation

RENEWABLE ENERGY INTEGRATION

Biomass energy

- Biomass is used for facility heating, electric power generation, and combined heat and power
- The term biomass encompasses a large variety of materials, including wood from various sources, agricultural residues, and animal and human waste
- Biomass can be converted into electric power through several methods:
  - Direct combustion of biomass material, such as agricultural waste or woody materials
  - Gasification of biomass produces a synthesis gas with usable energy content by heating the biomass with insufficient oxygen
  - Pyrolysis yields bio-oil by rapidly heating the biomass in the absence of oxygen
  - Anaerobic digestion produces a renewable natural gas when organic matter is decomposed by bacteria in the absence of oxygen



Source: Swiss Agency for Development and Cooperation and International Institute for Energy Conservation

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

IKI Independent Complaint Mechanism

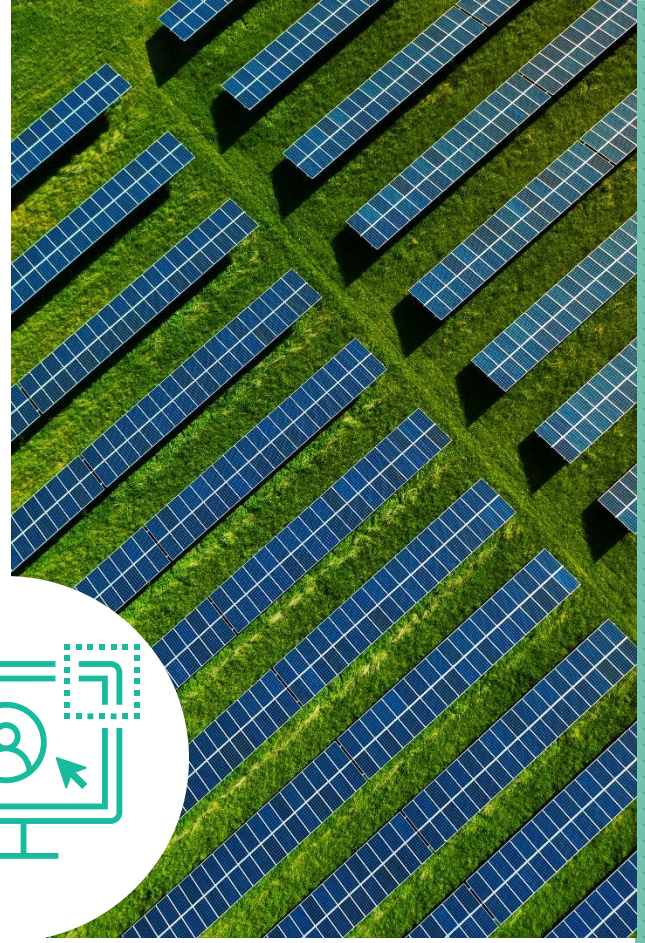
Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

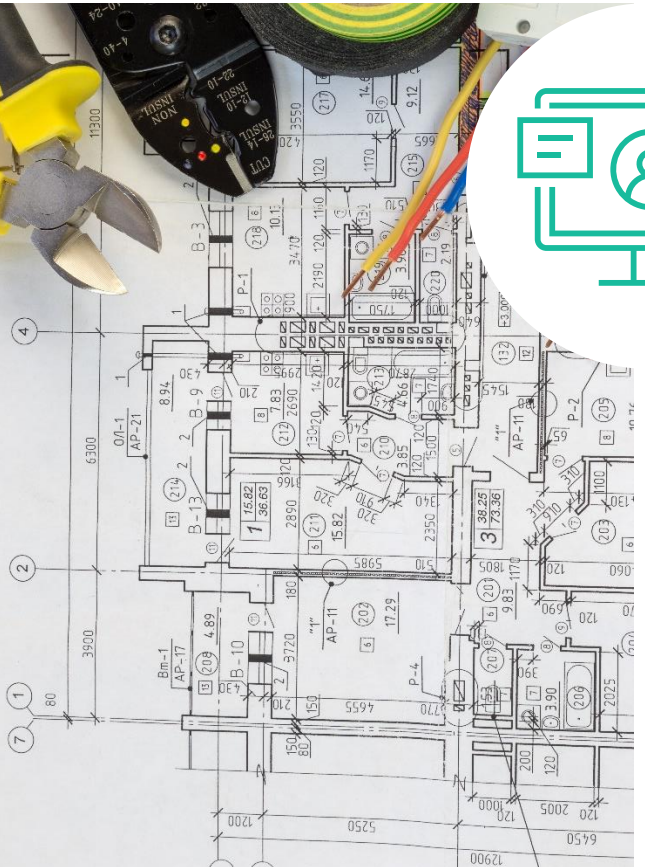
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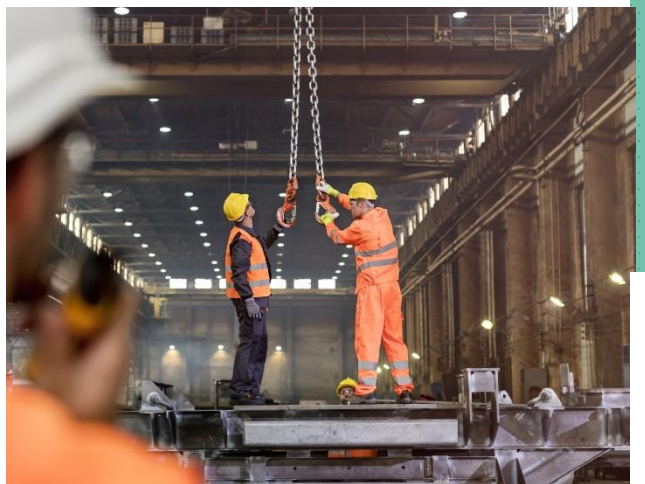
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on the basis of a decision by the German Bundestag









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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy | PROJECT

2.6 Understanding the Basics of Energy Management

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

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on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

01 Classification of building types and energy use requirements

02 Energy benchmarks for different building types, including building star rating thresholds in India

03 Energy management approaches, systems and tools available for building facility managers

04 Building management and automation systems for energy optimization

05 Case examples



Image source: https://damiaglobalservices.com/building-energy-management-system/

BUILDINGS

Classification by type



Hospitality

- No Star
- Resorts
- Star Hotels

Healthcare

- Hospitals
- Out-patient Care

Assembly

- Theaters
- Transport Service Facilities
- Multiplexes

Business

- Small Offices: <10,000 sqm
- Medium Offices: 10,000–30,000 sqm
- Large Offices: >30,000 sqm

Education

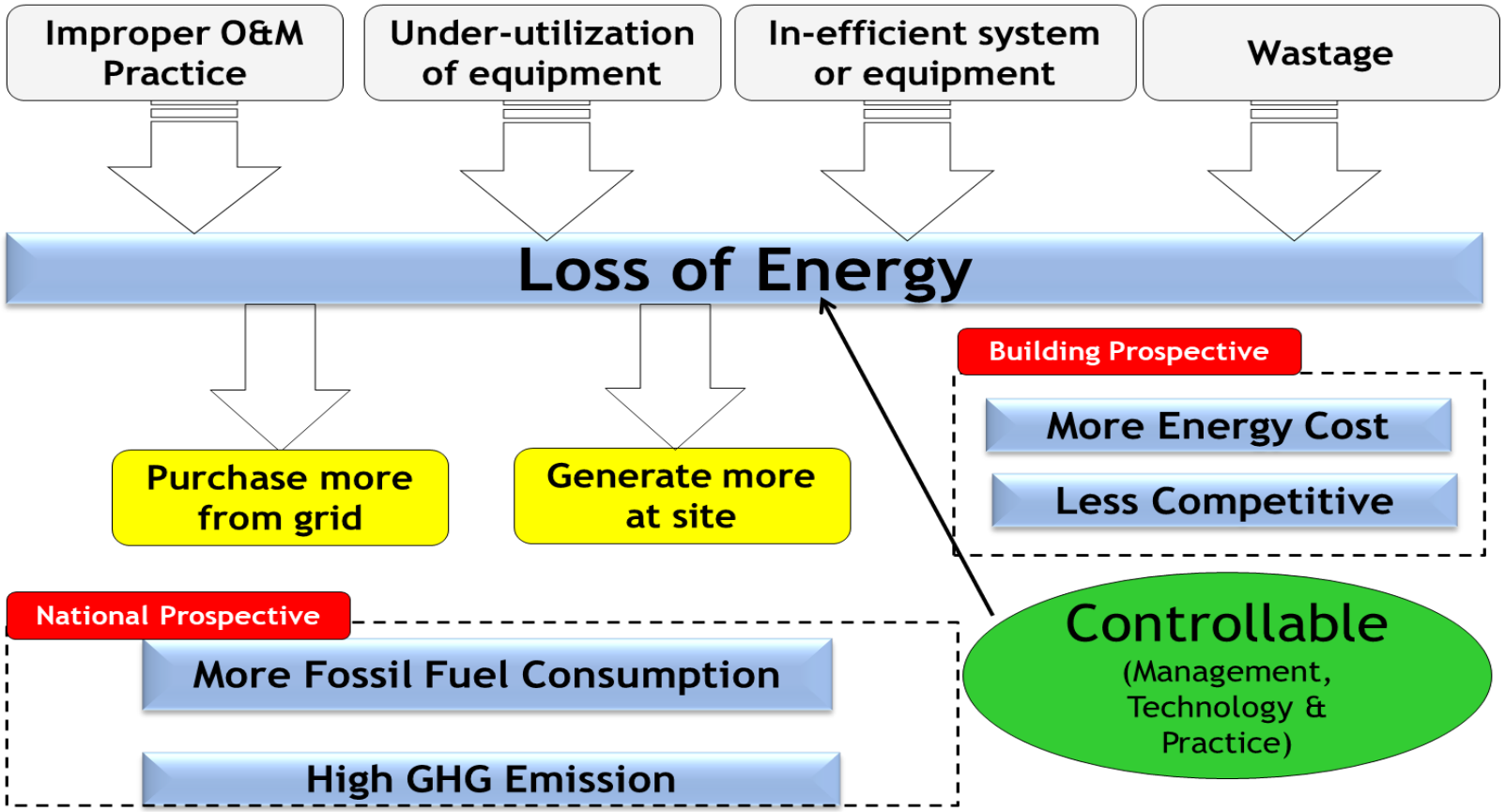
- Schools
- Colleges
- Universities
- Training Institutions

Retail

- Shopping Malls
- Stand-alone Retails
- Open Gallery Malls
- Supermarkets

ENERGY USAGE IN BUILDINGS

Issues and opportunities



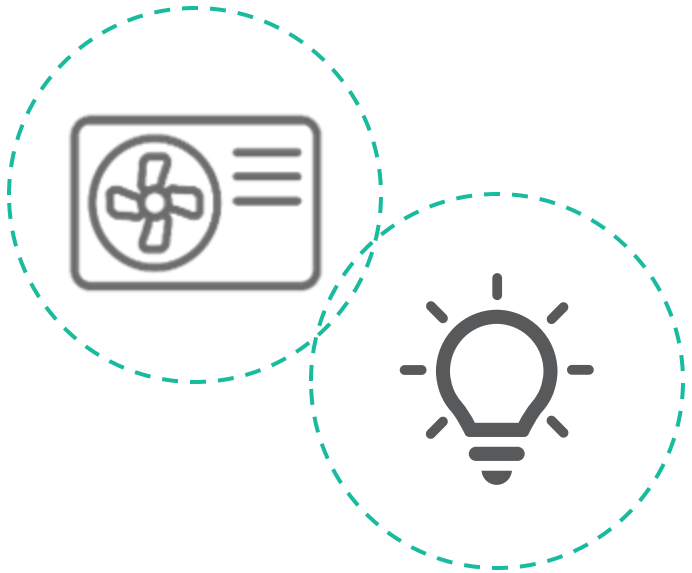
TYPICAL ENERGY SNAPSHOT

Example: Hotel building in Chiang Mai, Thailand

Location	:	Chaing Mai, Thailand
Building	:	5-Star, 5 Floors
Building Type	:	Resort
Hotel Area	:	12,825 m^2
Source of Supply		22 KV from Authority
		Own Generation from DG Sets
Transformers	:	2 x 800 KVA
DG Sets	:	1 x 500 KVA
Major Electrical Loads	:	Lighting and Power, Air Conditioning, Water Pumping, Hot Water Generator
Estimated Connected Load	:	About 667 KW
Usage Hours	:	24 Hrs Operation
Air Conditioning System	:	Non-central AC
Annual Energy Consumption	:	344 Tons of Oil Equivalent
Annual Electricity Consumption	:	1.8 million kWh
Annual Energy Cost	:	THB 11.4 million

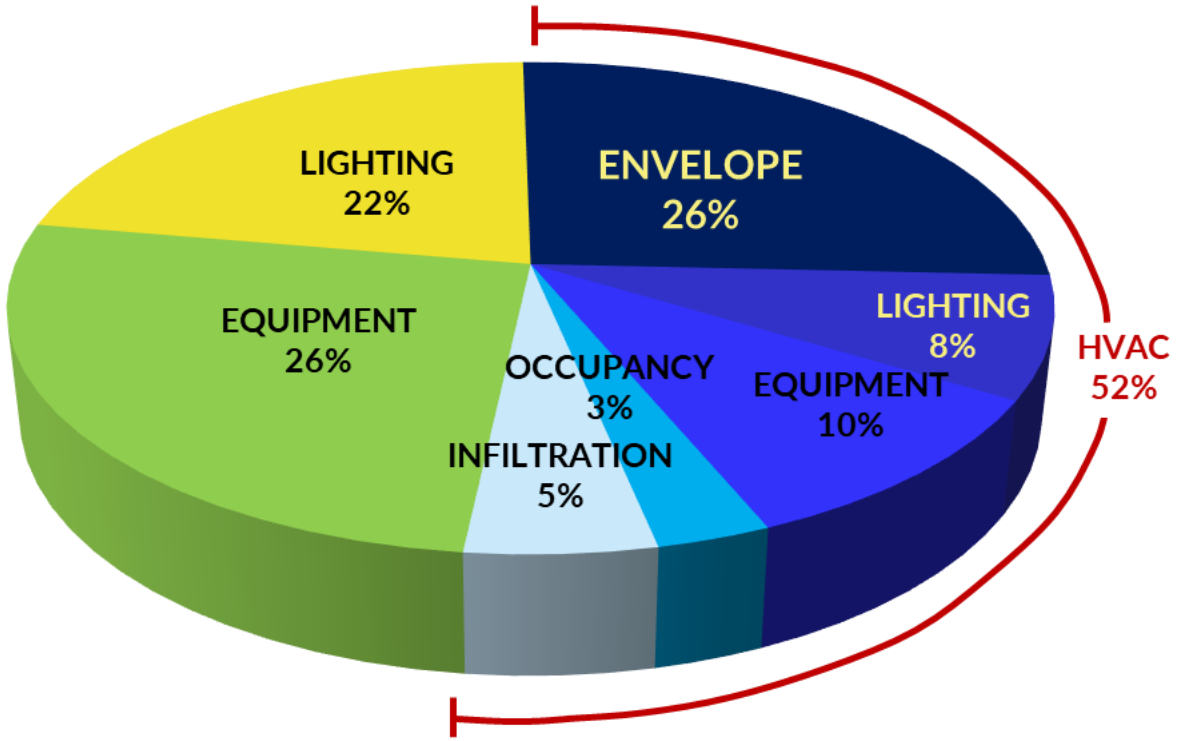
COMMERCIAL BUILDINGS

Typical energy consumption in commercial buildings



Air conditioning and lighting are the major focus area for energy management in buildings

Breakdown of energy consumption in a typical air-conditioned commercial building; note the contribution of heat load from various heat sources on the HVAC system; building envelope is usually the major contributor.

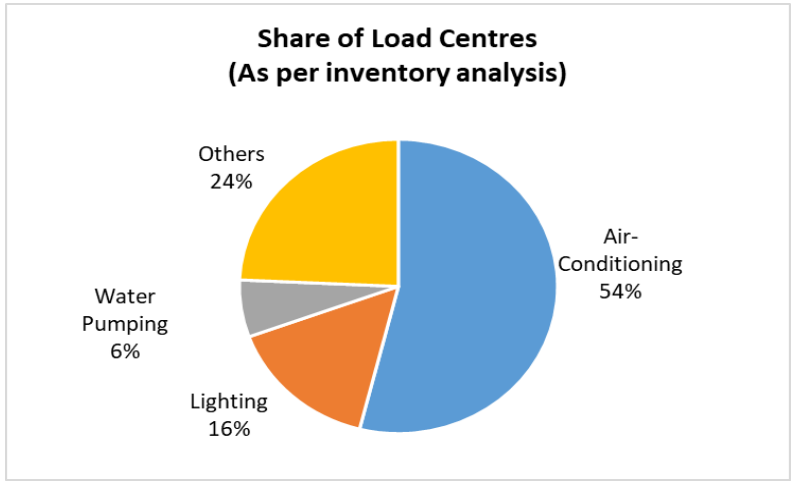


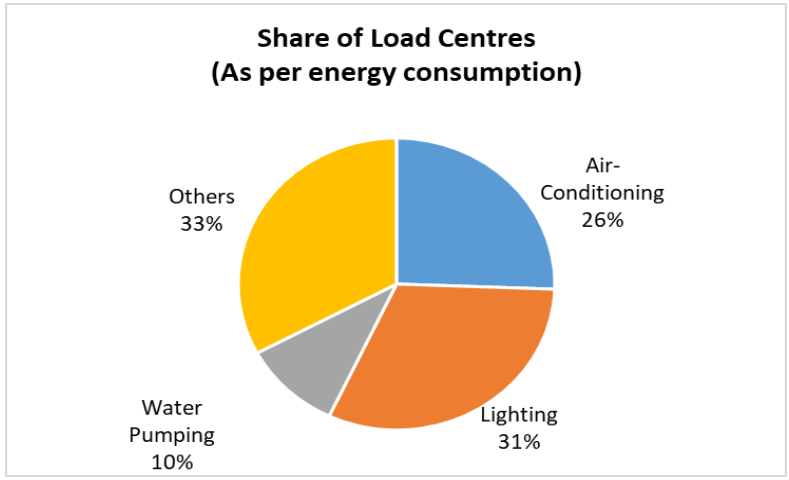
Source: Farheen Bano & Mohammad Arif Kamal. 2016. Examining the Role of Building Envelope for Energy Efficiency in Office Buildings in India. Architecture Research 2016.

TYPICAL INVENTORY ANALYSIS

Example: Share of connected load and energy consumption in a commercial building

Load Centers	Connected Load kW	Annual Energy Consumption, kWh
Air Conditioning	360	460,800
Lighting	104	566,734
Water Pumping	42	182,953
Others	162	591,886
Total	667	1,802,372

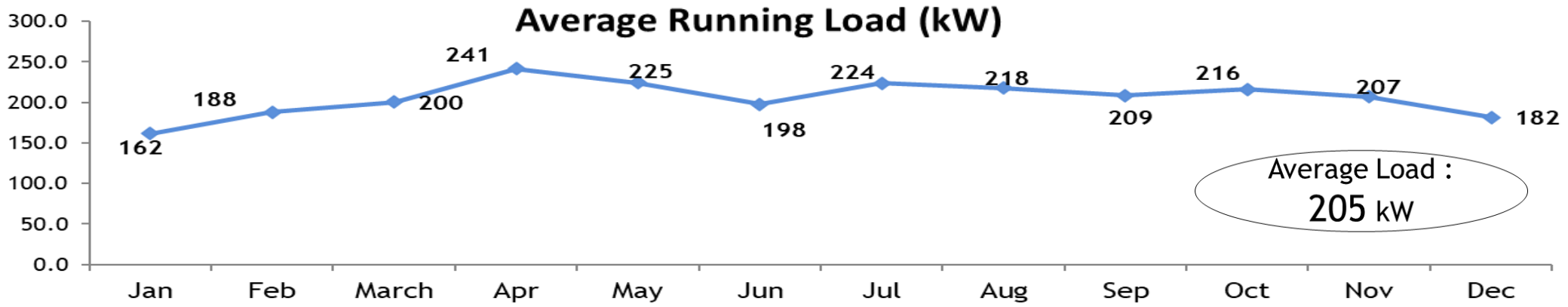


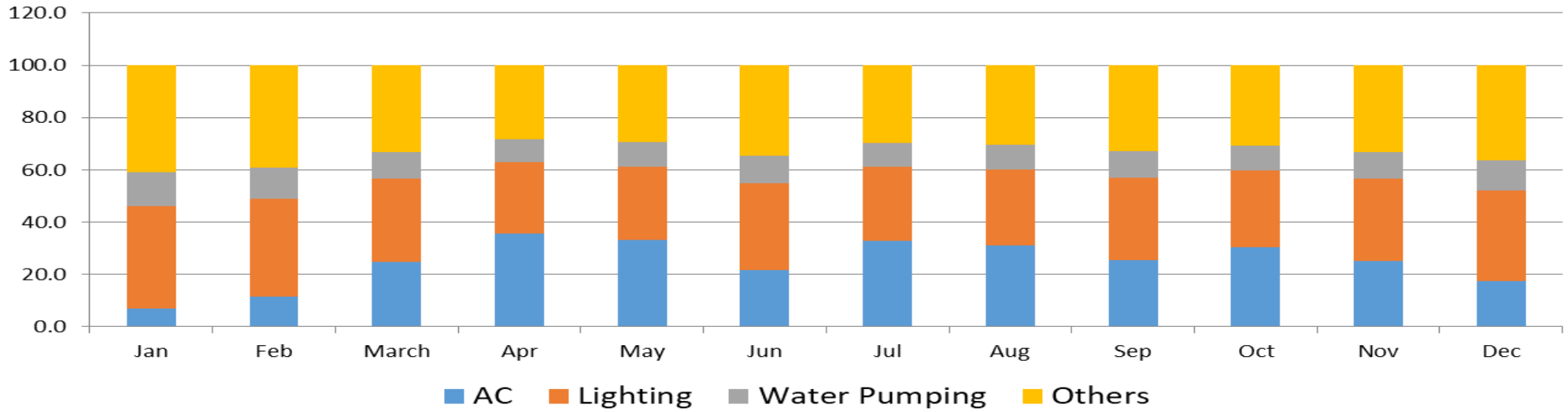


Connected Load
670 kW

TYPICAL LOAD CURVE

Example: Monthly electrical energy usage pattern in commercial buildings

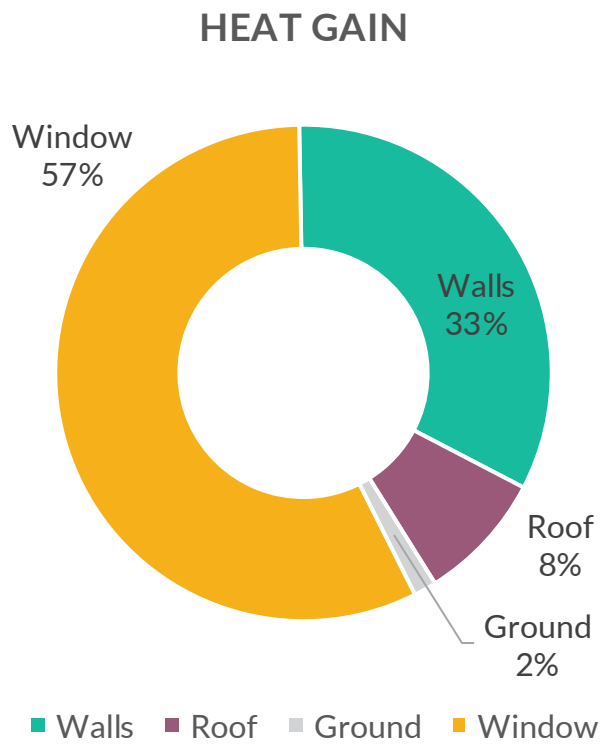




HVAC – EXAMPLE OF HEAT GAIN

Building envelope: Sources of heat load on HVAC in different climatic zones in India

Heat Gain through Building Envelope (Ground + 4 floors Office Building)								
Climate	**Hot and Dry**		**Warm and Humid**		**Composite (Hot and Dry, Warm and Humid, Cold)**		**Composite (Hot and Dry, Warm and Humid, Cold)**	
Building Component	**Ahmedabad (223.037 MWh)**		**Mumbai (201.892 MWh)**		**Nagpur (198.756 MWh)**		**Pune (137.764 MWh)**	
	Cooling Load (MWh)	**Annual Cooling Load (%)**	**Cooling Load (MWh)**	**Annual Cooling Load (%)**	**Cooling Load (MWh)**	**Annual Cooling Load (%)**	**Cooling Load (MWh)**	**Annual Cooling Load (%)**
Walls	81.141	36.4	66.532	33.0	71.151	35.8	36.487	26.5
Roof	18.996	8.5	15.148	7.5	17.845	9.0	12.288	8.9
Ground	4.957	2.2	4.557	2.3	3.000	1.5	0.129	0.1
Window (Conduction + Direct Solar)	117.941 (28.563 + 89.378)	52.9 (12.8 + 40.1)	115.654 (17.405 + 98.249	57.3 (8.6 + 48.7)	106.761 (19.608 + 87.153)	53.7 (9.9 + 43.8)	89.119 (6.180 + 82.939)	64.7 (4.5 + 60.2)

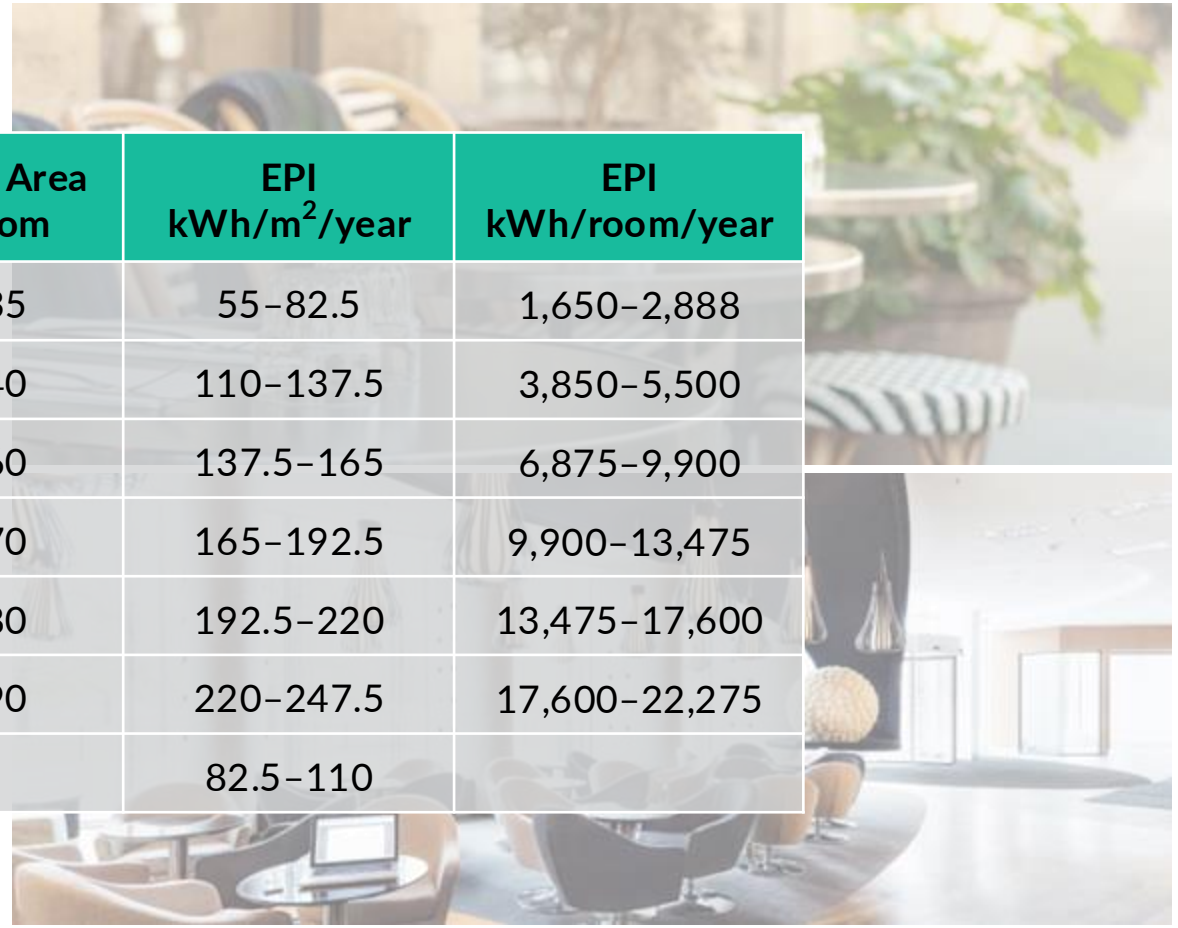


Source: Farheen Bano & Mohammad Arif Kamal. 2016. Examining the Role of Building Envelope for Energy Efficiency in Office Buildings in India. Architecture Research 2016.

HOTELS AND RESORTS

India: Estimated Energy Performance Index (EPI)

Category	Built-up Area m^2/room	EPI kWh/m^2/year	EPI kWh/room/year
1 Star	30–35	55–82.5	1,650–2,888
2 Star	35–40	110–137.5	3,850–5,500
3 Star	50–60	137.5–165	6,875–9,900
4 Star	60–70	165–192.5	9,900–13,475
5 Star	70–80	192.5–220	13,475–17,600
Heritage	80–90	220–247.5	17,600–22,275
Others	–	82.5–110	



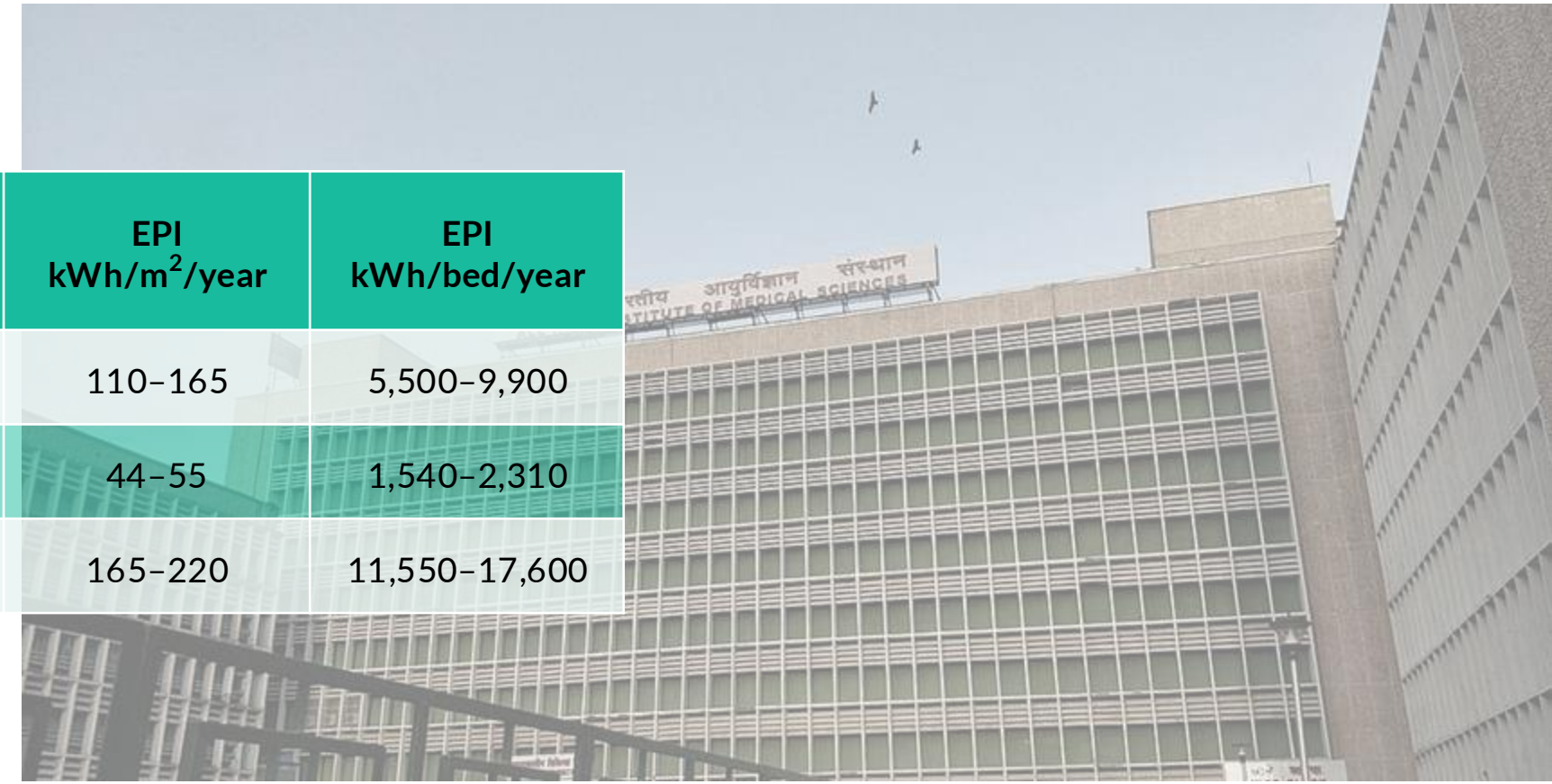


Source: Kumar et al., 2017

HOSPITALS

India: Estimated Energy Performance Index (EPI)

Category	Built-up Area m^2/bed	EPI kWh/m^2/year	EPI kWh/bed/year
Government –Urban	50–60	110–165	5,500–9,900
Government – Rural	35–42	44–55	1,540–2,310
Private – All	70–80	165–220	11,550–17,600



Source: Kumar et al., 2017

Image source: Vishnoi

OFFICE BUILDINGS

India: Estimated Energy Performance Index (EPI)

Category	Built-up Area m^2/employee	EPI kWh/m^2/year	EPI kWh/employee/year
PRIVATE OFFICES			
Information Technology-enabled Services	9–11	82.5–110	743–1,210
Banking Services, Finance and Insurance	6–8	55–82.5	330–660
PUBLIC OFFICES			
Central Government	12–15	77–99	924–1,485
State Government	10–12	66–77	660–924
Quasi Government	8–10	77–88	616–880
Local Government	3–5	22–33	66–165

Source: Kumar et al., 2017

EDUCATION BUILDINGS

India: Estimated Energy Performance Index (EPI)

Category	Built-up Area m^2/building	EPI kWh/m^2/year
SCHOOLS		
Primary	150–160	20–25
Upper Primary	301–310	20–25
Secondary	554–560	30–40
Higher Secondary	1,313–1,320	30–40
UNIVERSITIES / COLLEGES		
Rural	1,500–2,000	22–27.5
Urban	2,000–2,500	33–44
Institutes of National Importance	20,000–25,000	44–55
Stand-alone Institutions	500–600	22–33





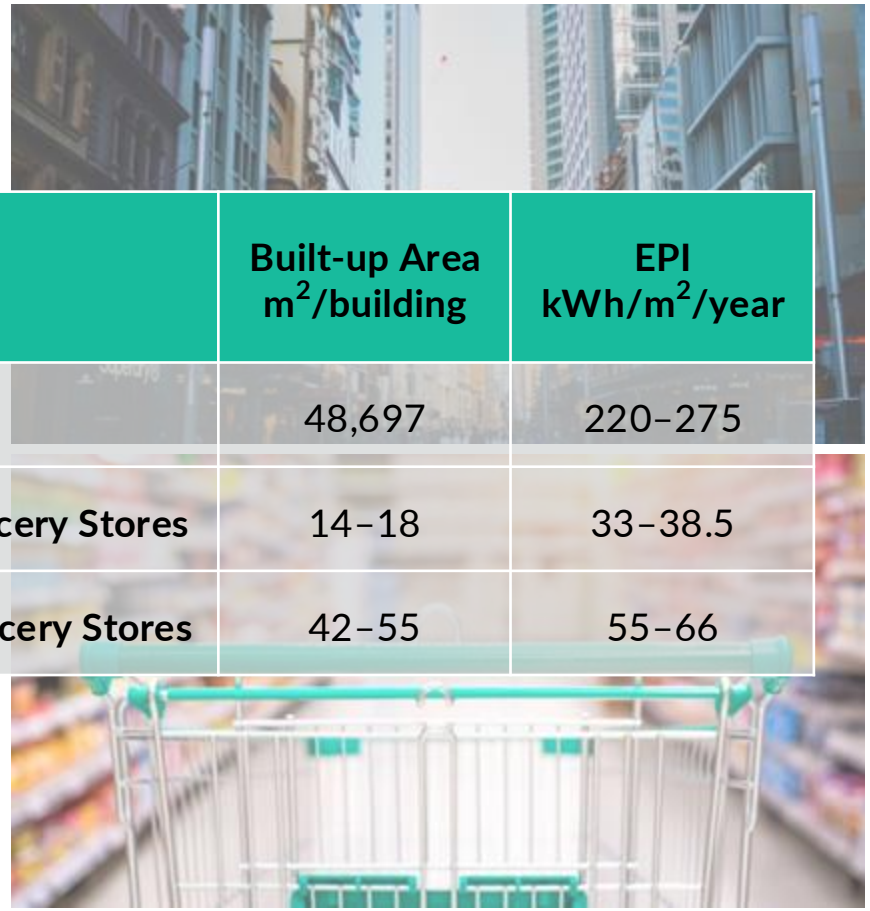
Source: Kumar et al., 2017

Image sources: Deanndamon; AjZock

RETAIL

India: Estimated Energy Performance Index (EPI)

Category	Built-up Area m^2/building	EPI kWh/m^2/year
Modern Malls	48,697	220–275
Traditional Small Grocery Stores	14–18	33–38.5
Traditional Large Grocery Stores	42–55	55–66





Source: Kumar et al., 2017

INDIA: STAR RATING THRESHOLDS

Business process outsourcing (BPO) buildings

Climatic Zone		1 Star	2 Star	3 Star	4 Star	5 Star
Composite	Threshold EPI (y)	y = 0.21x + 28	y = 0.18x + 24	y = 0.15x + 20	y = 0.12x + 16	y = 0.09x + 12
	Calculated EPI Value	41.7	35.7	29.8	23.8	17.9
Hot and Dry	Threshold EPI (y)	y = 0.1x + 24	y = 0.08x + 20	y = 0.06x + 16	y = 0.04x + 12	y = 0.02x + 8
	Calculated EPI Value	30.5	25.2	19.9	14.6	9.3
Warm and Humid	Threshold EPI (y)	y = 0.17x + 36	y = 0.14x + 32	y = 0.11x + 28	y = 0.08x + 24	y = 0.05x + 20
	Calculated EPI Value	47.05	41.1	35.2	29.2	23.3
Temperate	Threshold EPI (y)	y = 0.13x + 31	y = 0.11x + 27	y = 0.09x + 23	y = 0.07x + 19	y = 0.05x + 15
	Calculated EPI Value	39.45	34.2	28.9	23.55	18.3

Notes: 'x' is air-conditioned floor area as a percentage of total floor area
'y' is threshold Energy Performance Index (EPI)
Sample EPI calculated values are provided for air-conditioned area @ 65% of total floor area
EPI values of buildings must be below the threshold value to qualify for star rating
Energy generated from onsite renewable energy sources is excluded from EPI calculation

Source: Bureau of Energy Efficiency, Government of India, 2023b

INDIA: STAR RATING THRESHOLDS

Office buildings

Climatic Zone	Building Category	1 Star	2 Star	3 Star	4 Star	5 Star
Composite	Large Office Calculated EPI Value	y = 0.95x + 60 121.75	y = 0.9x + 50 108.50	y = 0.85x + 40 95.25	y = 0.8x + 30 82.00	y = 0.75x + 20 68.75
	Medium Office Calculated EPI Value	y = 1.1x + 60 131.50	y = 1.05x + 50 118.25	y = 1.0x + 40 105.00	y = 0.95x + 30 91.75	y = 0.9x + 20 78.50
	Small Office Calculated EPI Value	y = 0.65x + 60 102.25	y = 0.6x + 50 89.00	y = 0.55x + 40 75.75	y = 0.5x + 30 62.50	y = 0.45x + 20 49.25
Warm and Humid	Large Office Calculated EPI Value	y = 0.9x + 65 123.50	y = 0.85x + 55 110.25	y = 0.8x + 45 97.00	y = 0.75x + 35 83.75	y = 0.7x + 25 70.50
	Medium Office Calculated EPI Value	y = 0.9x + 65 123.50	y = 0.85x + 55 110.25	y = 0.8x + 45 97.00	y = 0.75x + 35 83.75	y = 0.7x + 25 70.50
	Small Office Calculated EPI Value	y = 0.7x + 65 110.50	y = 0.65x + 55 97.25	y = 0.6x + 45 84.00	y = 0.55x + 35 70.75	y = 0.5x + 25 57.50
Hot and Dry	Large Office Calculated EPI Value	y = 1.1x + 55 126.50	y = 1.05x + 45 113.25	y = 1.0x + 35 100.00	y = 0.95x + 25 86.75	y = 0.9x + 15 73.50
	Medium Office Calculated EPI Value	y = 1.25x + 55 136.25	y = 1.2x + 45 123.00	y = 1.15x + 35 109.75	y = 1.1x + 25 96.50	y = 1.05x + 15 83.25
	Small Office Calculated EPI Value	y = 0.75x + 55 103.75	y = 0.7x + 45 90.50	y = 0.65x + 35 77.25	y = 0.6x + 25 64.00	y = 0.55x + 15 50.75

Notes: 'x' is air-conditioned floor area as a percentage of total floor area
'y' is threshold Energy Performance Index (EPI)
Sample EPI calculated values are provided for air-conditioned area @ 75% of total floor area, 8–9 hours operation for 6 days/week
EPI values of buildings must be below the threshold value to qualify for star rating
Energy generated from onsite renewable energy sources is excluded from EPI calculation

Source: Bureau of Energy Efficiency, Government of India, 2023b

INDIA: STAR RATING THRESHOLDS

Ranking for hospitals with more than 50% air-conditioned space

	5 Star	4 Star	3 Star	2 Star	1 Star	No Star
Performance Rank	<= 4	> 4 and <= 12	> 12 and <= 24	> 24 and <= 40	> 40 and <= 60	> 60 and <= 100

Note: Energy generated from onsite renewable energy sources is excluded from energy calculation

- The ranking methodology compares the energy consumption of a hospital with its benchmark value'
- The benchmark value represents the average energy consumption of hospitals with similar characteristics and is derived from sample data, using regression analysis
- The ratio of the actual energy consumption of a hospital to its benchmark value depicts the relative energy efficiency of the building
- A performance rank is derived by comparing this ratio to a distribution derived from the sample data set
- The performance rank lies in the range of 1–100. A rank of 1 implies performance among the top 1% hospital buildings in the nation, while a rank of 50 represents an average performance. The star rating is based on the rank

Source: Bureau of Energy Efficiency, Government of India, 2023b

INDIA: STAR RATING THRESHOLDS

Shopping malls



Composite Climate	
EPI (kWh/m^2/year)	Star Label
350–300	1 Star
300–250	2 Star
250–200	3 Star
200–150	4 Star
Below 150	5 Star



Temperate Climate	
EPI (kWh/m^2/year)	Star Label
275–250	1 Star
250–225	2 Star
225–200	3 Star
200–175	4 Star
Below 175	5 Star



Hot and Dry Climate	
EPI (kWh/m^2/year)	Star Label
300–250	1 Star
250–200	2 Star
200–150	3 Star
150–100	4 Star
Below 100	5 Star



Warm and Humid Climate	
EPI (kWh/m^2/year)	Star Label
450–400	1 Star
400–350	2 Star
350–300	3 Star
300–250	4 Star
Below 250	5 Star

Note: Energy generated from onsite renewable energy sources is excluded from energy calculation

Source: Bureau of Energy Efficiency, Government of India, 2011

ENERGY MANAGEMENT

Genesis from the perspective of a building energy manger

- I should know my energy usage pattern
- I should know where I stand in comparison with other similar building(s)
- I should know the potential areas of energy saving
- My staff should manage energy in an efficient and sustainable manner
- I should be aware of the options for improving energy performance
- I should work toward continuous improvement of energy performance

Benchmarking

Data Monitoring

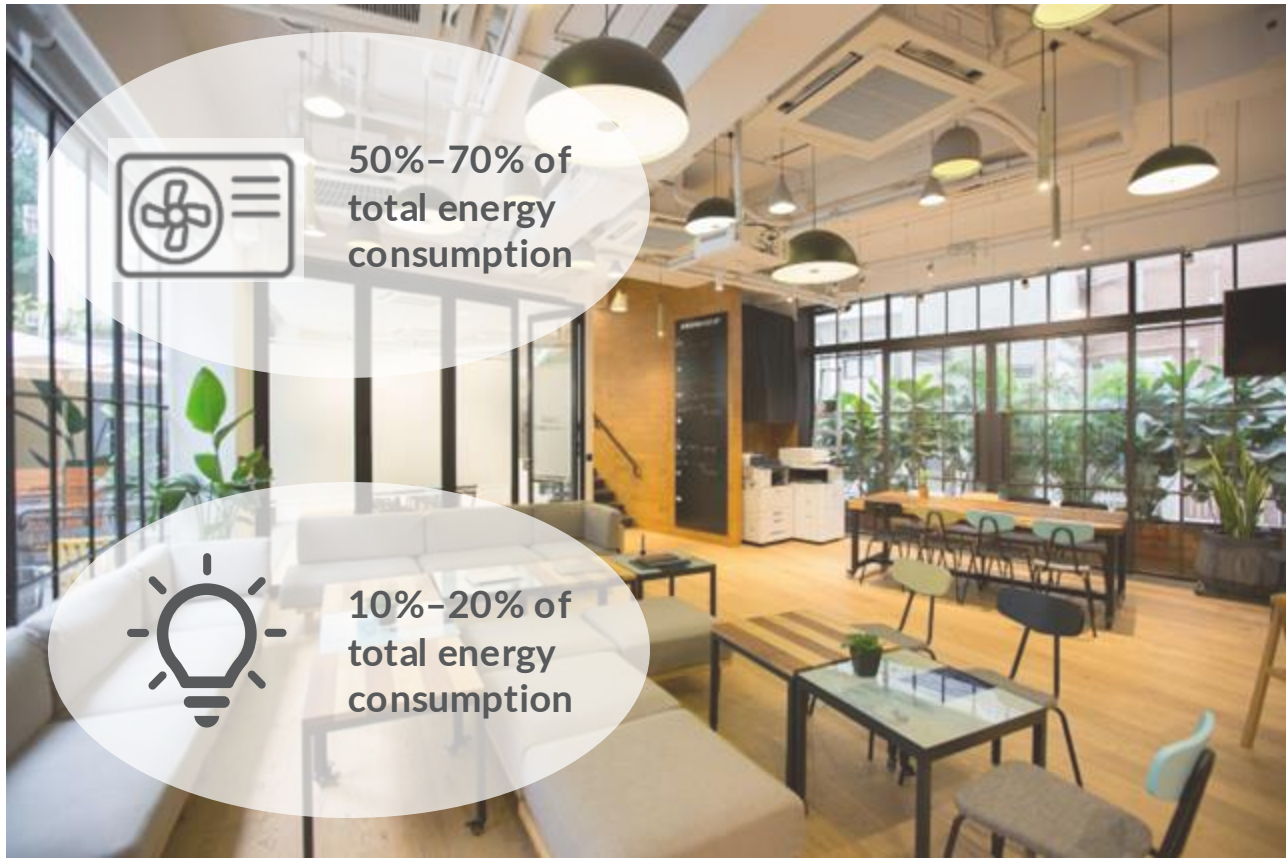
Energy Audit

Guidebook & Training

ENERGY MANAGEMENT

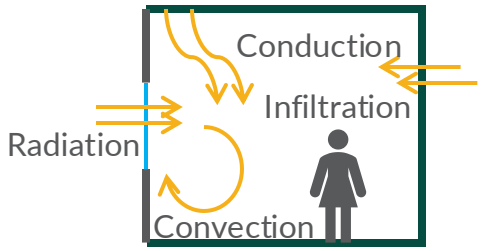
Understanding major loads in buildings

- In modern buildings, building cooling accounts for 50%–70% of total energy consumption, and lighting accounts for about 10%–20% of total energy consumption. The contribution to the HVAC heat load due to people and appliances vary significantly, depending on type of building i.e., office, hotel, hospital, BPO building, educational institution, etc.
- In naturally-ventilated buildings without air conditioning, ceiling fans may account for a significant portion of energy consumption
- The major energy saving potential is expected to be in building cooling and lighting. A holistic systems approach is recommended wherein opportunities for reduction in air conditioning and lighting load are addressed first, before focusing on equipment energy efficiencies

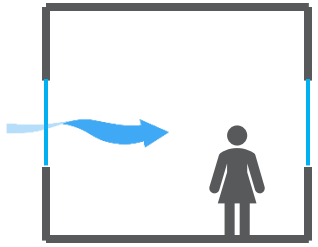


ENERGY MANAGEMENT

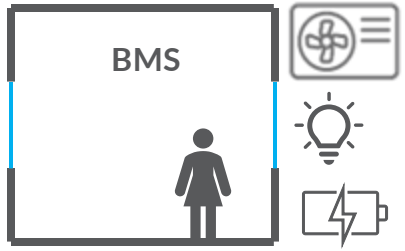
Holistic approach to energy savings in building cooling



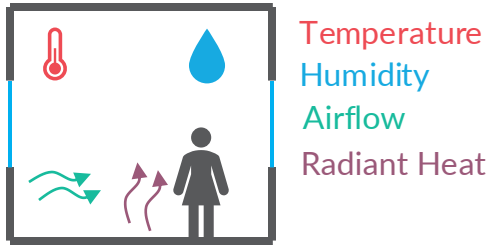
- Use principles of adaptive thermal comfort to vary HVAC temperature settings in relation to outside air temperatures and humidity



- Consider increasing convective air movement in rooms by providing low-speed fans to enable comfort at higher room temperature settings



- Consider increasing temperature settings of rooms without occupancy like unoccupied cabins, guest rooms, conference rooms, low occupancy foyers, document storage rooms, reprographics rooms, etc.
- Good control systems should be in place in the hydronic and air handling units (AHUs) or fan coil units (FCUs) to achieve higher temperature settings without the dripping of excessive water condensation, especially in FCUs
- A centralized building management system (BMS) with occupancy sensors is required for effective monitoring and control



- In most HVAC systems, the recirculating air quantity may be about 90% and the ventilation fresh air quantity about 10%
- Cooling has two components: (i) sensible heat removal by reduction of air temperature; and (ii) latent heat removal, which is heat removal due to condensation of moisture that helps in maintaining the room's relative humidity at a comfortable 50% to 60%
- Moisture is usually from two main sources: fresh air and gaseous bio-effluents from people (sweat, exhaled air, etc.)
- To ensure condensation of moisture, the air temperature has to be brought below dew point temperature of air

ENERGY MANAGEMENT

Holistic approach to energy savings in building cooling

- In conventional HVAC systems, the temperature of the entire recirculating and fresh air quantity is brought down to a low temperature, implying that along with moisture removal, the sensible cooling load also increases significantly, as the entire recirculating air quantity is brought down to a low temperature. Consider using a dedicated outside air system (DOAS) for removal of humidity from the fresh air at source with direct refrigerant cooled coil or desiccant wheel; this can enable temperature reset to higher temperature in the main air handling units, which are handling the large recirculating air quantity
- In the case of fixed speed chillers, monitoring of refrigeration load on chillers is essential to ensure that, to the extent possible, chillers are operating above 80% of the rated load to ensure operation close to the design COP
- In the case of variable speed chillers, operation at lower speeds increases the COP. In the case of fixed speed chillers, the improvement in COP may or may not be significant, depending on the capacity control method. There are no general rules, hence, the optimal trade-off between operating more chillers at lower load and additional auxiliary pumps should be established for each system and programmed into the operating control
- Operating COP of chillers should be established at normal loading. The performance should be correlated with chiller loading, logarithmic mean temperature differences (LMTD) in the evaporator and condenser, chilled water or cooling water flow rates in the chiller and condenser, water-side pressure drops across the evaporator and condenser, and refrigerant charge. Higher LMTDs may be an indication of fouling of evaporator and/or condenser; it may also be an indication of insufficient heat transfer area

ENERGY MANAGEMENT

Holistic approach to energy savings in building cooling (continued)

- Practical experience from energy audits indicates that the drop in efficiency of chillers are usually due to fixed speed compressors operating at partial loads or due to poor heat transfer in the evaporator and condenser; poor performance is rarely due to mechanical problem with the compressor
- Fouling of evaporators and condensers must be addressed through mechanical cleaning, retrofitting with in-line cleaning systems or resolving any chronic water quality issues
- In case the evaporator and condenser heat transfer areas are insufficient, replacement of these heat exchangers may be required to improve chiller efficiency
- The performance of chilled water pumps and cooling water pumps should be critically evaluated from the viewpoint of operating flow, pressure and operating efficiency; opportunities usually exist for optimization of flows, pressures and pump efficiencies. The operating head and flow should closely align with the pump's design head and flow within the optimal efficiency zone to ensure maximum pumping power
- Cooling tower performance impacts chiller operating efficiency. One of the critical parameters is ratio of water flow-to-air flow (L/G ratio). Insufficient heat transfer area, fouling of cooling tower and low air flow result in inefficient operation of chillers

ENERGY MANAGEMENT

Holistic approach to energy savings in building cooling (continued)

- Air flows in air-cooled condensers are difficult to measure under site conditions, but refrigerant condensing pressures and cooling air temperatures can provide guiding indicators for the performance and impact on chiller efficiency. Retrofitting evaporative coolers to reduce condensing pressure and temperature during high ambient dry bulb temperature (with low relative humidity) is an effective method to improve chiller efficiency
- Performance assessment of large AHU centrifugal fans needs critical review. Replacement of inefficient fans with energy efficient axial flow fans with permanent magnet and brushless direct current (BLDC) motors (the combination is popularly called EC fans in India) has energy saving potential in the range of 20% –30%, depending on the existing efficiencies of fans and motors
- All large AHUs should have variable speed drives to optimize air flow, while multi-speed motors are recommended for FCUs. For effective, trouble-free operation, each AHU or FCU should have proper controls for throttling and bypassing chilled water at lower air flows
- A good BMS is required wherein the cooling load of buildings and that of large areas are monitored by integration of chilled water temperatures and flows, and correlating them with energy consumption

ENERGY MANAGEMENT

Holistic approach to energy savings in lighting

- In the past decade, the widespread availability and reduction in prices of energy efficient LED lamps have led to their widespread use across various applications, from bedside lamps to flood lighting in sports stadiums. Available in a range of wattages and offering numerous designs variations in lamps and luminaires, the primary driver has been aesthetics. As a result, there may be limited scope for energy optimization through the replacement of lamps and luminaires, as was the case with conventional gas discharge lamps and luminaires
- Due to the reduced energy consumption in lighting due to LED lamps, it is often difficult to justify investments in dedicated control systems only for lighting. However, it makes economic sense if it is part of a BMS that also controls HVAC

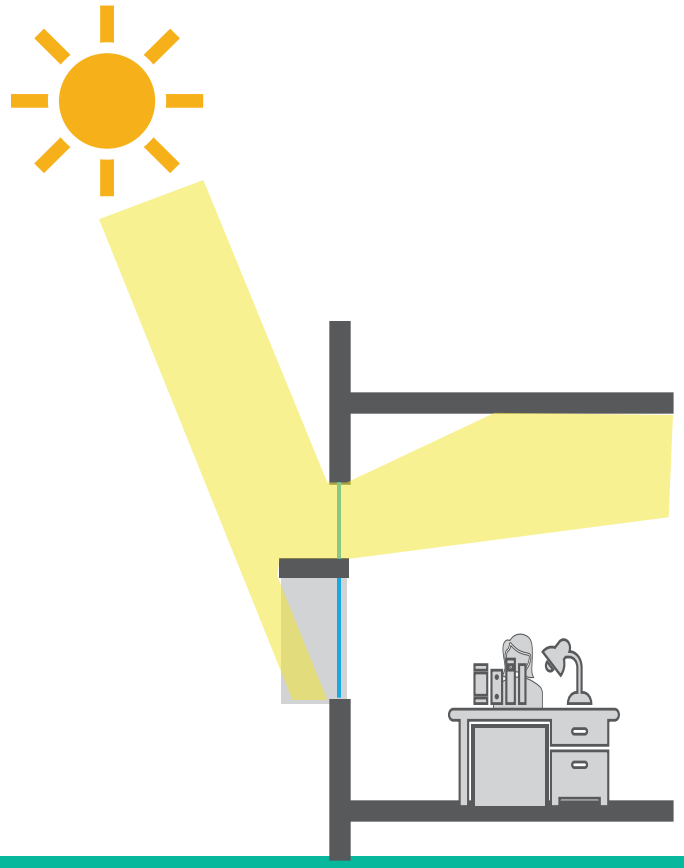


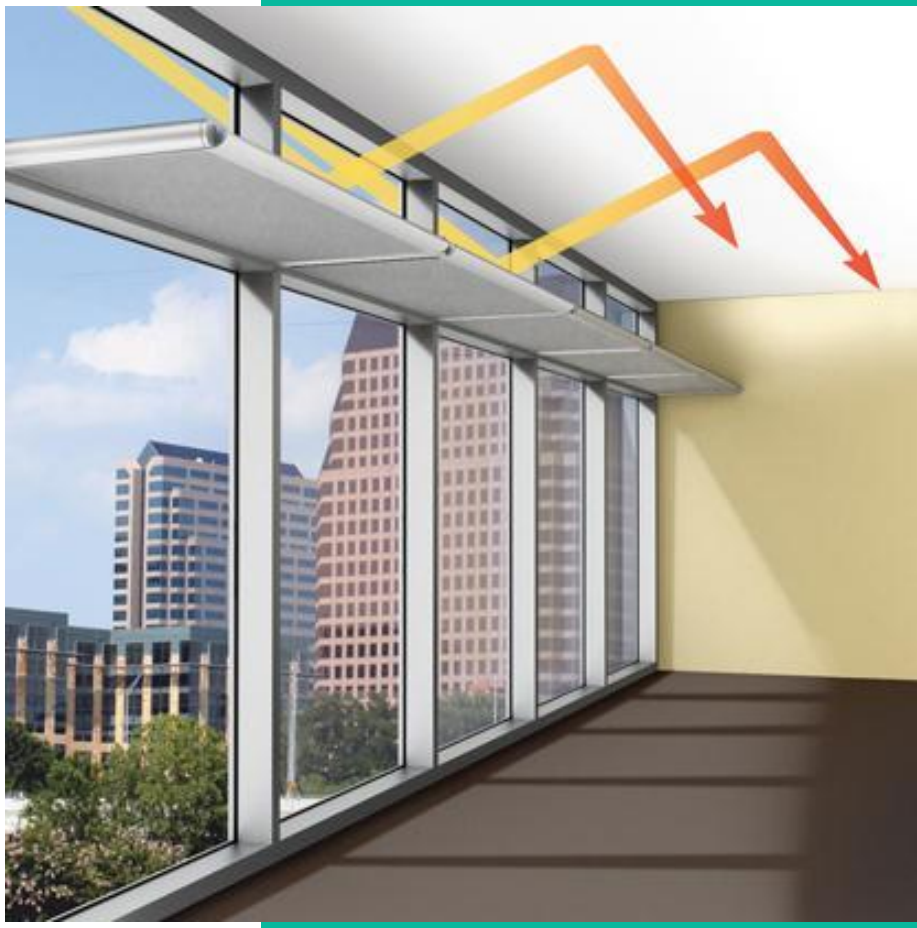
Image source: Wipro Lighting

ENERGY MANAGEMENT

Holistic approach to energy savings in lighting (continued)

- However, energy saving opportunities still exist for optimizing the use of electric lights during daytime. Although excessive glass is used in modern buildings for aesthetics, most buildings still use electric lighting during daytime
- In most buildings, due to glare or excessive light and solar radiation, occupants usually prefer to draw the blinds and use electric lights
- The absence of light shelves to allow natural light without glare in building architectural design augments the problem. However, possibilities exist to innovatively and aesthetically retrofit light shelves in existing buildings to reduce daytime use of electric lighting





Retrofitting light shelves

Image source: https://www.designingbuildings.co.uk/wiki/Light_shelf

ENERGY MANAGEMENT

Integration of renewable energy

- The goal of net zero buildings cannot be achieved by energy efficiency measures alone. Integration of renewable energy with grid energy systems is required
- The simplest way forward is to source renewable electrical power from solar power plants or wind farms through offsite generation, although it may be more expensive if it is sourced from independent power producers
- Sizing of onsite solar power systems depends on space availability and matching electrical load availability during sunshine hours
- Onsite generation of solar power may give greater operational energy savings but will involve high initial capital cost
- Ideally, the solar power system should be sized to meet the building's entire energy demand, as the greatest cost savings are likely achieved when expensive grid electricity is offset. Exporting solar power typically reduces the return on capital investment, as the revenue from exported power is usually much lower than the cost of imported grid electricity



ENERGY MANAGEMENT

Integration of renewable energy (continued)

- Technical issues related to the electrical power system require attention, especially the point of connection to the power system. It is desirable for the solar power system to be connected on the upstream side of the main automatic power factor controller (APFC) to avoid malfunction in power factor control if the power is not fully absorbed in the building and power is exported. Most passive power factor controllers are designed to operate in power export mode
- Fixed charges of grid power should be factored in the calculations of economics of solar power systems, as higher contracted grid power is required for overcast days and nights. Operation with low margins of contracted power may demand automated electrical power management systems with non-critical load shedding capability
- The integration of wind power is usually from offsite wind farms. This is because the power capacities of onsite wind turbines are generally too small and dependent on highly unpredictable wind velocities, and hence, not popular
- The integration of thermal renewable energy in the form of solar hot water systems or biomass fired systems can be easily integrated and do not have the complications associated with electrical power integration



OFFICE BUILDING

Case example: Large office building in the IT/ITES sector

- Capgemini's EPIP Campus in Bengaluru, India, is the first information technology (IT) and information technology-enabled services campus in India to achieve the Net Zero Energy – Platinum (Operation) certification from IGBC
- The project team worked for almost three years to explore new and innovative measures for energy efficiency and retrofit old equipment to industry-benchmarked high performing equipment and systems. They included water-cooled chillers, inline primary pumps integrated with VFD, AHUs fitted with EC motors and ESP filters along with UVGI lamps, LED lighting fixtures, and integrated solar lighting fixtures for exterior illumination and street lighting
- Additionally, the project produces onsite renewable energy (over 20%) and imports green power to offset 100% grid energy use by renewables



Capgemini's EPIP Campus in Bengaluru, India

Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

OFFICE BUILDING

Case example: Large office building in the IT/ITES sector (continued)

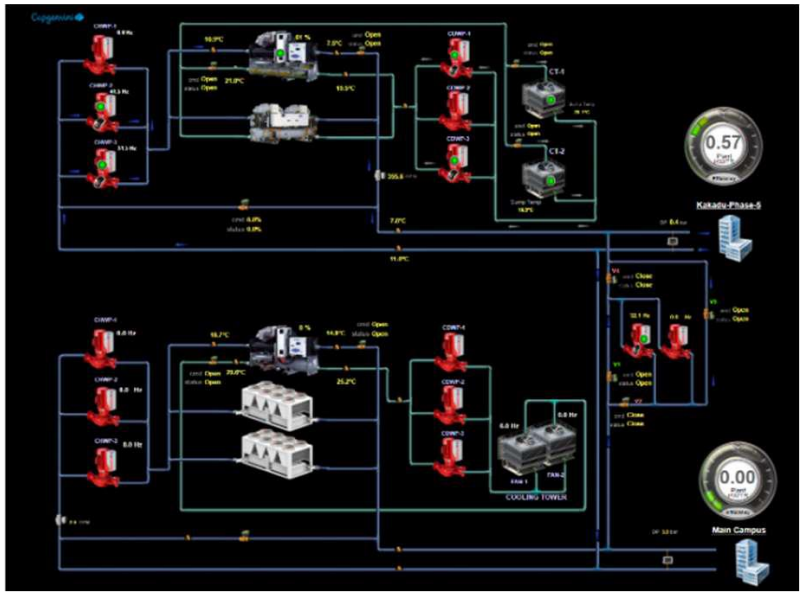
The integration of renewable energy:

- Significant increase in onsite renewable energy generation (1.35 MWp)
- Source about 78%–80% green power through purchase power agreement
- Installation of 100% solar-based street lighting
- Use of solar-powered chiller for maximum reduction in energy demand

Other measure include:

- Reduction in data center energy consumption by retro-commissioning, retrofitting, and managing hot and cold aisle containment and sophisticated control of cool air
- Rigorous metering and monitoring of energy at end use. It includes the monitoring of each equipment on real-time basis (at 15-minute intervals) and diagnose performance with respect to rated capacity and energy consumption
- Inferred decisions from online management system. It includes a central command center to map out energy usage and create alarms when performance deviates from design goals

These implementations reduced energy use of the facility by 16%. The Energy Performance Index ratio of the campus is 0.73



Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

HOSPITAL BUILDING

Case example: Design interventions to improve EPI

A 350-bed multi-specialty hospital building in warm-humid climate (Pune, India) implemented measures for improving the Energy Performance Index (EPI) at the design stage; the main focus being on HVAC

The built-up area is 26,580 m^2 (excluding parking and service floor: ~9,500 m^2), with 3 underground floors and 9 overground floors + 1 service floor. The types of spaces include technical areas like MRI, ICUs, Cath lab, OTs; patient indoor rooms and recovery rooms; restaurants, emergency rooms, etc.

The measures implemented for the building envelope were:

- Roof insulation: 150mm of RCC roof slab was insulated with 100mm extruded polystyrene (XPS) which gives a U-value of 0.31 $W/m^2.K$
- External wall: External walls were made of 150mm AAC block with plaster on both sides, resulting in a U-value of 0.9 W/m2.K
- Glazing: The project team emphasized the importance of daylight in faster recovery of patients and clear glass was selected. Double glazed units were selected for a lower U-value of 2.8 $W/m^2.K$



A multi-speciality hospital in Pune, India

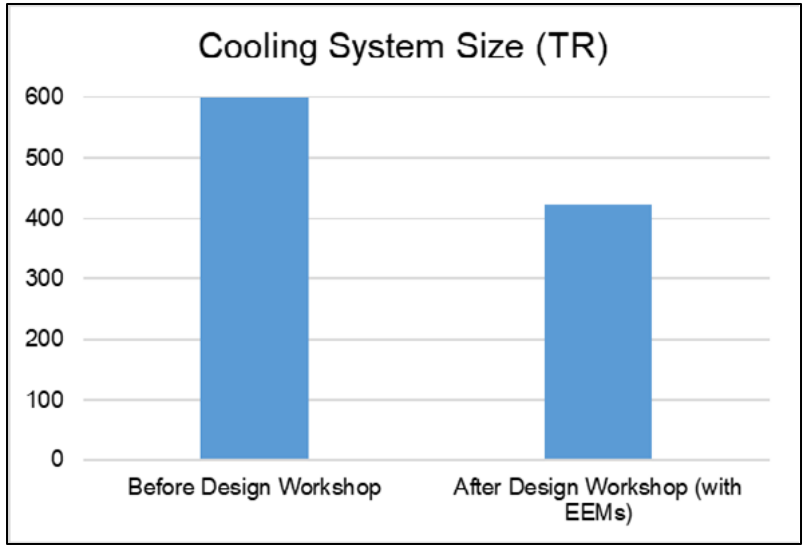
Source: Bhanware et al., 2020

HOSPITAL BUILDING

Case example: Design interventions to improve EPI (continued)

The measures implemented for the HVAC system were:

- Use of dynamic energy simulation software for chiller plant sizing instead of simplified calculation based on static design conditions. Installed chiller capacity is 560 TR (280 x 3 [2 working + 1 standby])
- Selection of a high efficiency chiller with a COP of 5.92 and very good part load performance (NPLV: 0.367)
- Integration of enthalpy recovery wheels in fresh air AHUs with 75% effectiveness for both latent and sensible heat recovery
- Use of condenser water for reheating the air in AHUs to maintain relative humidity. Backup hot water is provided by a heat pump system with a COP of 2.81
- Provisions for free cooling on patient floors, which means if the outside air is suitable for space cooling, it can directly be supplied without passing through the cooling coil



A multi- speciality hospital in Pune, India

Source: Bhanware et al., 2020

HOSPITAL BUILDING

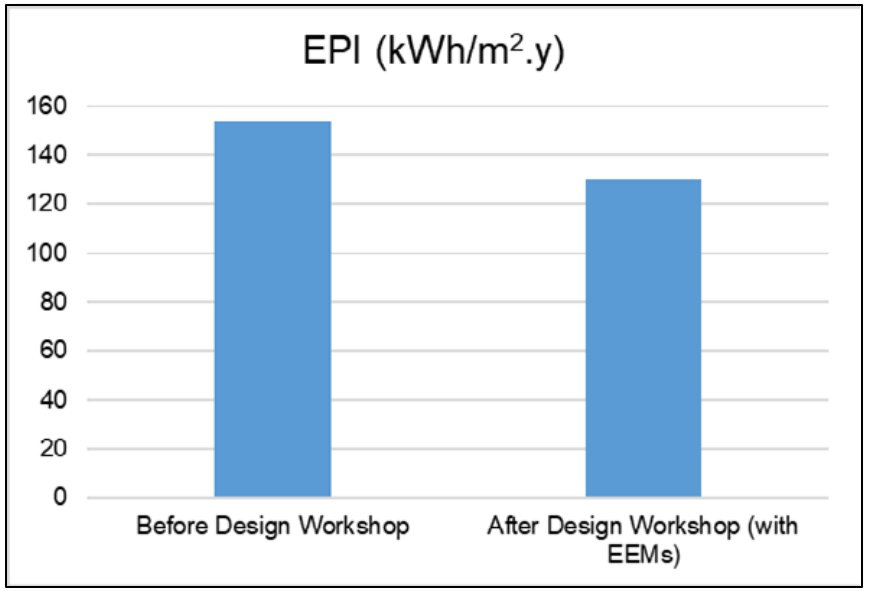
Case example: Design interventions to improve EPI (continued)

The system sizing calculation was done using HAP software and energy simulation of the building was conducted using DesignBuilder software to quantify the benefits of the integration of energy efficiency measures. The key results of the energy simulation were:

- Reduction in cooling system size – The cooling system size was reduced from 600 TR (before the design workshop) to 424 TR (after the integration), a 29% reduction in size
- Reduction in energy consumption – The Energy Performance Index (EPI) was reduced from 154 kWh/m^2.y to 130 kWh/m^2.y (16% reduction) after considering energy efficiency measures in energy simulation

The actual EPI achieved by the hospital was 136 kWh/m^2.y, which was very close to the predicted performance of 130 kWh/m^2.y. The hospital received a 4-star rating under BEE star rating for hospitals

Subsequently, operational improvements, namely, increasing chilled water generation temperature, reducing condenser water temperature, change in heat pump control, etc. were implemented, which resulted in approximately additional10% energy saving



A multi- speciality hospital in Pune, India

Source: Bhanware et al., 2020

EDUCATIONAL INSTITUTE

Case example: Hybrid air conditioning system

- Centre Point School is located at Nagpur, India
- It has been awarded the IGBC Green School Gold rating
- Air conditioning is provided by water-cooled variable speed screw chillers along with CTI-certified cooling towers
- For providing 50 CFM of fresh air per student in each classroom, on each floor, two 3,000 CFM treated fresh air (TFA) units per floor have been installed
- These TFAs are equipped with dual coils for cooling water (for lowering air temperature) and chilled water coils for dehumidification of air
- When the weather is favorable, cooling water is used (in conjunction with the humidity sensor coupled with control valve) for pre-cooling the air
- Indirect evaporative cooling system coils have been installed in TFA units to substitute chilled water-based air conditioning during dry weather



Source: Centre Point School, Nagpur, India

EDUCATIONAL INSTITUTE

Case example: Hybrid air conditioning system (continued)

- At locations with predominantly dry climate, hybrid cooling system can be cost effective, with cooling mode switching between conventional chillers and the evaporative cooling system, depending on the ambient temperature and humidity
- Evaporative cooling is effective only during dry weather
- During operation of the conventional chillers, the TFA unit ensures adequate moisture removal from fresh air, permitting operation of the air conditioning at higher temperature setting
- During cool and dry ambient weather, chillers can be switched off, and chilled water is substituted by 'cold' cooling water from the cooling tower, thus, almost achieving 'free cooling' with minimal cooling tower fan power
- The school has installed 60 kWp of roof top solar PV panels, which generate enough energy for all applications, other than chiller operations



Vapor compression screw chillers with VFD



Treated fresh air system with dual coil

Source: Centre Point School, Nagpur, India

EDUCATIONAL INSTITUTE

Case example: Hybrid air conditioning system (continued)

- All classrooms have three-speed FCUs with controls for room temperature and humidity
- Brushless direct current (BLDC) fans are used for room air circulation, for enhancement of thermal comfort, while operating chillers at higher chilled water temperatures



Ceiling fans retained in air-conditioned classrooms

Source: Centre Point School, Nagpur, India

BUILDING MANAGEMENT AND AUTOMATION

BMS and BAS for HVAC, lighting and other utilities

Building automation is the automatic centralized intelligent monitoring and control of a building's technical systems and services, such as heating, ventilation and air conditioning (HVAC), lighting and other systems through a building management system (BMS)

Controllers regulate the performance of various facilities within the building environment, which includes:

- Mechanical systems
- Plumbing systems
- HVAC systems
- Lighting
- Electrical system and meters
- Security system
- Surveillance system
- Fire alarm
- Lifts, elevators and escalators



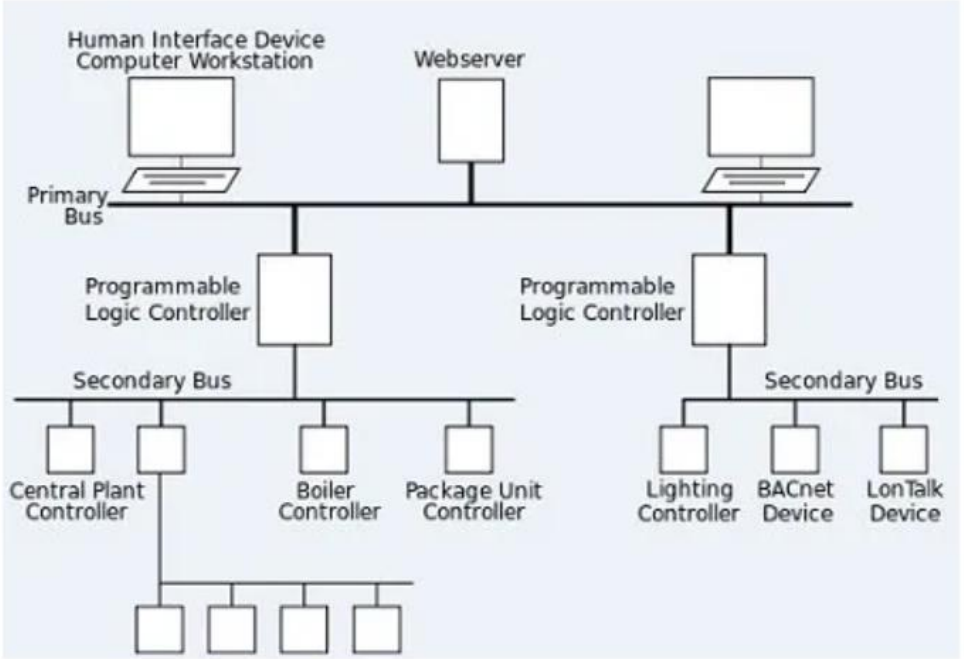
BAS applications in a commercial building

Source: Deorukhkar, 2017

BUILDING MANAGEMENT AND AUTOMATION

BMS and BAS for HVAC, lighting and other utilities (continued)

- The building automation system (BAS) plays a vital role in automating system operation and optimizing energy consumption of HVAC utility equipment. The BAS can help maintain the desired cooling conditions and modulate the system in relation to the load variations due to occupancy or seasonal changes
- Close monitoring and analysis of operations and energy consumption can improve control, reduce operating cost and even increase the life of equipment. Many green buildings have incorporated BAS to optimize ventilation air, energy and water consumption
- Most building automation networks consist of a primary and secondary bus that connects high-level controllers (generic system or network type, terminal unit type or PLC-based) with lower-level controllers, sensors, input-output devices and user interface (a computer workstation with graphical interface)
- For networking, various type of protocols are used, such as open protocols like ASHRAE's BACnet or LonWorks, or other protocols like SNMP, TCP/IP and Modbus



Typical three-tier system architecture for BAS

Source: Deorukhkar, 2017

BUILDING MANAGEMENT AND AUTOMATION

BMS and BAS for HVAC, lighting and other utilities (continued)

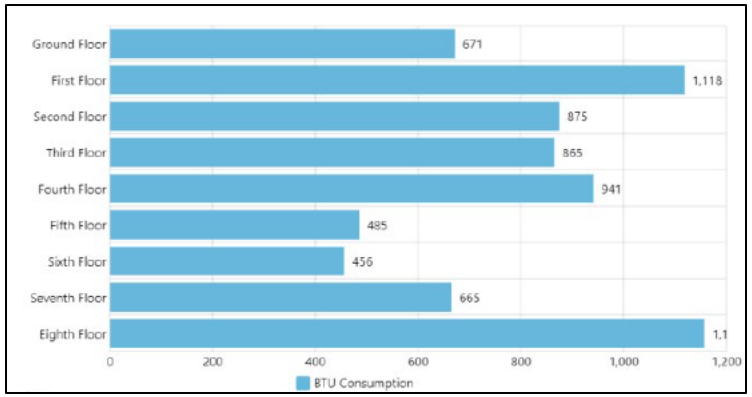
- Field devices and sensors for measuring various HVAC parameters like temperature, humidity, pressure, flow, speed, air quality, lighting intensity, etc. are connected by dedicated optical fiber, Ethernet, ARCNET, RS-232, RS-485 or a low-bandwidth special purpose wireless network
- The user interface involves a PC workstation having graphic interface with various dashboards, graphs or charts. BAS helps facility managers understand and analyze trends, enabling quick troubleshooting and real-time monitoring and control of building operation and performance
- BAS also eases the work of facility managers by providing reports on:
  - Operational data for an equipment or system (with available data points that are integrated with the system)
  - Historical trend (with graphs or charts) for various operational parameters
  - Alarms and/or alerts
  - Incident reports
  - Equipment energy consumption and operating time
- Smart buildings are transitioning from traditional BAS technology to cloud-based information systems, using web-based software

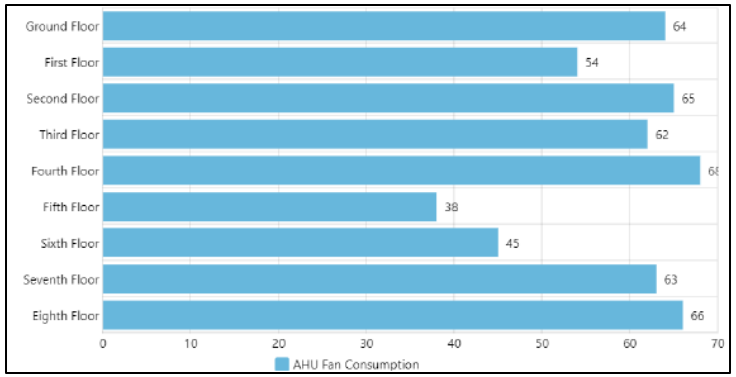
Source: Deorukhkar, 2017

BUILDING MANAGEMENT AND AUTOMATION

Case example: Large office complex of online retail company

- The campus of Flipkart, located at Bengaluru, India, comprises three blocks with an approximate total carpet area of 837,279 sq. ft. Space cooling is by a centralized air conditioning system with air-handling units (AHUs)
- One of the issues was **inconsistent cooling with cold and hot spots** across the office spaces. Additionally, in the absence of a building management system (BMS), the facility **lacked AHU scheduling**; all control was manual
- As a retrofit energy-saving project, a BMS with dynamic airflow and chilled water balancing and indoor air quality (IAQ) monitoring systems was incorporated. The system aims to eliminate thermal discomfort, deliver end-to-end automation, and provide customizable dashboards for energy management and IAQ and AHU-level monitoring
- The AI-backed data analysis tool provides a single-pane view of key metrics in real time to analyze critical factors, such as heat maps and occupancy trends for granular-level reporting. The insights and analysis offered in an intuitive graphical user interface empowers the facility team to control buildings with minimal intervention while increasing energy efficiency and maximizing comfort

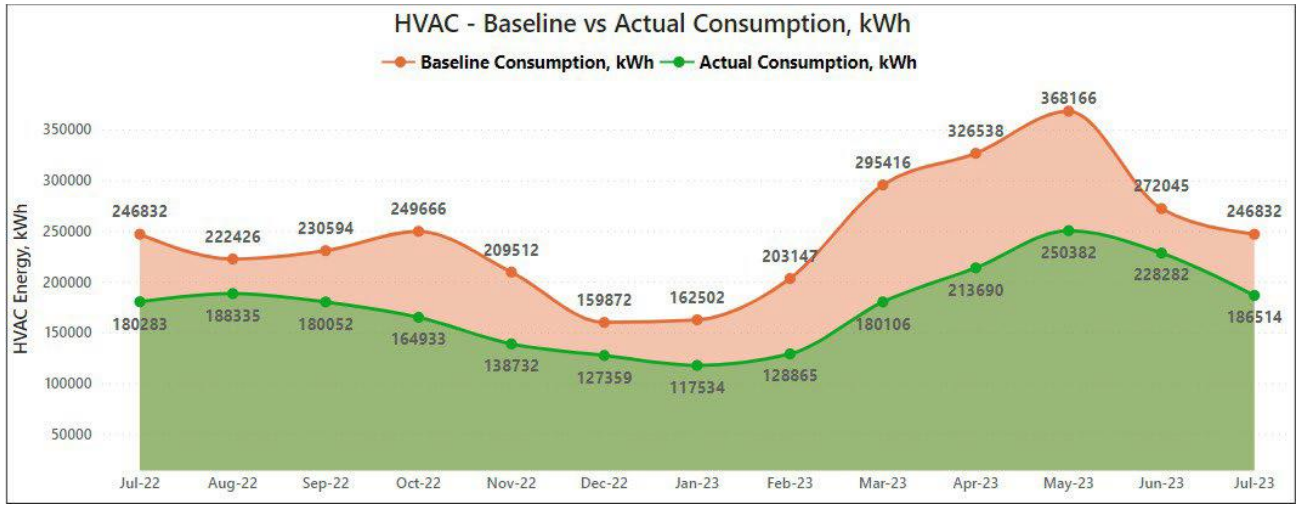


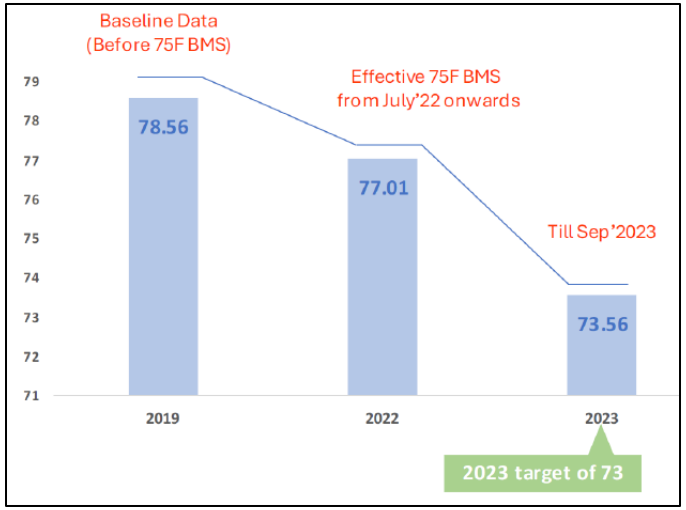


Source: Nawathe, 2023

BUILDING MANAGEMENT AND AUTOMATION

Case example: Large office complex of online retail company (continued)





- Within a short span of the project commissioning, the complaints related to hot and cold spots reduced by 60%
- Additionally, the improved air quality helped earn the prestigious UL Certification for IAQ Management
- The energy saving in comparison to the baseline was 27%, with estimated carbon emissions reduction of 711.4 metric tons

Source: Nawathe, 2023

BUILDING MANAGEMENT AND AUTOMATION

Case example: Small office space of a banking and financial services company

Mode	Manual	Auto	Savings (kWh)	Savings (%)
Total electrical unit (KWh)	183.2	74.2	109	59.4
Total heat load (KWh)	2627	1191	1436	54.6

- A banking and financial services company in Chennai, India, has a HVAC system with an AHU capacity of 9,000 CFM. All controls were manual with variable frequency drives operating at fixed frequency and no modulation of chilled water flow, resulting in uneven cooling across rooms
- Variable air volume sensor boxes were installed to optimize air flows depending on room occupancy. Deployment of an automated air conditioning system ensured that the centralized air conditioning equipment operates at variable speeds, thus optimizing power in relation to prevailing air conditioning loads
- The estimated reduction in cooling load and energy consumption were 54.6% and 59.4%, respectively

Source: ZEDBEE Technologies

ENERGY MANAGEMENT

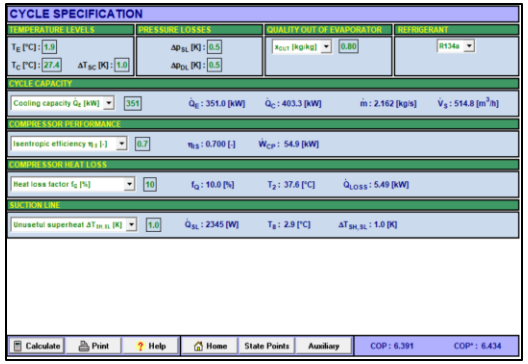
Effective monitoring and control by integrating BMS with EMS

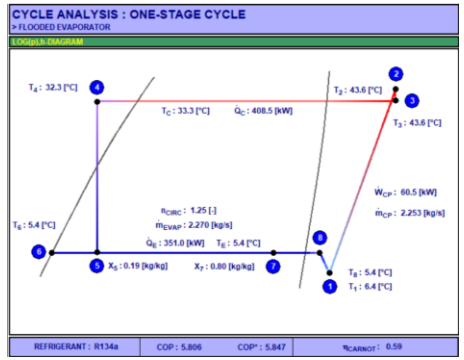
- Many modern buildings still operate with manual controls, based on physical observation of operations or fixed switching at pre-decided clock time. While this strategy may be acceptable for small buildings, large air-conditioned buildings need more sophisticated control
- It is observed that building management system (BMS) in many buildings is used only for monitoring, while controls are manual; automation is necessary for energy optimization. Another common issue is that the BMS is not integrated with the energy management system (EMS), resulting in separate reports for HVAC and energy. The EMS should be an integral part of the BMS to enable creation of a dashboard that can report figures of merit like EPI, kW/TR, cooling kW/sqm, lighting power, etc. in real time
- Simulation studies indicate that BMS based on Internet of Things (IoT) can reduce energy consumption in building HVAC systems by 13%–15% across climatic zones
- Critical review of the trends of important parameters during different weather conditions and building occupancy levels can help identify practical and implementable opportunities for optimizing energy consumption in all areas, especially HVAC through automatic setting resets for temperatures, chilled water flows, HVAC air flows and switching of chillers and auxiliaries. It provides indicators for deterioration in equipment performance due to fouling of heat exchangers, malfunctioning or erratic operation of HVAC and lighting controls, etc.

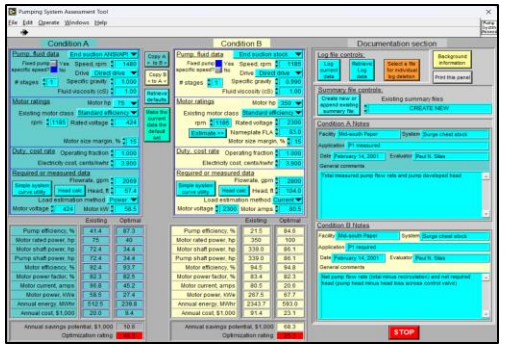
EQUIPMENT EFFICIENCIES

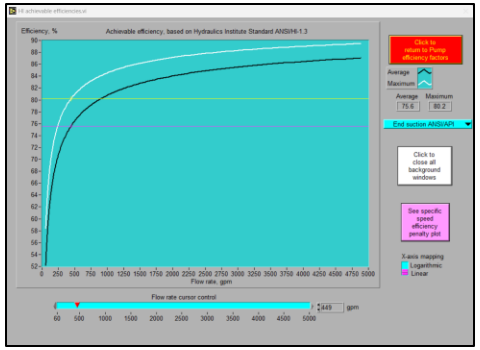
Chillers, pumps and fans: Tools to understand achievable equipment efficiencies

- Building managers and engineers are often not sufficiently aware of the achievable energy efficiency levels for various energy-intensive equipment such as chillers, pumps and fans. Often, decisions are made based on rule of thumb or guidance from equipment vendors, which may not be optimal solutions
- Building engineers should be familiar with simple software tools that are relevant for chillers, pumps and fans to help understand achievable efficiencies for relevant operating parameters of equipment. Some of the free tools available are:
  - CoolPack for chillers (from the Technical University of Denmark)
  - PSAT for pumps (from the Department of Energy, USA)
  - FSAT for fans (from the Department of Energy, USA)
- These tools are discussed in module 3.2(b) on HVAC Systems: Performance Assessment









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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy | PROJECT

2.7 Building Energy Audits

November 2024

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WHAT WILL YOU LEARN?

01 Objectives of energy audit

02 Building energy audits: Scope and methodology

03 Instruments required for site measurements

04 Holistic systems approach to energy audit

05 Energy saving opportunities in pumps and water chillers

06 Major energy consuming equipment in buildings

07 Buildings: Areas demanding detailed site study and analyses



ENERGY AUDIT

A diagnostic tool for energy management

- The most commonly-practiced energy performance assessment tool
- Walk-through energy audits
- Detailed energy audits

Energy Auditor



Portable Gadgets



Data Analysis



Energy audit is NOT a fault-finding exercise, but an approach to identify energy saving opportunities and scope for performance improvement

ENERGY AUDIT

A diagnostic tool for energy management

An *energy audit* can be defined as a systematic exercise for collection and analyses of information on energy consumption and energy costs at macro and micro levels with the following objectives:

- Understand energy consumption and associated costs
- Quantify energy in: per unit of building floor area, per bed in a hospital, per room in a hotel, per employee in a commercial building, per unit of delivery service, per unit of production in an industry, etc.
- Quantify operating energy efficiencies in processes and equipment, supplementing gaps in comparison with best practices
- Identify opportunities to reduce energy consumption and costs through operational changes, retrofits and energy efficient alternatives
- Explore opportunities for substitution of conventional fossil fuel-based energy sources with renewable energy sources
- Explore energy supply side opportunities to reduce energy costs



Image source: https://comelectrical.com/energy-audit-importance-and-why-you-should-be-prioritizing-it/

ENERGY AUDIT (EA)

Types based on objectives, time and resources employed



Preliminary walk-through EA

A walk-through study usually takes one or two days, depending on the size of the facility, for a quick review of energy consumption and costs, and physical observations of operations without any measurements, to identify areas with potential for energy savings (without detailed measurements or quantification)



Detailed EA

A detailed study is conducted over a few days or weeks, depending on the size of the facility, involving detailed observations, measurements and analyses for quantification of process and equipment efficiencies, identification of energy and cost saving opportunities, and detailing of recommended measures, with cost-benefit analyses

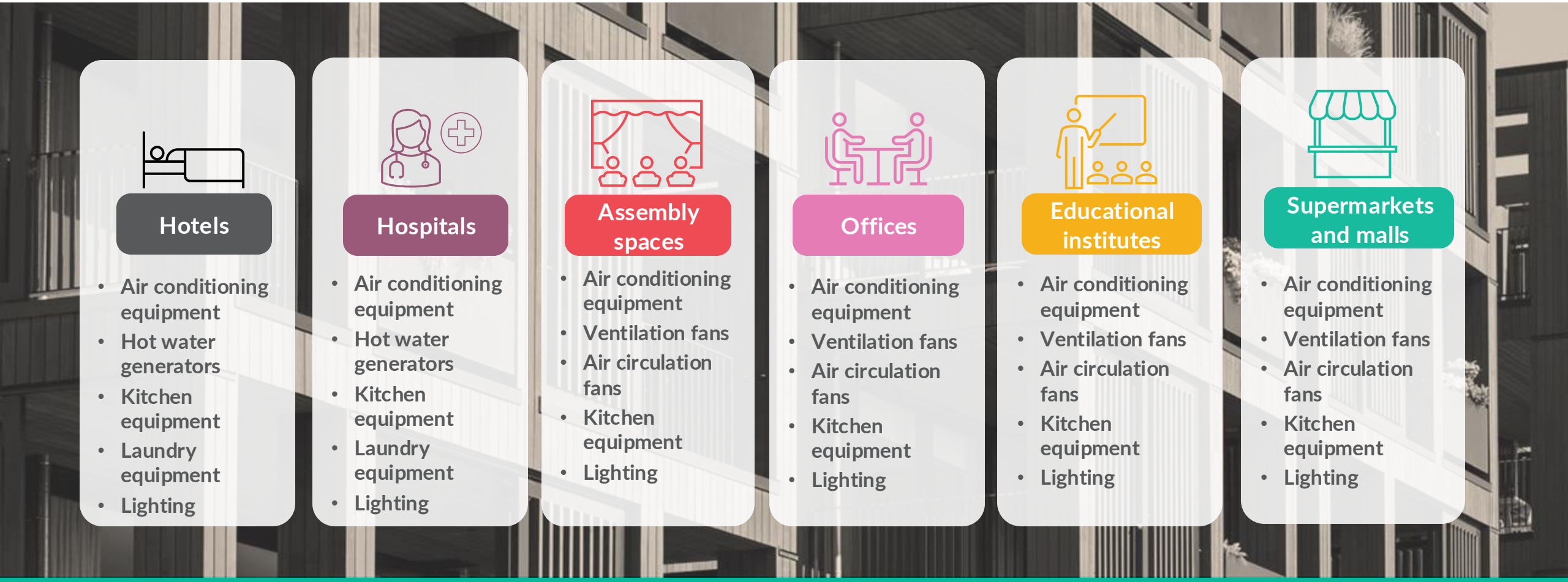


Investment grade EA

A very detailed study for preparation of a bankable project report for selected processes and equipment with accurate quantification of energy and cost saving potential, detailing of required project hardware and software, with accurate cost estimates (supported with budgetary quotes from solution providers), and financial analyses

BUILDINGS

High-energy-consuming equipment



Hotels

- Air conditioning equipment
- Hot water generators
- Kitchen equipment
- Laundry equipment
- Lighting

Hospitals

- Air conditioning equipment
- Hot water generators
- Kitchen equipment
- Laundry equipment
- Lighting

Assembly spaces

- Air conditioning equipment
- Ventilation fans
- Air circulation fans
- Kitchen equipment
- Lighting

Offices

- Air conditioning equipment
- Ventilation fans
- Air circulation fans
- Kitchen equipment
- Lighting

Educational institutes

- Air conditioning equipment
- Ventilation fans
- Air circulation fans
- Kitchen equipment
- Lighting

Supermarkets and malls

- Air conditioning equipment
- Ventilation fans
- Air circulation fans
- Kitchen equipment
- Lighting

BUILDING ENERGY AUDITS

Typical scope of work

- Energy usage pattern (billing and inventory)
- Transformer (loading and operation)
- DG set (loading and specific fuel consumption)
- Lighting system (inventory, lighting index and illumination survey)
- Air conditioning system (energy efficiency ratio and operation)
- Boiler (efficiency and operation)
- Water pumping system (specific water consumption, pump operation and pump efficiency)
- Hot water generating system (specific energy consumption and efficiency)
- General observation (laundry and kitchen)

Critical aspects of energy audits

- **Scope of audit**
- **Quality auditor**
- **Quality data**
- **Gadgets and instrument**
- **Participative**

BUILDING ENERGY AUDITS

Important equipment

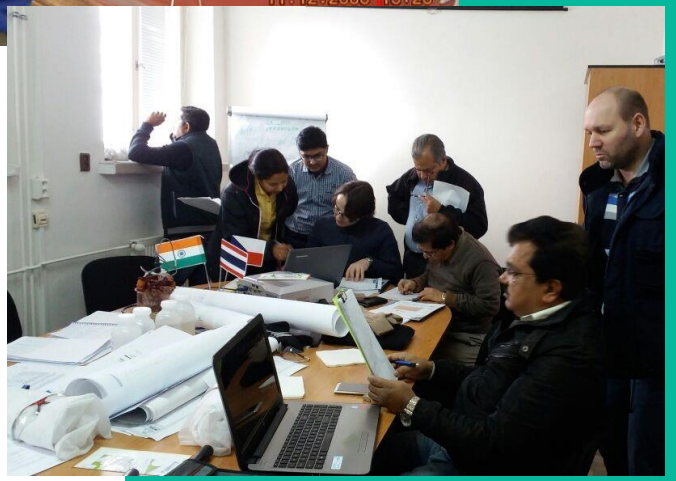
- Electric motors
- Central water chillers
- Unitary air conditioners
- Precision air conditioners
- Steam and hot water generators
- Heat pumps
- Air handling units
- Cooling towers
- Pumps
- Fans and blowers
- Kitchen and pantry equipment
- Laundry equipment
- Office equipment
- Lighting

BUILDING ENERGY AUDITS

Objectives

- Correlate monthly energy consumption and cost with service delivered, floor area, occupancy, weather parameters, etc. for establishing Energy Performance Indexes (EPIs) with appropriate metrics and benchmarking
- Understand energy sources and accounting of energy consumption in significant end uses. Typical energy guzzlers are building air conditioning, hot water generation, kitchen equipment, laundry equipment and lighting
- Establish energy efficiencies or alternative figures of merit for energy-intensive equipment and systems
- Identify gaps and opportunities for energy optimization by improving energy efficiencies, reduction of losses and other innovative measures
- In buildings with both heating and cooling applications, explore possibilities for heat integration, including waste heat and cold recovery, to reduce the demand for cooling and heating
- Explore scope for using renewable energy for electricity generation and heating and cooling applications
- Suggest improvements in the energy monitoring and control system





BUILDING ENERGY AUDITS

Approach and methodology

- Walk through building and utility areas to understand energy sources, energy-intensive end-use equipment and systems, building utilization, occupancy patterns, etc.
- Collect monthly energy consumption data (overall and area-wise), energy costs, inventory of electrical and fuel-fired equipment, and weather data
- Critically review information from building management system or energy management system (if available)
- Holistically study energy-intensive equipment and systems. In most buildings, high energy consumption can be expected in air conditioning, water heating, water pumping and lighting
- Perform spot measurements and prolonged data logging (if required) of operating parameters of relevant equipment and systems
- Confirm segregation and utilization of air-conditioned and naturally-ventilated building spaces. This includes quantification of building cooling and heating load (sensible and latent heat loads) and contribution of heat ingress from building envelope (roof, walls, glass and air ingress)





BUILDING ENERGY AUDITS

Approach and methodology (continued)

- Quantify equipment and system energy efficiencies or appropriate figures of merit
- Quantify energy consumption in lighting during daytime and nighttime, with the objective of reducing daytime electric lighting
- Understand the energy consumption of energy-intensive appliances, such as unitary air conditioners, hot water generators, laundry equipment, kitchen equipment, etc.
- Identify unused roof area and other open areas for possible installation of solar photovoltaic systems or solar heating systems
- Critically analyze data to identify energy saving opportunities from operational changes, retrofits or replacements with more efficient equipment
- Firm up energy saving recommendations, along with quantification of energy saving potential, estimates of investment required, projected returns on investment, and contacts of relevant vendors and solution providers
- Draft the energy audit report, followed by presentation and discussion with clients
- Finalize the energy audit report, incorporating clients' concerns and modifications in recommendations



ENERGY AUDIT

Instruments used in site studies



Power analyzer with clamp-on current transformers

Image source: Krykard



Ultrasonic flow meters

Image source: Acorn Controls



Anemometer

Image source: UNI-T



Flue gas analyzer

Image source: Testo



Thermometers

Image source: Artech

ENERGY AUDIT

Instruments used in site studies (continued)



Sling psychometer

Image source: BHI



Manometer with pitot tube

Image source: Sunflow Technologies



Pressure gauges

Image source: Nishka Instruments



Lux meter

Image source: Lutron



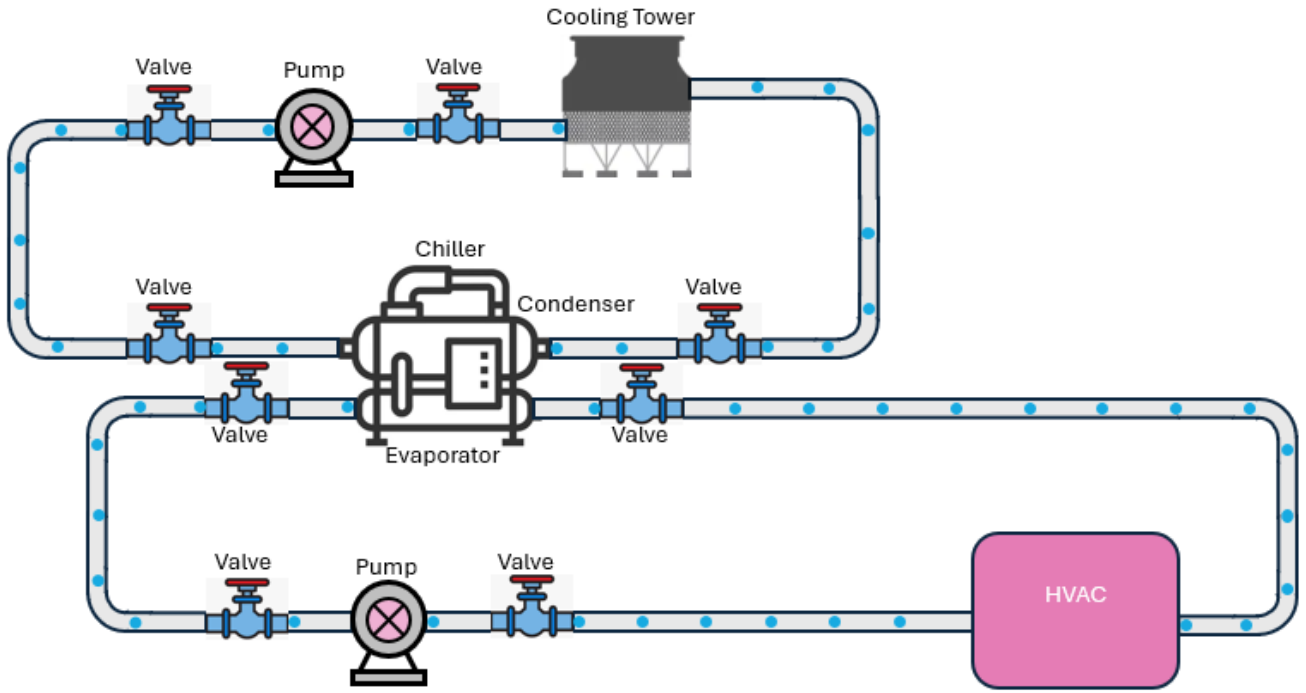
Thermal imager

Image source: Testo

ENERGY AUDIT

HVAC system: A holistic approach is recommended

- To achieve significant energy savings, it is recommended that each energy-intensive equipment is not studied in isolation, but as part of the larger system in which it operates
- For example, a pump operates in a system involving piping, valves, heat exchangers, etc. Even when the pump efficiency is good, the overall pumping system efficiency may be poor due to excess flow or avoidable pressure losses in the system
- Similarly, a water chiller may be efficient, but the heat of load on the chiller may comprise of some spurious, avoidable heat loads
- In the case of lighting, the priority should be to maximize the use of natural lighting before focusing on energy efficient lamps, gears and controls



Typical chilled water system

Image source: Devki Energy Consultancy Pvt. Ltd., India

HVAC PUMPING SYSTEM

Energy losses in HVAC system circulation pumps

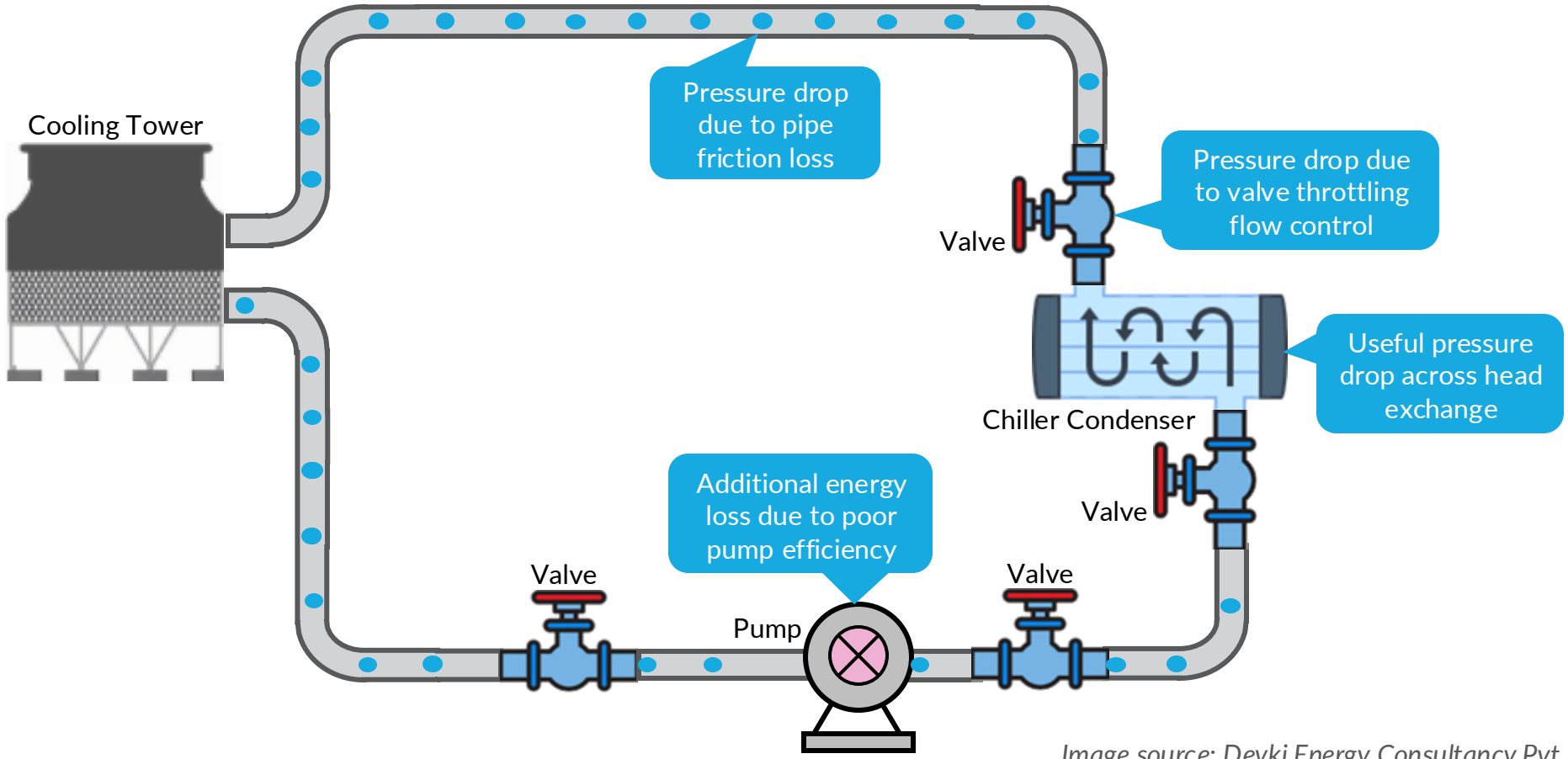
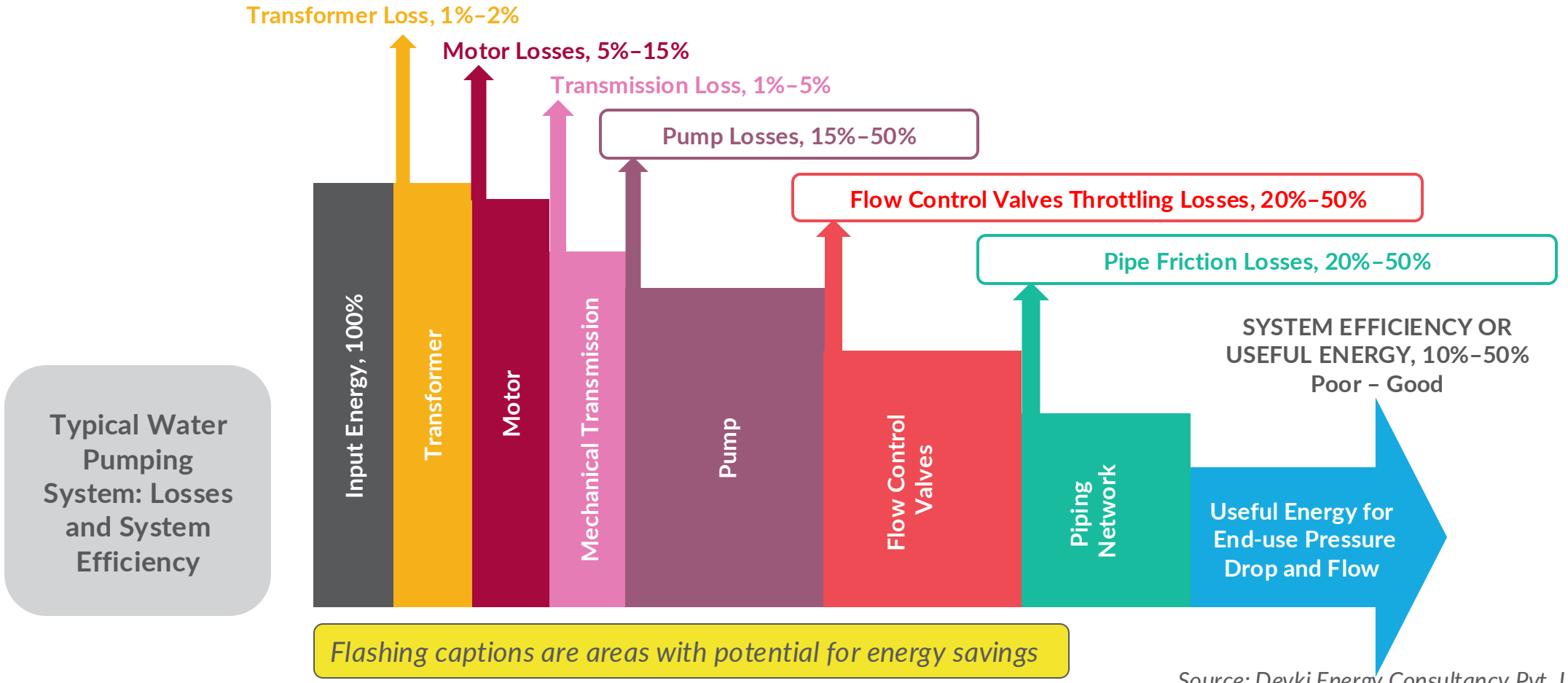


Image source: Devki Energy Consultancy Pvt. Ltd., India

HVAC PUMPING SYSTEM

A holistic understanding of energy losses and system efficiency



Source: Devki Energy Consultancy Pvt. Ltd., India

HVAC PUMPING SYSTEM

Typical energy saving opportunities

- Optimization of chilled and cooling water circulation rates and operating head
- Elimination of valve throttling losses by incorporating variable speed drives for flow control
- Optimization of the number of parallel pumps in a system for achieving good operating efficiency and reliability
- Ensuring optimal sizing of pipes to reduce pressure losses due to pipe friction
- Selection of appropriately-sized high efficiency pumps
- Regular pump maintenance, monitoring and control to ensure optimal operation

Pumping system efficiencies (including all system losses) can be improved from usually prevailing levels of 10%–20% to 40%–50% by minimizing or eliminating valve throttling losses and ensuring selection of pumps with optimal head and flow, with the highest available pump efficiency

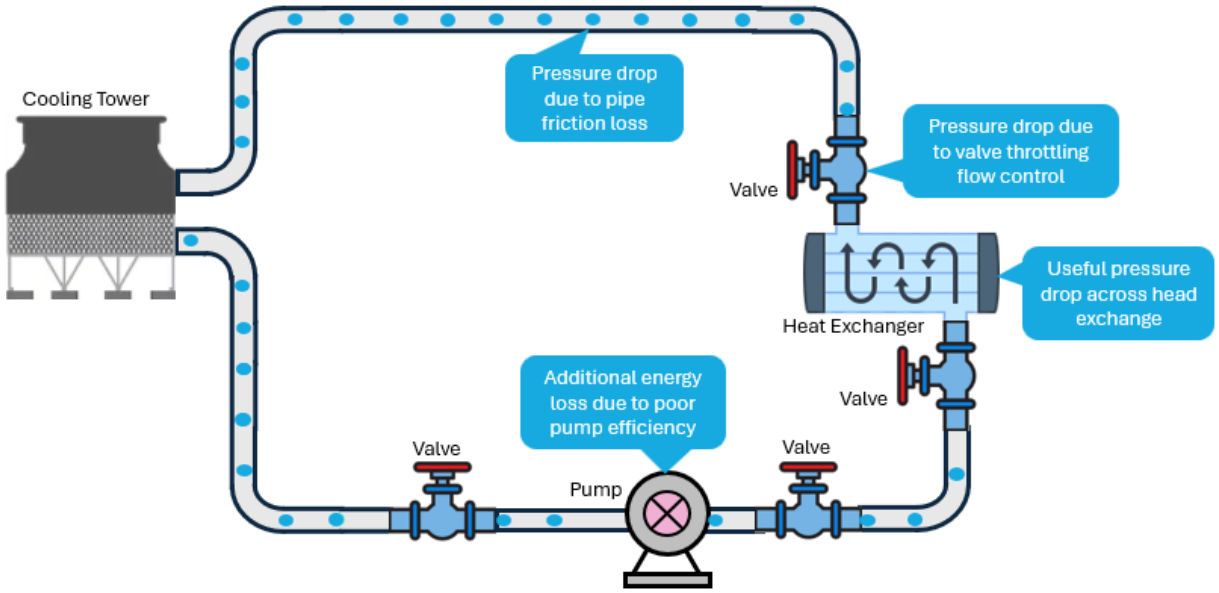


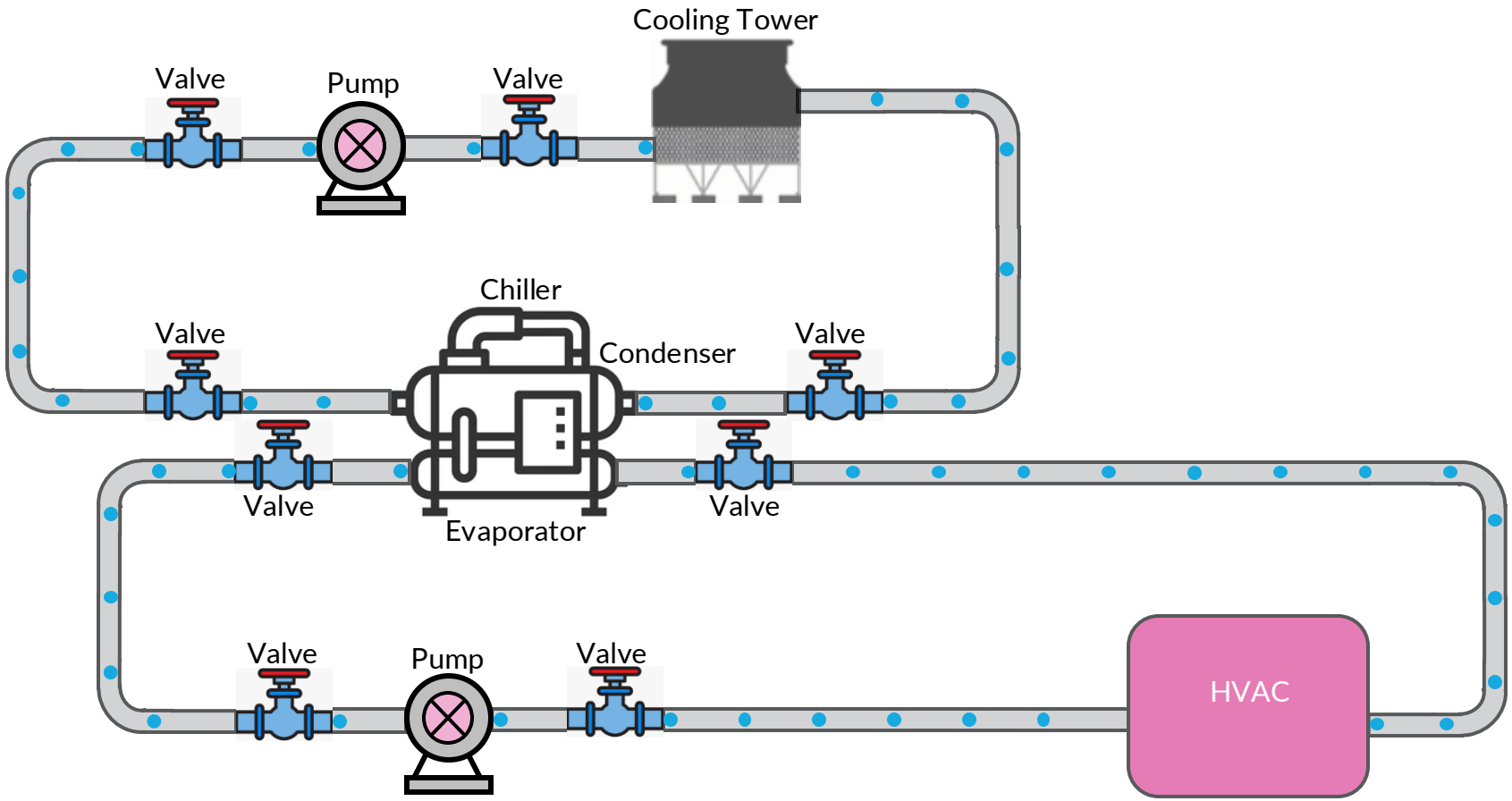
Image source: Devki Energy Consultancy Pvt. Ltd., India

HVAC WATER CHILLERS

Energy losses in HVAC water chilling systems

Likely reasons for poor chiller performance

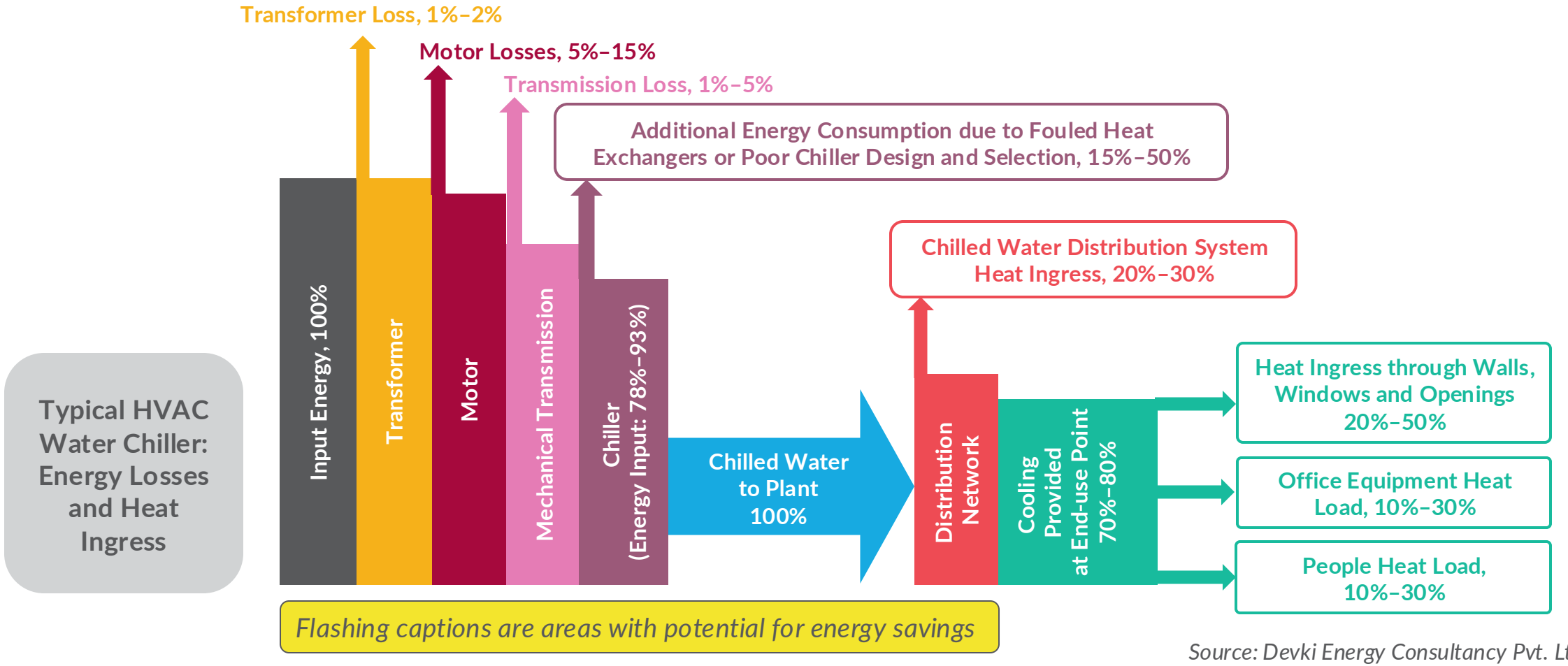
1. Poor chilled water temperature control
2. Prolonged chiller operation at partial load
3. Inadequate chilled water and/or cooling water flows
4. Fouling of evaporator and/or condenser
5. Poor cooling tower or air-cooled condenser performance
6. Inadequate heat transfer area in evaporator or condenser



Source: Devki Energy Consultancy Pvt. Ltd., India

HVAC SYSTEMS

Holistic system approach to identify efficiency gaps and energy losses



Source: Devki Energy Consultancy Pvt. Ltd., India

HVAC SYSTEMS

Energy saving opportunities

- Maintenance of optimal temperature and humidity levels with effective feedback controls and optimal AHU fan flows using variable frequency drives
- Minimization of demand for energy-intensive room air conditioning by using natural ventilation to the extent possible and other innovative, less energy-intensive solutions, such as evaporative cooling
- In warm and humid climatic zones, use of *treated fresh air (TFA) units* to reduce humidity of fresh air enables operation of air conditioning system at higher temperatures without causing discomfort
- Reduction of heat ingress into buildings by optimizing glass-to-wall ratio, ensuring proper thermal insulation and integrating ventilation air heat recovery
- Use of *precision air conditioners with e*nergy recovery technologies for *low relative humidity* air conditioning



Image source: https://www.rsi.edu/blog/hvacr/introduction-to-energy-efficient-hvac-what-hvac-students-need-to-know/

HVAC SYSTEMS

Energy saving opportunities (continued)

- In chillers, ensure adequate evaporator and condenser heat transfer areas with optimal fluid flows to improve the coefficient of performance (COP)
- Maintenance of cleanliness of heat transfer surfaces with special coatings and automatic cleaning systems
- Use of variable speed drives on chiller compressors that operate at variable load to achieve significantly higher COP (compared to design values) at partial loads
- Use of appropriately-sized higher efficiency pumps
- Use of high efficiency fans with BLDC motors in AHUs



Image source: https://www.rsi.edu/blog/hvacr/introduction-to-energy-efficient-hvac-what-hvac-students-need-to-know/

ENERGY OPTIMIZATION

HVAC systems: Typical issues

- Excessive heat load through building envelope, especially due to high glass-to-wall ratio
- External air ingress and poor control over ventilation
- Operation at lower temperatures to overcome end-use temperature issues due to improper air distribution
- Excessive air recirculation flows in rooms
- Absence of control over chillers and air conditioners during low room occupancy hours
- Low operating COP of chillers due to operation at multiple loads
- Low operating COP due to issues in condenser cooling, such as low coolant flow, fouling of heat transfer surfaces, poor performance of cooling towers, etc.
- Low operating COP of unitary air conditioners due to poor maintenance or selection of less efficient air conditioners
- Inadequacy of refrigerant charge in the system
- Poor efficiencies of pumps due to inappropriate selection
- Significant valve throttling losses in pumps
- Poor efficiencies of AHU fans
- High *time of day (TOD)* charges due to absence of thermal storage system

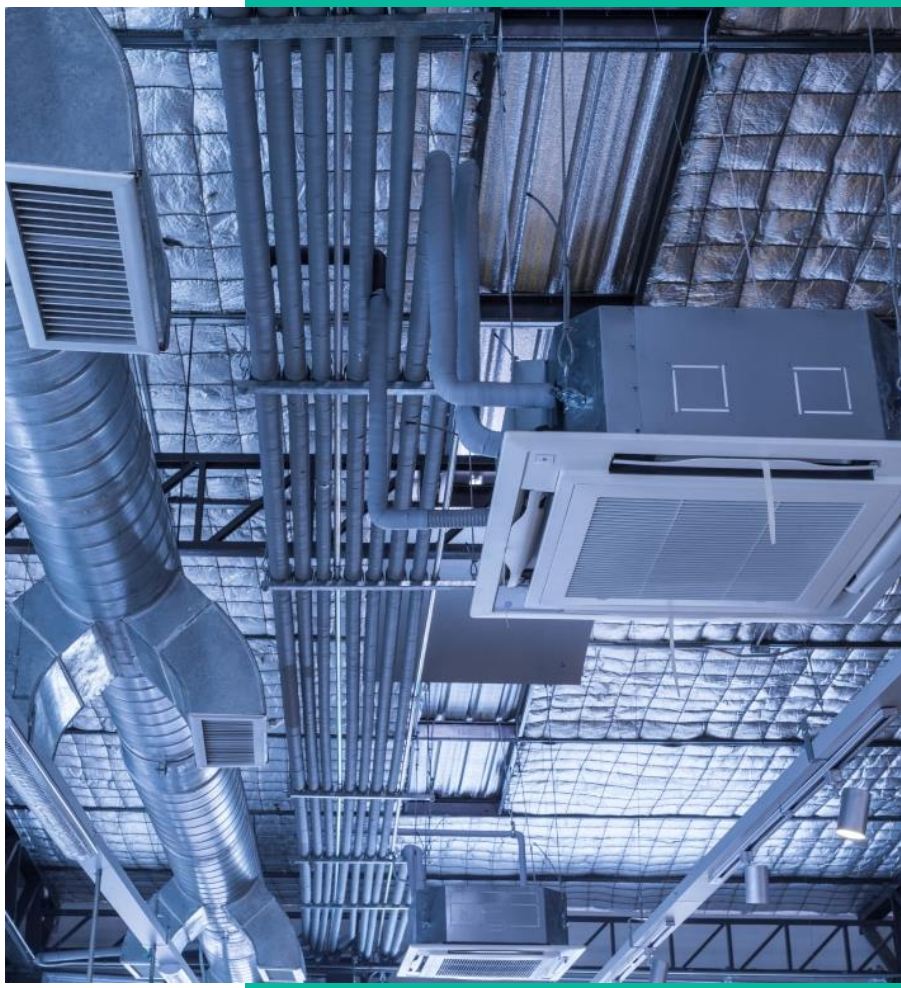


Image source: https://galooli.com/glossary/what-is-hvac/

ENERGY SAVING OPPORTUNTIES

Lighting: Typical issues

- Use of electric lighting during daytime
- Possibility of retrofitting of light shelves
- Possibility of retrofitting lamp dimming devices
- Possibility of use of low wattage lamps with improved luminaires
- Optimization of building façade lighting
- Control and optimization of outdoor lighting



Image source: Wipro Lighting

ENERGY AUDIT REPORT

Contents

- Summary of major recommendations
- Introduction to the facility
- Description of building and activities within
- Analyses of energy consumption and correlation using appropriate metrics
- Presentation of collected data, analyses and energy saving recommendations, with quantified savings
- Cost-benefit analyses for all recommendations
- Benchmarking of energy consumption
- Suggestions for improved energy monitoring and control
- A comprehensive list of good operating practices
- Annexures: Detailed compilation of measurements, references, etc.

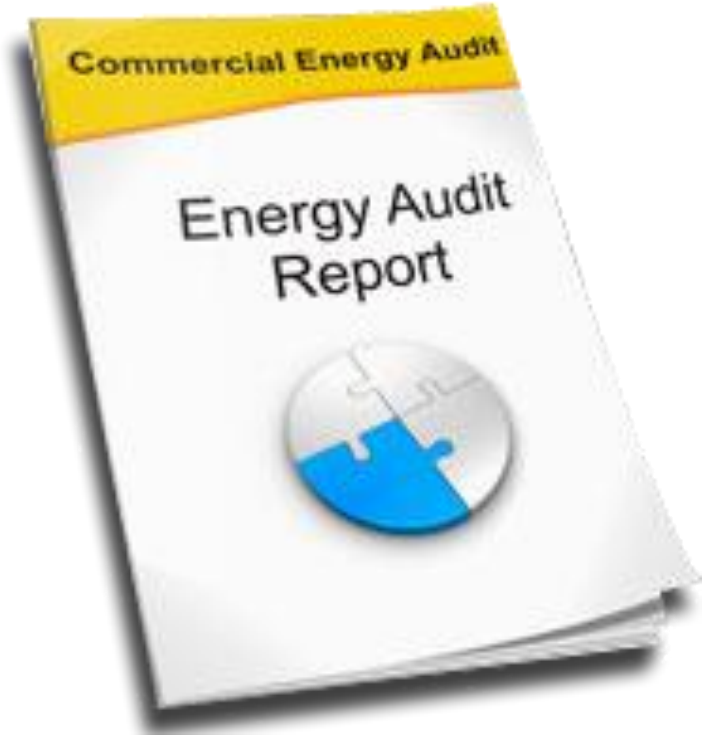


Image source: https://www.minzinc.com/products-20-6.html

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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

2.8 Tools for Planning and Design of Low Carbon Buildings

November 2024

ASEAN CENTRE FOR ENERGY ACE

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WHAT WILL YOU LEARN?

01 Integrated Design Process

02 Building Energy Simulation

03 Daylight Simulation

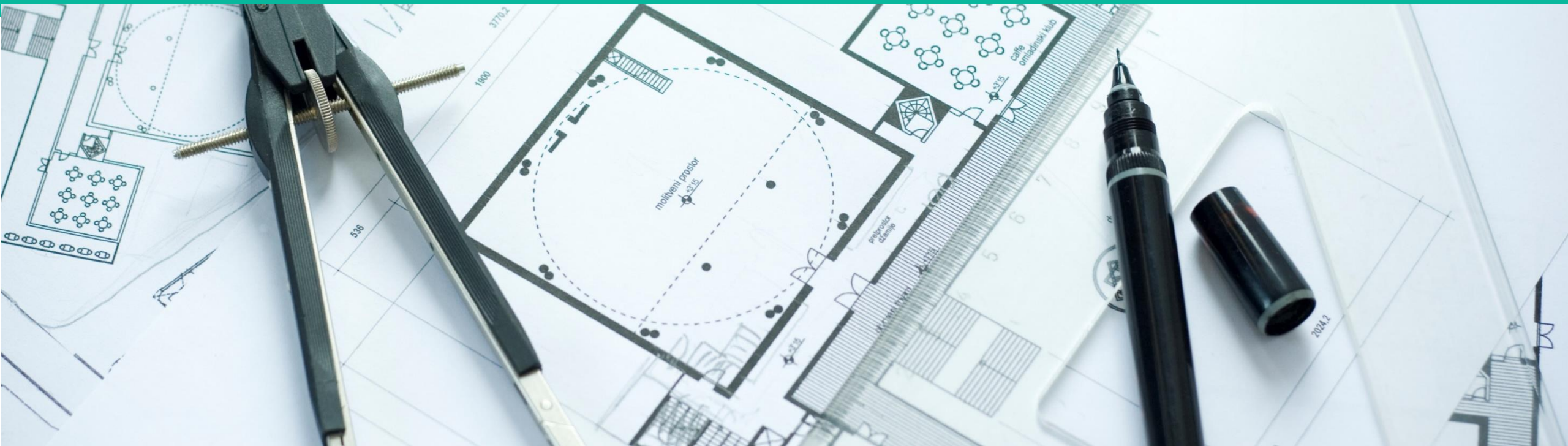
04 Natural Ventilation Simulation

05 Case Examples



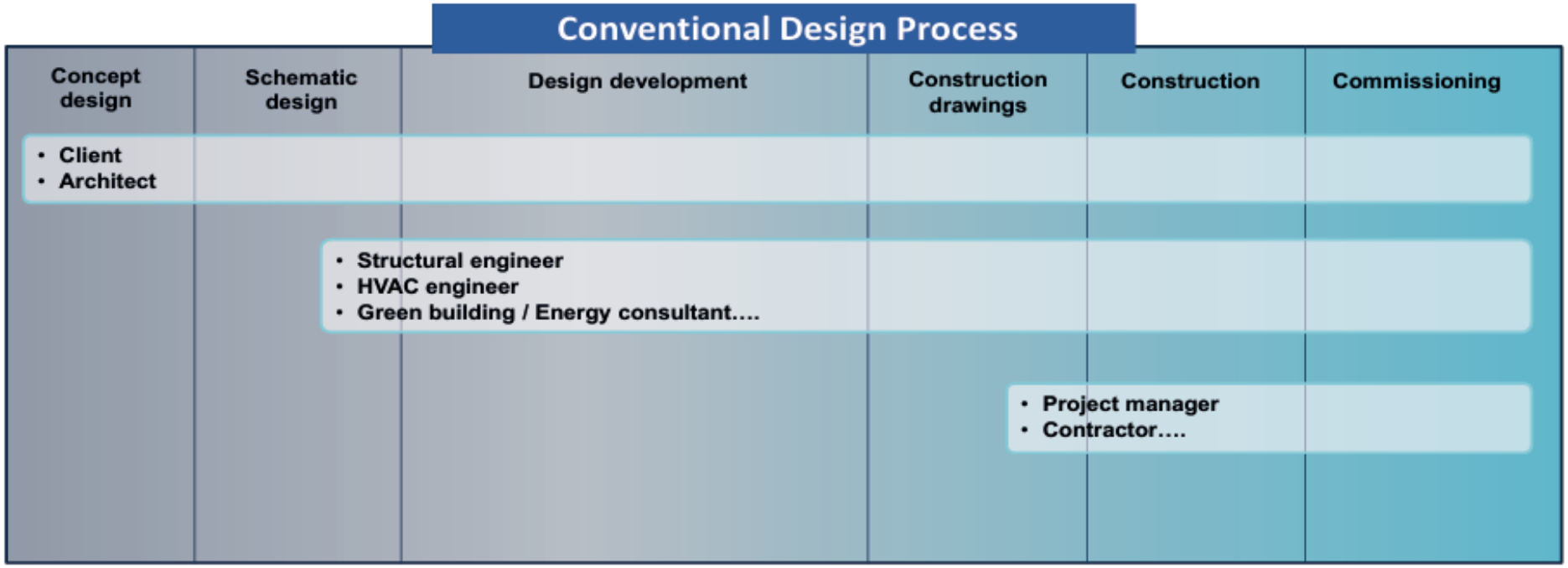
Integrated Design Process

A Design Tool



CONVENTIONAL DESIGN PROCESS

Lack of integrated view of the project



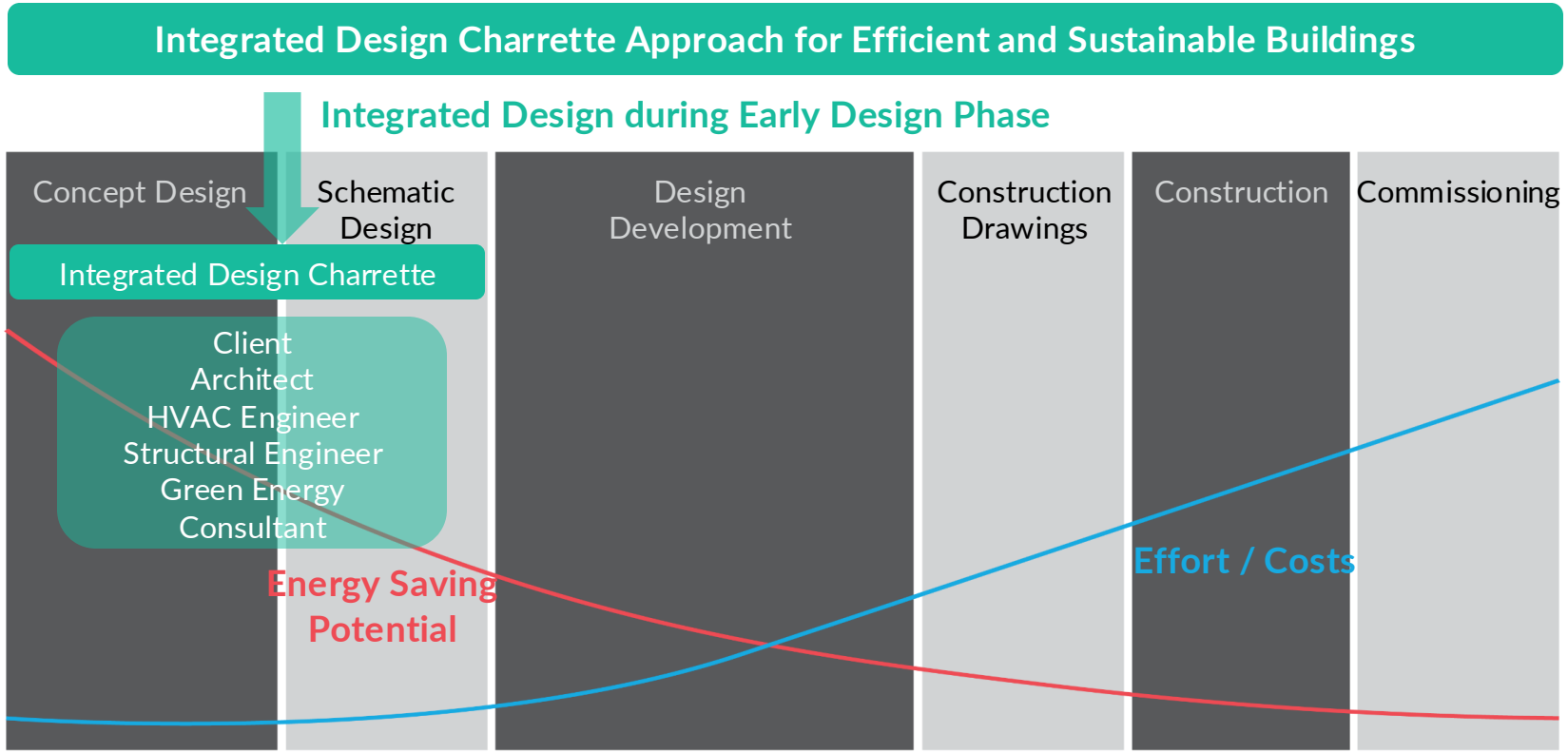
A **sequential process** where different specialist design consultants and stakeholders are brought in separately after much of the architectural design has been fixed to give their respective technical inputs

Source: BEEP Design Charrette Manual

INTEGRATED DESIGN PROCESS

When to have an integrated design charrette?

- **Integrated design** means that most of the stakeholders, if not all, start **working on the project together** right from the beginning, based on the design brief
- The best and most effective time to have the first charrette is at the **conceptual stage of the design**, with all or most of the stakeholders (the decision-makers, the people financing the project, the ones designing and constructing, and the ones operating and using it) on board

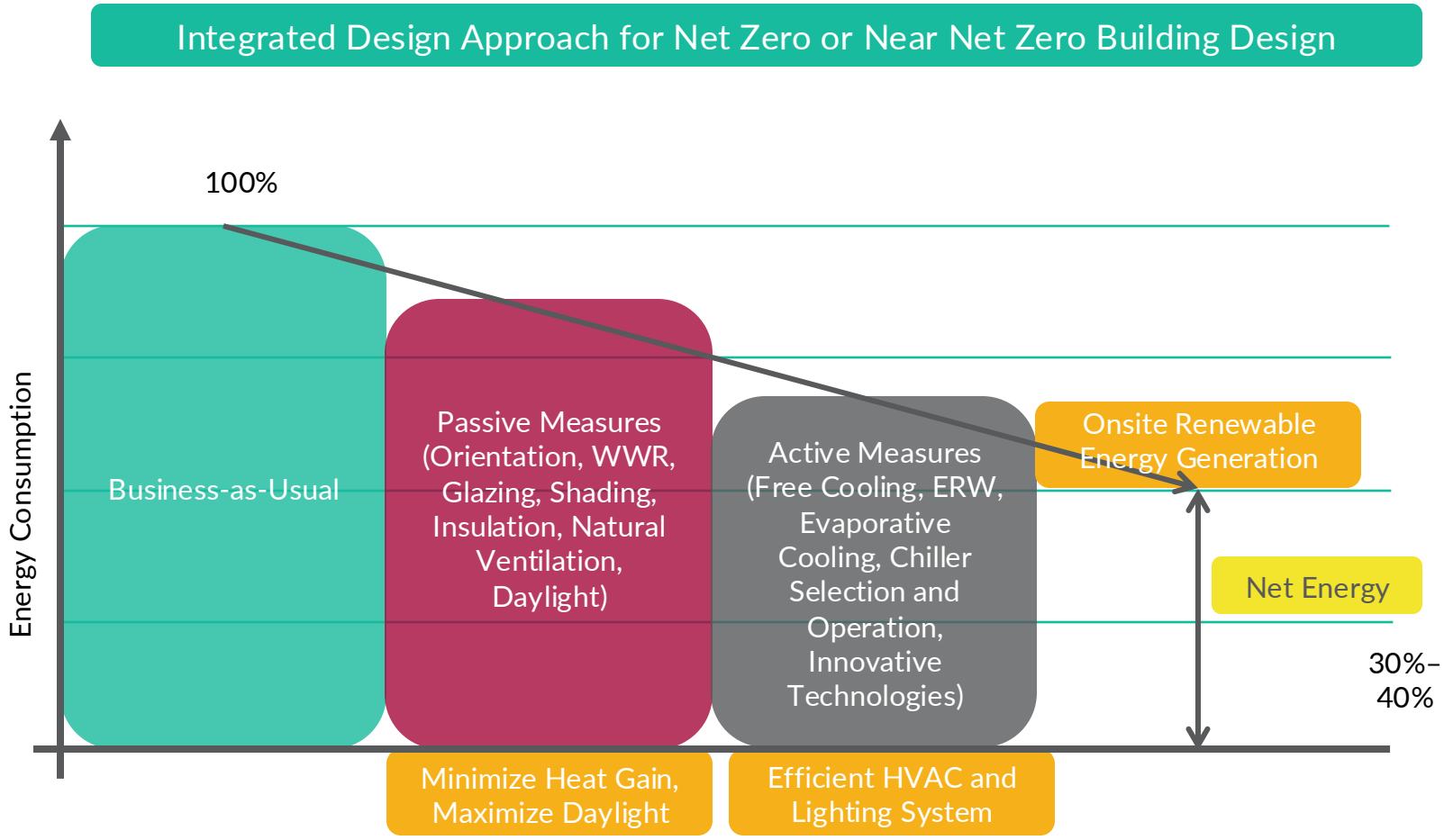


Source: BEEP Design Charrette Manual

WHAT DO YOU INTEGRATE?

Step-by-step strategies to reduce operational energy consumption

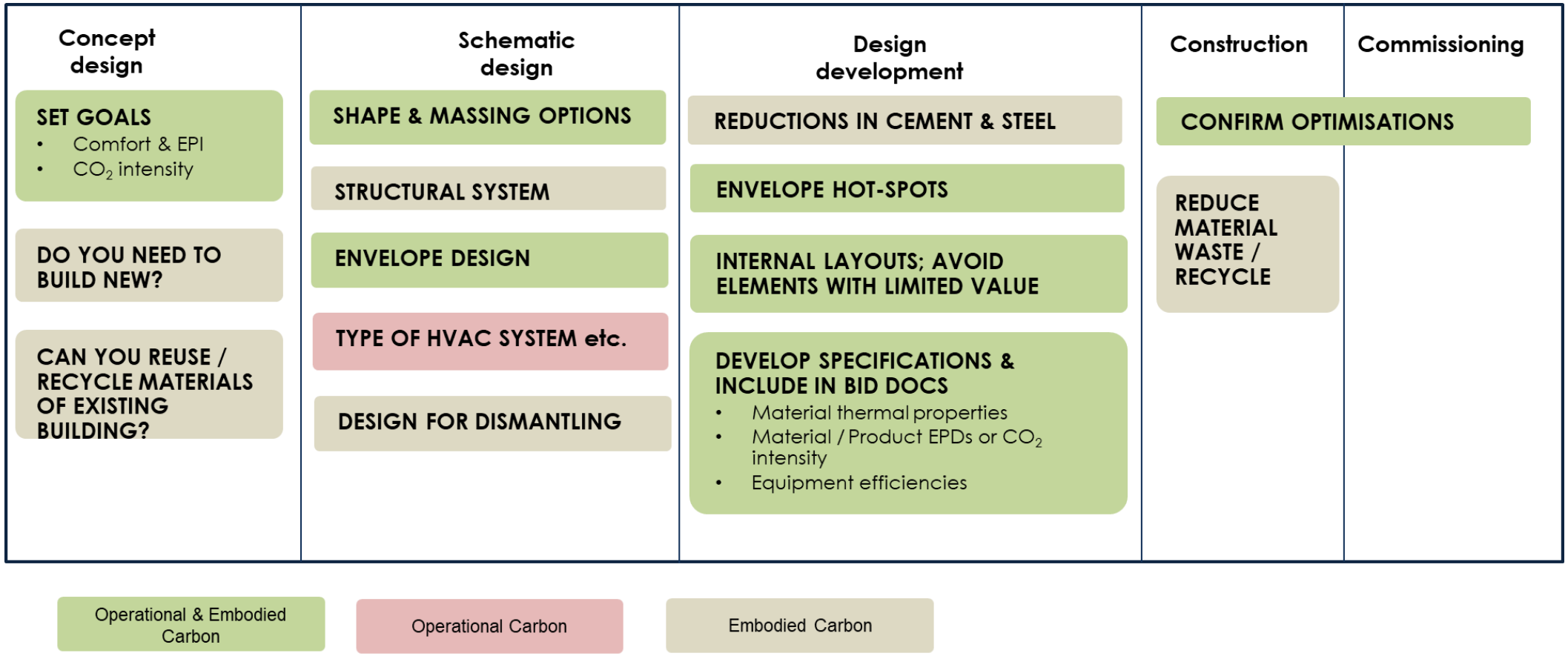
- An **Integrated design process** aims to get a **climate responsive design first**, and then complements it with efficient and sustainable mechanical technologies
- A **charrette** is a tool to implement an integrated design process, wherein all stakeholders work together in an intense manner over a short time period



Source: BEEP Design Charrette Manual

WHAT DO YOU INTEGRATE?

Integrating materials with low embodied carbon



Source: BEEP Design Charrette Manual

INTEGRATED DESIGN CHARRETTE

Setting goals

Commercial buildings

- **Mostly air-conditioned**
- Narrow band of expected comfort
- Air conditioning used for longer duration and may be used throughout the year
- Heat loads in the building may have equal or more contribution from internal loads, i.e., from occupants and equipment

Charrette goals

- Reduction in Energy Performance Index (EPI), either in comparison to the base design as per an existing benchmark EPI, specifically cooling EPI
- Additional parameters evaluated for specific problem identification or problem solving:
  - Heat gains from different building components
  - HVAC system size and efficiency
  - Daylight
  - Free cooling potential

Residential buildings

- **May or may not be air-conditioned**
- Broader band of expected comfort
- Air conditioning intermittently during the day and used mainly in summer
- Heat loads in the building dominated by external loads i.e., those from the building envelope

Charrette goals

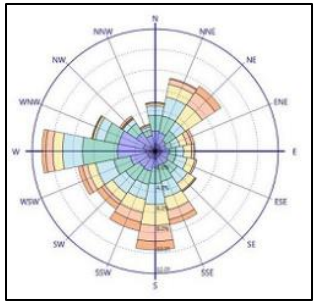
- Reduction in peak summer internal operative temperature, in comparison to the base design
- Minimizing the discomfort degree hours (DDH), mainly in summer, when assessed as per the IMAC (NV) or IMAC (MM) comfort bands
- Additional parameters evaluated for specific problem identification or problem solving:
  - Heat gains from different building components or building envelope as a whole (RETV)
  - Cooling energy if the assessed space is air conditioned
  - Natural ventilation potential

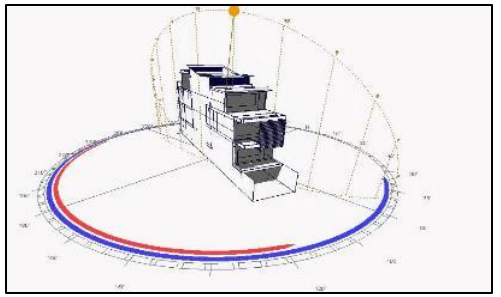
Source: BEEP Design Charrette Manual

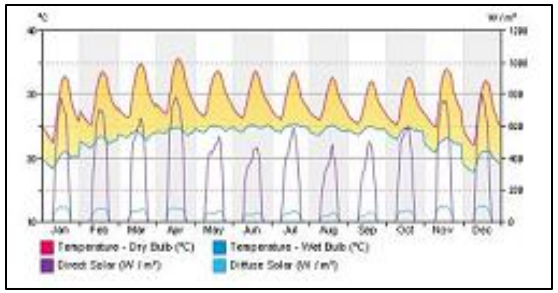
STRATEGIES AND ANALYSIS TOOLS

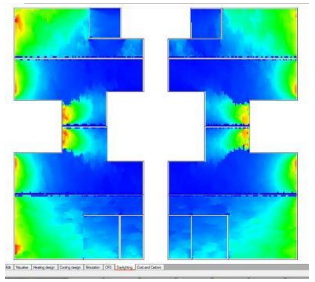
To reduce operational energy

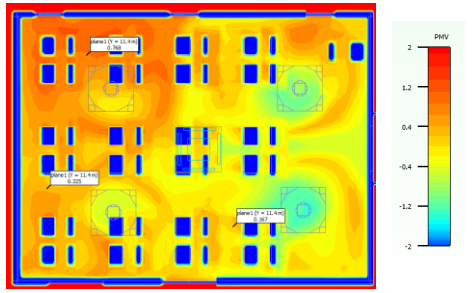
- **Weather data (.epw files, etc.)**
- **Climate analysis tool (ClimateConsultant, Rhino + grasshopper, etc.)**
- **Sun-path and solar radiation analysis (Rhino + grasshopper, etc.)**
- **Thermal comfort and energy simulation tool (EnergyPlus, DesignBuilder, etc.)**
- **Daylight simulation tool (Radiance, DesignBuilder, etc.)**
- **Natural ventilation potential**

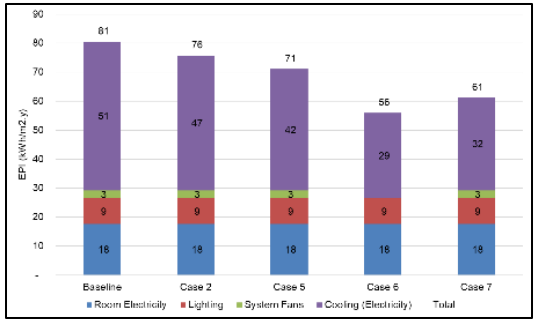


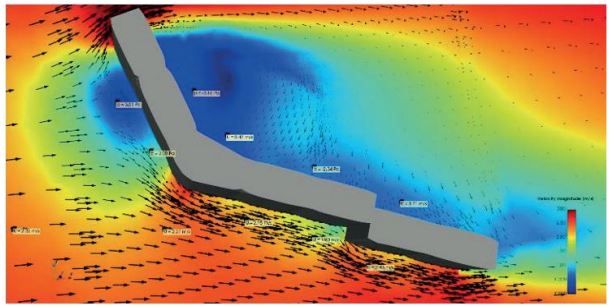












DESIGNERS' ROLE

Elements to be addressed

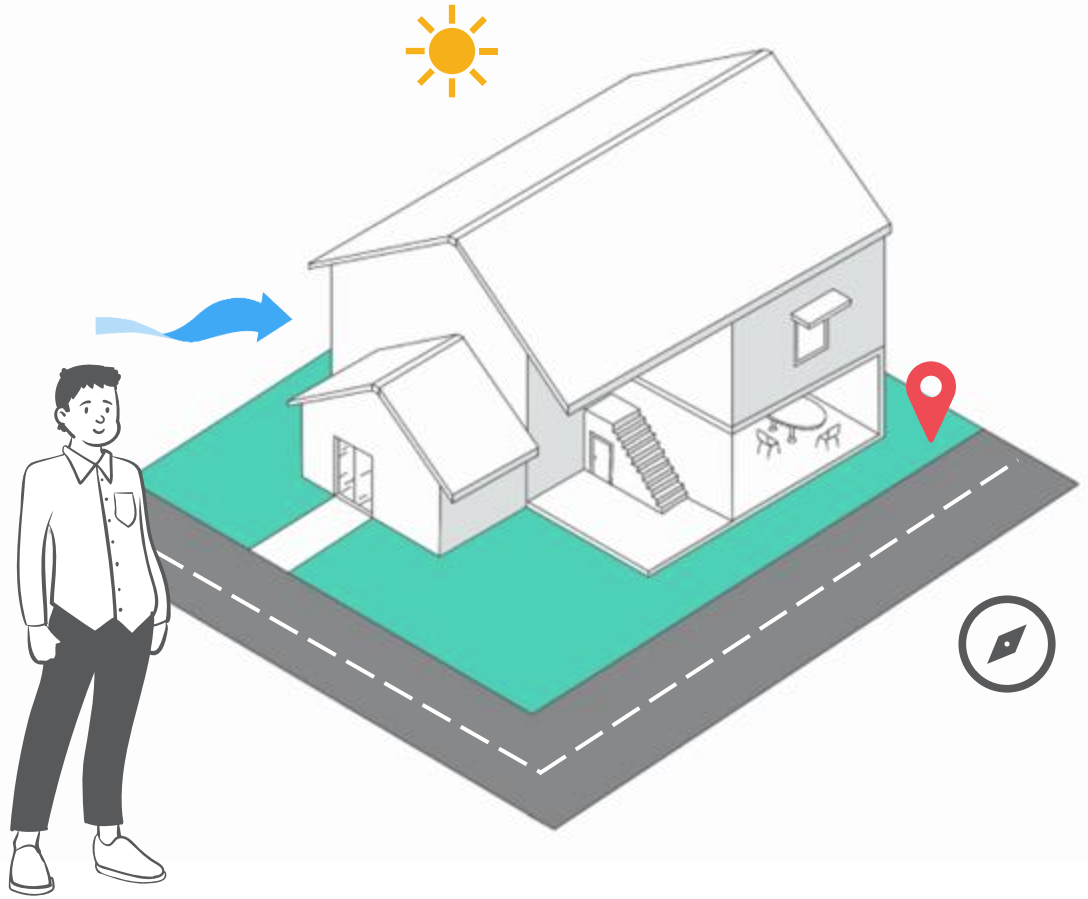
An architect's primary function is to

'create an environment'

This environment has both **psychological and physiological** effects on the occupants

The environment impacts

- **Human productivity**
- **Visual comfort**
- **Thermal comfort**



- Site location
- Building orientation and geometry
- Building envelope
- Arrangement of space
- Local climatic characteristics

Building Energy Simulation

Tool for Whole Building Analysis



Image source: https://www.azobuild.com/article.aspx?ArticleID=8520

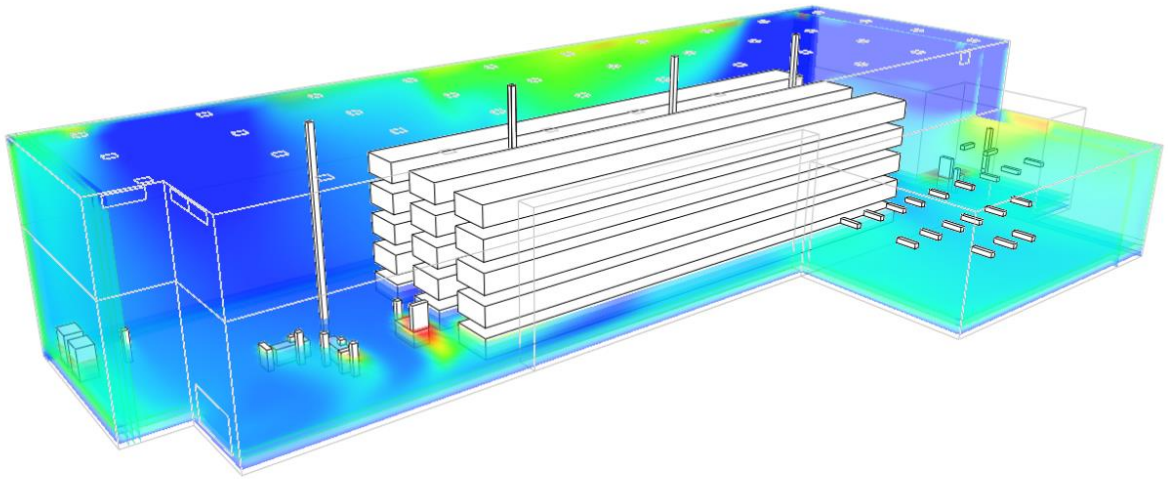
BUILDING PERFORMANCE SIMULATION

Understanding fundamentals

Simulation: An **approximate imitation** of the operation of a **process or system**; that represents its operation over time

Computer simulation: To **model a real-life or hypothetical situation on a computer** so that it can be **virtually** studied to see how the system works with **change in variables**

Building performance simulation: The replication of aspects of building performance using a **computer-based mathematical model** created on the basis of **fundamental physical principles** and **sound engineering practice**. The objective of building performance simulation is the quantification of aspects of **building performance** that are relevant to the design, construction, operation and control of buildings



Sources: https://en.wikipedia.org/wiki/Simulation; https://en.wikipedia.org/wiki/Building_performance_simulation
Image source: https://baumann-us.com/services/building-performance-simulations/

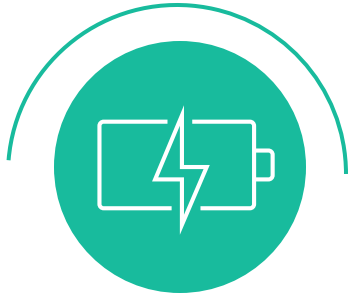
BUILDING PERFORMANCE SIMULATION

Why is it needed?

To arrive at the **best possible** building design solution by **quantitative evaluation** of various design options

To estimate **energy performance:**

Energy consumption by different end uses such as lighting, air conditioning, etc.





To estimate the **thermal comfort** inside the building

To understand the **impact of climate** on energy performance





To identify **key areas** that has more **potential**

To **quantify** energy saving and improvement in thermal comfort through different energy conservation measures (ECMs); helping in **decision-making**





To **save time** (manual calculations are complex and require more time)

BUILDING SIMULATION SOFTWARE

Selecting the right package

List of software packages

- **Energy Plus** (graphical user interface e.g., Design Builder, Sefaira, Simergy)
- DOE 2.2 based (e.g., eQUEST, VisualDOE)
- ApacheSim based IES
- TRNSYS
- IDA Indoor Climate and Energy (IDA ICE)
- ESP-r
- TRACE700
- HAP

Selecting a software

- Must be a validated or approved software
- Modeling capability
  - HVAC
  - Advanced components
  - Natural ventilation
  - Adiabatic, evaporative cooling
  - Parametric analysis
  - Possibility to add specific capability?
    - Source code well described? Accessible?
    - Co-simulation capabilities?
- Technical support, user forum, tutorials, etc.

Source: https://www.ibpsa.us/best-directory-list/
_https://climate.onebuilding.org/papers/2005_07_Crawley_Hand_Kummert_Griffith_contrasting_the_capabilities_of_building_energy_performance_simulation_programs_v1.0.pdf

BUILDING SIMULATION SOFTWARE

Proceeding with the simulation

Early design stage

- Simulate a small portion of the building in detail

  E.g., typical floor of an office building, typical spaces of an apartment building

- Simulate specific parts or features of the building

  E.g., consider a specific model for down-draft evaporative cooling, CFD

- Simulate the whole building in less detail

  Look at global orientations, façades, solar gains

What to check?

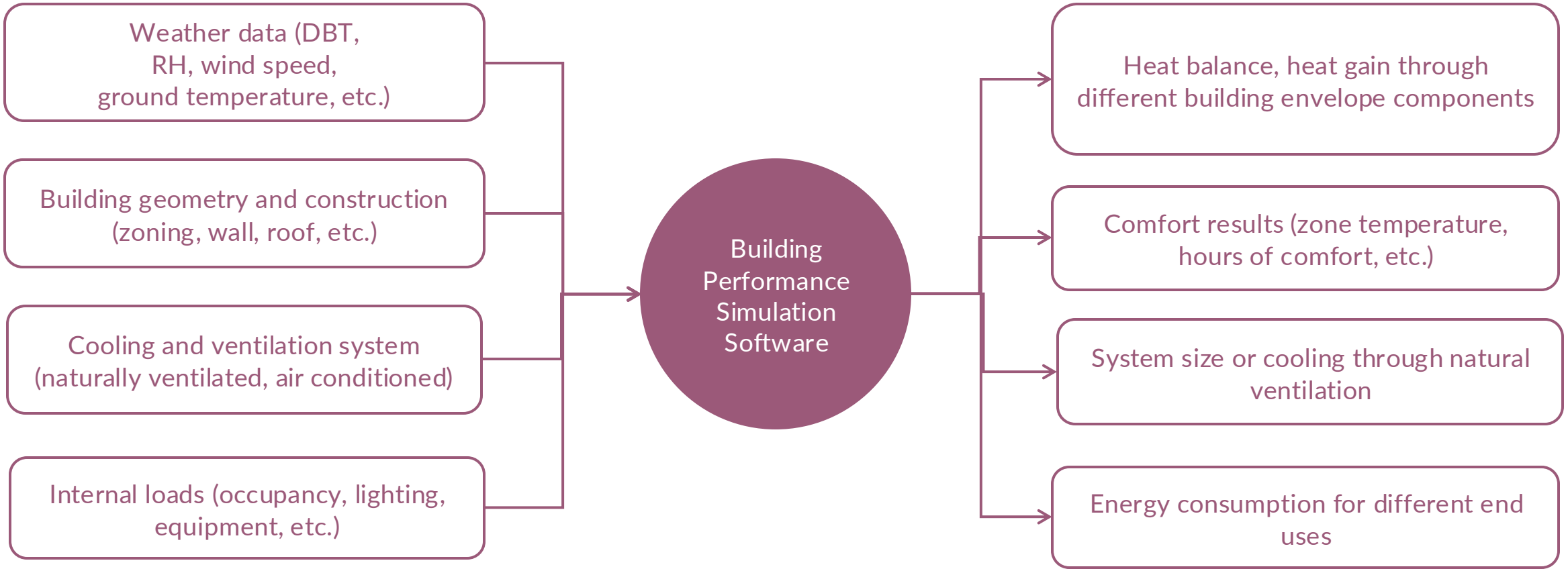
- Feasibility of different options
- Extreme conditions
- Focus on extreme conditions to check feasibility of different option
- Quick check of energy performance for comparison

Later stages

- Provide a more detailed focus on energy performance and more complete modeling for the zones

BUILDING SIMULATION SOFTWARE

Inputs and outputs



BUILDING SIMULATION SOFTWARE

Essential skills required

User

- Knowledge and understanding of the building physics, HVAC
- Good technical common sense:
  - Ability to relate results to physical understanding, memory of previous situations
  - Ability to analyze results and question them
- Ability to make quick parallel calculations
  - Simple back of the envelope
  - Equation-based models
- Representation of results data for coherent checking
- Ability to identify important parameters upfront
  - Define relevant parametric studies
- Willingness to discuss inputs and results with others
- Needs patience

Guidelines and Tips

- Weather data:
  - Be careful with synthetic data
  - When using weather data for the first time for a location, plot the data to be sure that they are consistent
- Check for non-library materials, components and systems
- Check for extreme conditions, then conduct an annual run:
  - Identify hottest, most humid and coldest weeks
  - Prepare outputs to compare the results of different runs on these weeks on the same plot (post treatment may be needed)
- Check the hourly results:
  - Check if set-points are met
  - Check if strategies play out as expected e.g., sequence of natural ventilation, evaporative cooling and active cooling
  - Check if movable blinds are operated

Daylight Simulation

Tools for Visual Comfort

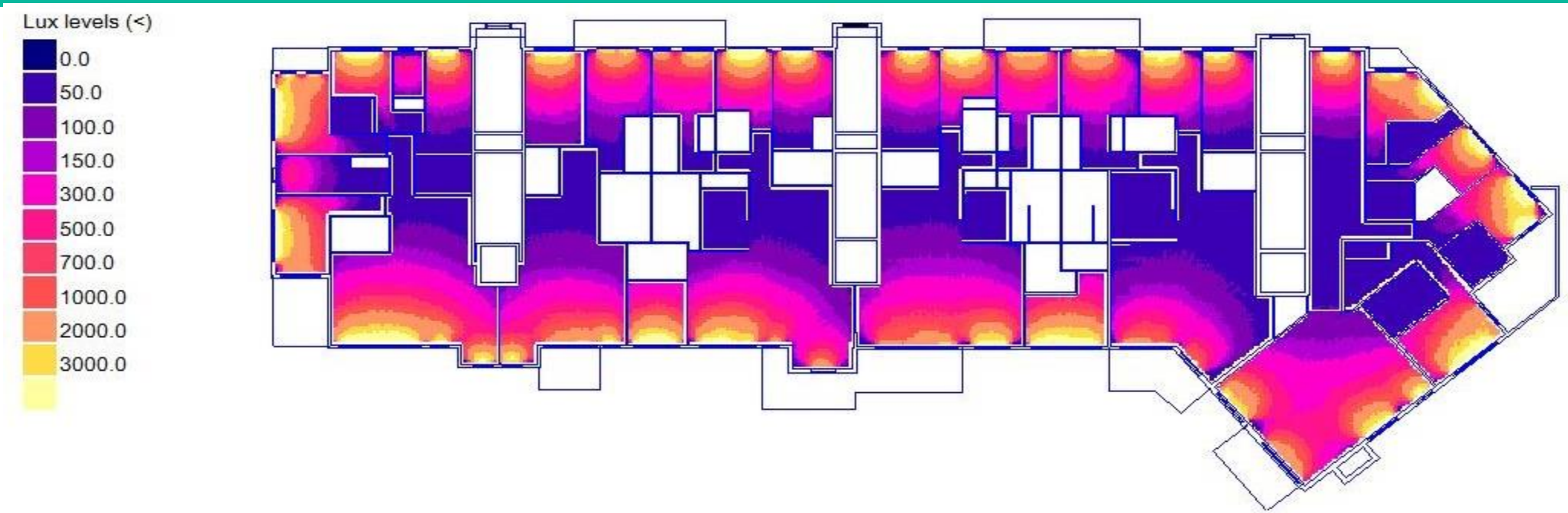


Image source: https://egreenideas.com/green-ideas-daylight-modeling-services/

DAYLIGHT SIMULATION

Understanding objectives

- Daylight analysis and simulation are processes that help determine the amount and quality of natural light in a building, and how it affects the occupants and energy consumption
- It involves simulating light behavior, using physical models or digital tools to predict light distribution, intensity and impact on interior spaces
- Helps to understand how building form interacts with light availability at different times of day and seasons. It can help reduce the need for artificial lights, which can lower energy costs and emissions
- These processes are often used in the early stages of the design process to optimize designs and meet sustainability goals

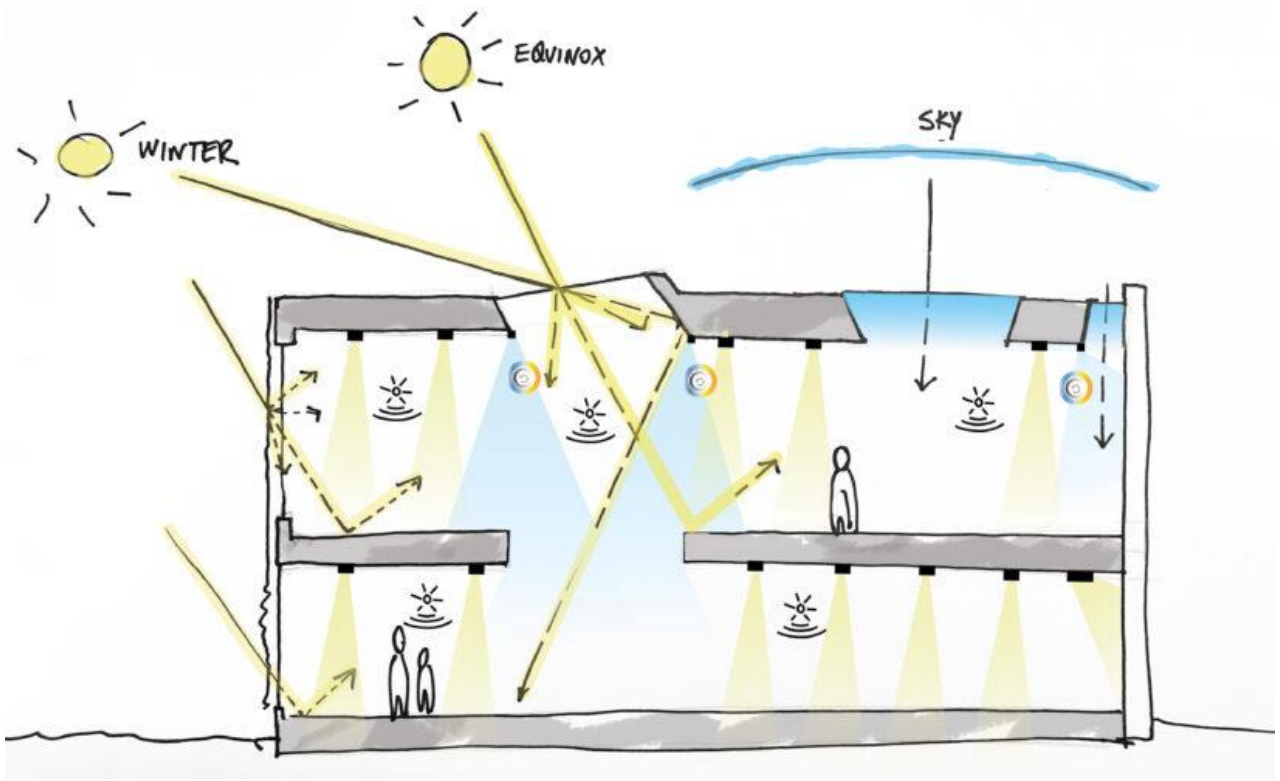


Image source: https://whitearkitekter.com/news/daylight-simulation-tools-and-their-integration-in-the-design-workflow/

DAYLIGHT ANALYSIS

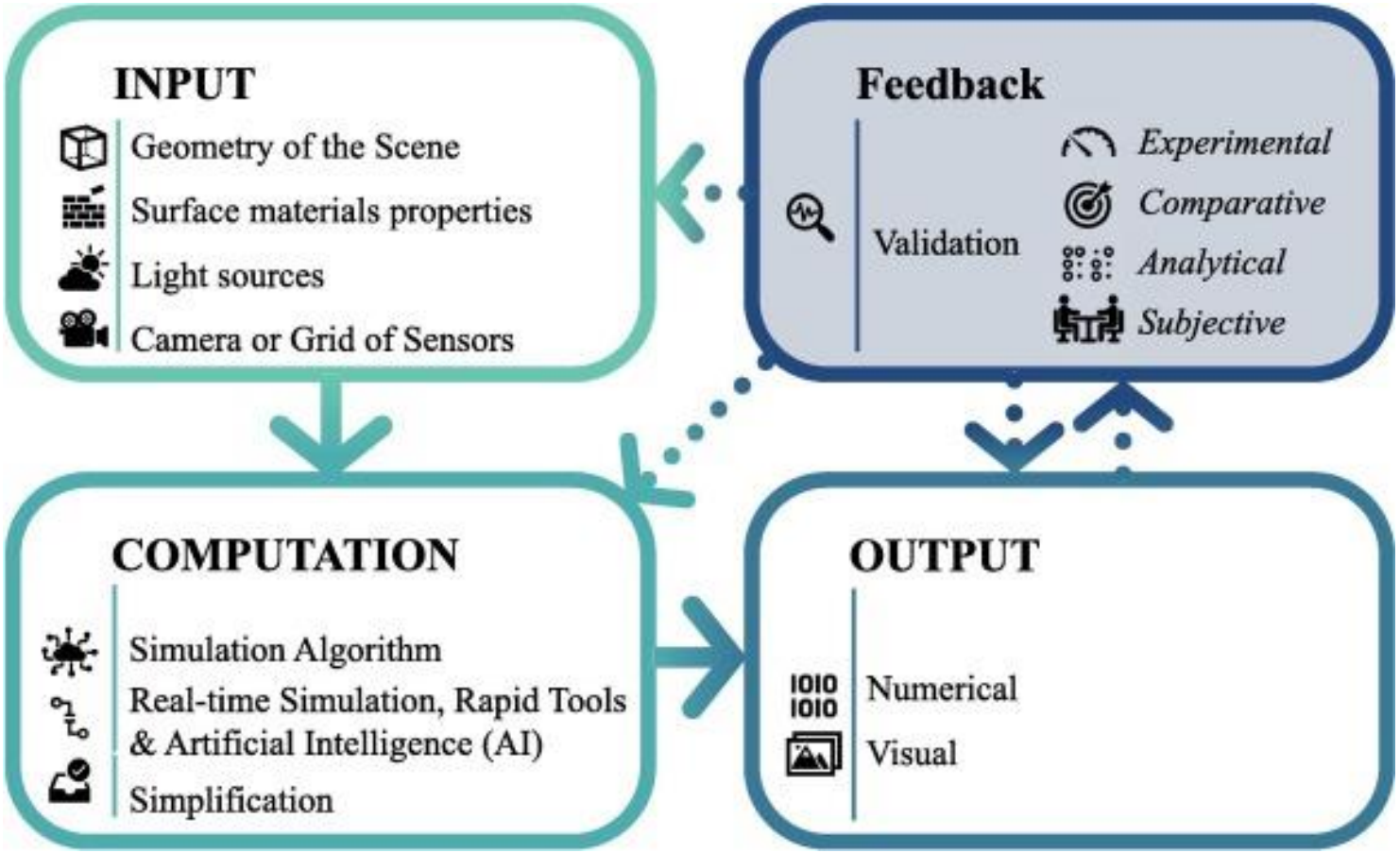
Inputs required

Input parameters for simulation:

- Building geometry
- Surface material properties (color, texture, reflectance)
- Light source (location, sky model)
- Sensors grid location and size

Software used in the simulation:

- Radiance
- LightStanza
- Ladybug Tools (Honeybee)
- Daysim
- Open Studio
- VELUX Daylight Visualizer
- IESve, etc.



DAYLIGHT ANALYSIS

Metrics

Illuminance (Lux)

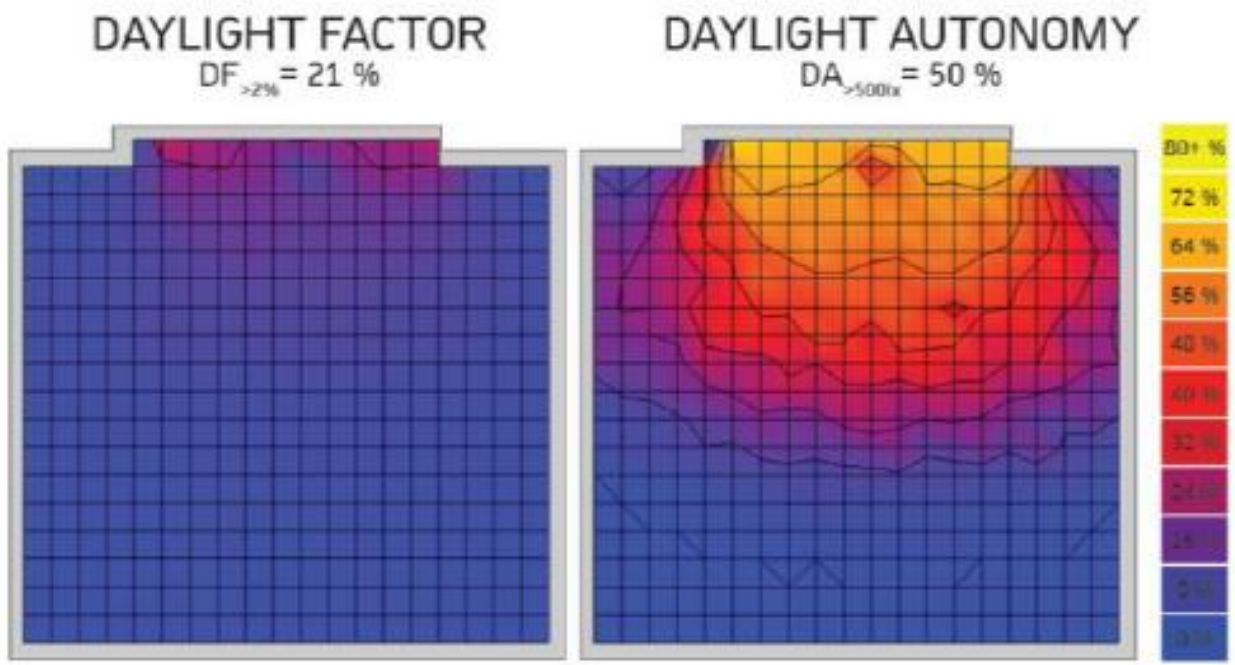
The amount of light that falls on a surface per unit area. Daylight illuminance levels <100 lux are generally insufficient for most tasks

Daylight Factor (DF)

The ratio of indoor illuminance to available outdoor illuminance under overcast sky conditions indicates daylight availability

Daylight Autonomy (DA)

The percentage of time that a building or space's daylight levels are above a specified illuminance level



DAYLIGHT ANALYSIS

Metrics

Annual Sunlight Exposure (ASE)

Measures areas that receive excessive direct sunlight over a year, useful for glare and overheating analysis

Spatial Daylight Autonomy (sDA)

The percentage of an area that receives sufficient daylight (usually 300 lux) for a specific period, measuring daylight sufficiency

Useful Daylight Illuminance (UDI)

The percentage of annual occupied hours that falls within predefined lower and higher illuminance limits (100 to 3000 lux)

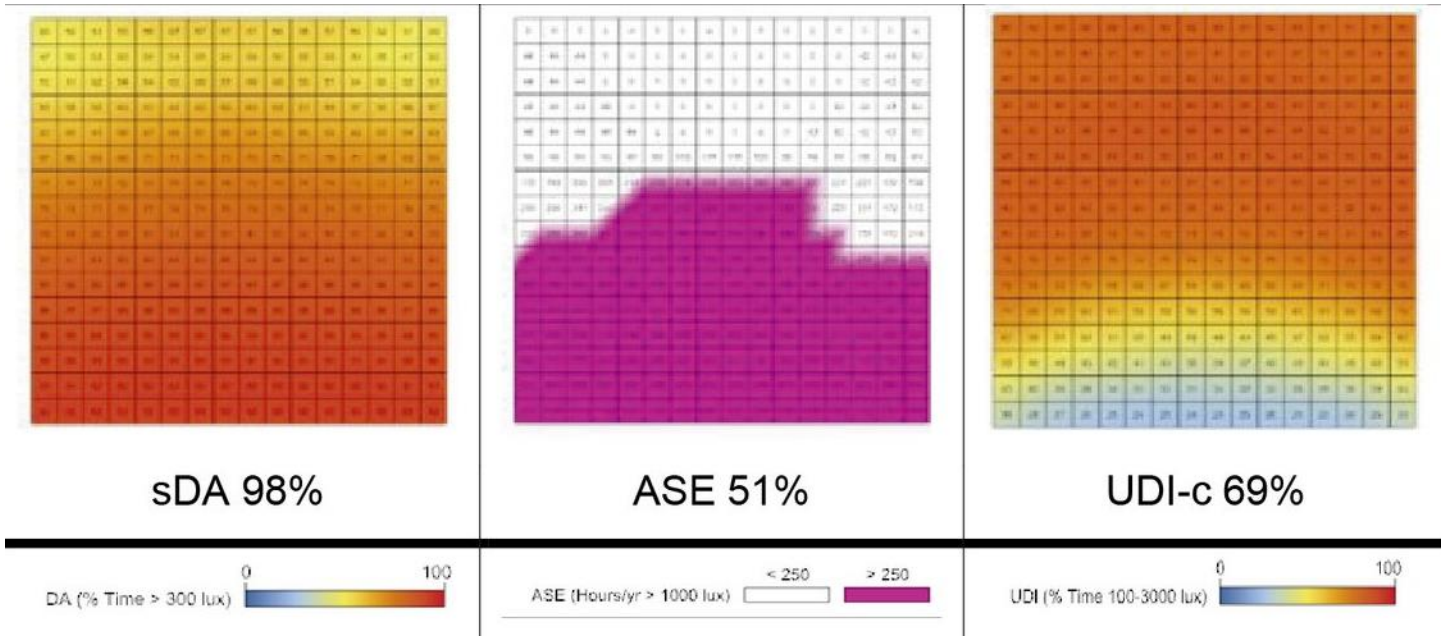


Image source: https://solarlits.com/jd/7-107

DAYLIGHT ANALYSIS

Metrics

Glare Metrics (DGP)

- Daylight glare probability (DGP) is a metric that predicts the likelihood of an observer experiencing discomfort glare at a given orientation and view position
- DGP is typically calculated using a fisheye rendering with an opening angle of 180 degrees. The values for DGP range from 0% to 100% and are divided into four bands:

DGP	
< 0.34	Imperceptible
0.34 – 0.38	Perceptible
0.38 – 0.45	Disturbing
> 0.45	Intolerable

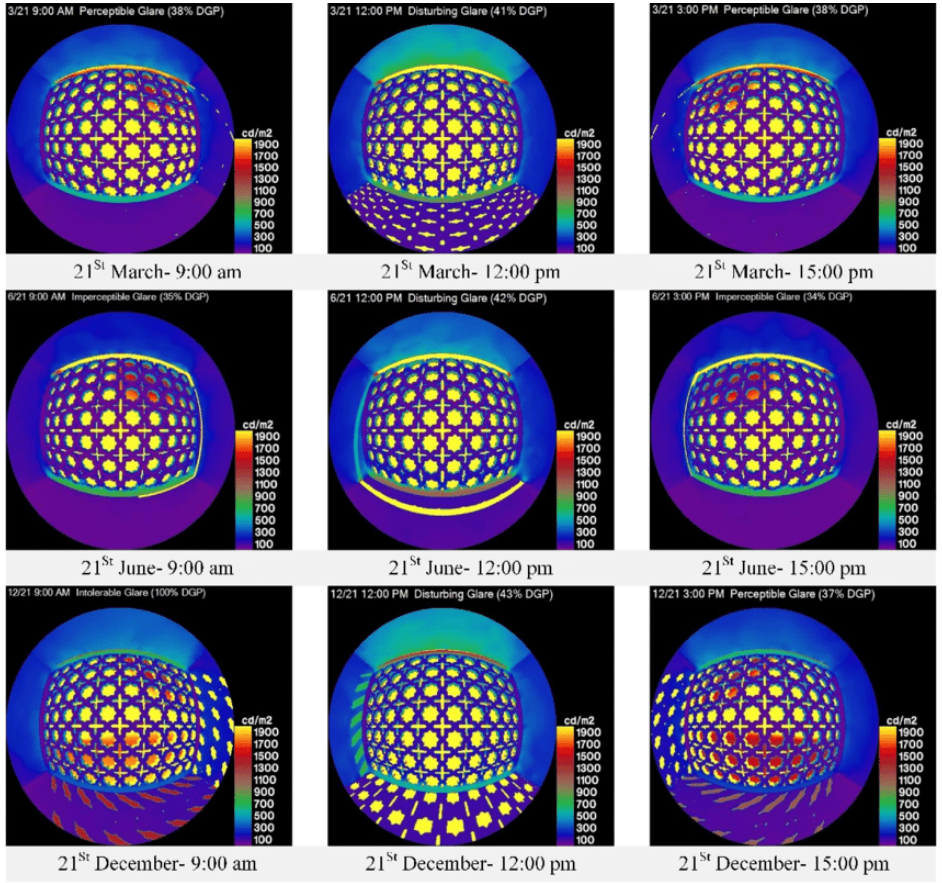


Image source: https://www.researchgate.net/figure/Daylight-Glare-Probability-DGP-in-three-different-days-of-8-Point-Star-for-south-facade_fig8_345505966

CFD Simulation

Tools for Ventilation Potential

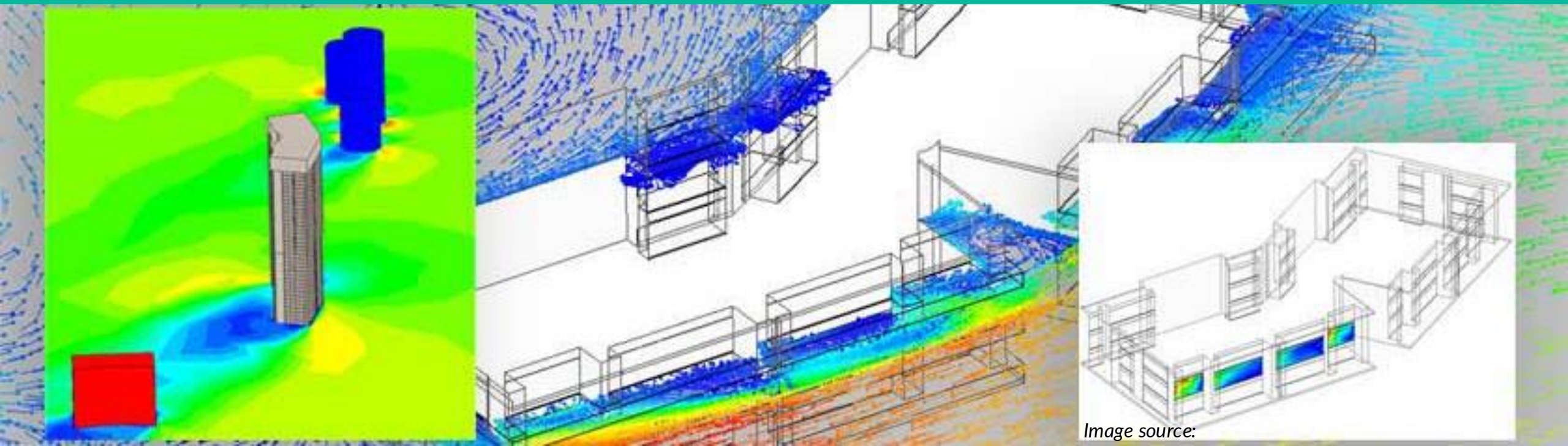
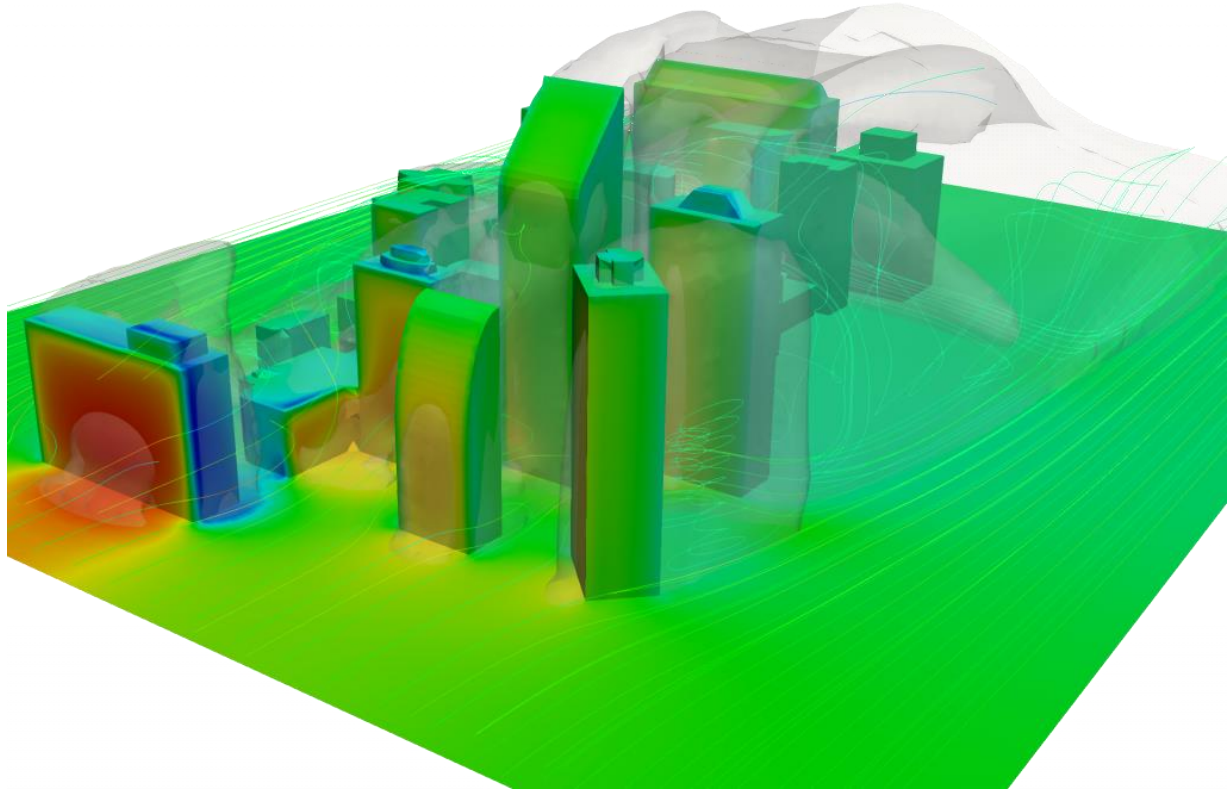


Image source:

CFD SIMULATION

Utility of computational fluid dynamics (CFD)

- CFD is used to **visualize and quantify** velocity and pressure profiles in and around buildings
- The effect of both **mechanical and wind-driven** natural ventilation can be accessed
- It is seen as an **early design** decision tool
- Useful for architects, engineers, town/city planners and consultants



Quick decision-making to optimize building design with better **wind-driven ventilation**

Image source: https://www.idealsimulations.com/applications/architecture/

CFD SIMULATION SOFTWARE

Software packages and considerations for simulation

List of software packages

- **Energy Plus** (graphical user interface e.g., Design Builder, Sefaira, Simergy)
- TRNSYS
- Vayu Pravah (an OpenFOAM software)
- MicroFlo-CFD
- SimFlow
- Ansys Fluids

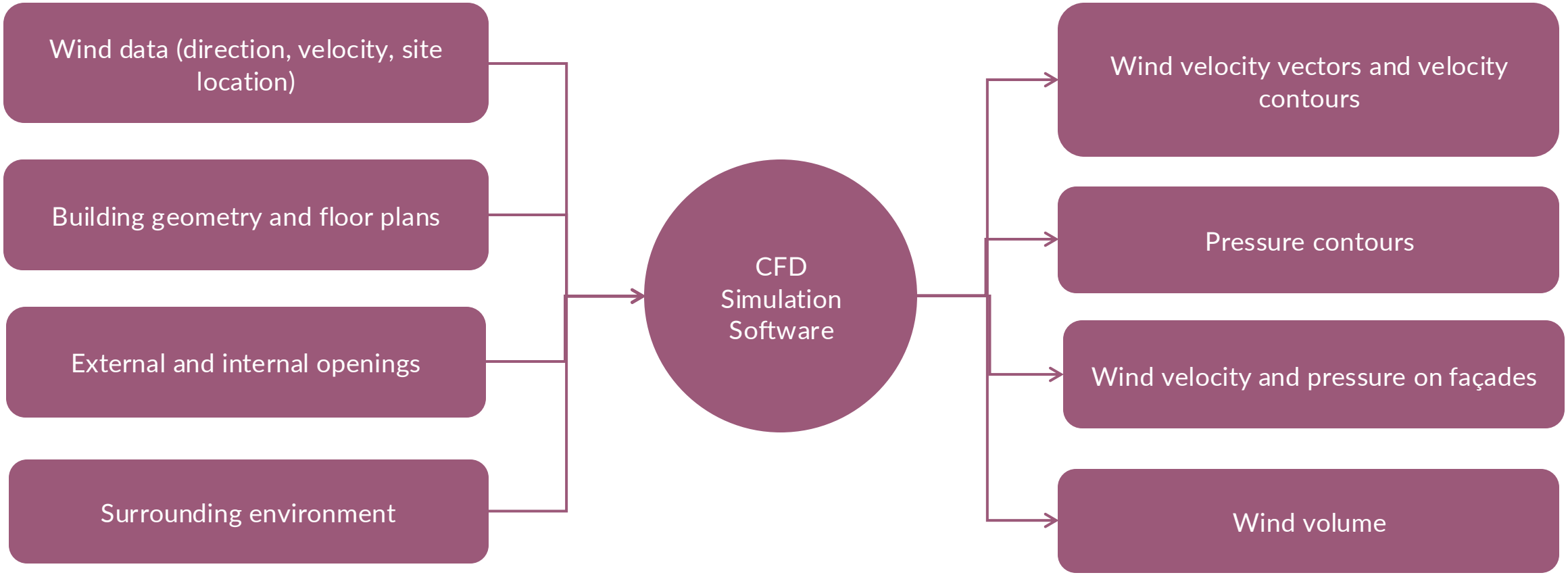
Simulation and other considerations

- Simulate at neighborhood level
  - Identify the target and surrounding buildings for the analysis (cover up to 3H radius)
- Simulate at building
  - Refer to Google Earth for site details
- Consider ground slope of each block
- Set surrounding environment
- The predominant wind direction with magnitude
- The reference wind height of magnitude
- Optional custom wind profile

Source: https://www.ibpsa.us/best-directory-list/
_https://climate.onebuilding.org/papers/2005_07_Crawley_Hand_Kummert_Griffith_contrasting_the_capabilities_of_building_energy_performance_simulation_programs_v1.0.pdf

CFD SIMULATION SOFTWARE

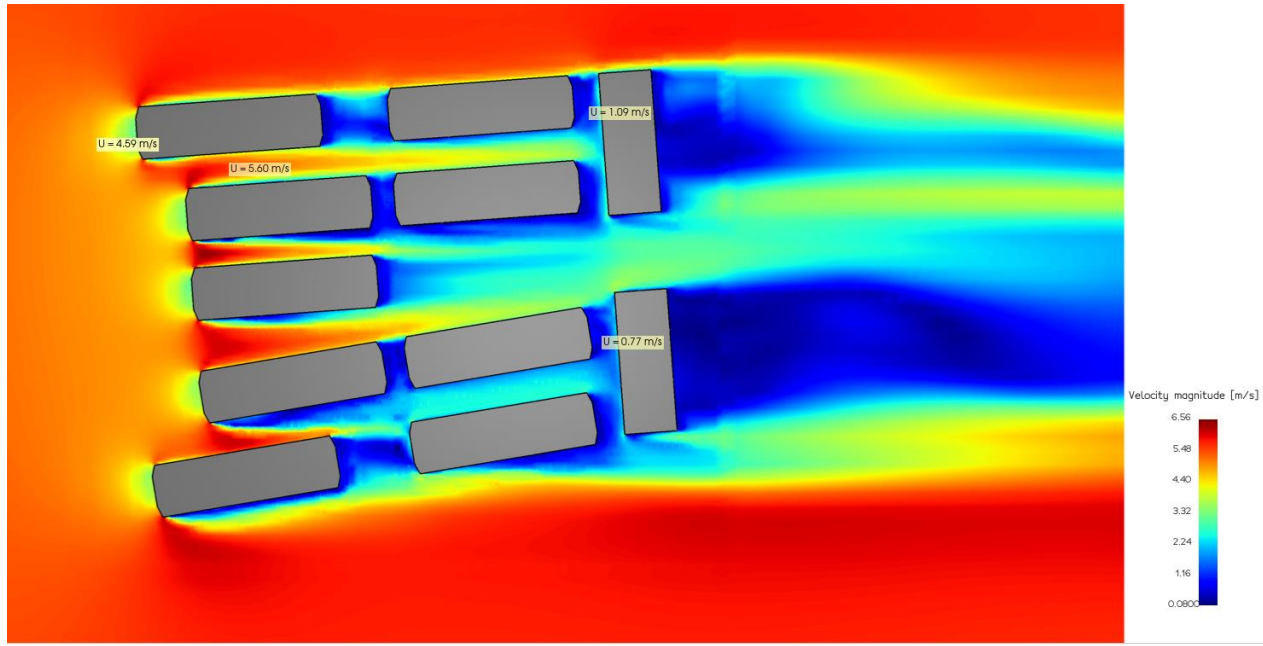
Inputs and outputs



CFD SIMULATION SOFTWARE

Using the results

- Identification of **strong and weak spots** for utilizing natural ventilation potential
- **Variation** of wind potential from bottom ground floor to top floor
- Data representation using various techniques for better explanation of results
- Identification of **strong spots** for assisted mechanical ventilation
- Ideas for **design alteration** to improve wind-driven ventilation



Representation of wind movement around multiple buildings

Case Example

Aranya Bhawan, Jaipur, India

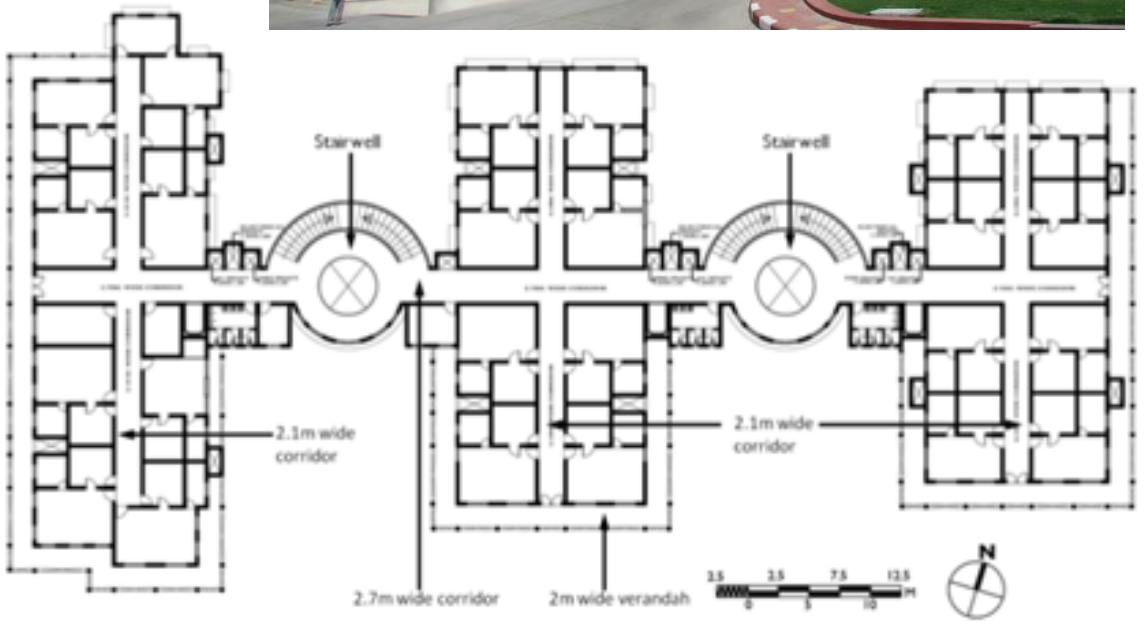


ARANYA BHAWAN

Case example: Government office building

- **Client:** Rajasthan Forest Department
- **Executing Agency:** Rajasthan State Road Development and Construction Corporation Ltd. (RSRDC)
- **Architects:** Mathur, Ugam and Associates
- **Built-up area:** ~10,000m^2 (excluding basement parking and service area)
- **Number of floors:** 5 (Ground + 4 floors) + one basement level for parking and services
- **Number of users:** ~350
- **Types of spaces:** Offices, auditorium, guest rooms, museum and library





ARANYA BHAWAN

Project timeline

December 2012
- Design Charrette

2013–2015
- Construction
- Technical Support by BEEP

March 2015
- Inauguration

2015–2016
- Energy Monitoring









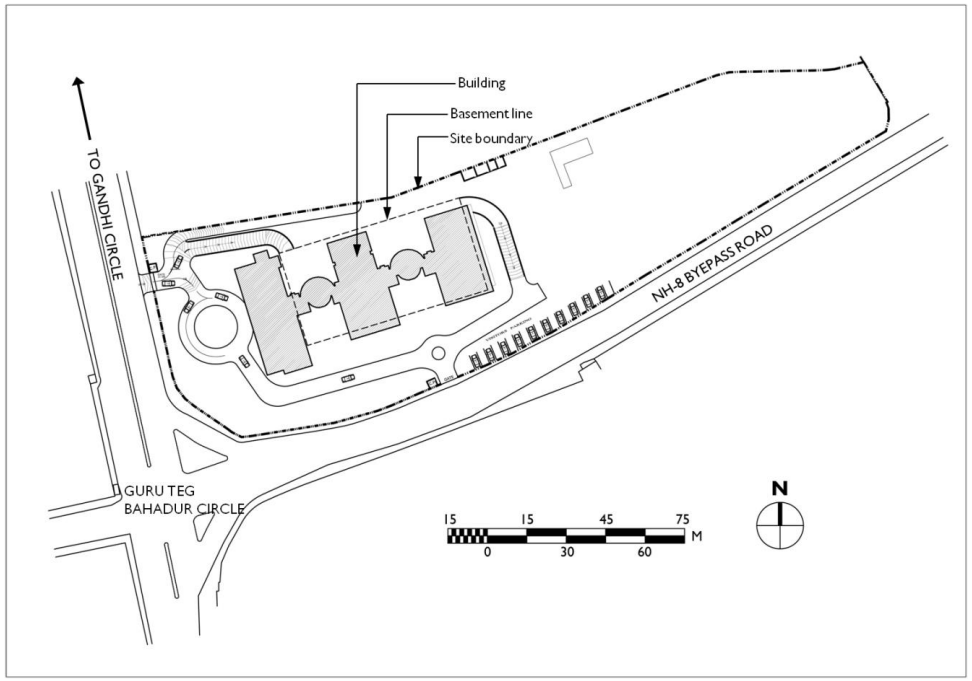


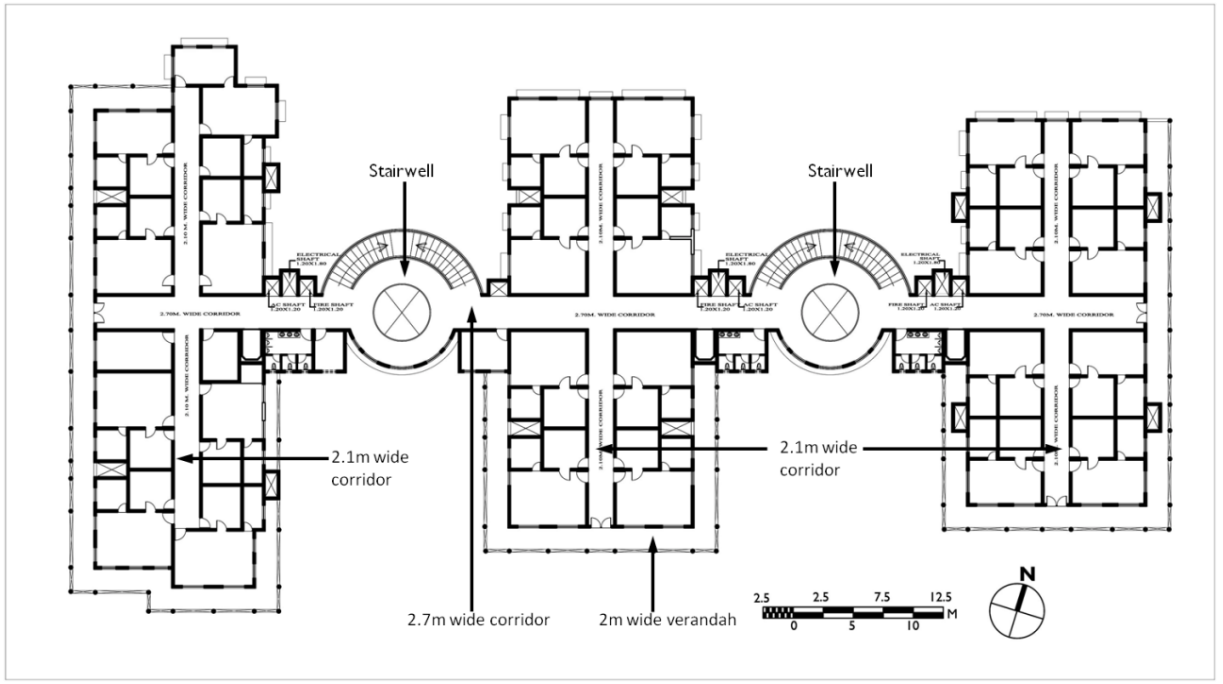


ARANYA BHAWAN

Original building design

Approved architectural drawings





ARANYA BHAWAN

Original building design

Key specifications

Building envelope:

- Walls: 230mm brick wall (U-value: 2.05 W/m^2.K)
- Roof: 150mm RCC slab (U-value: 3.2 W/m^2.K)
- Glazing: Single glazing 5mm clear glass (U-value: 5.8 W/m^2.K ; SHGC: 0.8 ; VLT: 85%)
- Veranda on each floor for shading of walls and windows

LPD: ~7 W/m^2

EPD: ~10 W/m^2

HVAC system:

- Air cooled VRV system (COP: 2.75)
- Cooling system size: 230 TR (~320 ft^2/TR)

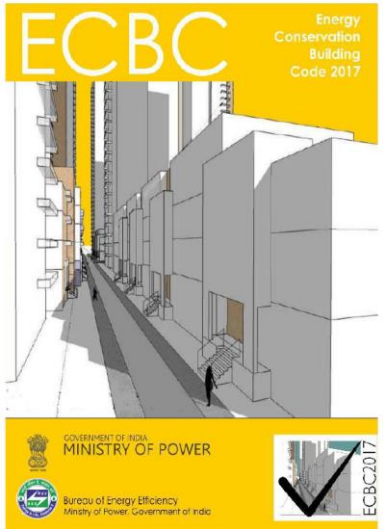
Budget: INR 300 million (~INR3,000/ft^2, including services)

Charrette goals

- Budget: Should not deviate much from the approved budget
- ECBC compliance
- Target EPI: <90 kWh/m^2.year (5-star rating as per BEE star rating for air-conditioned office buildings)

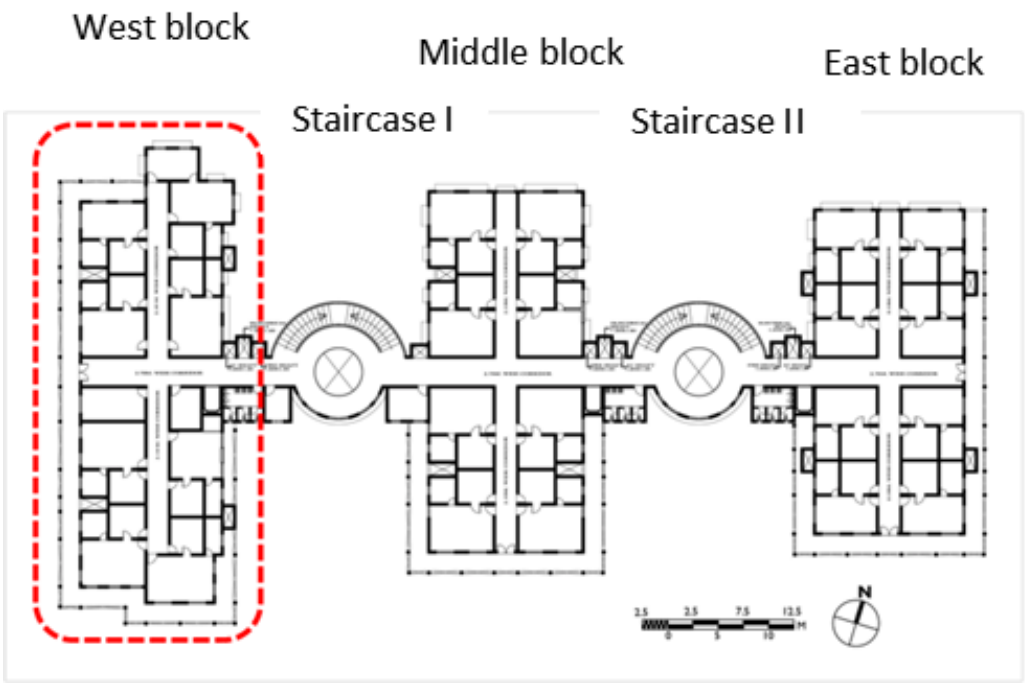
Energy Star Rating Program
(more than 50% air-conditioned built-up area)
Climatic Zone: Composite

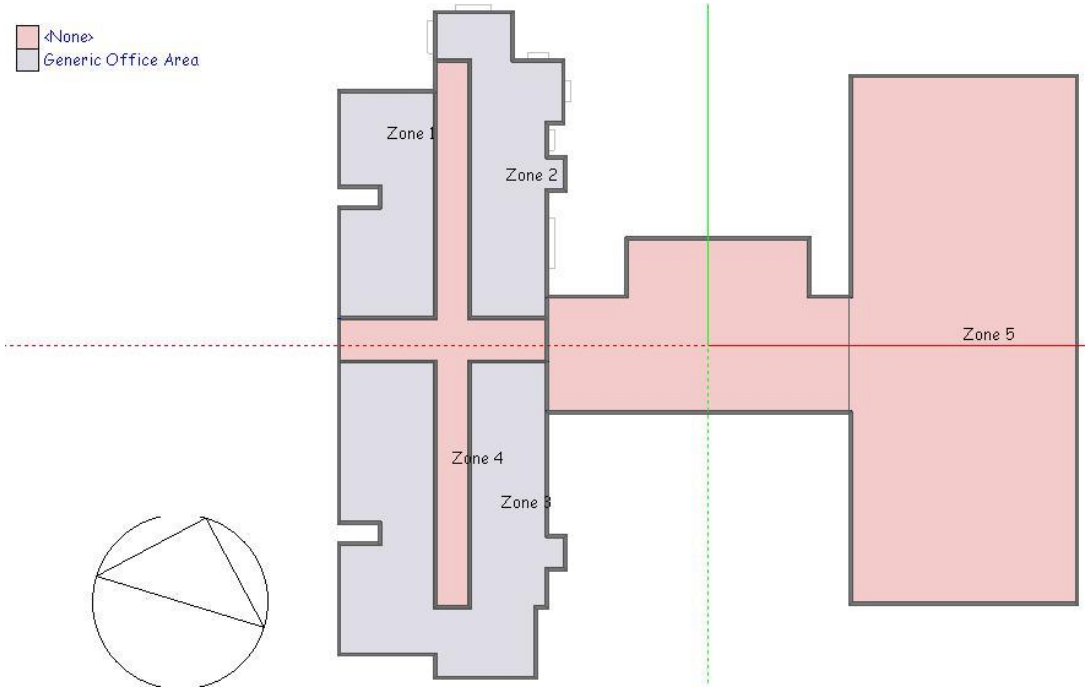
EPI(Kwh/sqm/year)	Star Label
190-165	1 Star
165-140	2 Star
140-115	3 Star
115-90	4 Star
Below 90	5 Star



ARANYA BHAWAN

Area simulated under charrette



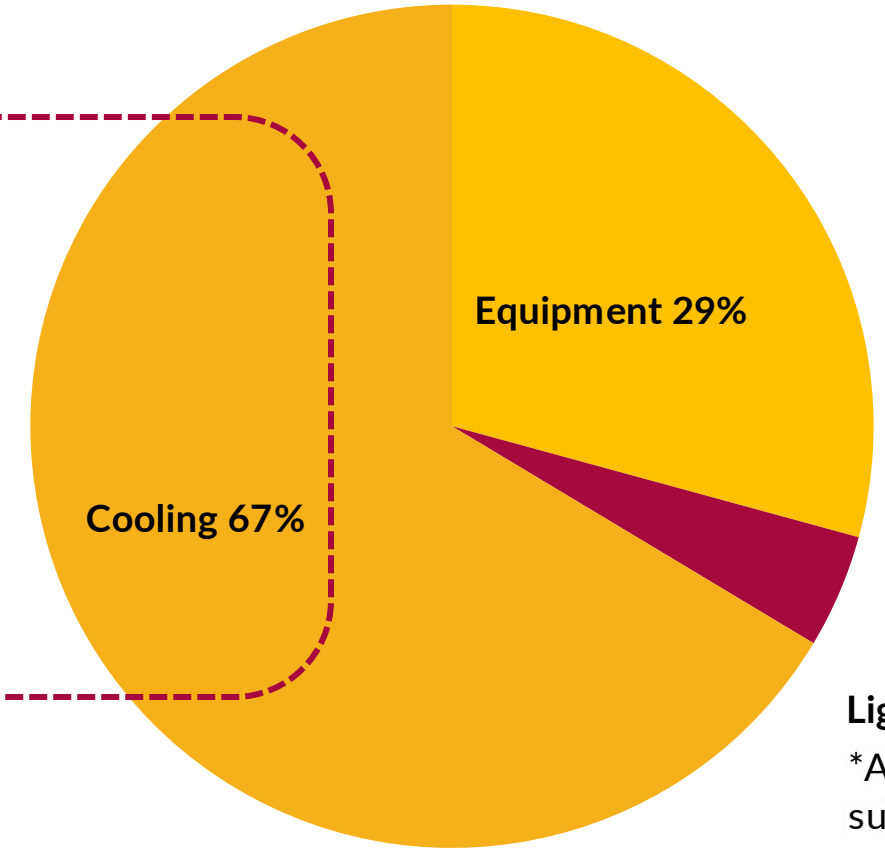


Occupancy: 25 people in one typical floor of the western block (09:30 am to 05:30 pm)

ARANYA BHAWAN

Original design: Energy demand break-up

- Reduce cooling load
  - Reduce heat ingress
- Provide cooling efficiently



EPI: 77 kWh/m^2.year

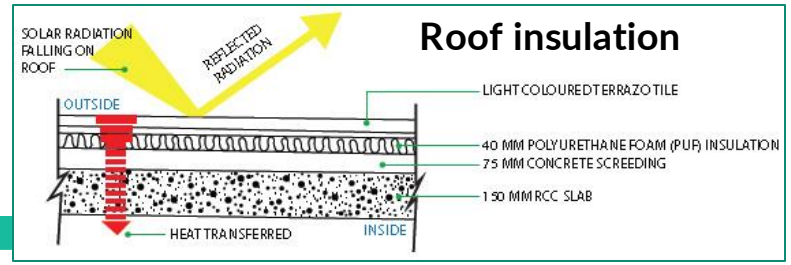
Lighting 4%

*Artificial lighting remains OFF, if daylight is sufficient

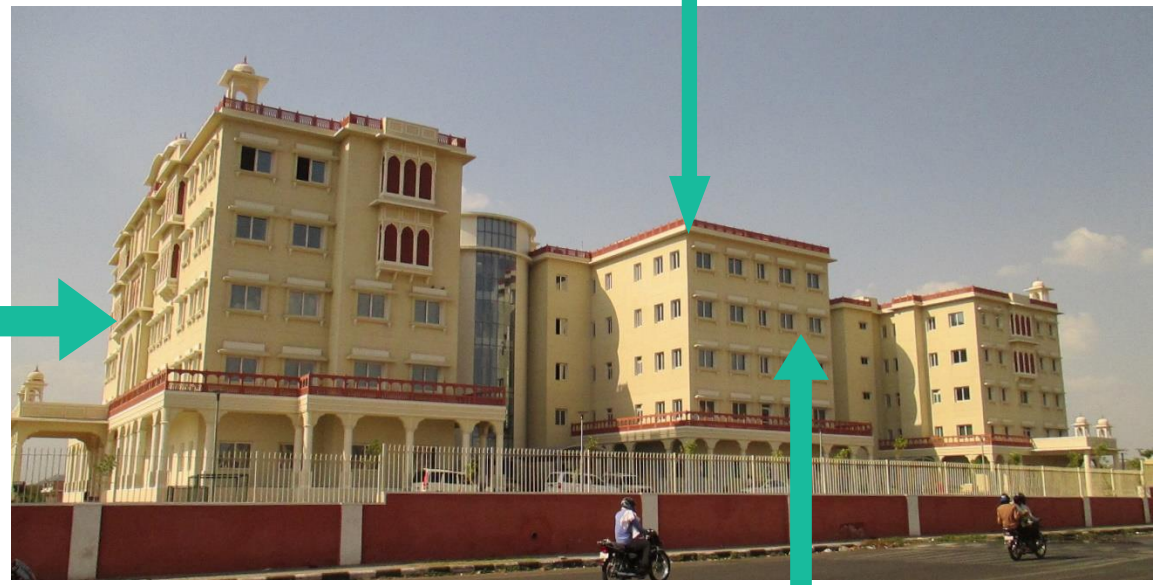
ARANYA BHAWAN

Proposed design: With passive measures

Roof U-value: 0.6 W/m^2.K

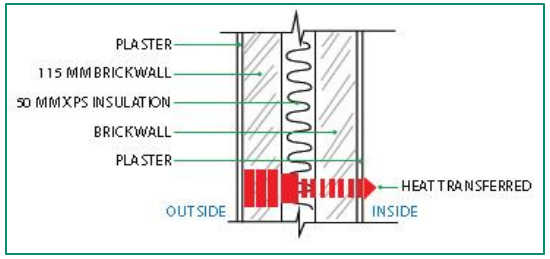






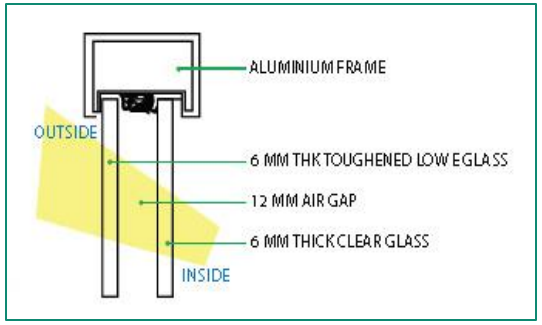
Wall U-value: 0.5 W/m^2.K

Wall insulation



Reduction in glazed area (WWR: ~20%)

Double-glazed windows



Window U-value: 1.8 W/m^2.K
SHGC: 0.24
VLT: 36%

ARANYA BHAWAN

Proposed design: Active measures and renewable energy

Energy efficient lighting

- LEDs and T5
- Lighting power density (LPD) of ~6 W/m^2

Energy efficient cooling system

- Centralized high efficiency water-cooled chiller (COP: 5.8)
- Sewage treatment plant (capacity: 15 m^3/d) to provide water for cooling towers

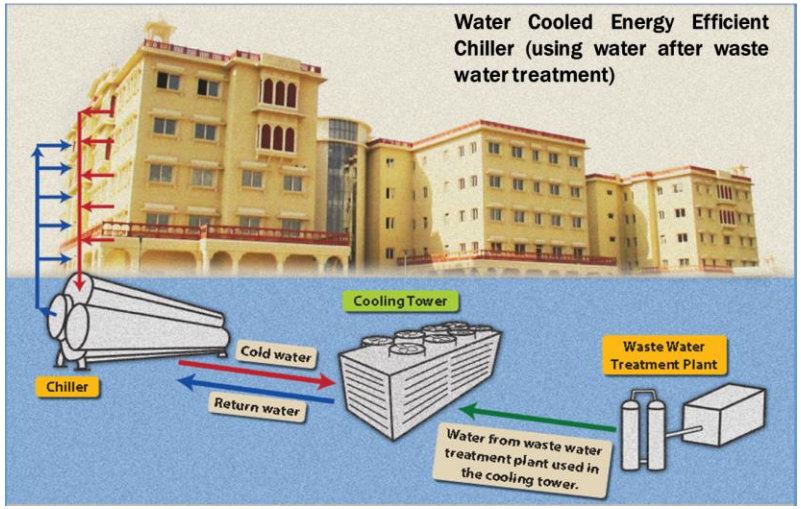
Solar photovoltaic (SPV) system

- Rooftop 45 kWp grid-connected SPV system with net-metering

Solar photovoltaic: Thumb rules

- **Area required:** ~10 m^2/kWp
- Only shadow-free area should be considered for solar photovoltaic system
- **Energy generation:** 1,400–1,600 kWh/kW per year
- **Cost:** INR40,000 per kWp (without batteries)

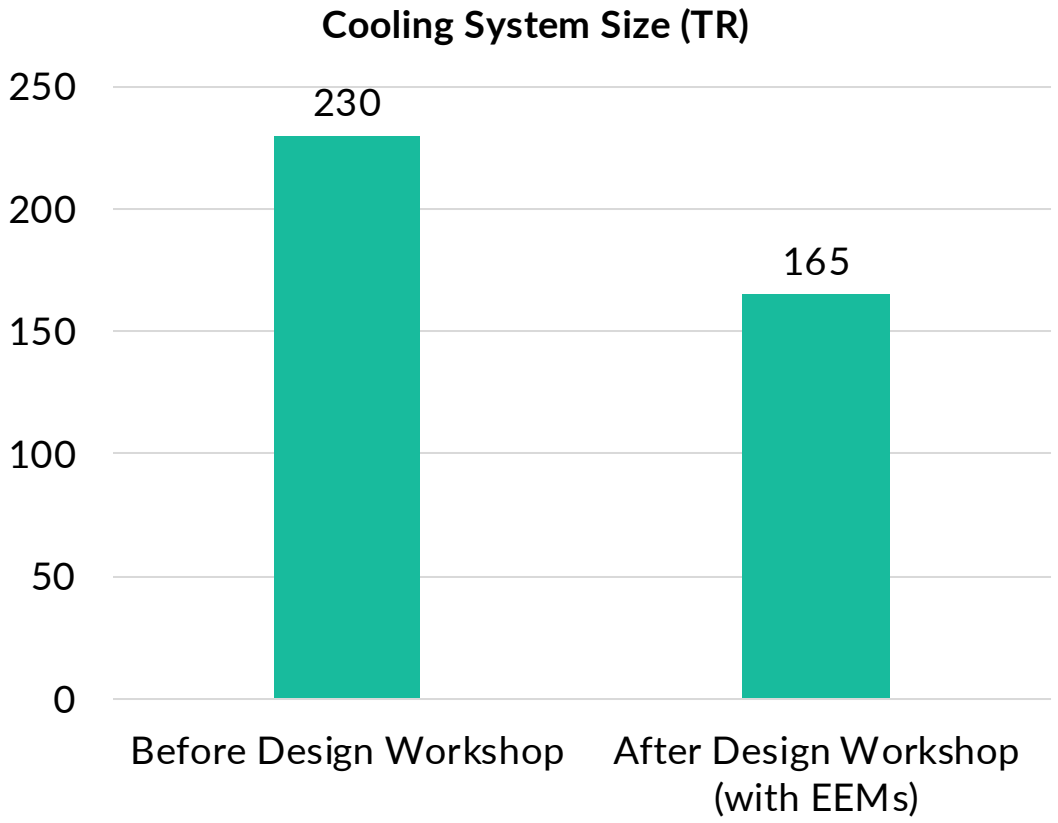




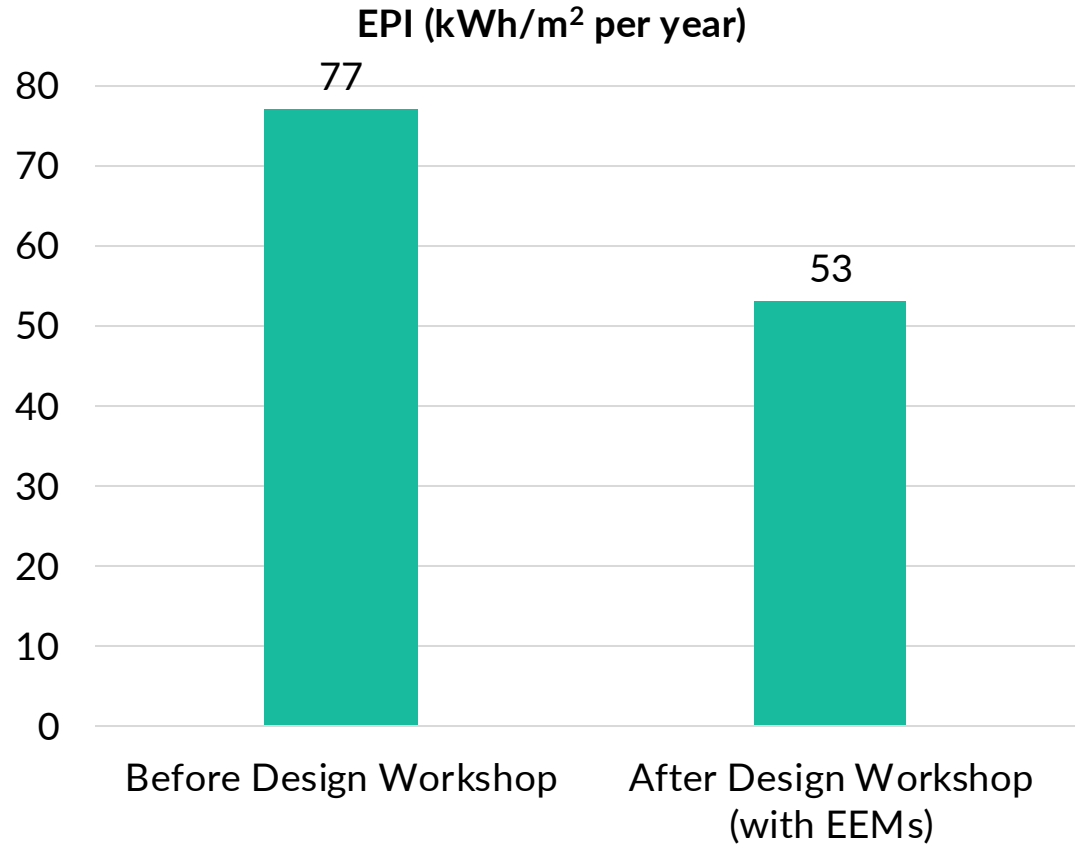


ARANYA BHAWAN

Calculated savings through simulation



28% reduction



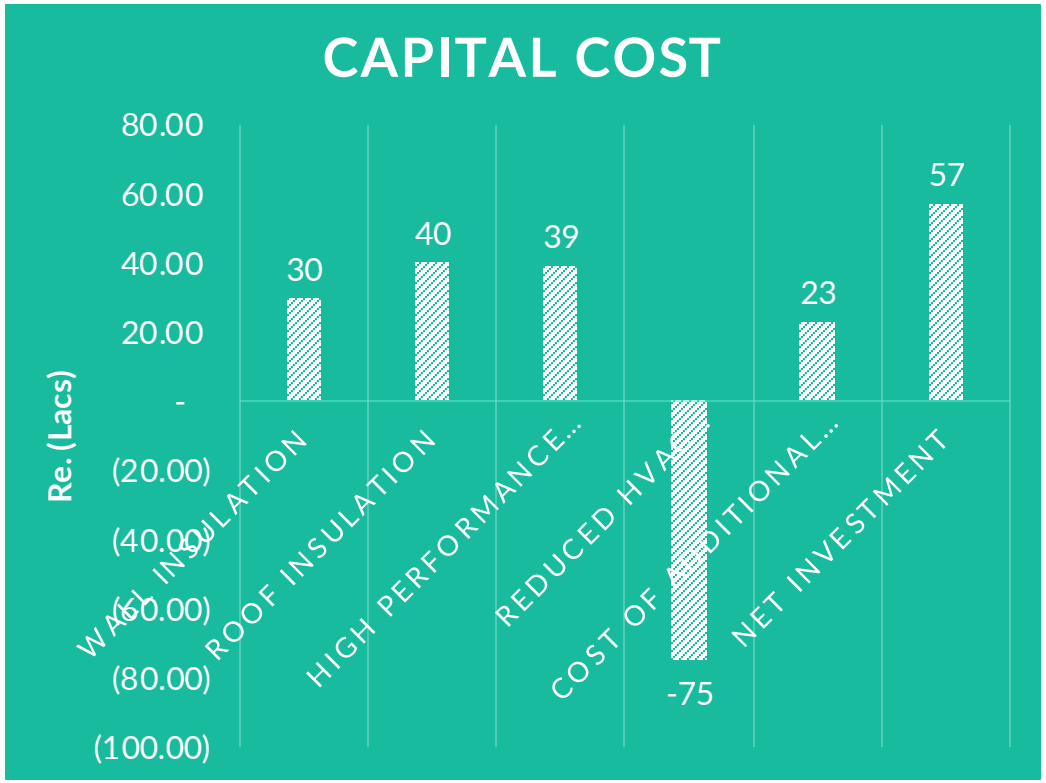
**(Solar Photovoltaic contribution not included)*

31% reduction

ARANYA BHAWAN

Cost estimates and payback calculation

- **Increase in budget**: ~INR 6 million
- **Approved budget:** INR 300 million
- **Increase in budget**: 2% (acceptable ☺)
- **Typical cost for envelope measures:**
  - Cost of adding 50mm EPS in brick cavity wall: ~INR700/m^2
  - Cost of adding 50mm PUF insulation on roof slab: ~INR900/m^2
  - Additional cost of high performance (low SHGC) glazing as compared to single clear glazing: ~INR3,000/m^2
- **Savings from operational energy:** ~INR2.0 million/year
- **Payback period:** ~3 years



Note: Additional equipment includes cost of STP and additional cost for improved lighting system

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

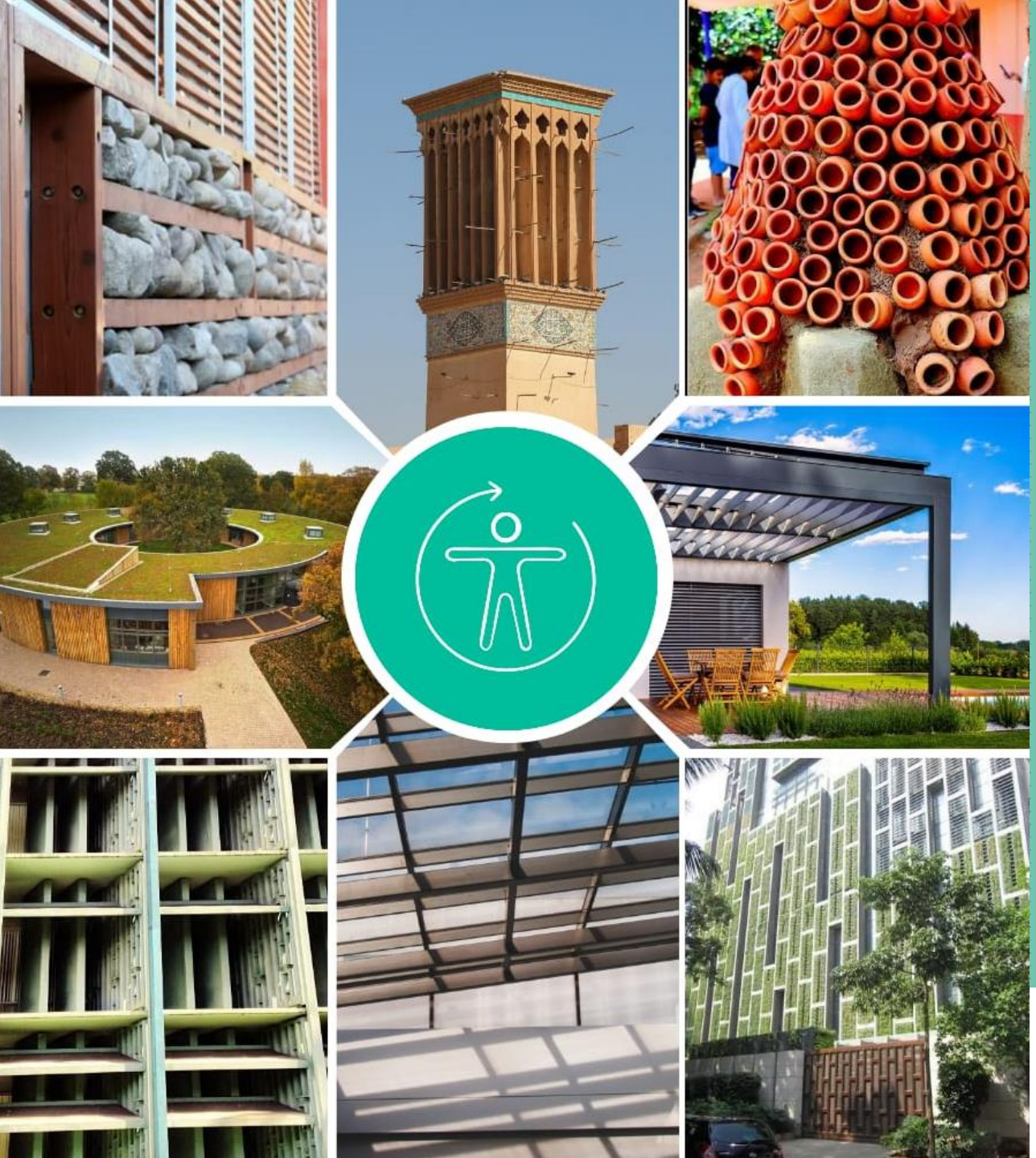
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on the basis of a decision by the German Bundestag



GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

3.1 Concept of Net Zero Carbon Buildings

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

01 Climate Change and Carbon Footprint

02 Net Zero Carbon Buildings: Concepts and Approaches

03 Global Net Zero Building Commitments

04 Net Zero Building: Case Examples



Climate Change and Carbon Footprint

Emissions and Global Warming



CLIMATE CHANGE AND CARBON

Greenhouse gases

Since the 1800s, greenhouse gases (GHGs) from human activities have been the main driver of climate change, primarily due to the burning of fossil fuels like coal, oil and gas.

Key GHGs emitted by human activities are:

- **Carbon dioxide** (CO_2): Primarily from burning fossil fuels. Also, through deforestation, land clearance for agriculture or development, degradation of soils and land management
- **Methane** (CH_4): From agricultural activities, waste management, energy production and use, and biomass burning
- **Nitrous oxide** (N_2O): From agricultural activities, such as fertilizer use, chemical production and fossil fuel combustion
- **Fluorinated gases** (F-gases): From industrial processes, refrigeration, and the use of a variety of consumer products including hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF6)

Global net anthropogenic GHG emissions

65% from CO_2 (fossil fuels and industry)

18% from CH_4

11% from CO_2 (land use, land use change and forestry)

6% from N_2O and fluorinated GHG gases

Source: United States Environmental Protection Agency, 2024

CLIMATE CHANGE AND CARBON

Global warming potential and CO_2 equivalent

- The global warming potential (GWP) allows comparisons of the global warming impacts of different GHGs
- It is a measure of how much energy the emission of 1 ton of a gas will absorb over a given time duration, relative to the emission of 1 ton of carbon dioxide (CO_2)
- The time duration usually used for GWPs is 100 years
- The metric used for measuring GWP of a GHG is CO_2 equivalent (CO_2e)

Global warming potential of greenhouse gases

Greenhouse gases	GWP over 100 years
Carbon dioxide (CO_2)	1
Methane (CH_4)	27–29.8
Nitrous Oxide (N_2O)	273
Sulfur hexafluoride (SF_6)	24,300
Perfluorocarbon (PFC)	7,380 – 12,400
Hydrofluorocarbon (HFC)	4.84–14,600

Table source: IPCC, 2021

CARBON EMISSIONS

Global impact of the construction and building industry

Globally, buildings consume more than 30%–34% of the total energy demand for operational requirements and production of construction materials. In 2022, CO_2 emissions from building operations and construction reached a new high of 37% of total emissions *(Direct emissions are from resources owned and controlled by the user, while indirect emissions are due to generation of purchased electricity)*

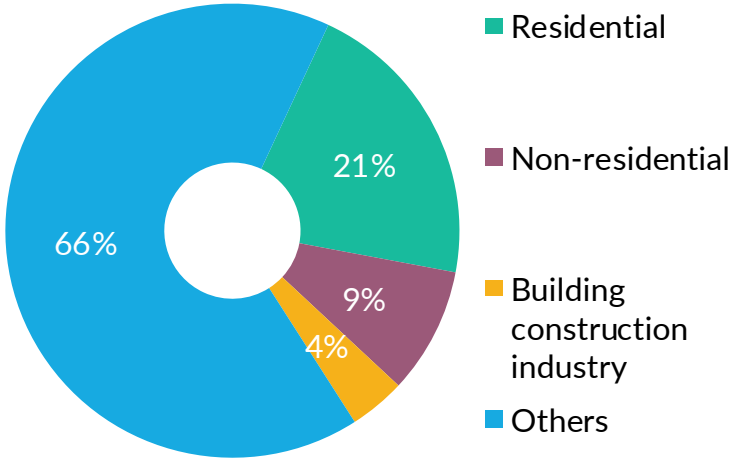


30%–34%
of total energy
consumed by buildings

37%
of total CO_2 emissions

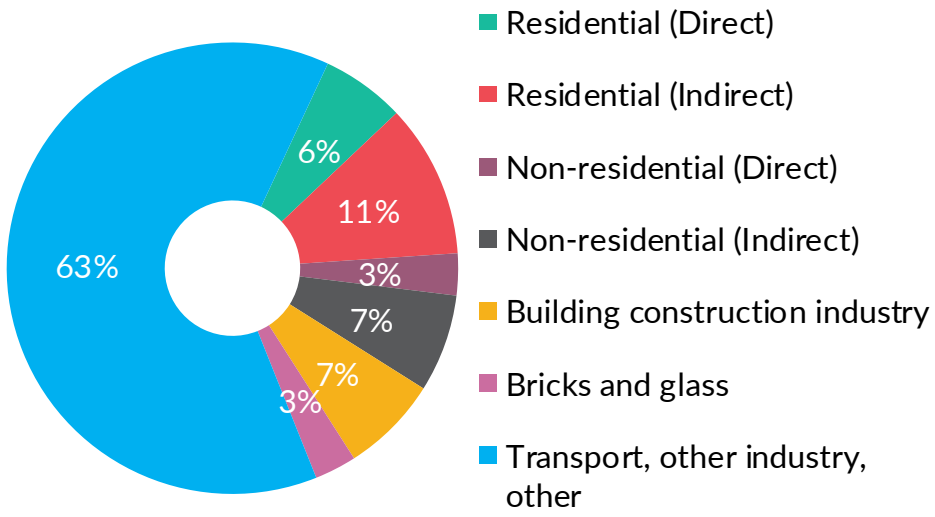
Share of buildings in total final energy consumption (2022)

Energy demand by sector 2022



Share of buildings in global energy and process emissions (2022)

Emissions by sector 2022

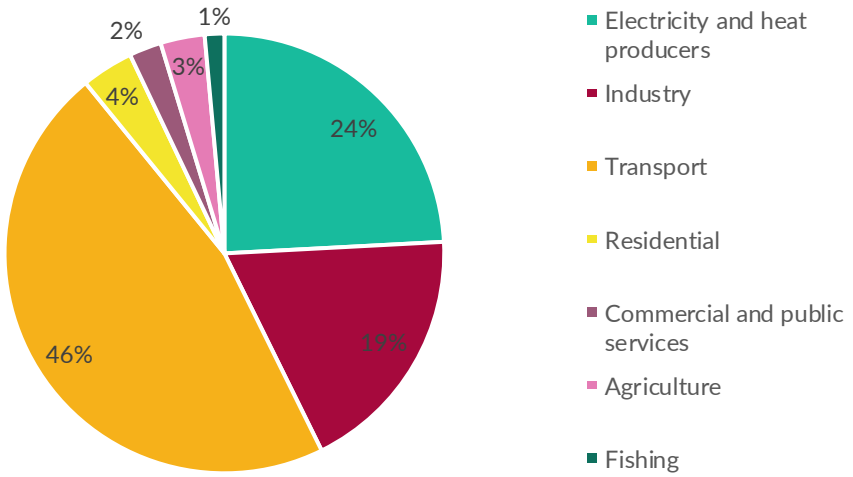


Sources: International Energy Agency, 2023a; United Nations Environment Programme, 2024

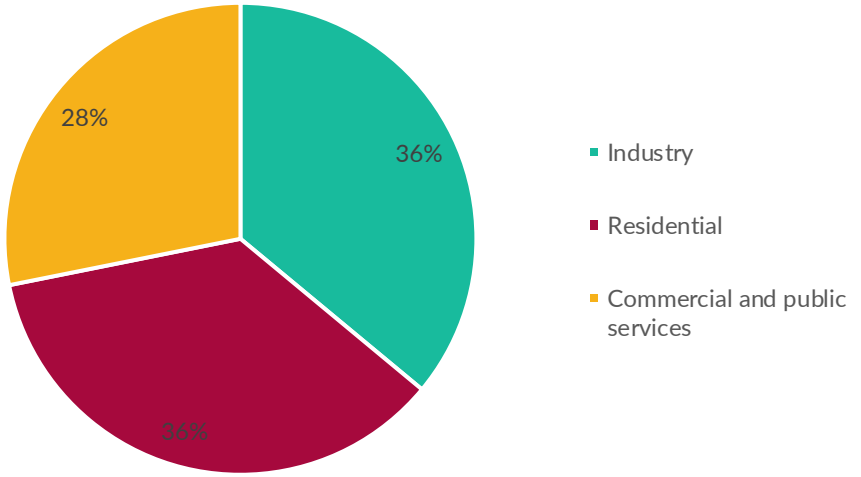
EMISSIONS AND ELECTRICITY CONSUMPTION

Cambodia

Emissions by sector, 2022



Electricity consumption by sector, 2022



Largest sources of emissions:

- Transport = 46%
- Electricity and heat producers = 24%

Largest consumers:

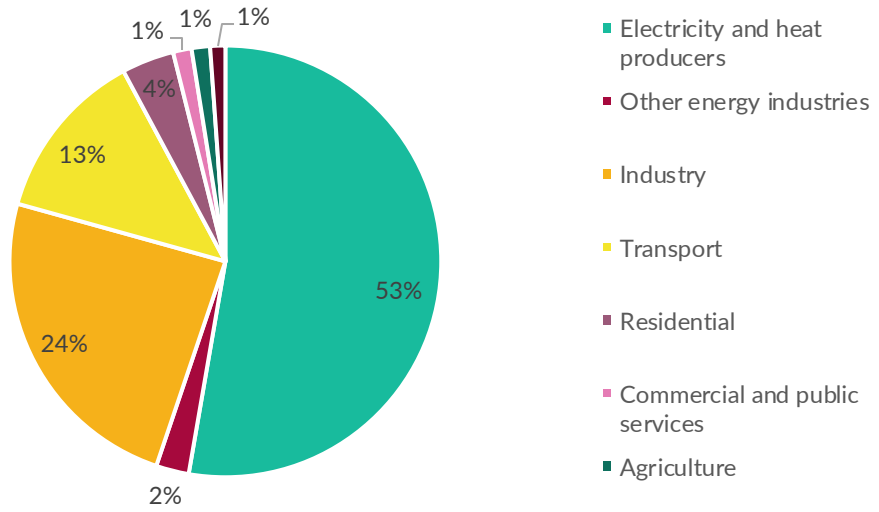
- Industry = 36%
- Residential = 36%

Source: https://www.iea.org/countries/cambodia

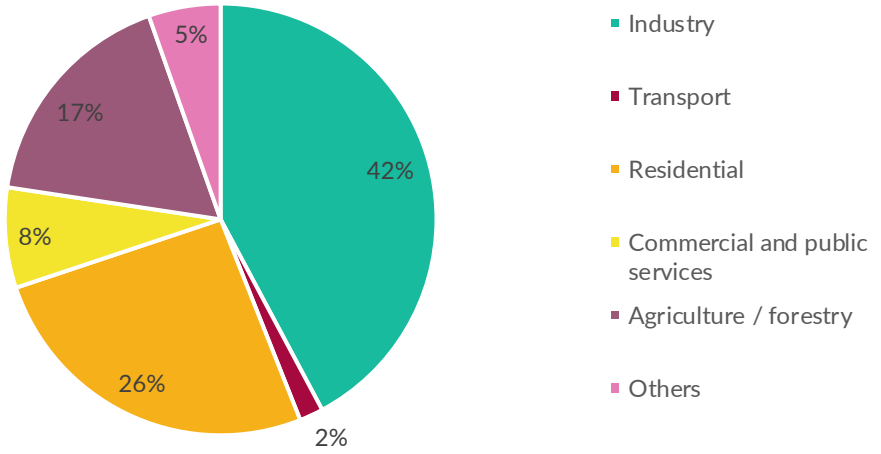
EMISSIONS AND ELECTRICITY CONSUMPTION

India

Emissions by sector, 2022



Electricity consumption by sector, 2022



Largest sources of emissions:

- Electricity and heat producers = 53%
- Industry = 24%

Largest consumers:

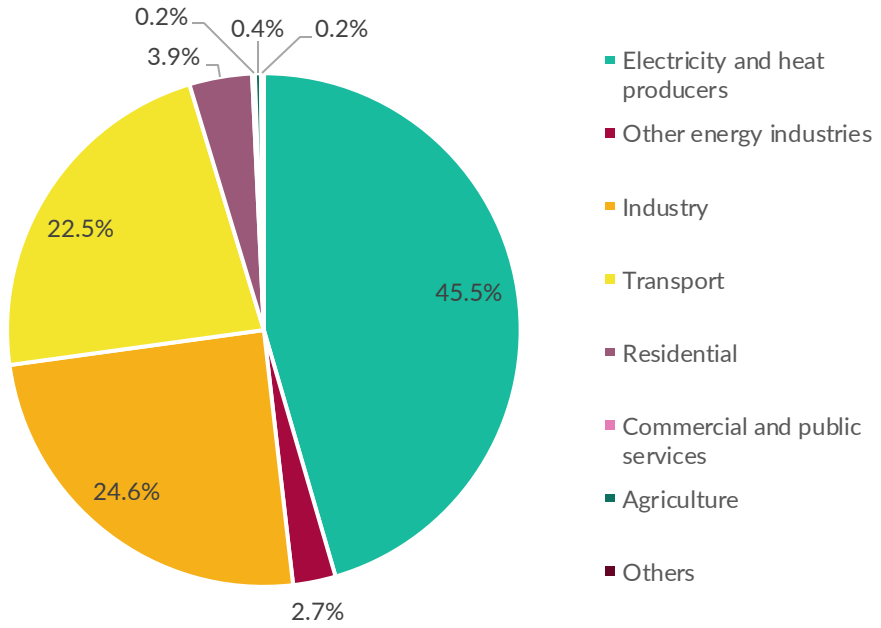
- Industry = 42%
- Residential = 26%

Source: https://www.iea.org/countries/india

EMISSIONS AND ELECTRICITY CONSUMPTION

Indonesia

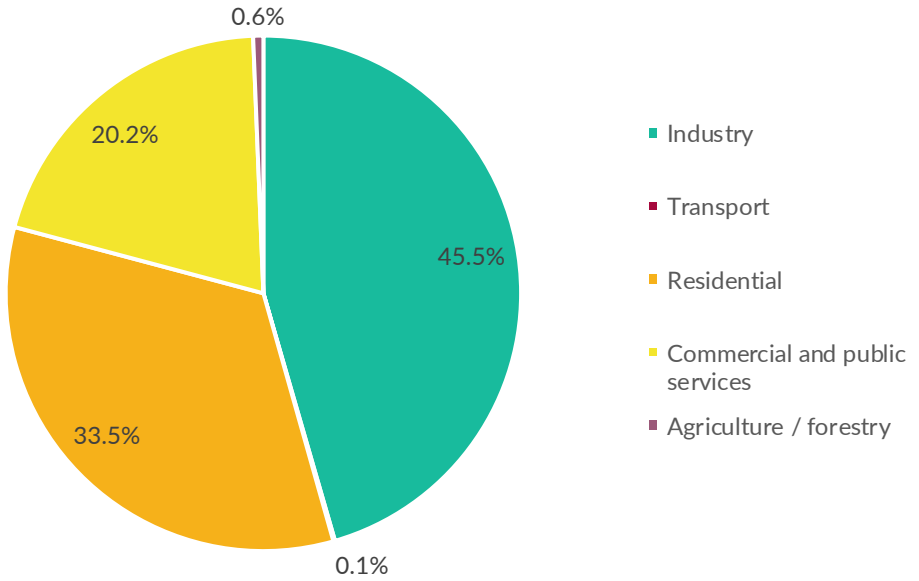
Emissions by sector, 2022



Largest sources of emissions:

- Electricity and heat producers = 45%
- Industry = 25%

Electricity consumption by sector, 2022



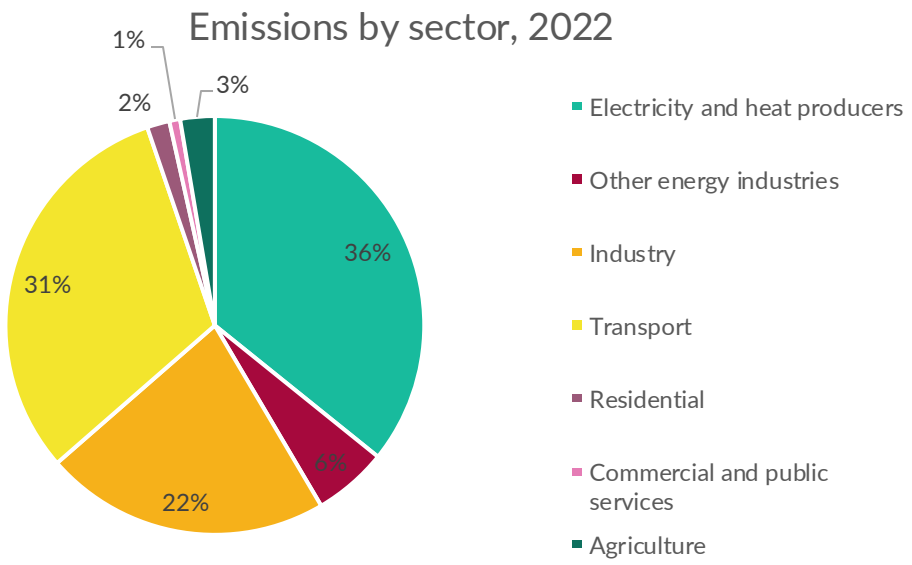
Largest consumers:

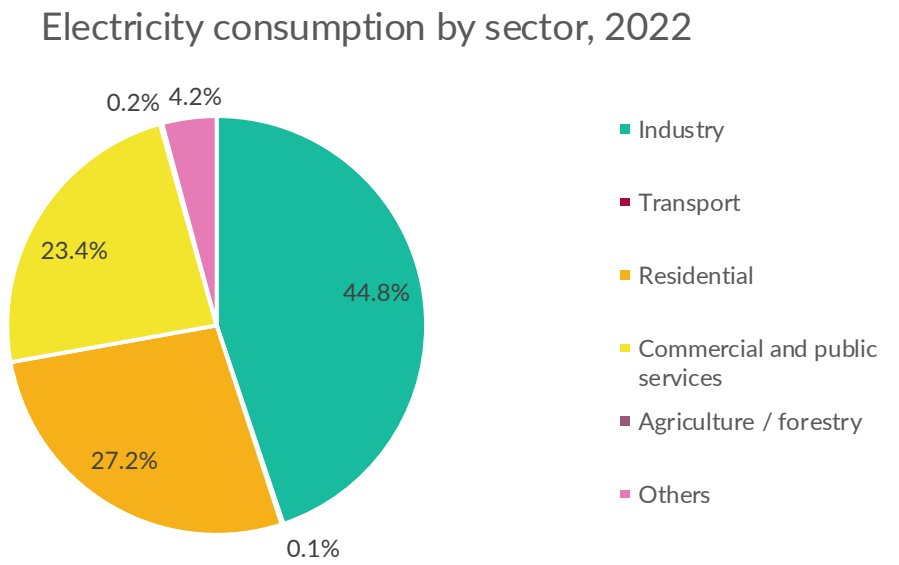
- Industry = 46%
- Residential = 34%

Source: https://www.iea.org/countries/indonesia

EMISSIONS AND ELECTRICITY CONSUMPTION

Thailand





Largest sources of emissions:

- Electricity and heat producers = 36%
- Transport = 31%

Largest consumers:

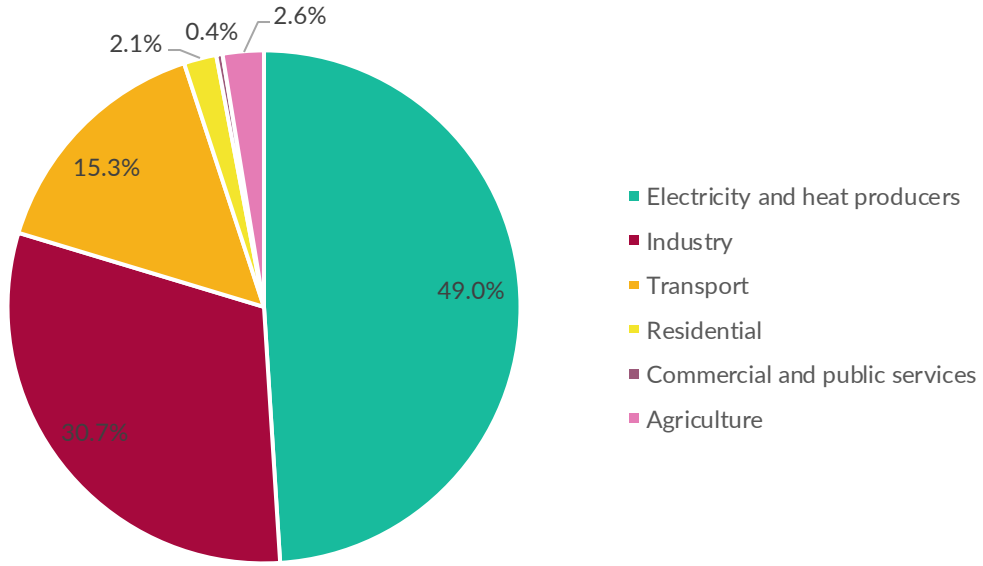
- Industry = 45%
- Residential = 27%

Source: https://www.iea.org/countries/thailand

EMISSIONS AND ELECTRICITY CONSUMPTION

Vietnam

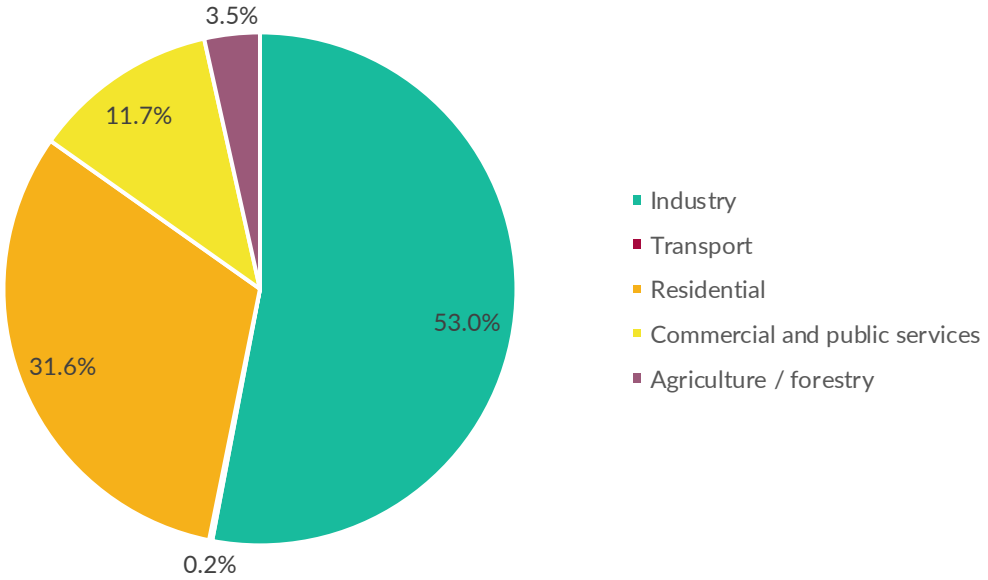
Emissions by sectors, 2022



Largest sources of emissions:

- Electricity and heat producers = 49%
- Transport = 31%

Electricity consumption by sector, 2022



Largest consumers:

- Industry = 53%
- Residential = 32%

Source: https://www.iea.org/countries/vietnam

Net Zero Carbon Buildings

Concepts and Approaches



NET ZERO CARBON BUILDINGS

The concept

- **Net zero carbon** means cutting carbon emissions to a small value of residual emissions that can be absorbed and durably stored by nature and other carbon dioxide removal measures, leaving zero in the atmosphere[1]
- **Net zero carbon buildings** are designed so that the total greenhouse gas emissions from their entire life cycle amount to zero or less[2]
- However, there are different definitions and types of net zero buildings depending on the scope



[1] *Source: United Nations Climate Action*
[2] *Source: Ramachandran, 2024*

NET ZERO CARBON BUILDINGS

Definitions

- **Net zero carbon – construction** when the amount of carbon emissions associated with a building's product and construction stages up to practical completion is zero or negative, through use of offsets or the net export of onsite renewable energy
- **Net zero carbon – operational energy** when the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net zero carbon building is highly energy efficient and powered from onsite and/or offsite renewable energy sources, with any remaining carbon balance offset
- **Net zero carbon – whole life** when the amount of carbon emissions associated with a building's embodied and operational impacts over the life of the building, including its disposal, are zero or negative



Source: UK Green Building Council, 2019

NET ZERO CARBON BUILDINGS

Levels of adoption

The adoption of net zero carbon buildings will need various approaches:

i. **Energy efficient buildings:** Provide significant energy savings through optimized construction and systems for heating, cooling, lighting and other services

ii. **Low carbon buildings:** Incorporate low carbon energy sources and may require upgrades in existing equipment to reduce carbon emissions fully

iii. **Nearly zero carbon building:** Achieve high energy efficiency and include some form of zero-emission energy but fall short of completely neutralizing their energy consumption



Source: United Nations Environment Programme, 2024

Image source: https://theleaflet.in/indias-challenges-towards-achieving-net-zero-goals/

NET ZERO CARBON BUILDINGS

Levels of adoption (continued)

iv. **Net zero carbon buildings:** Meet their energy needs with zero-emission sources over a set period, typically a year. Zero carbon buildings are similar but ensure that all energy demands are met with zero-emission energy throughout the period

v. **Carbon negative buildings:** Produce more renewable energy than they consume, contributing the surplus to the grid for external use

vi. **Whole life cycle net zero carbon buildings:** Represent the pinnacle of sustainability, maintaining a zero-carbon energy status while also ensuring that the embodied emissions from their construction materials are net zero, achieved through either decarbonization or offsets

vii. **Green buildings:** Also known as green construction, sustainable building, or eco-friendly building, refer to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life cycle from planning to design, construction, operation, maintenance, renovation and demolition



Source: United Nations Environment Programme, 2024

Image source: https://theleaflet.in/indias-challenges-towards-achieving-net-zero-goals/

NET ZERO CARBON BUILDINGS

Whole life carbon approach

Total decarbonization of the built environment calls for the industry to adopt the **whole life carbon approach** that addresses emissions from operational energy use in buildings, and the embodied carbon, which comes from the building materials and construction or renovation processes



Source: World Green Building Council

WHOLE LIFE CARBON

Embodied and operational carbon

- The **whole life** of a building is the entire life of a building from the material sourcing, manufacturing, construction, use over a given period, demolition, and disposal or reuse
- **Whole life carbon** refers to the carbon impacts over the entire life cycle of a built asset, from its construction through to its end of life
- The whole life carbon of a building broadly consists of **embodied carbon and operational carbon**
- In addition, there are user carbon impacts from the activities of the users of a built asset, outside of the use of energy and water to operate the asset



Source: Royal Institute of Chartered Surveyors, 2023

Image source: Gensler, Garett Rowland

Global Net Zero Buildings

Commitments



REDUCING CARBON EMISSIONS

Way forward for buildings

Lower reliance on fossil fuels by reducing operation energy consumption

- Passive design and improve building envelope
- Systems efficiency
- Energy management

Minimize embodied carbon, both upfront and during building life cycle

- Repurpose existing buildings and materials
- Reduce the need for material replacements
- Optimize material usage and design with low carbon materials
- Use low carbon construction technologies and eliminate waste

Increase renewable energy use

- Prioritize onsite renewable energy generation
- Procure offsite renewable energy

Offset any remaining carbon

Sources: UK Green Building Council, 2019; Ramachandran, 2024

NET ZERO BUILDINGS

Global commitments

World Green Building Council Commitment

By 2030, all new buildings, infrastructure and renovations must reduce embodied carbon by at least 40%, with significant upfront carbon reduction. Additionally, all new buildings must achieve net zero operational carbon. By 2050, all buildings, including existing ones, along with new infrastructure and renovations, must achieve net zero embodied carbon and net zero operational carbon

UK Green Building Council Advancing Net Zero Program

Aims to drive the transition toward net zero carbon buildings in the UK, focusing on reducing emissions from the construction and property sectors

The 2030 Challenge for Embodied Carbon by Architecture 2030

The target is to achieve a GWP of 40% below the current industry average immediately, with the following goals:

- 45% or better by 2025
- 65% or better by 2030
- Zero GWP by 2040

Source: Ramachandran, 2024

NET ZERO BUILDINGS

Global commitments

Race to Zero

UN-backed global campaign rallying non-state actors — including companies, cities, regions, financial and educational institutions — to take rigorous and immediate action to halve global emissions by 2030 and deliver a healthier, fairer zero carbon world in time

The American Institute of Architects (AIA) 2030 Commitment

A climate strategy that sets standards and goals for achieving net zero emissions in the built environment, with architects, engineers and owners urged to take immediate and decisive action to reach net zero emissions by 2030

C40 Cities Pledge

Aims to inspire and mobilize stakeholders to take action and implement policies that:

- Reduce embodied emissions by at least 50% for all new buildings and major retrofits by 2030, with a target of 30% by 2025
- Reduce embodied emissions by at least 50% for all infrastructure projects by 2030, with a target of 30% by 2025
- Procure and, where possible, use only zero-emission construction machinery from 2025 and ensure all construction sites are zero emission by 2030

The Royal Institute of British Architects (RIBA) 2030 Climate Challenge

A framework that sets ambitious targets for architects to help reduce the built environment's carbon footprint and contribute to global climate goals

Source: Ramachandran, 2024

Net Zero Buildings

Case Examples



ENERGY EFFICIENT BUILDINGS

Case example: Indira Paryawaran Bhavan, India

- Indira Paryawaran Bhawan, the new building of the Ministry of Environment and Forest, located in New Delhi is India's highest green rated building. It has achieved an **LEED platinum and GRIHA 5-star rating**
- The building uses **70% less energy** than a conventional building by applying several passive design strategies like adequate **natural light, shading and landscaping to reduce ambient temperature and energy use**



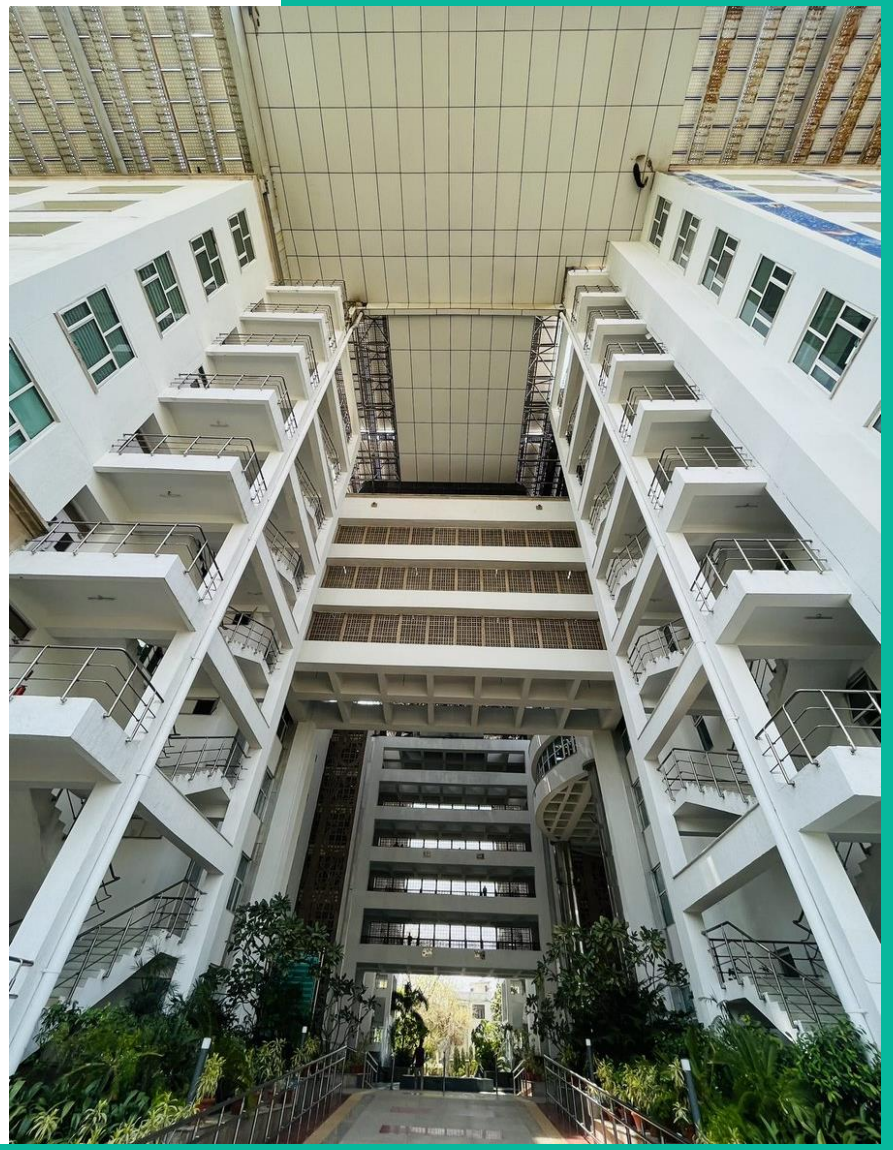
Image source: NBM and CW, 2018

Source: Bureau of Energy Efficiency, Government of India and United States Agency for International Development

ENERGY EFFICIENT BUILDINGS

Case example: Indira Paryawaran Bhavan, India (continued)

- Received **several awards** for exemplary demonstration of renewable energy technologies
- Demonstrates an **Energy Performance Index of 44 kWh/sqm/year**
- Generates about **1.43 million units per year** through solar panels that power the facility, and exports surplus power to the grid
- Integrates several effective passive and active measures:
  - Optimum orientation and building envelope
  - Energy efficient lighting systems
  - Sustainable cooling using strategies like chilled beams
  - Variable speed screw chillers
  - Precooling of fresh air is by a geothermal system
- Heating, ventilation and air conditioning (HVAC) load is 40 sqm/TR, surpassing India's Energy Conservation Building Code requirement of 20 sqm/TR



Source: Bureau of Energy Efficiency, Government of India and United States Agency for International Development

ZERO ENERGY BUILDINGS

Case example: Santa Monica City Hall East, USA

- The new city hall of Santa Monica is a **mid-rise office building** with a gross area of **50,000 sq. ft.**, designed to meet the standards of **Living Building Challenge aiming for a net zero energy performance certification**
- Modeled **Energy Use Intensity (EUI) is 7.9 kWh/ sq. ft. /year**
- The project has a **292 kW DC solar PV system that produces 7.9 kWh/sq. ft./year,** achieving the net zero energy goal



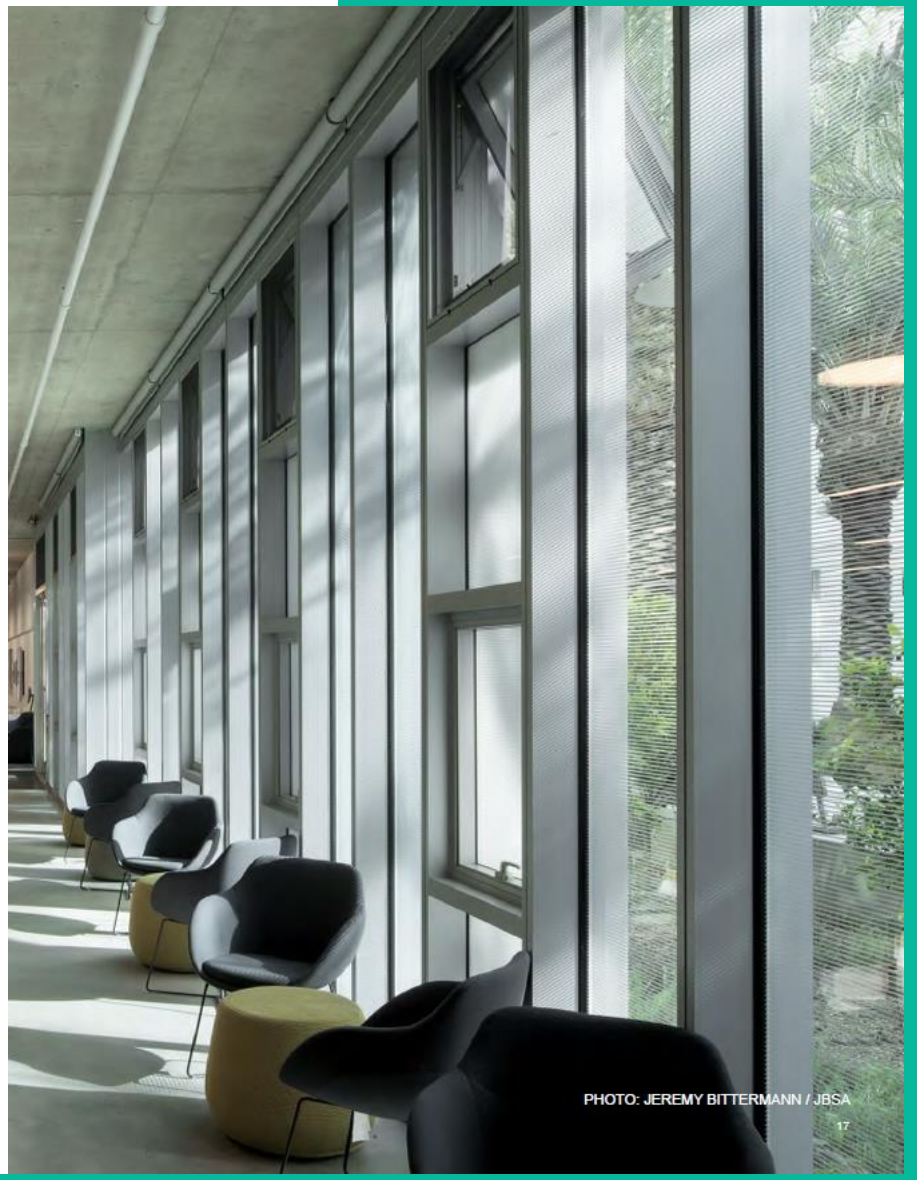
Source: Dean, 2022

ZERO ENERGY BUILDINGS

Case example: Santa Monica City Hall East, USA (continued)

Salient sustainable design features of the **building envelope**:

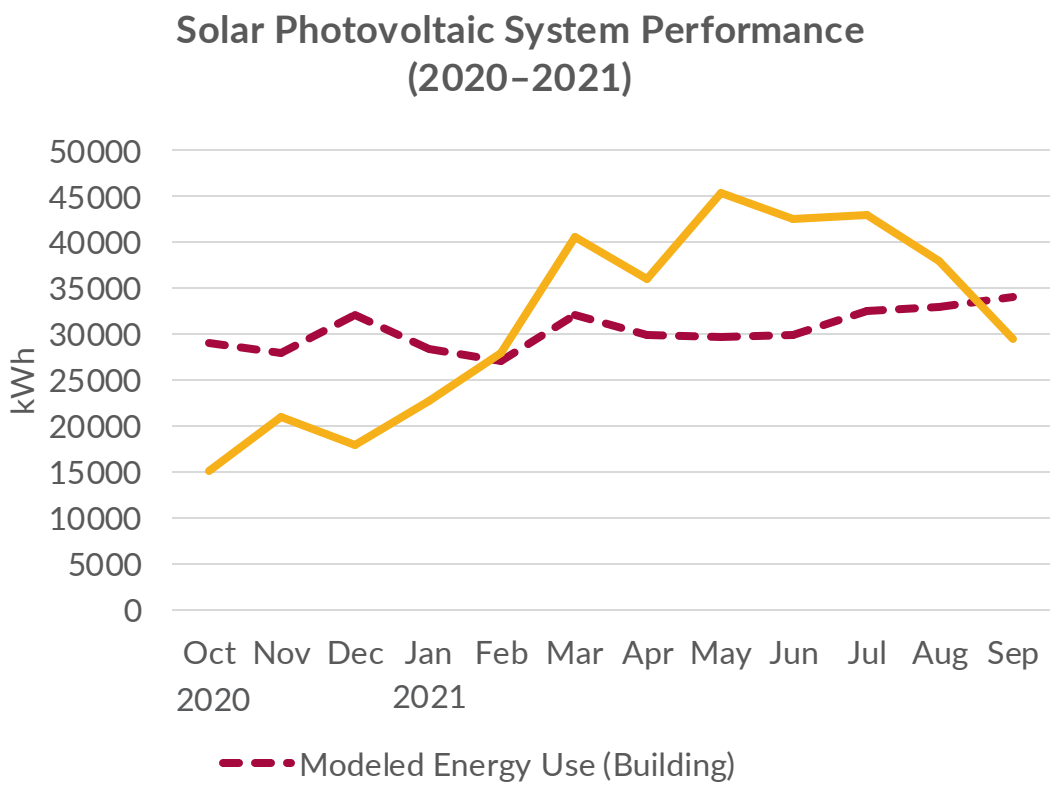
- The design requirement was to have a strong architectural contrast to the historic city wall where in the proposal for an all-glass curtain wall was approved
- **A highly-optimized double curtain wall design** with a **balance of openable windows** and choice of glass with **low-e coating** was chosen to optimize the daylighting and control solar loads
- The envelope could not have a very low U-value; however, several energy efficient strategies were integrated

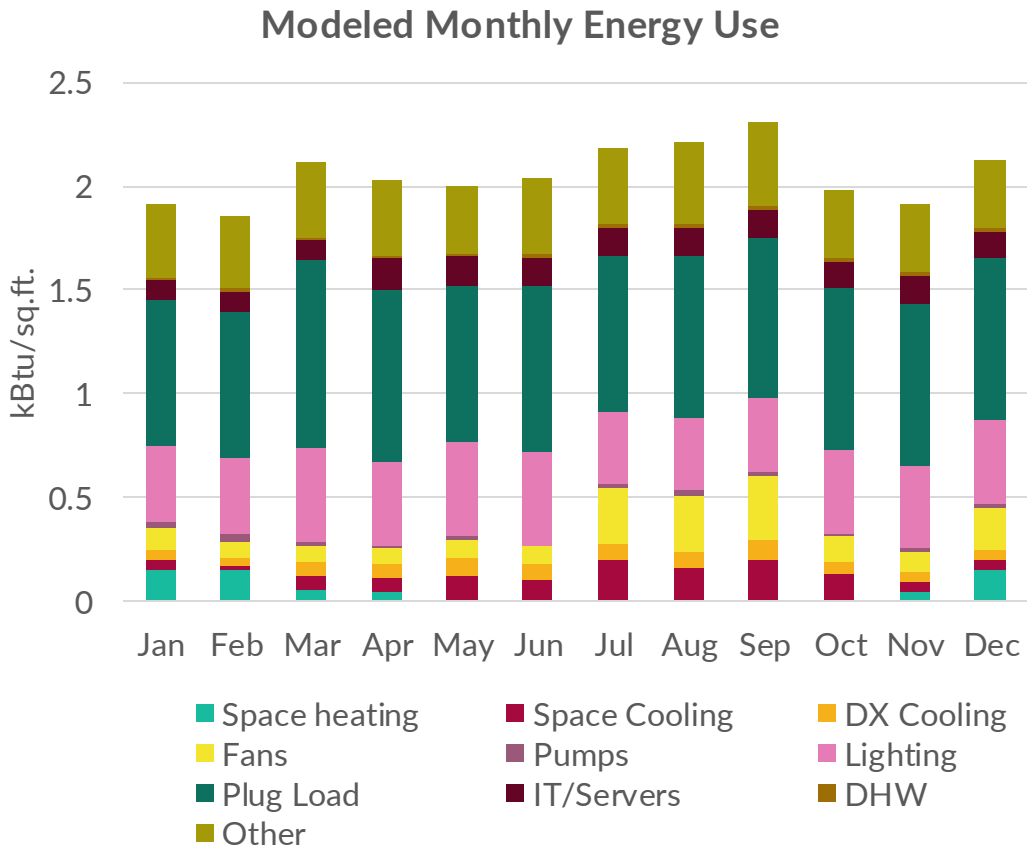


Source: Dean, 2022

ZERO ENERGY BUILDINGS

Case example: Santa Monica City Hall East, USA (continued)





Source: Dean, 2022

ZERO ENERGY BUILDINGS

Case example: Santa Monica City Hall East, USA (continued)

Strategies for energy efficiency

Thermal storage and phase change material

- Added phase change material to certain ceilings and walls and spandrel glass of the curtain wall as thermal mass to reduce peak load
- Installed large operable windows located at two heights on each floor, one at occupant level and a second one just below the ceiling, controlled by building management systems for optimum **cross ventilation and night purging**
- HVAC uses **air source heat pumps** to generate chilled water or hot water to circulate through concrete slabs
- **Reduced plug loads by having staff use only laptops**
- Conducted training for occupants on using the energy efficient features of the building

Source: Dean, 2022

NET ZERO BUILDING

Case example: Godrej Office Building, India

- Plant-13 Annexe Building of Godrej & Boyce Ltd., located in Mumbai, India, is a multi-use office built in the year 2010
- The building is equipped with facilities like offices, conference and meeting rooms, training rooms, auditorium, banquet rooms, cafeteria, food court, and 24x7 kitchen facilities
- The building is constructed over a site area of 4 acres and has ground + 4 floors with an area of 250,000 sq. ft.
- The building is occupied by around 400 employees and common facilities like cafeteria, and conference and meeting rooms are shared by over 2,000 staff members



Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

NET ZERO BUILDING

Case example: Godrej Office Building, India (continued)

Main features:

- Optimized window to wall ratio, north-south orientation, punched windows and light wells for daylight
- Double glass with low heat (25%) and high-light transmission values (40%)
- Walls with autoclaved aerated concrete (AAC) blocks and roof with thermal insulation and green vegetation to reduce heat ingress and mitigate urban heat island effects
- Central air-conditioning system with chilled water system and water-cooled screw chillers with coefficient of performance (COP) of 5.9 at full load, and COP of 8–9 at 50% load; and 2x250 TR (with twin compressors) and 2x125 TR distributed sizing for operational flexibility
- Variable frequency drives (VFDs) on cooling tower fans, chilled water pumps and AHU fans with temperature-based controls
- A building management system controls the air conditioning system

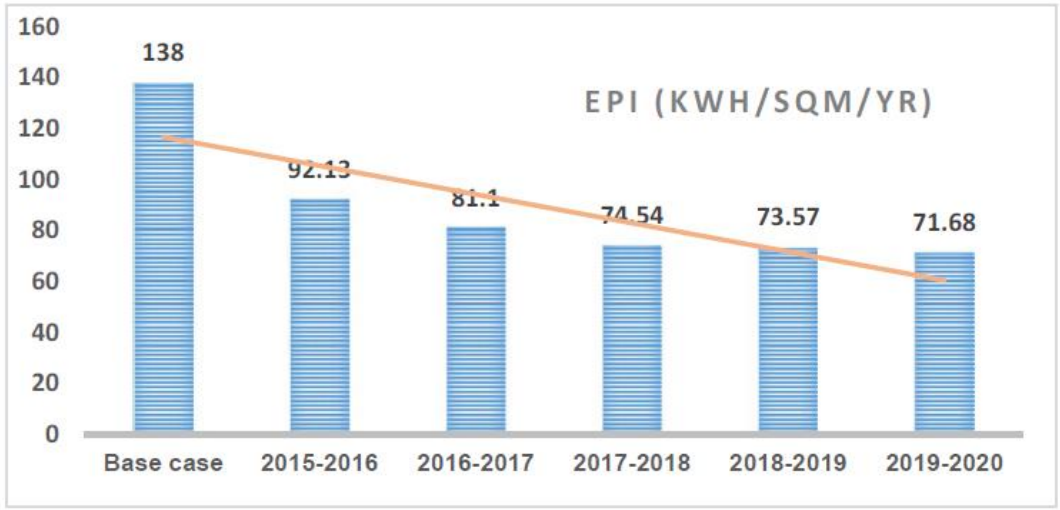
Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

NET ZERO BUILDING

Case example: Godrej Office Building, India (continued)

Main features (continued):

- A 120 kWp solar PV installed to provide 8% of the annual energy demand
- A tripartite power purchase agreement signed to receive wheeled solar power of approximately 1,200 kWp from a solar plant located at Sangli, India
- With the combination of 120 kWp onsite and 1,200 kWp offsite, Plant-13 Annexe Building can meet the Net Zero Energy targets



Source: Confederation of Indian Industry and Shakti Sustainable Energy Foundation, 2022

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

3.2 Understanding Embodied Carbon in Buildings

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

Federal Ministry for Economic Affairs and Climate Action

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WHAT WILL YOU LEARN?

01 Embodied Carbon and its Importance

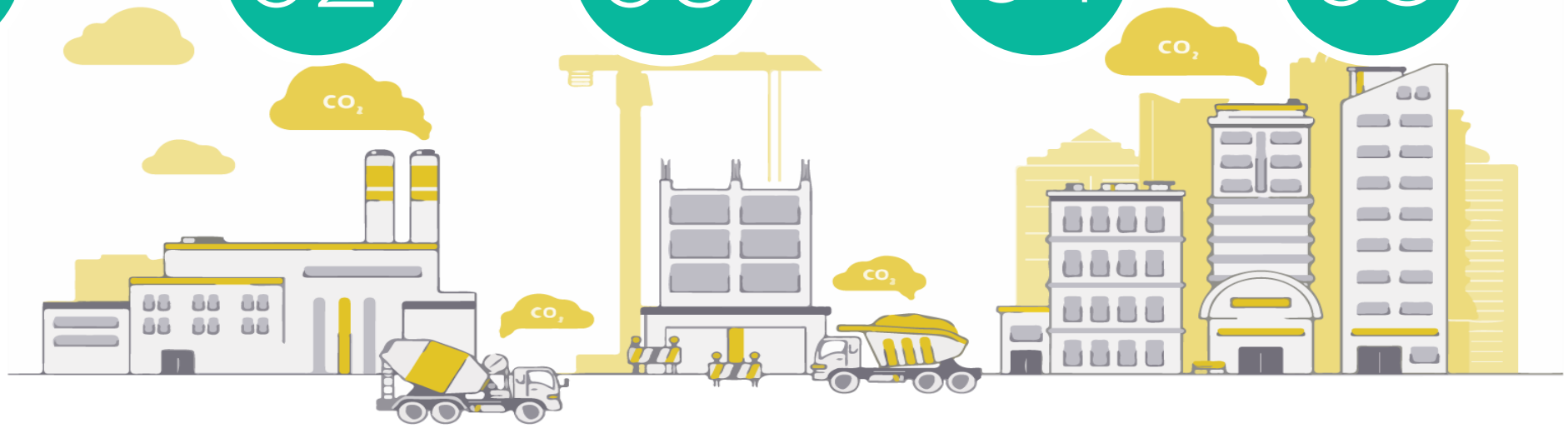
02 Key Materials Driving Embodied Carbon

03 Calculating Embodied Carbon

04 Reducing Embodied Carbon

05 Embodied Carbon Regulations

06 Case Examples



WHOLE LIFE CARBON

Embodied and operational carbon

- The **whole life** of a building is the entire life of a building from the material sourcing, manufacturing, construction, use over a given period, demolition, and disposal or reuse
- **Whole life carbon** refers to the carbon impacts over the entire life cycle of a built asset, from its construction through to its end of life
- The whole life carbon of a building broadly consists of **embodied carbon and operational carbon**
- In addition, there are user carbon impacts from the activities of the users of a built asset, outside of the use of energy and water to operate the asset



Source: Royal Institute of Chartered Surveyors, 2023

Image source: Gensler, Garett Rowland

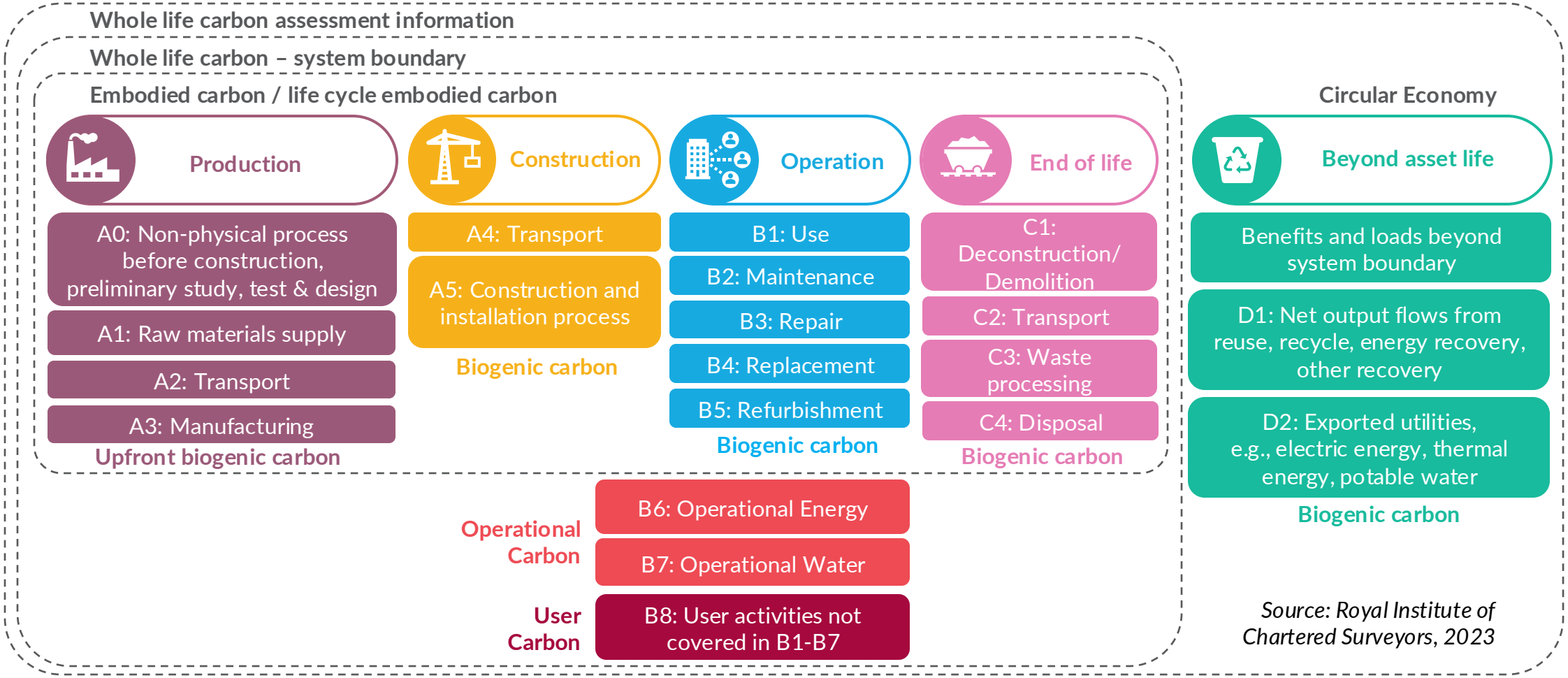
Embodied Carbon in Buildings

Relevance and Importance



Image source: https://www.lek.com/insights/by/building-materials-supply-chain-disrupted-changes-consumer-behaviour

BUILDING LIFE CYCLE STAGES



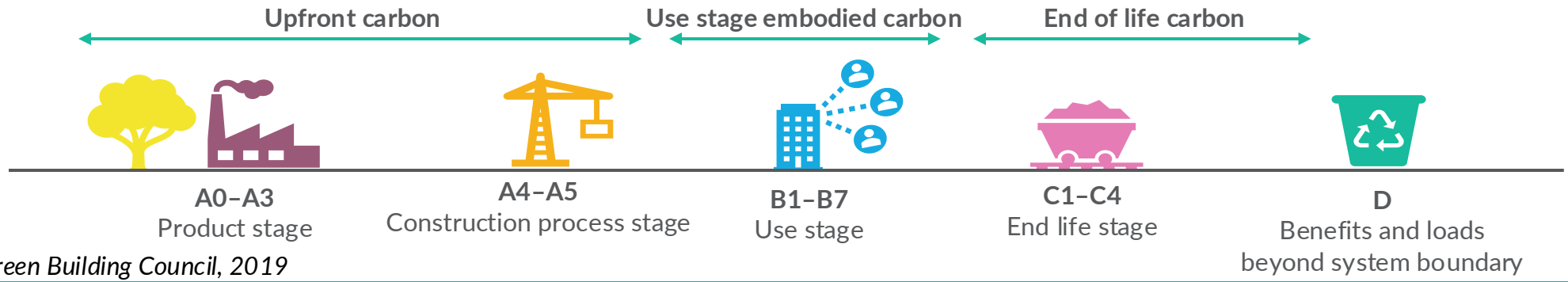
Source: Royal Institute of Chartered Surveyors, 2023

EMBODIED CARBON

Upfront, during use and end of life

Embodied carbon denotes carbon emissions associated with materials and construction processes throughout the whole life cycle of a building. This includes:

- **Upfront carbon:** The emissions caused during the building material production and construction phases (A0–A5) of the building's life cycle before it is used. In contrast to other categories of emissions, these emissions have already been released into the atmosphere before the building is occupied or the infrastructure begins operation
- **Use stage embodied carbon:** Emissions associated with building materials and processes needed to maintain the building or infrastructure during use, such as for refurbishments (B1 –B5). These are additional to operational carbon emitted due to heating, cooling and power etc.
- **End of life carbon:** The carbon emissions associated with deconstruction and demolition (C1), transportation from site (C2), waste processing (C3) and disposal (C4) phases of a building or infrastructure's life cycle which occur after its use



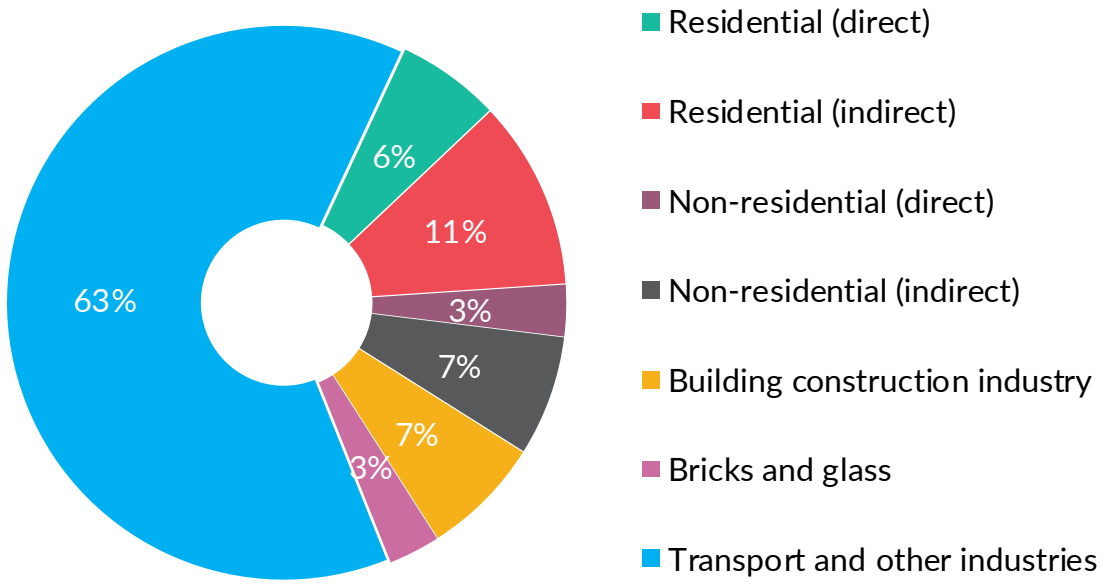
Source: World Green Building Council, 2019

EMBODIED CARBON

Its relevance and importance

- At least one-quarter of global emissions from buildings result from embodied carbon, i.e., carbon emissions associated with building materials and construction
- As global construction continues to rise, and existing building operations become more efficient, embodied carbon will become an increasingly significant issue – accounting for approximately 50% of global building sector emissions between now and 2050
- This will account for a significant amount of the remaining carbon budget, and it needs to be urgently addressed by policymakers and practitioners

Share of building in global energy and process emissions
Emissions by sector, 2022



Source: Jungclaus, M. et al., 2021

Source: United Nations Environment Programme, 2024

EMBODIED CARBON

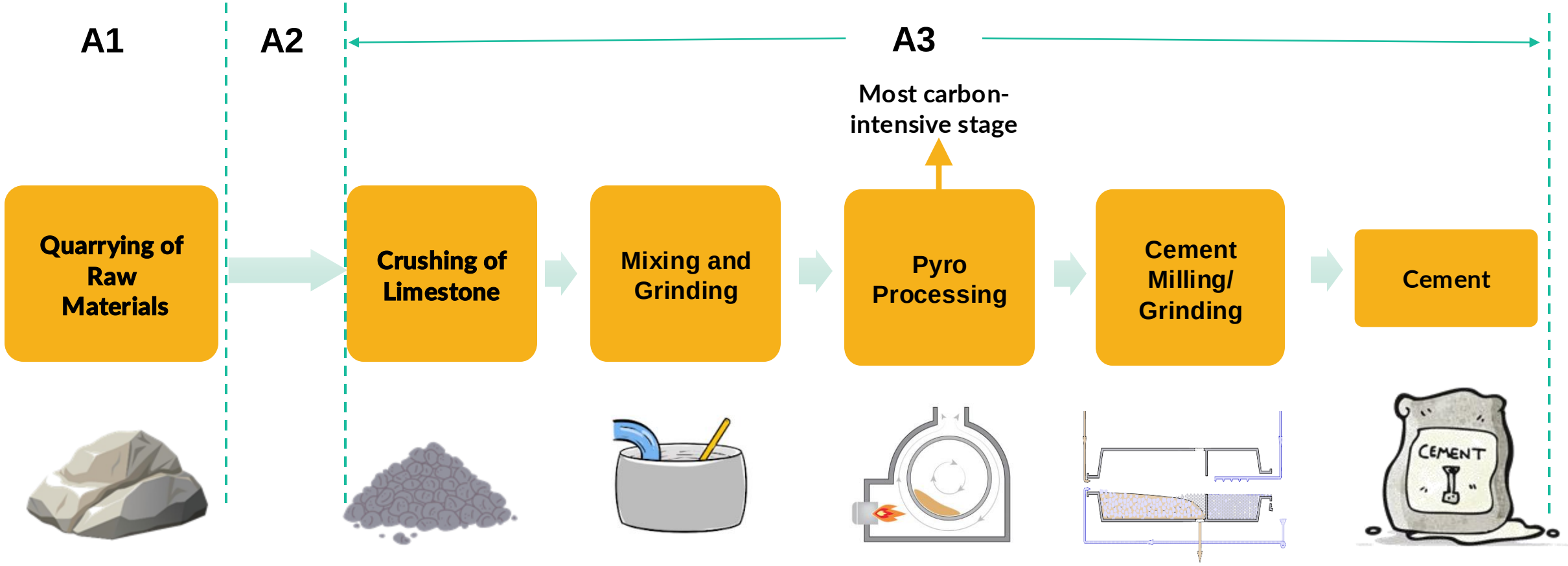
Its relevance and importance

- **Time value of carbon:** Unlike operational carbon emissions, which can be reduced over time with building energy efficiency renovations and the use of renewable energy, embodied carbon emissions are locked in place as soon as a building is built. It is therefore critical to reduce embodied carbon emissions as quickly as possible
- **Lowering embodied carbon can drive value:**
  - Reducing cost by reducing the construction materials needed in a project
  - Carbon-reduction strategies in the production of high-emitting materials like concrete can also reduce cost
  - Unless their process is driven by carbon-intensive chemical reactions, low embodied-carbon products will, by nature, result in energy savings upstream of a material's end use, resulting in cost savings for material manufacturers
  - Projects that reduce embodied carbon and/or include a whole-building life cycle assessment can help to meet green building certification requirements
  - Low-embodied-carbon building design will be better prepared for future code or policy changes that incentivize or require low embodied carbon
  - Reducing emissions in the extraction, manufacturing and transportation of low-embodied carbon materials improves air quality and public health in communities located close to industrial centers

Source: Jungclaus, M. et al., 2021

CEMENT MANUFACTURING

Manufacturing process outline



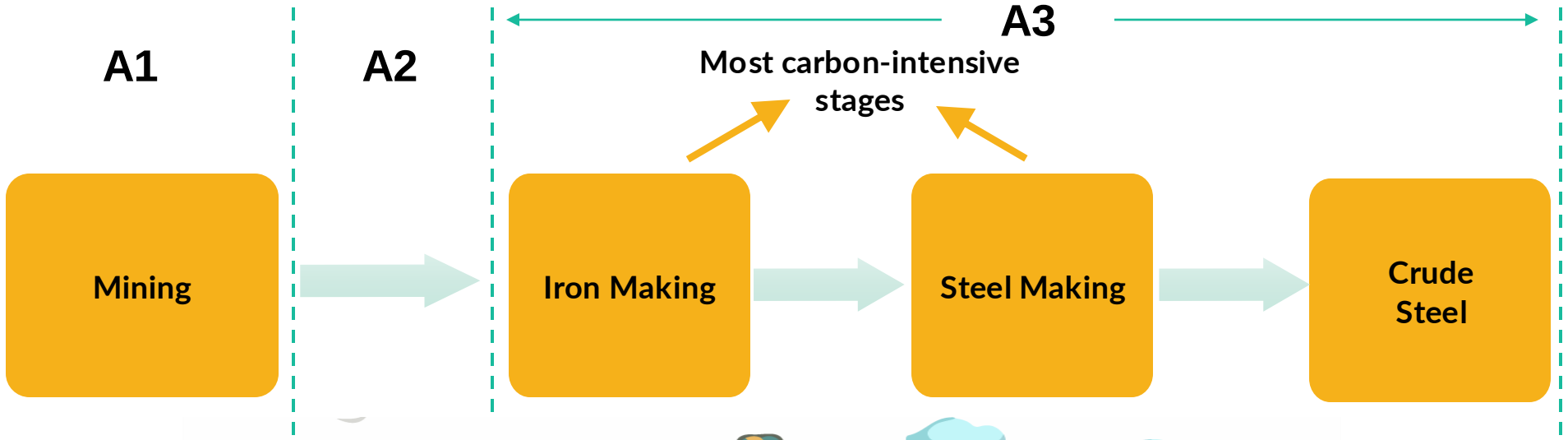
CEMENT MANUFACTURING

Options for reducing carbon footprint

- **Use of alternative raw materials like fly ash, slag and other supplementary cementitious materials (SCMs)**
- **Use of alternative energy sources for reducing carbon footprint**
  - Using waste materials like tyres, fabrics, paper, municipal solid waste, hazardous waste, etc. as supplementary fuels in kilns for pyro processing
  - Using sustainable fuels like biomass for partial substitution of fossil fuels in kilns
  - Increasing pre-calciner stages to reduce exhaust gas temperature
  - Generating electrical power from process waste heat
  - Using renewable energy sources (biomass / solar) for electricity power
  - Using green hydrogen as fuel in the pyro-processing / clinker-making process
  - Exploring possibility for electrification of kilns (technology is at a nascent stage)
- **Carbon emissions management through carbon capture, utilization and storage (CCUS) and carbon offsets**

STEEL MANUFACTURING

Manufacturing process outline



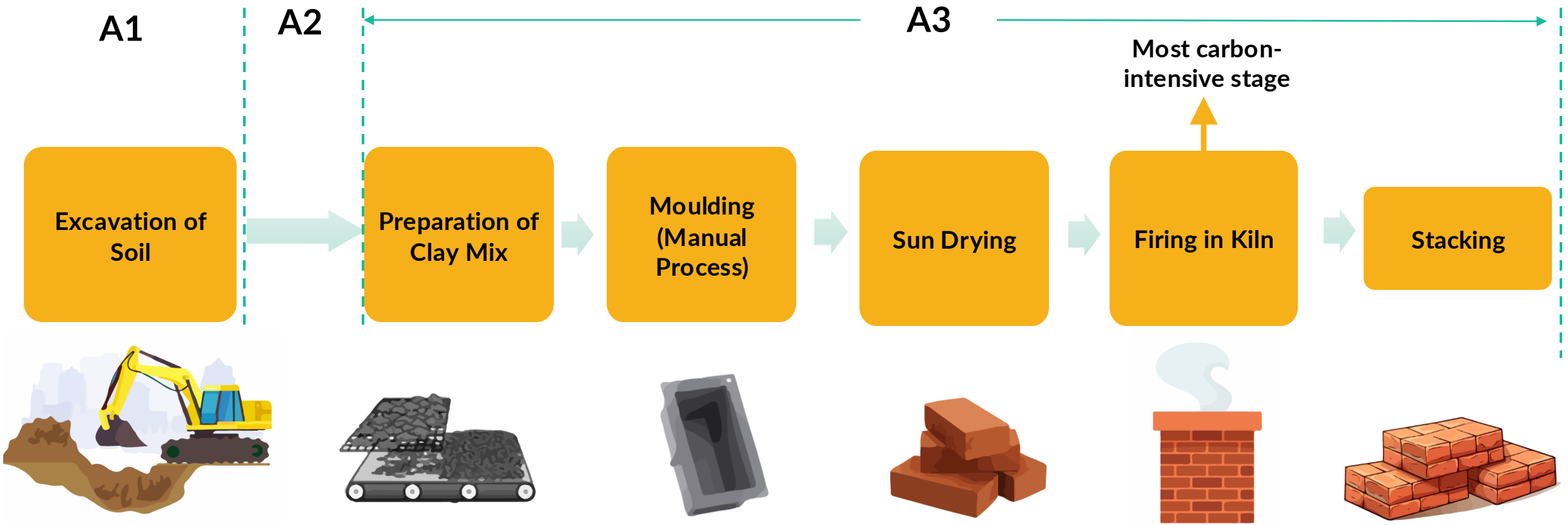
STEEL MANUFACTURING

Options for reducing carbon footprint

- **Energy efficiency measures**
  - Optimization of raw material consumption
  - Improvement in process and energy efficiencies
  - Augmenting waste heat recovery
  - Minimizing re-heating of intermediate products
- **Use of renewable energy for electricity power**
- **Alternative fuels for combustion and as reducing agents**
  - Explore possibilities for shifting from coal-based process to natural gas, biomass and green hydrogen; however, these options may be practically difficult to implement in existing plants
- **Carbon emissions management through carbon capture, utilization and storage (CCUS) and carbon offsets**

FIRED CLAY BRICK MANUFACTURING

Manufacturing process outline



FIRED CLAY BRICK MANUFACTURING

Options for reducing carbon footprint

- **Energy efficiency measures**
  - Efficient combustion of fuels
  - Manage and monitor use of raw materials and fuel as well as emissions
- **Alternative fuels for combustion**
  - Explore possibility of fuel substitution from coal to natural gas, biomass, etc.
- **Use of renewable energy for electrical power**
- **Changing the fired walling product**
  - Manufacturing alternative fired walling blocks like hollow or perforated bricks etc., which requires less raw material and fuel. This will entail changes in the production process

Embodied Carbon in Buildings

Key Driving Materials



Image source: https://www.bricknbolt.com/blogs-and-articles/construction-guide/building-material-density-importance-

KEY DRIVING MATERIALS

Cement and steel

- A building's structure and substructure typically constitute the largest source of its upfront embodied carbon (up to 80%, depending on building type). However, because of the relatively rapid renovation of building interiors associated with tenancy and turnover, the total embodied carbon from interiors can account for a similar order of emissions over the lifetime of a building[1]
- **Globally, cement and steel are two of the most significant sources of material-related emissions in construction.** Cement manufacture is responsible for 7% of global carbon emissions, with steel contributing 7%–9% of the global total (with half attributed to buildings)[2]
- Both cement and steel are used in buildings in large quantities. These materials are carbon intensive as the manufacturing processes demand very high temperatures, achieved by firing of fossil fuels; carbon dioxide emissions occur due to combustion of fuels and also as part of chemical reactions during the manufacturing process[2]
- **Cement / concrete and steel are the highest contributors in typical construction in India.** One study of residential buildings shows concrete and steel together account for 75%–94% of product stage carbon[3]

[1] *Source: Jungclaus, M. et al., 2021*
[2] *Source: World Green Building Council, 2020*
[3] *Source: Chetia, S. et al., 2024*

KEY DRIVING MATERIALS

Other building materials

- **Walling materials are significant contributors to carbon emissions**, as large number of buildings are RCC-framed structures with masonry infill. Some of the walling materials like fired clay bricks and concrete blocks are carbon intensive
- **Glass and aluminum, which have manufacturing processes at high temperatures, are carbon intensive, although their impact on buildings is smaller in comparison with cement and steel**
- Depending on the type of buildings and the prevalent construction technology used in a region or country, the major materials driving embodied carbon may differ

Embodied Carbon in Buildings

Calculation Methodology



EMBODIED CARBON

Calculation Methodology

- Embodied carbon in buildings is commonly measured in **$kgCO_2e/m^2$ (kilograms of carbon dioxide equivalent per square meter of building)**. This allows comparison of embodied carbon in different buildings
- The calculation is:

Inventory		Impacts		Total
Quantity of materials or products used in building	×	Carbon factor or GWP of respective material or product	=	Total embodied carbon emissions

- The product stage (A1–A3) emissions relating to the raw material extraction, shipping to factory and manufacturing is what is most commonly available in embodied carbon databases
- The calculation above, using figures from the carbon database, gives the carbon emissions of materials only for A1–A3 stages of the building life cycle

Source: Hrivnak, 2023

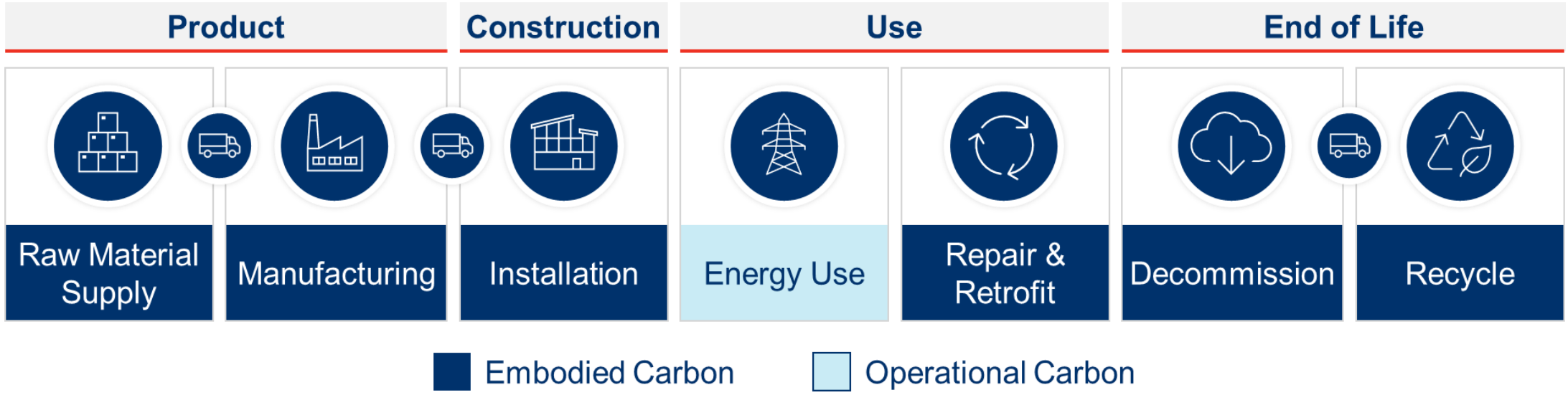
GLOBAL WARMING POTENTIAL (GWP)

Major building materials

Material / Product	Unit	GWP ($kgCO_2$/unit) (A1-A3 stages)	Geography	Source
Ordinary Portland Cement (OPC)	kg	0.842	India	*Centre for Science and Environment, 2023*
Portland Pozzolana Cement (PPC)	kg	0.582	India	
Portland Slag Cement (PSC)	kg	0.381	India	
Concrete	m^3	~450 to ~240 (varies as per mix used)	Global	*Witte and Garg, 2024*
Steel	kg	2.3–2.5	India	*Various, including Ministry of Steel, 2020; CEEW, 2023; Centre for Science and Environment, 2023*
Solid Burnt Clay Brick	m^3	198.87	India	*Maithel, 2023*
Solid Concrete Block	m^3	~200	India	*India Construction Materials Database of Embodied Energy and Global Warming Potential, 2017*
Aluminium	kg	26	India	
Glass (6mm thick)	m^2	~19	India	*Manufacturer's EPD*

LIFE CYCLE ASSESSMENT (LCA)

- Elements of an LCA: Goal and scope definition, inventory analysis, impact assessment, interpretation
- For all the segments reflected below, carbon emissions are quantified for the product level, transportation level, construction phase, use phase and end of life



Source: London Energy Transformation Initiative, 2020

EMBODIED CARBON

Quantifying upfront carbon

Acquiring the bill of quantities (BOQ) from the builder

↓

Identifying all the materials to be included for assessment

↓

Splitting down the composite materials

↓

Identifying the most relevant and suitable emission factors

↓

Calculating the embodied carbon (A1–A3)

Identifying the supplier location, mode of transport, vehicle pay load capacity and emission factor to calculate the transport-based emissions (A4)

Getting information about the energy usage at the construction site (electricity and other fuels usage), multiplying the total quantities used with their most relevant emission factors to get the construction-based emissions (A5)

CALCULATING EMBODIED CARBON

Challenges in calculating embodied carbon from different life cycle stages

- **Product stage (A1–A3)** has been shown to have the highest contribution to the total embodied carbon of buildings. Hence, calculating product stage embodied carbon already shows the embodied carbon hotspots and direction for reduction
- **Emissions for transport to site (A4) and the construction process (A5)** need to be added to fully evaluate a project's upfront carbon. The easiest way to do this is to use industry-accepted proxies at the national level (if available) or global level
- **Use phase stages (B1–B5) emissions** are difficult to estimate as not all have methodologies for accurate estimation
- **End of life stages (C1–C4) emissions** depend heavily on how materials are handled during and after the building demolition. This data is not readily available

Percentage share of product stage carbon to total embodied carbon for buildings in UK

Building type	Percentage share of product stage carbon
Small-scale housing	80%
Medium and large-scale housing	64%
Commercial offices	48%
Schools	65%

Source: London Energy Transformation Initiative, 2020

EMBODIED CARBON

Calculations

Inventory		Impacts		Total
Quantity of materials or products used in building	×	Carbon factor or global warming potential (GWP) of respective material or product	=	Total embodied carbon emissions

Material quantities: Data for material quantities used in a building are usually available with the project proponent in the form of a bill of quantities (BoQ).

Building information modeling (BIM) design tools can provide material quantity estimates in the design phase

Carbon factor / GWP of building materials:

Sources in order of preference:

- Manufacturer's specifications or product-specific environmental product declaration (EPD)
- Generic government, market-based or industry databases or life cycle inventories (LCIs)
- Other databases like the Inventory of Carbon and Energy (ICE) database

CALCULATING TOOLS

For life cycle assessment (LCA) and embodied carbon

Calculators	Simple online or spreadsheet-based tools designed to allow for targeted and quick decision-making: • **Building calculators** help designers get a quick sense of the order of magnitude of embodied carbon. These are typically most helpful in early design stages before modeling has begun and are not typically appropriate for reporting embodied carbon to meet the requirements of standards or rating systems **Examples: Build Carbon Neutral, Athena EcoCalculator** • **Material-specific or assembly-specific calculators** help designers quickly evaluate design or sourcing decisions related to a single material or assembly, such as wood or façades **Examples: Kaleidoscope, Upstream Forestry, Carbon LCA Tool**
Product selection/ procurement tools	These collect product data, such as EPDs, and facilitates comparison to help users select a product or supplier **Example: Embodied Carbon in Construction Calculator (EC3)**

Source: Lewis, M. et al., 2023

CALCULATING TOOLS

For life cycle assessment (LCA) and embodied carbon (continued)

Design integrated LCA tools

These may be integrated into software that architects already use, or they may be freestanding tools:

- **Whole building LCA tools** allow users to easily model the whole building at a fair level of detail (in terms of material types and material quantities) and perform the calculations to produce the LCA results **Examples: Tally (a plug-in for Revit), One Click LCA, Athena Impact Estimator**
- **Assembly-specific design tools** have been developed to track and manage embodied carbon for a specific physical scope, such as structure or façade
  Examples: Beacon, Building and Habitats object Model (BHoM)

Professional LCA software

These are primarily used by LCA experts and consultants for all types of products, not just those related to the building industry. These tools are commonly used to perform the LCA that an EPD is based upon, and are used to create the background datasets used in most whole building LCA tools
Examples: SimaPro, OpenLCA, GaBi

Source: Lewis, M. et al., 2023

TOOL SELECTION CRITERIA

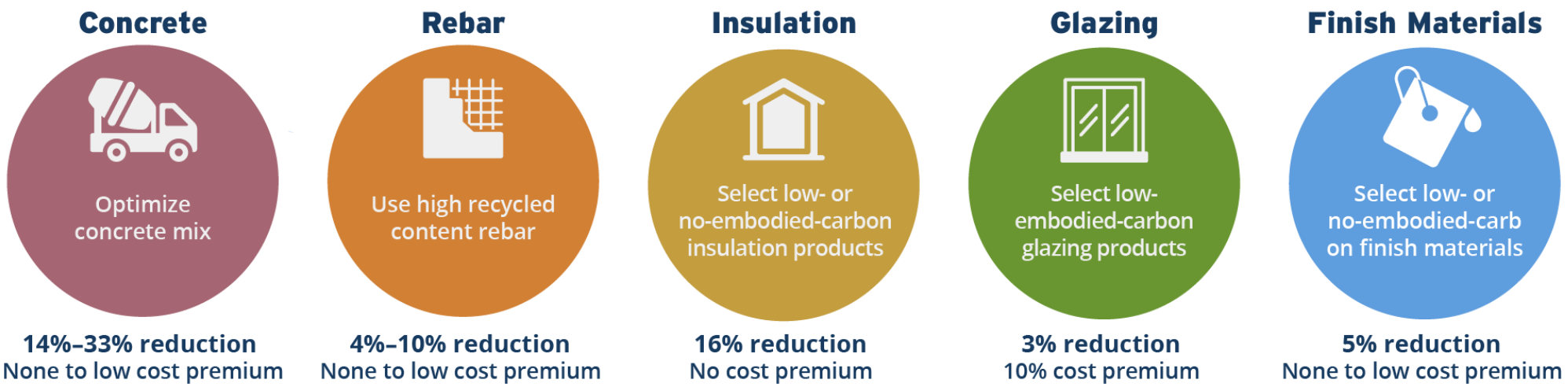
For life cycle assessment (LCA)

- **Background data:** **Life cycle inventories (LCIs)** are datasets that report emissions for different processes that contribute to the creation of a material or product. Different tools may use different LCIs, so it is important to know which datasets each tool uses, since the results can differ. LCI databases are created and managed by governmental, non-governmental and private organizations
- **Geographic location:** LCIs can have different geographic scopes. Ideally, the dataset in the tool should match the geographic location of the project
- **Life cycle scope:** Different standards and rating systems may require reporting of few or all the life cycle stages. If it is being used to report the results of a whole building LCA, the tool must include life cycle stages (product, construction, use and optionally end of life)
- **BIM integration:** BIM-integrated LCA tools are plug-in tools embedded into BIM software, such as Revit. They automate parts of the LCA process by extracting inventory data from the BIM model, increasing integration with the design process and reducing the chance of human errors from manual takeoffs

Source: Lewis, M. et al., 2023

Reducing Embodied Carbon in Buildings

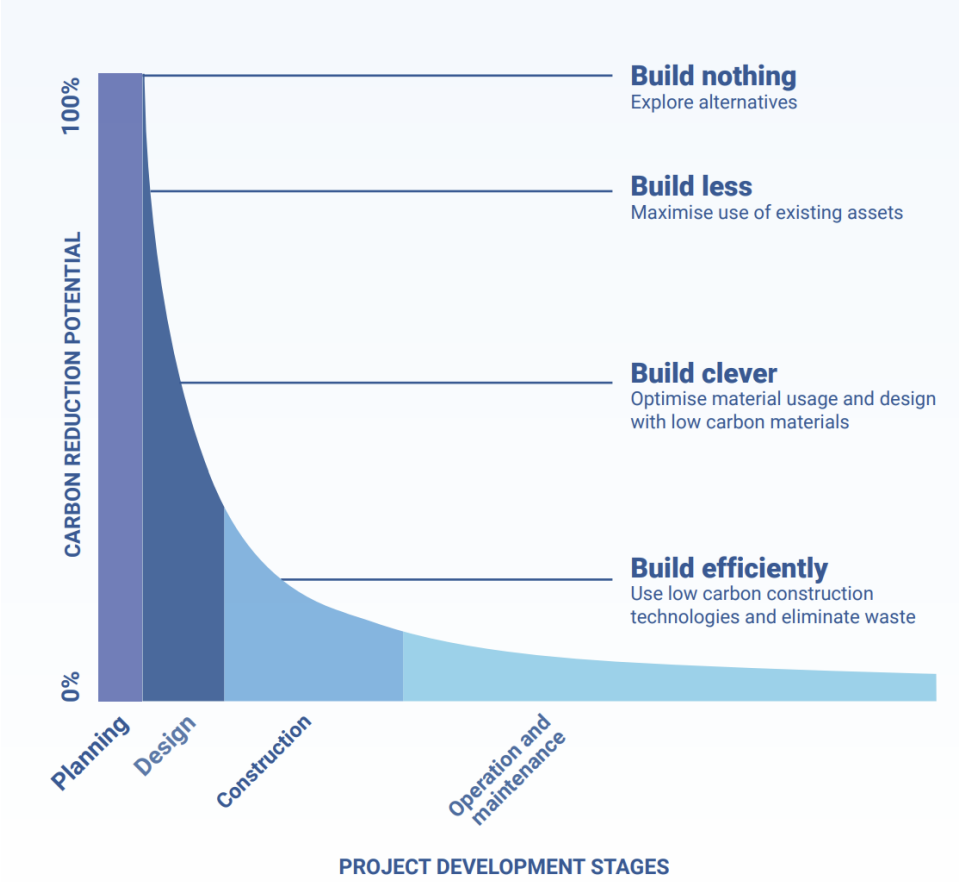
Principles and strategies



REDUCING EMBODIED CARBON

Factors involved

- Embodied carbon emissions are affected by many factors:
  - Type and volume of structure installed
  - Materials used
  - Carbon intensity of manufacturing the materials
  - Modes and distances by which materials are transported
  - Processes by which these materials are constructed, maintained, and removed and treated at the end of life
- Opportunities for reducing or eliminating embodied carbon vary and will differ between types of projects and regions
- Greatest savings can usually be realized at the early stages of a project



Source: World Green Building Council, 2019

REDUCING EMBODIED CARBON

Principles

1. PREVENT	• Question the need to build new or use materials at all • Encourage reuse, renovation and retrofitting part or whole of an existing building, rather than demolishing to build anew • Reduce new floor area • Reduce below-grade construction

2. REDUCE AND OPTIMIZE	• Apply design approaches that minimize the quantity of new material required to deliver the desired function, e.g., designing efficient structural system, minimize finishes where not required for functional performance, etc.
	• Prioritize materials that are low or zero carbon (including MEP systems with low carbon refrigerants), responsibly sourced, and have low life cycle impact in other areas, such as:
	  ▪ Operational energy use
	  ▪ Health of occupant
	• Choose low or zero carbon construction techniques having maximum efficiency and minimum waste on site

Sources: World Green Building Council, 2019; Lewis, M. et al., 2021

REDUCING EMBODIED CARBON

Principles (continued)

3. PLAN FOR THE FUTURE	• Consider future use scenarios and end of life, maximizing the potential for maintenance, repair and renovation, and ensure flexibility for future adaptation • Design for disassembly and deconstruction to facilitate future reuse, selecting materials that can be recycled, and can be extracted and separated easily for processing
4. OFFSET	• As a last resort, offset residual embodied carbon emissions, either within the project or organizational boundary, or through verified offset schemes

Sources: World Green Building Council, 2019; Lewis, M. et al., 2021

REDUCING EMBODIED CARBON

Specifications and procurement strategies

- **Integrate EPDs and GWP limits into project specifications:** An environmental product declaration (EPD) is a document that transparently reports the environmental impact of a product or material, based on a product LCA. Embodied carbon limits can be integrated into the performance requirements for a product, requiring an EPD to document compliance with an embodied carbon limit
- **Optimize concrete specification and mix design:**
  - Using performance-based specifications (rather than prescriptive requirements)
  - Minimizing the volume of Portland cement by other supplementary cementitious materials (SCMs), allowing for longer cure times (specifying strength at 56 days instead of 28 days to allow more time for strength gain), etc.
- **Source sustainable wood:**
  - Using reclaimed/salvaged wood
  - Asking for chain-of-custody certificates or other supply chain transparency information
  - Asking for sustainable forest management certifications (e.g., FSC or SFI)
  - Specifying wood that is locally harvested and harvested from working (not primary) forests

Sources: Lewis, M. et al., 2021; Zacharia, M., 2024

REDUCING EMBODIED CARBON

Specifications and procurement strategies (continued)

- **Specify lower-carbon alternatives:**
  - For example, hollow clay bricks, autoclaved aerated concrete (AAC) blocks and cement stabilized earth blocks (CSEB) are low carbon alternatives to fired clay bricks
  - Two materials with the same performance may differ in their carbon footprints due to differing energy source, product design and/or lower-carbon ingredient sourcing
  - Due to the way products are specified and selected, EPDs are typically the best (or only) way for a project team to identify products made with the above strategies
- **Evaluate cost and carbon in the bid process:** Evaluate carbon, in addition to cost and other criteria, as award criteria in the bid process for both private and public projects

Source: Lewis, M. et al., 2021

REDUCING EMBODIED CARBON

Examples of possible routes for low carbon cement in India

Eliminate use of OPC	• Product stage carbon of OPC= 0.842 kg CO_2e/kg • Product stage carbon of PPC (with 31% fly ash)= 0.582 kg CO_2e/kg
Increase percentage of fly ash and slag in PPC and PSC	• India: Maximum 35% fly ash allowed in PPC • India: Maximum 70% slag allowed in PSC (average 57% current share) • Brazil: Maximum 50% fly ash and 75% BF slag allowed • Canada: 50%–60% fly ash allowed • Europe: 36%–55% fly ash allowed
Use of calcined clay or other materials to replace clinker	• Limestone calcined clay cement (LC3) can reduce CO_2 emissions by up to 40%

Source: Centre for Science and Environment, 2023

REDUCING EMBODIED CARBON

Design with whole life carbon in mind

- While minimizing embodied carbon is vitally important, it must not create adverse or negative outcomes for both operational carbon and whole life carbon. A low embodied carbon building that performs poorly in operation has adverse financial, environmental and social implications
- Action to tackle upfront carbon must be done while designing with whole life carbon in mind. This holistic approach enables a concerted focus on transformational pathways for both net zero embodied carbon and net zero operational carbon

Source: World Green Building Council, 2019

Embodied Carbon in Buildings

Regulations



Image source: https://www.storaenso.com/en/newsroom/news/2022/1/good-for-wood-new-embodied-carbon-

EMBODIED CARBON

Certifications and regulations

Significant improvements have been made in the area of operational carbon since the fuel crisis of the 1970s. Efforts to tackle embodied carbon emissions at a global scale needs to be increased, while continuing to address operational carbon.

One Click LCA in their report, *The Embodied Carbon Review* (2018, updated 2021) studied 156 certification and national regulation systems worldwide that address embodied carbon:

- These embodied carbon reduction systems were largely in the form of voluntary certifications (69%), with regulations (14%), standards like ISO and EN (12%) and guidelines (4%) being the remaining
- 105 included direct measures for embodied carbon, and almost all address it through practices like recycled material use, waste reduction and material efficiency measures
- The highest rates of adoption are in some European regions, and the lowest adoption rates are in Middle East, South America and Asia

Source: One Click LCA, 2018

EMBODIED CARBON REGULATIONS

Typical regulations

- **Carbon reporting:** Calculate the construction project's embodied carbon and report it
- **Carbon comparison:** Compare design options for carbon; e.g., design baseline and proposed designs and show improvements against a self-declared baseline value
- **Carbon rating:** Evaluate carbon performance based on variable scale from best to worst on which a project's carbon is rated, but no effective maximum value applied
- **Carbon cap:** Calculate the project's embodied carbon and prove it is not exceeding the CO_2e limit
- **Decarbonization:** Reduce carbon to a minimum, then compensate all residual emissions by own energy export or buying offsets

Source: One Click LCA, 2018

EMBODIED CARBON REGULATIONS

Incentives for applying carbon reduction policies



Most common form of incentive is better rating in rating systems or building certifications



Embodied carbon reduction policies being a funding condition for building



Provision of density bonus, similar to additional floor area ratio (FAR) provided for green certified buildings in India



Cash impact in the form of funded carbon offsetting or carbon performance payment



Being a mandatory criterion for building

Source: One Click LCA, 2018

EMBODIED CARBON

Benchmarks

- A benchmark establishes a reference point to evaluate the relative performance of a building. For example, Energy Use Intensity (EUI) or Energy Performance Index (EPI) benchmarks are used for operational energy
- Benchmarking for building-level embodied carbon and whole life carbon are not yet widely available. Most available benchmarking studies and standards are for European countries. The quality, representativeness, life cycle scope and included building components also vary greatly

EMBODIED CARBON

Benchmarks

Source	Geographic region	Reference study period	System boundary		Embodied carbon benchmarking values ($kgCO_2e/m^2$)				
			Life cycle scope	Physical scope	Building type				
					Residential	Office	School	Industrial	Mixed
CLF	North America	Assumptions unknown	A only	*Foundation* *Structure* *Enclosure* *Interiors*	200–660	270–540	230–460	–	200–640
LETI	UK	Assumptions unknown	A1–A5	*Substructure* *Superstructure* *Façade* *Internal finishes* *MEP*	800	1,000	1,000	–	–
RIBA	UK	Assumptions unknown	A1–A5 B1–B5 C1–C4	*Substructure* *Superstructure* *Finishes / fixed FF&E* *Building services (and associated refrigerant leakage)*	1,200	1,400	1,400	–	–

Source: Lewis, M. et al., 2023

EMBODIED CARBON

Benchmarks (continued)

Source	Geographic region	Reference study period	System boundary		Embodied carbon benchmarking values ($kgCO_2e/m^2$)				
			Life cycle scope	Physical scope	Building type				
					Residential	Office	School	Industrial	Mixed
One Click LCA	Europe	Assumptions unknown	A1–A3, A4 B4–B5 C1 – C4	*Varies*	–	520–680	380–490	500–560	–
Zimmerman et al.	Denmark	60 years	A1–A3, B4, B6 C3–C4	*Substructure* *Superstructure* *Façade* *Building services* *Vertical circulation*	315–425		–	–	–

Source: Lewis, M. et al., 2023

NET ZERO

Actions for embodied carbon

Government	Investors	Developers	Designers	Manufacturers	NGOs, networks and researchers
• Deliver education and training • Provide financial incentives • Create national roadmaps • Set low carbon public procurement policy • Set benchmarks, targets and require disclosure	• Require a holistic whole life cycle approach • Provide sustainable financial products to incentivize low or zero carbon products or projects • Investor groups to agree and set embodied carbon benchmarks and targets • Collaborate with stock exchanges	• Use LCA and whole life cycle approach • Optimize structural design • Prioritize low carbon materials and require disclosure • Seek innovative solutions • Use financial incentives or contractual obligations	• Educate clients • Specify low carbon materials • Use LCA and whole life cycle approach • Optimize structural design • Seek innovative solutions	• Develop product-specific EPDs • Implement recycling and circularity principles • Maximize process energy efficiency • Implement renewable energy sources • Work with industry to standardize EPDs • Develop innovative low or zero carbon construction materials and products	• Contribute to collection of embodied carbon data • Promote findings of key research • Work with government, public and private sector • Deliver training • Certification schemes require disclosure, EPDs, and set measurement and performance targets

Source: World Green Building Council, 2020

Embodied Carbon in Buildings

Case Examples



Microsoft's headquarters in Redmond, Washington

Image source: https://www.archdaily.com/976015/strategies-to-reduce-embodied-carbon-in-the-built-

CASE EXAMPLE

Houston Advanced Research Center



20% **Embodied Carbon Reduction** **(structural and enclosure)**

0% **Cost Impact** **(No cost premium)**

Strategies:

- Structural system optimization
- Achieved a lighter overall structural framework
- Reduced the need for extensive foundations by minimizing long-span elements
- Optimized concrete slab thickness, reducing material usage
- Utilized advanced concrete mixes with extended strength development times and incorporated alternative cement materials
- Pursued LEED Platinum certification to meet top-tier sustainability standards

Source: Huynh, T. et al., 2023

CASE EXAMPLE

Toronto Emergency Medical Services Station



Strategies:

- Utilized low-impact extruded polystyrene (XPS) insulation
- Increased the percentage of supplementary cementitious materials (SCMs) in the concrete mix
- Applied an environmentally-friendly concrete slab sealant
- Incorporated steel with high recycled content
- Substituted traditional concrete masonry units (CMU) with hempcrete blocks
- Employed recycled glass gravel as insulation

30% Embodied Carbon Reduction

0% Cost Impact (No cost premium)

Source: Huynh, T. et al., 2023

CASE EXAMPLE

Mixed use mid-rise office building



46% Embodied Carbon Reduction

0% **Cost Impact**
Premiums due to lower carbon glazing products and strategic procurement of steel

Strategies:

- Used concrete mixes with reduced cement content
- Opted for mixes with extended concrete curing times
- Replaced XPS insulation with polyiso or mineral wool alternatives
- Incorporated steel with a high recycled content
- Substituted standard gypsum sheathing with alternative materials
- Used glazing products with a lower carbon footprint

Source: Huynh, T. et al., 2023

CASE EXAMPLE

SDE1 and SDE3 Blocks, NUS Kent Ridge Campus



- SDE1 and SDE3 are among the oldest buildings on the National University of Singapore (NUS) Kent Ridge Campus, built in the 1970s
- By adaptive reuse of the building, embodied carbon of the building is to be lower than a third of a similar new construction
- Cost of renovating the buildings is substantially lower than demolishing it and constructing a new building
- By incorporating strategies like extended west façade, hybrid cooling system, and building management system for better operation, it is targeting to achieve net zero operational carbon emissions

Adaptive reuse of old building

Net zero operational carbon

Source: National University of Singapore, 2023

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

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Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy | PROJECT

3.3 Understanding Operational Energy in Buildings

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

01 Operational energy and its end uses for different services

02 HVAC: Basics and commonly-used systems

03 Lighting: Basics and commonly-used systems

04 Commonly-used systems for other services

05 Operational energy indices

06 Energy star rating for buildings and key appliances



BUILDING OPERATIONAL ENERGY

The energy used for operating equipment in a building

Operational energy of buildings is the energy in the form of electricity and fuels for operating various equipment for providing comfortable room conditions for the occupants and operate various building equipment



HVAC equipment: Heating, ventilation and air-conditioning equipment to maintain comfortable indoor temperature and air quality



Electric lighting: Artificial lighting system to perform task when daylight is not sufficient or available



Hot water systems:

Electric or fuel-fired equipment providing hot water for bathing, cooking, laundry, cleaning, etc.



Appliances: Refrigerators, deep freezers, computers, printers, projectors, television sets, etc.



Other services: Elevators, escalators, water pumps, kitchen and pantry appliances, etc.

OPERATIONAL CARBON

Emissions associated with operational energy use

$$Operational\ carbon\ (kgCO_2e) = Total\ Opertional\ energy\ usage\ (kWh)\ *\ Emission\ factor\ fuel\ used\ (\frac{kgCO_2}{kWh})$$

- In most cases, the fuel used is grid electricity, thereby emission factor of grid electricity for the particular country is considered
- For other fuels, standard emission factors accepted globally are considered

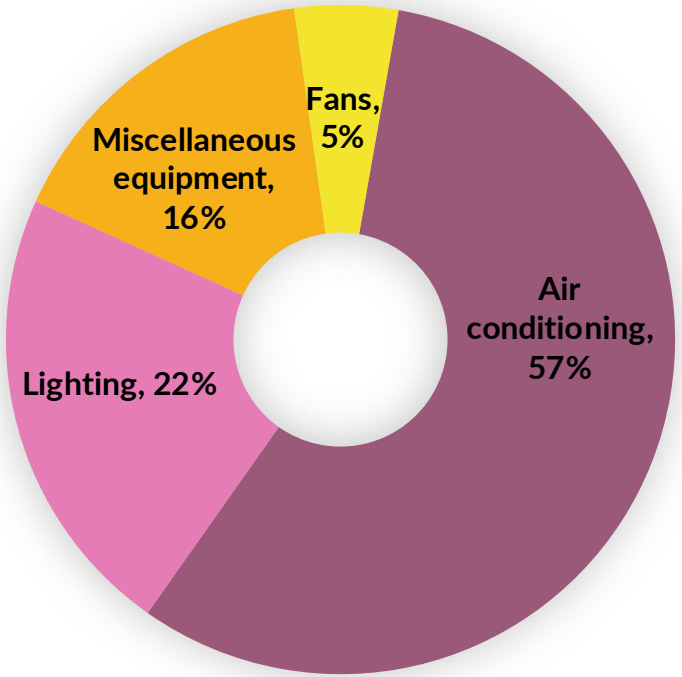
BUILDING OPERATIONAL ENERGY

End-use energy distribution in commercial buildings

Typically, in an air-conditioned commercial building, the energy consumption has four major components:

i. HVAC system (50%–70%)
ii. Lighting (5%–20%),
iii. Appliances (10%–20%)
iv. Ventilation and exhaust fans (1%–5%)

End-use energy distribution in a typical commercial building



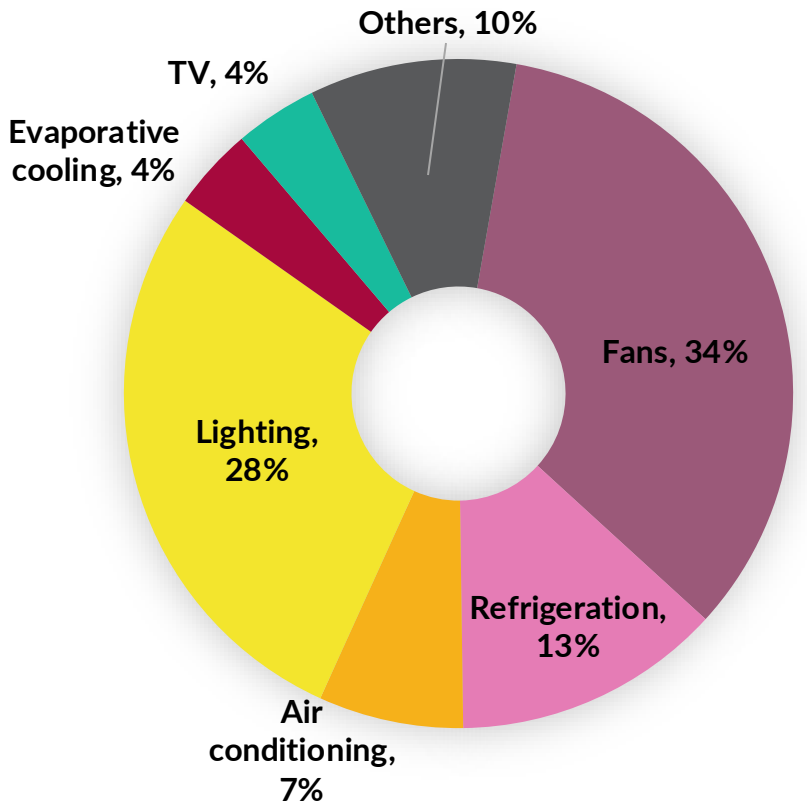
BUILDING OPERATIONAL ENERGY

End-use energy distribution in residential buildings

In India, studies of end uses in residential buildings show the following estimates:

- Energy for thermal comfort (air conditioning, evaporative coolers and fans) is about 45%
- Lighting is the second large end use accounting for about 28%
- Other appliances (including television sets, refrigerators, water heaters and various appliances) account for about 27%

End-use energy distribution in a typical residential building



Source: Bureau of Energy Efficiency, Government of India

HVAC

Basics and Commonly-used Systems

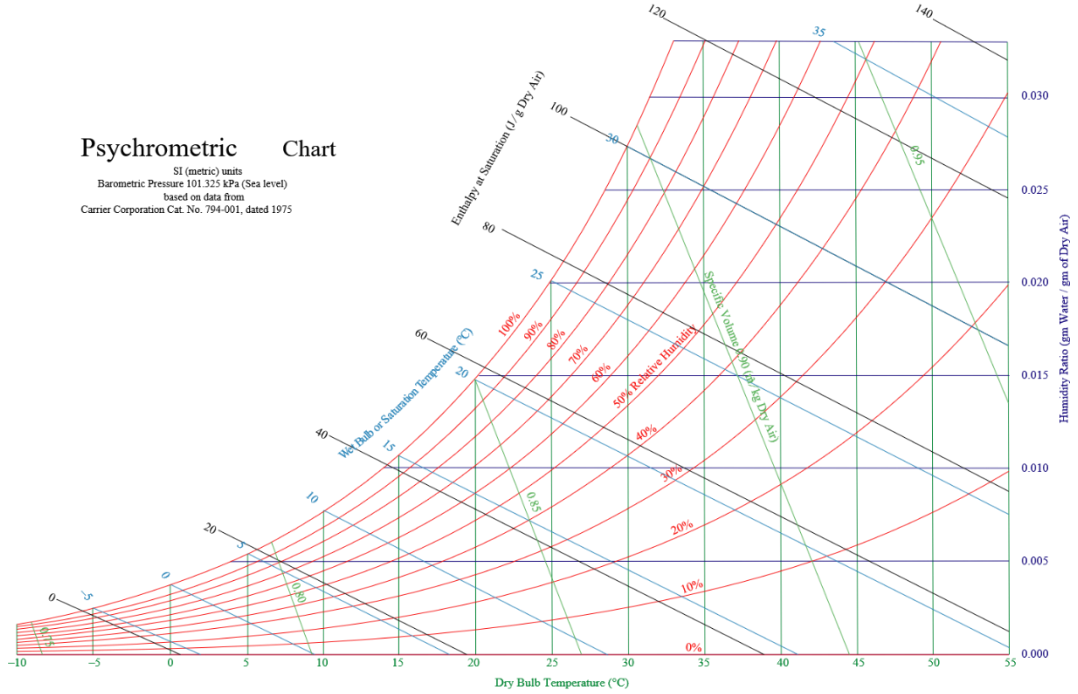


Image source: https://envigaurd.com/topics/what-is-hvac-

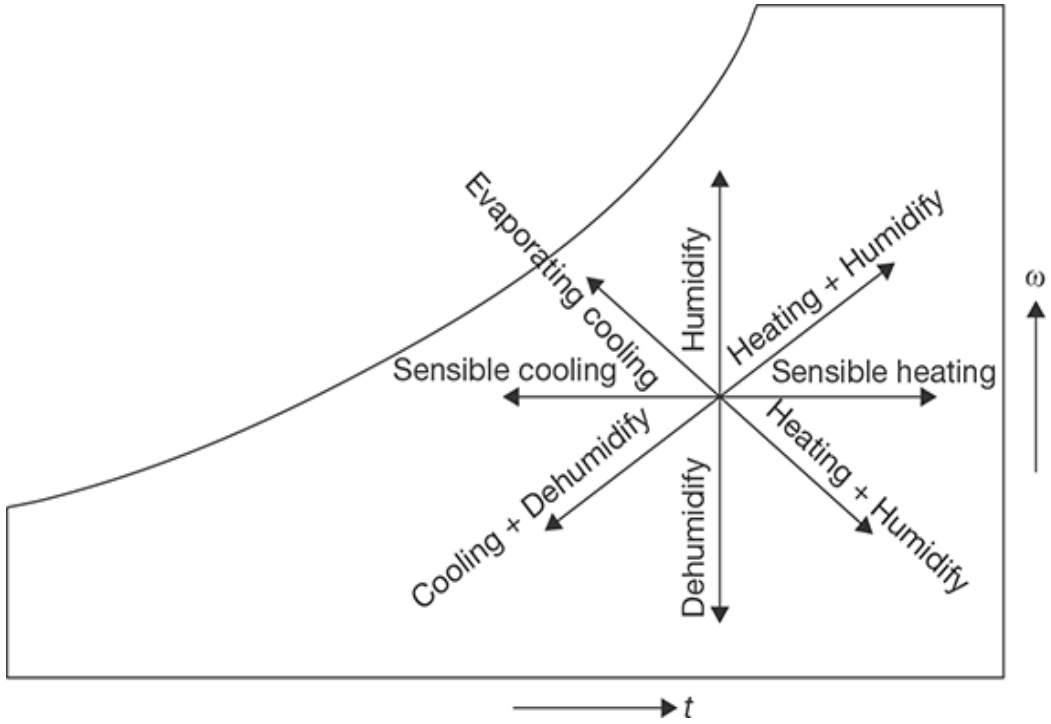
AIR PROPERTIES

Understanding condition of air on the psychrometric chart

A psychrometric chart is a family of graphs that shows the properties of air – dry bulb temperature, wet bulb temperature, relative humidity, dew point temperature, humidity ratio, total heat content (enthalpy) and specific volume at a specific barometric pressure



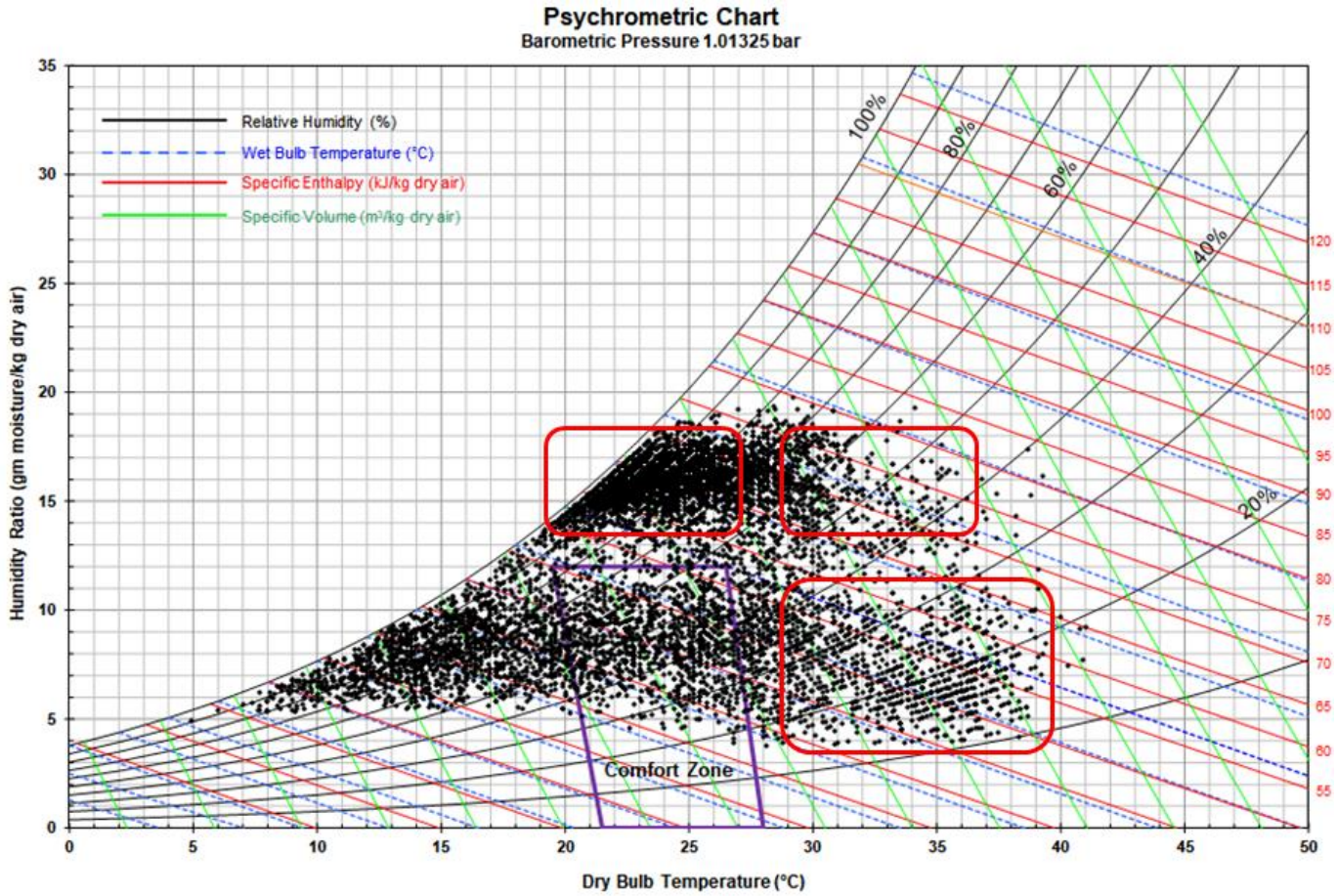
It is important to assess thermal comfort and understand the process of cooling, heating, dehumidification and humidification of air properties



THE NEED FOR HVAC

An example of Pune, India: Ambient conditions

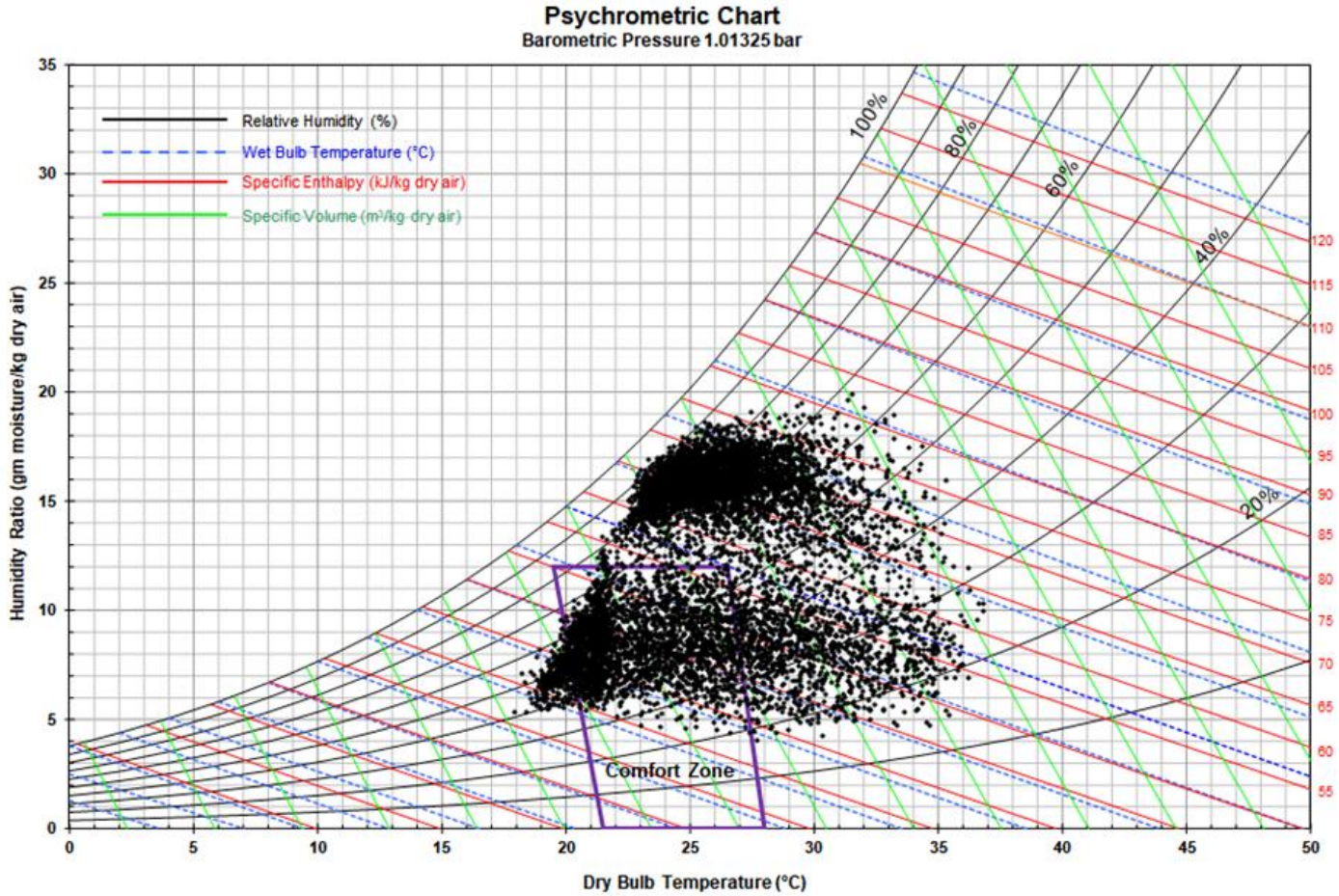
On an annual basis, the ambient conditions (indicated by black dots) are outside the human thermal comfort zone for a significant duration of the time



THE NEED FOR HVAC

Room conditions inside the building without HVAC

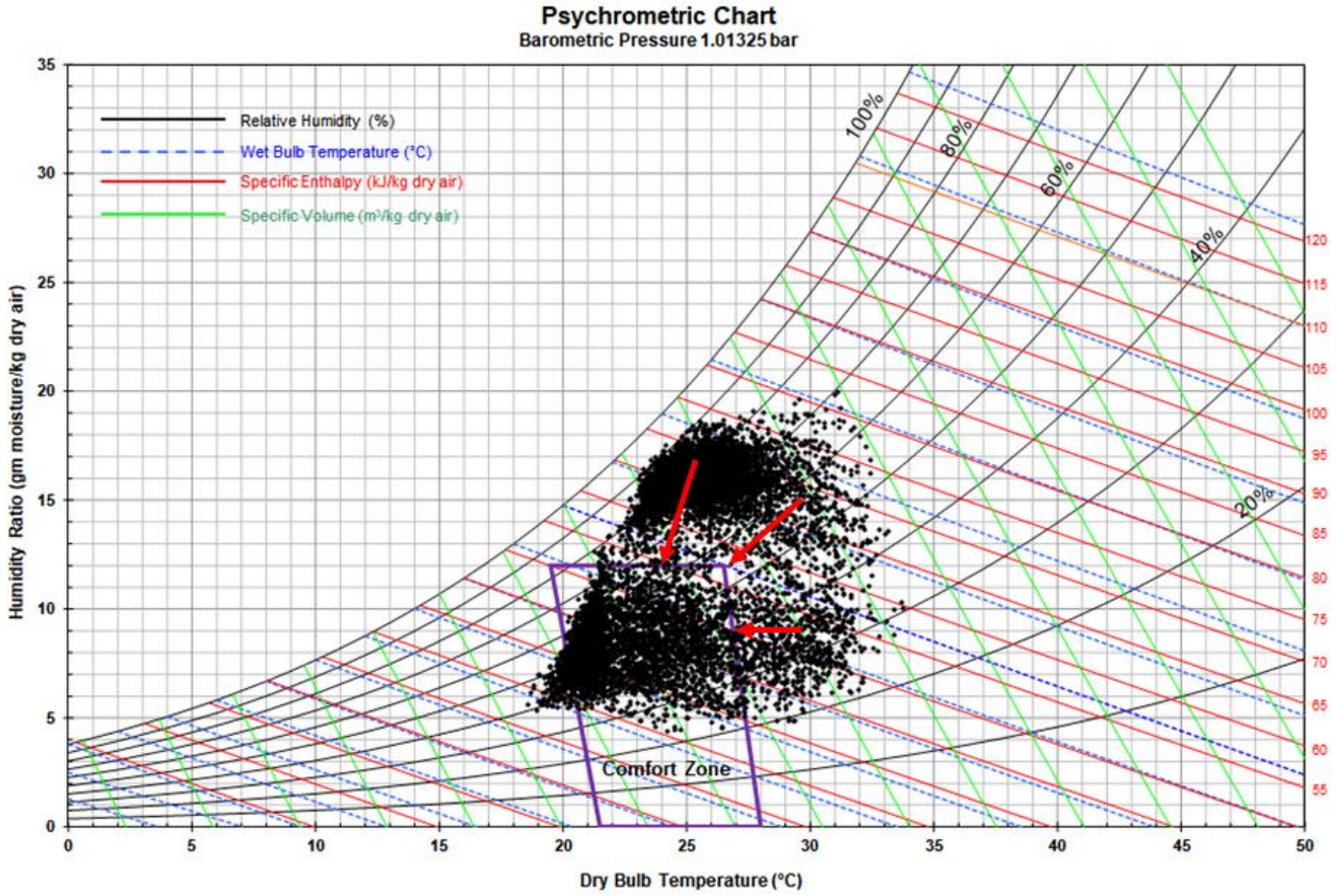
- Even with a business-as-usual building design, the conditions inside the building, compared to the ambient conditions, have less variations (observe the higher density of black dots in the comfort zone)
- However, for significant duration of time, the inside conditions fall outside the thermal comfort zone



UNDERSTANDING THE NEED FOR HVAC

Room conditions with passive architectural measures

- Passive architectural measures help in partially moving inside conditions toward the thermal comfort zone
- Still, a significant portion of time duration will remain outside the thermal comfort zone
- **HVAC systems are needed to ensure that the entire time duration is within the comfort zone**



AIR CONDITIONING

Objectives

- Remove sensible heat from a confined place to maintain constant temperature inside the space
- Remove water (latent heat) from a confined space to maintain constant humidity inside the space
- Remove dust generated and contaminants in a confined space by air-sweeping
- Prevent dust and atmospheric contaminations from entering into a confined space
- Prevent microbial growth and cross-contamination between spaces

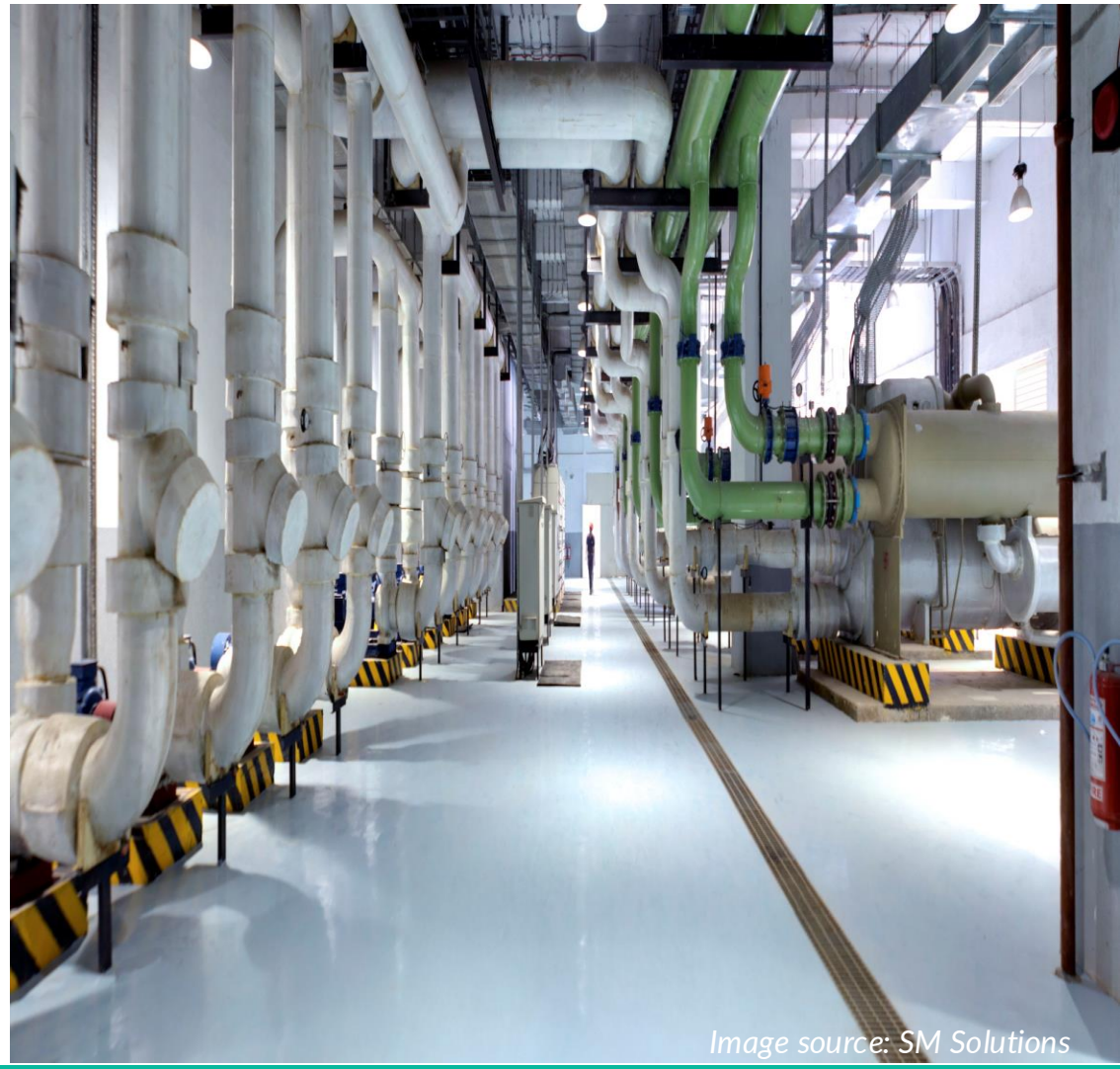
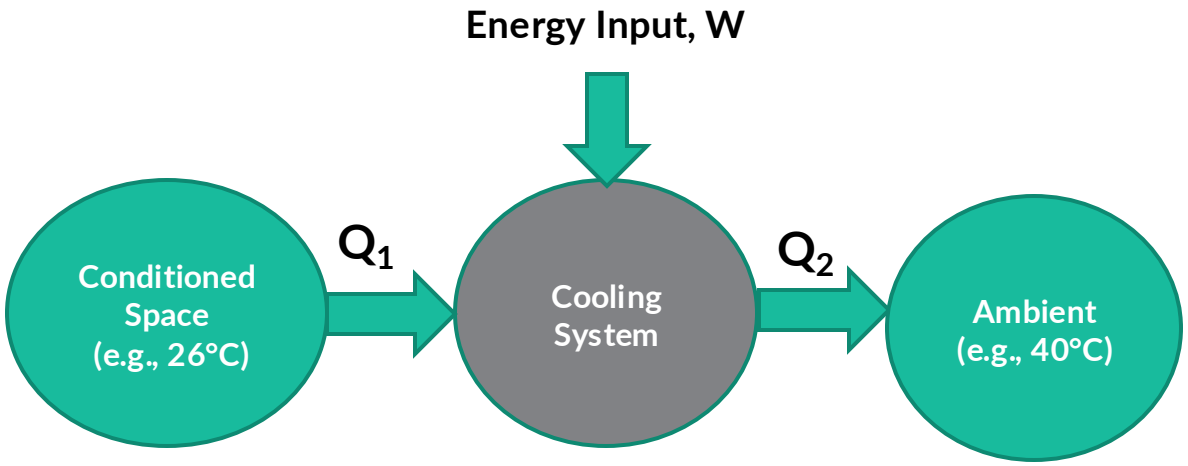


Image source: SM Solutions

TYPICAL COOLING AND HEATING SYSTEMS

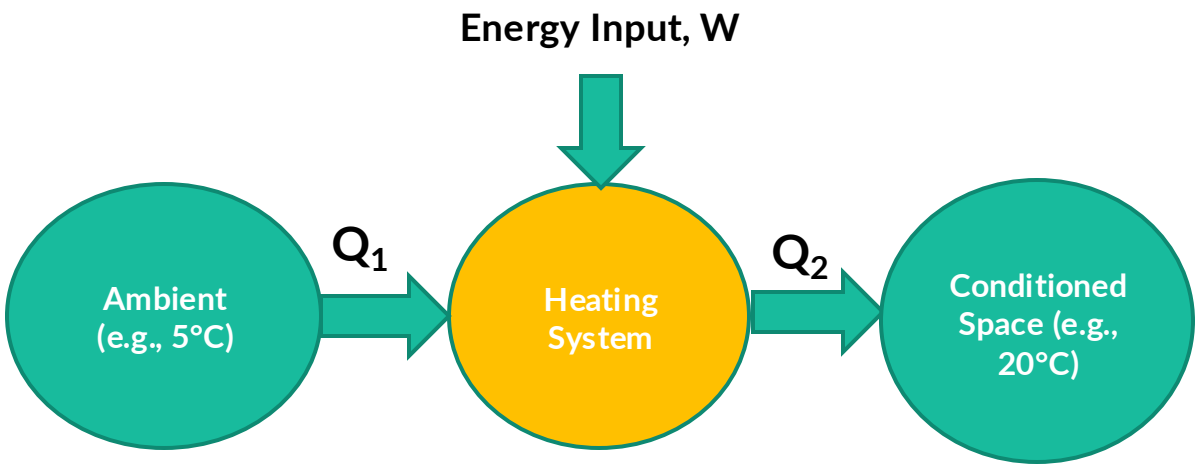
Basic heat balance and figure of merit

- Typical cooling uses some amount of energy (work) to move heat from low temperature to high temperature
- The figure of merit for assessing the efficiency is the coefficient of performance (COP)



$$Energy\ Balance, Q_1 + W = Q_2$$

$$Coefficient\ of\ Performance\ (COP) = \frac{Desired\ effect\ Q_1}{Required\ Input\ W}$$



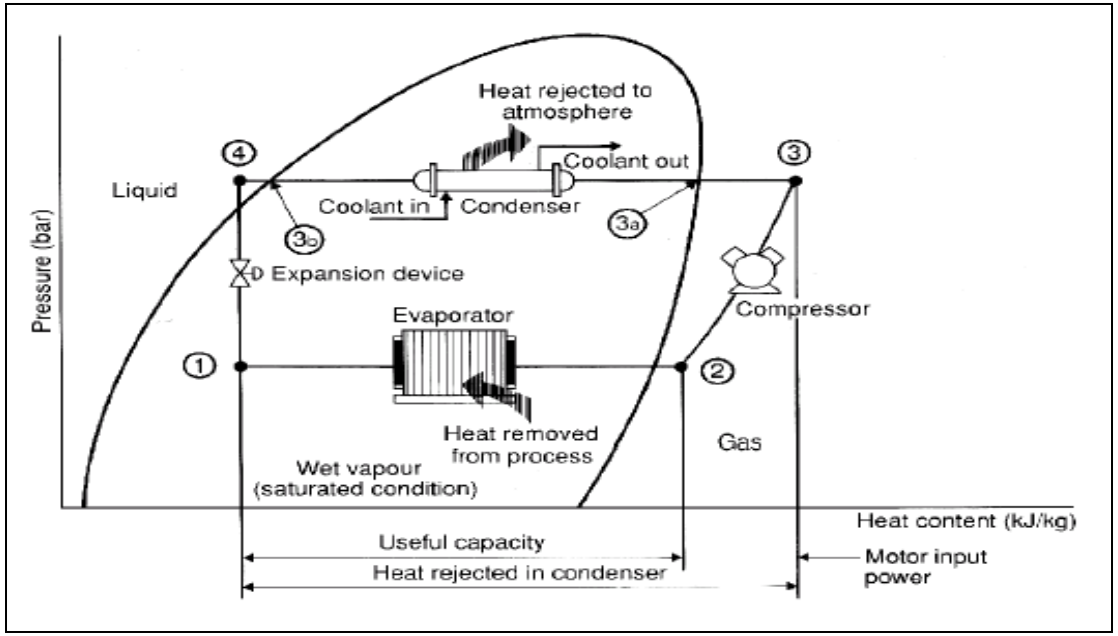
$$Energy\ Balance, Q_1 + W = Q_2$$

$$Coefficient\ of\ Performance\ (COP) = \frac{Desired\ effect\ Q_2}{Required\ Input\ W}$$

VAPOR COMPRESSION SYSTEM

Understanding the thermodynamics

- Heat naturally flows from higher to lower temperature. However, in refrigeration, heat must be transferred from a lower temperature to the ambient at a higher temperature. The second law of thermodynamics says that for transferring heat from a lower temperature to a higher temperature, work must be done
- In a vapor compression refrigeration system, this work is done by the condenser. The figure shows the vapor compression process on a pressure – enthalpy (or heat content) diagram:
  - Refrigerant evaporates in the evaporator at low temperature and pressure to chill water or air (1–2)
  - The vaporized refrigerant gas is compressed to raise its pressure and temperature above ambient temperature (2–3)
  - The heat is rejected to the atmosphere in water-cooled or air-cooled condenser, resulting in the condensation of the refrigerant gas into liquid at high pressure and low temperature (3–4)
  - The high pressure, low temperature liquid refrigerant from the condenser returns to the low pressure evaporator, resulting in evaporation of the refrigerant, providing cooling; the cycle repeats



Pressure – enthalpy (heat content) diagram

AIR-CONDITIONING (AC) SYSTEMS

Typical equipment and configurations

- Window air-conditioners
- Split ductable / non-ductable systems
- VRV ductable / non-ductable systems
- Centralized AC systems comprising of:
  - The chiller (chilled water generator)
  - Chilled water storage and pumping system
  - Air handling units (AHUs)
  - Ducting of air and its filtration



Window air conditioner



Split air conditioner



VRV AC system



Centralized AC system

SMALL COOLING SYSTEMS

Window and split air conditioners

Window air conditioner

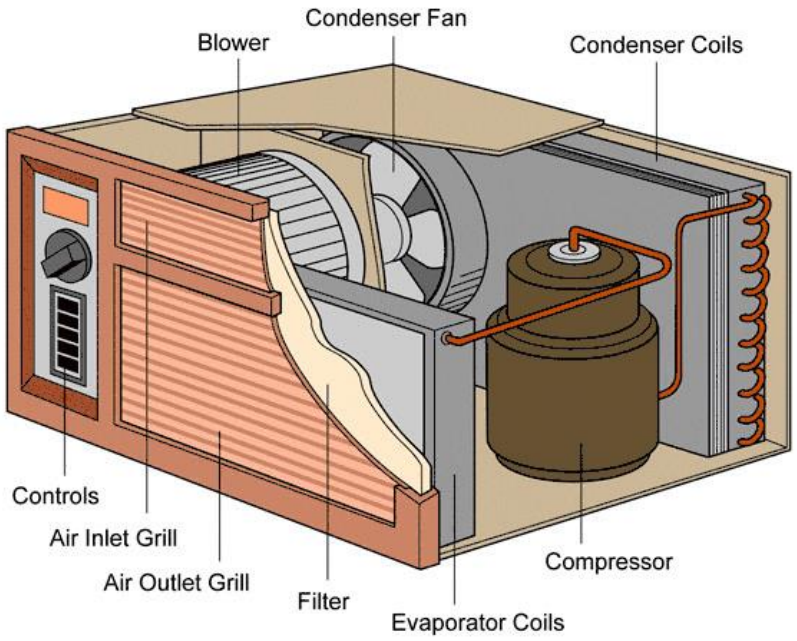


Image source: https://www.hometips.com/how-it-works/air-conditioners-room-window.html

Split air conditioner

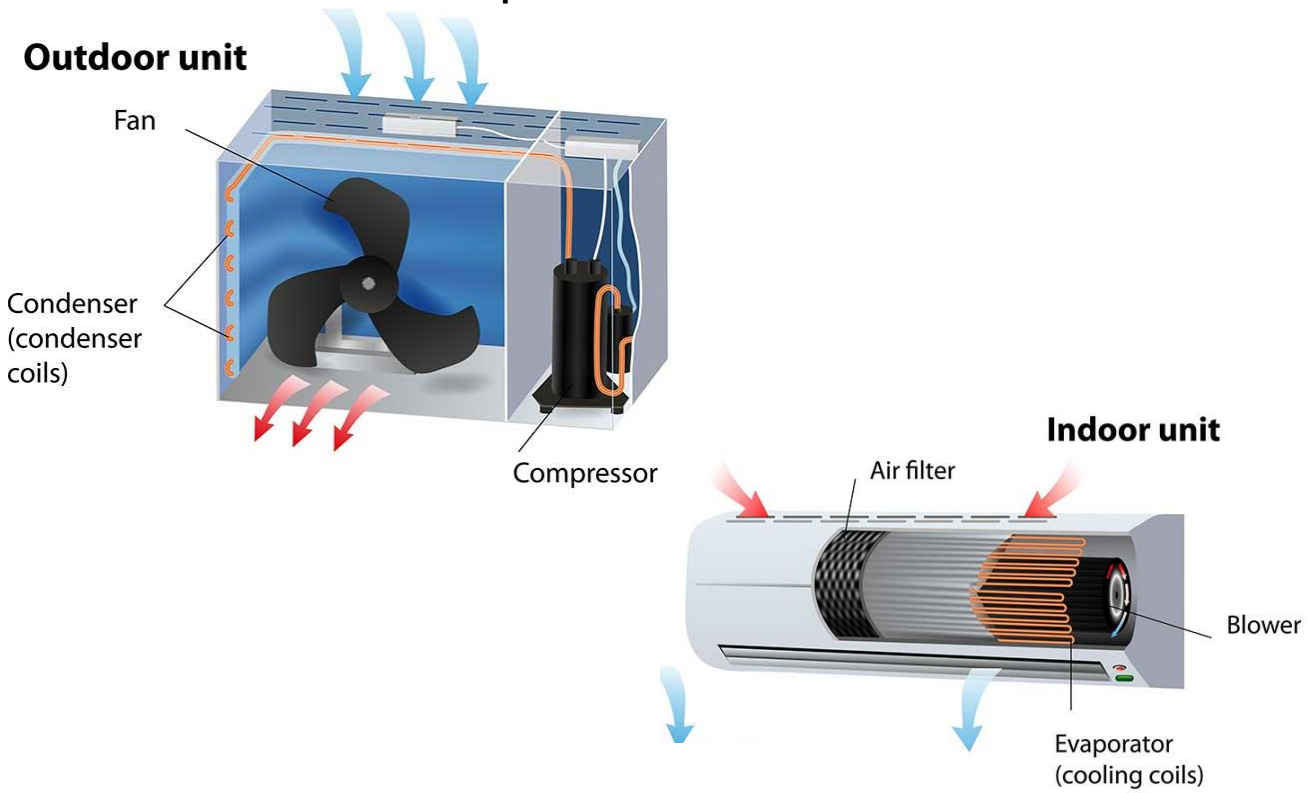


Image source: https://bprassets.s3.amazonaws.com/blogfiles/assets/images/post/Body%20Pics/05-03-12_images/split-system-indoor-and-outdoor-air-conditioning-units-diagram.jpg

VRF AIR CONDITIONERS

Variable refrigerant flow (VRF) for mid-sized applications

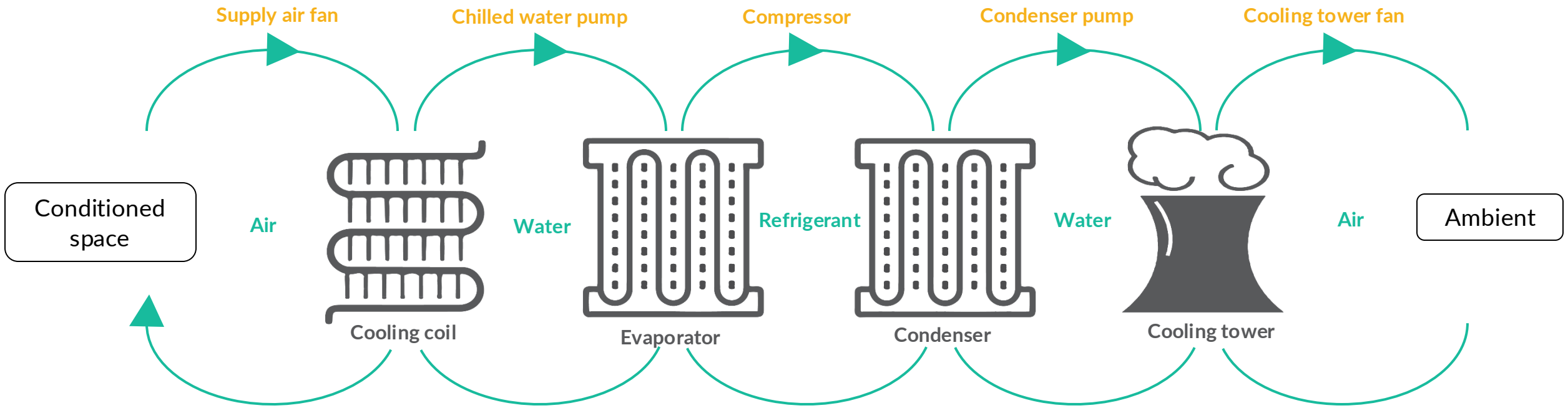
- For addressing variable loads, VRF type DX systems are gaining popularity
- It avoids installation of large ducts in user areas and avoids issues related to managing false ceiling heights
- In the user areas, cassette units or hi-wall units can be installed, depending on convenience of installation
- Even DX type AHUs can be designed to cater to special requirements of high static head and filtration levels



Image source: SM Solutions

CENTRAL COOLING SYSTEM

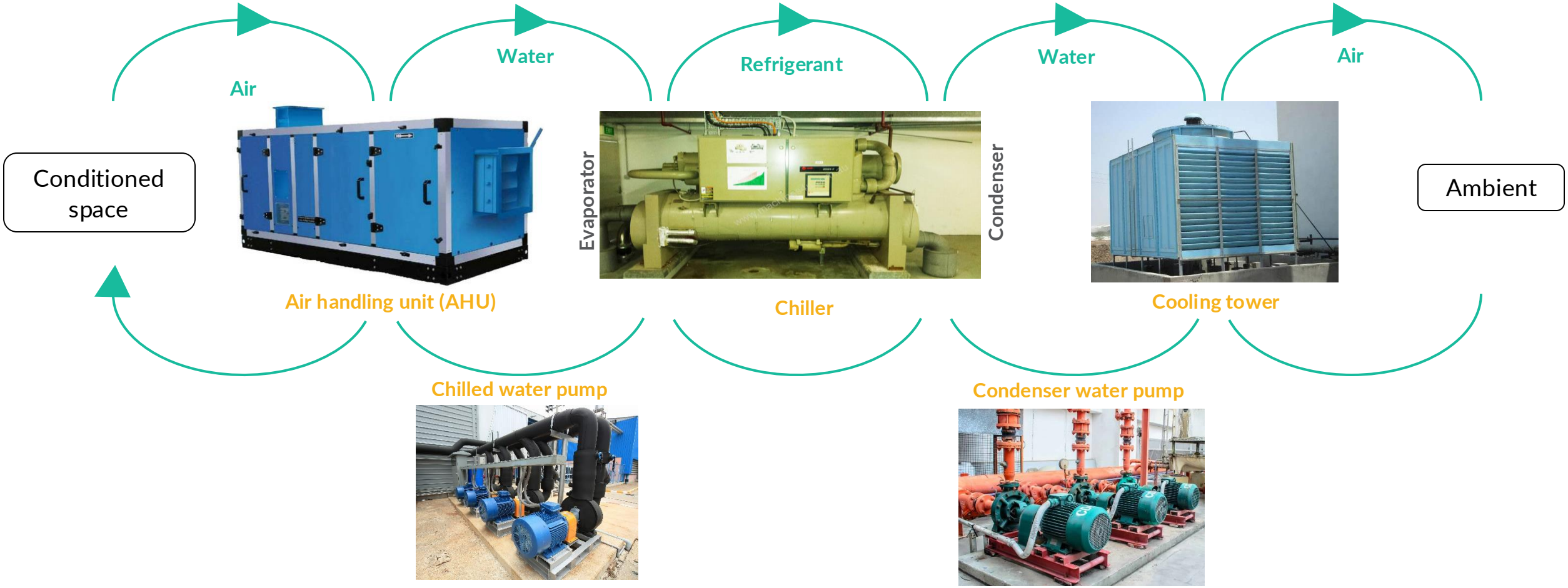
A conceptual overview



Thermodynamically, heat rejected at cooling tower is equal to summation of cooling effect delivered at evaporator and energy consumed by the chiller compressor

CENTRAL COOLING SYSTEM

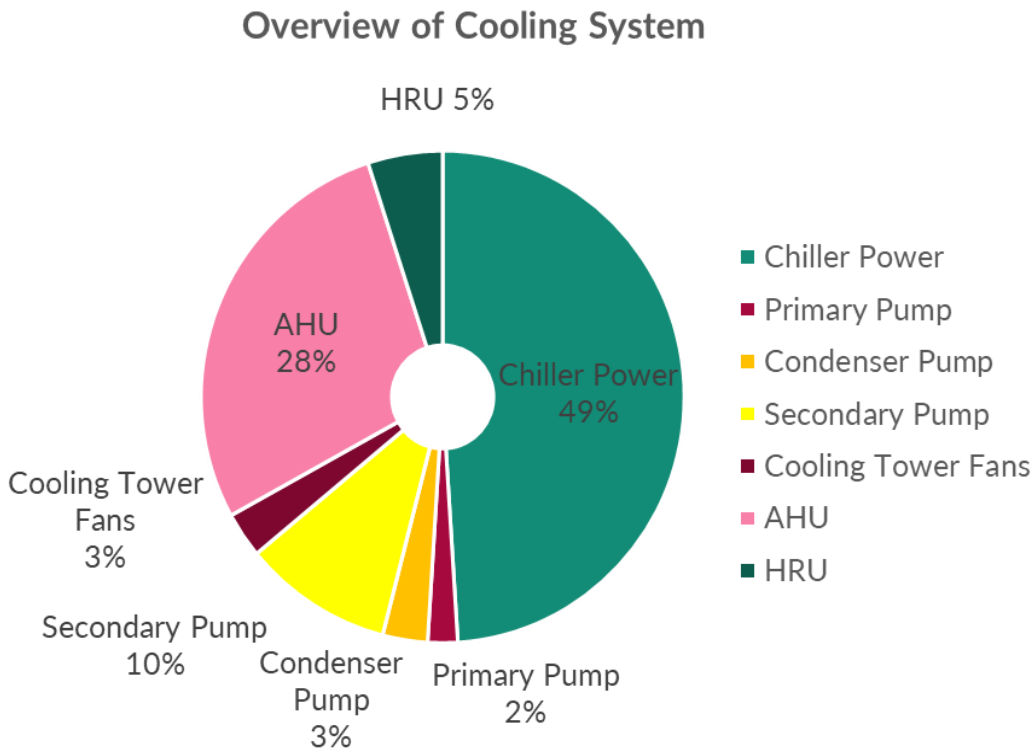
Main components



HVAC: ENERGY DISTRIBUTION

Water chillers are the major load

- In HVAC systems in commercial buildings, the water chillers account for almost 50% of load
- The other loads account for the following:
  - AHUs (28%)
  - Pumps (15%)
  - Heat recovery wheels (5%)
  - Cooling tower fans (3%)



QUANTIFYING COOLING EFFECT

Common terminologies and conversions

Definition of 'ton of refrigeration (TR)':

The amount of energy required to convert 1 ton of water at 0°C into ice within 24 hours

The relation between TR and its equivalent energy terms is as follows:

1 TR equals to:

- 3,024 kcal/h
- 3.51 kW
- 12,000 Btu/h

REFRIGERATION

Energy efficiency: Figures of merit

Quantification of Refrigeration Effect

1 Ton of Refrigeration (TR) = 3,023 kcal/h

= 3.51 $kW_{thermal}$

= 12,000 Btu/h

Coefficient of Performance (COP) = Refrigeration Effect / Work Done

Energy Efficiency Ratio (EER) = Refrigeration Effect (Btu/h) / Work Done (Watts)

Specific Power Consumption (SPC) = Power Consumption (kW) / Refrigeration Effect (TR)

Sample calculations

Refrigeration Load = 50 TR, say

= 175.5 $kW_{thermal}$

= 600,000 Btu/h

Compressor power consumption = 40 kW, say

$$COP = \frac{175.5}{40} = 4.39$$

$$EER = \frac{600{,}000}{(40 \times 1{,}000)} = 15$$

$$SEC = \frac{40}{50} = 0.80 \text{ kW/TR}$$

CHILLER EFFICIENCY

Figures of merit for water-cooled and air-cooled chillers

For water-cooled chillers:

SEC = 0.45 kW/TR – 0.65 kW/TR

COP = 5.4–7.8

EER = 18.5–26.7

For air-cooled chillers:

SEC = 0.90 kW/TR – 1.20 kW/TR

COP = 2.9–3.9

EER = 10–13.3

Higher COP / EER and lower SEC imply better system performance

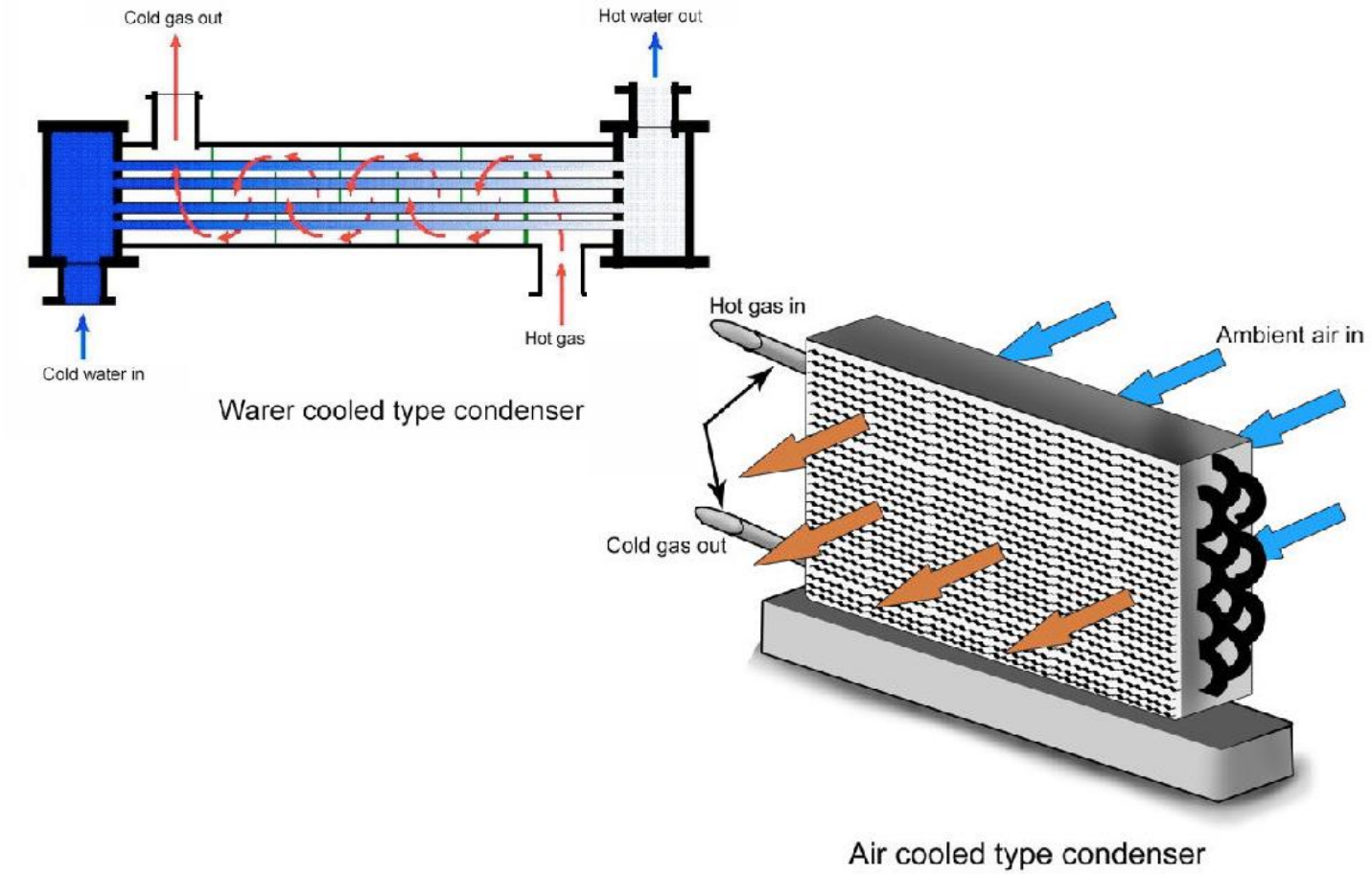


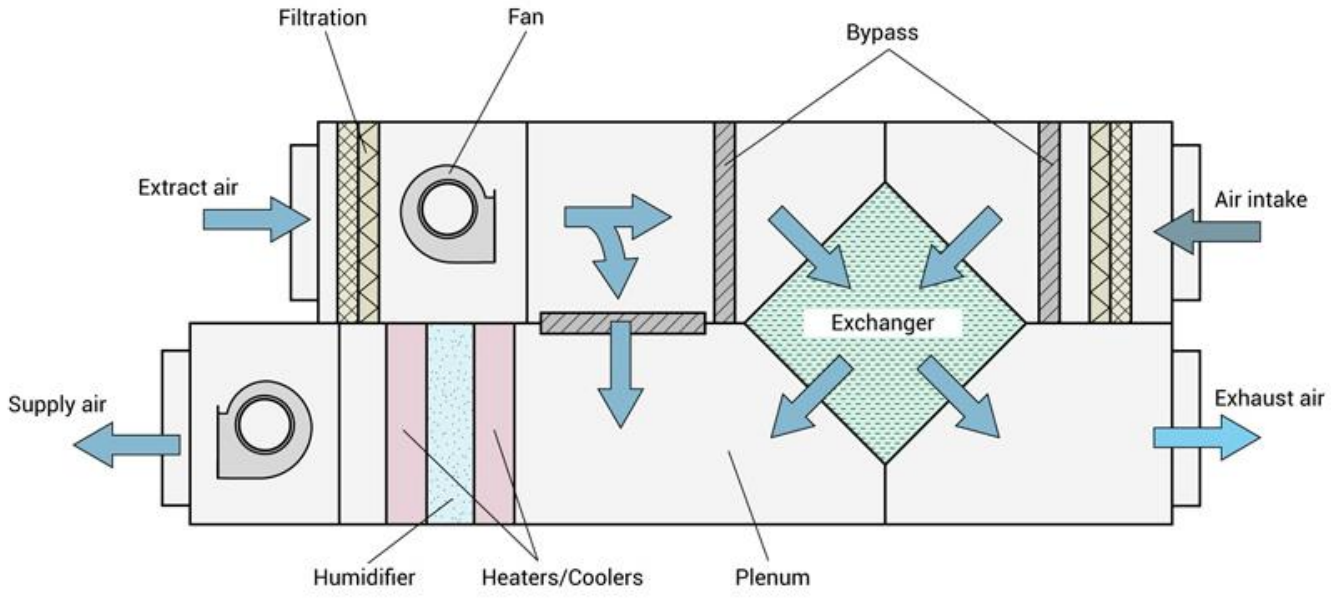
Image source: https://www.senho-chiller.com/technical-suport/difference-between-air-cooled-and-water-cooled-chiller.html

AIR HANDLING UNIT (AHU)

Components and energy consumption

- Key components
  - Supply fan
  - Return fan
  - Filters
  - Heating / cooling coils
  - Heat exchanger (optional)

- The energy consumption is determined by the air flow, pressure, and fan and motor efficiencies
- Operation at optimal air flows, determined by cooling load, optimal pressure (without excessive damper control), and use of appropriately-sized, high-efficiency fans and motors, preferably controlled by variable frequency drives, are desirable



Air handling unit

Image source: https://www.airtecnics.com/news/what-is-an-air-handling-unit-ahu

PUMPS IN HVAC SYSTEM

Components and energy consumption

- **Chilled water pumps** supply chilled water to AHU, which is cooled through the chiller. The connecting pipes are insulated to reduce heat loss
- **Condenser water pumps** circulate water to the cooling tower, removing heat from the condenser (heat rejection side) of the chiller. The connecting pipes are generally not insulated

The energy consumption is determined by the water flow, pressure, and pump and motor efficiencies

Operation at optimal water flows, determined by cooling load, optimal pressure (with excessive valve throttling), and use of appropriately-sized, high-efficiency pumps and motors, preferably controlled by variable frequency drives, are desirable



Chiller water pump

Image source: https://www.durapump.co.uk/how-to-improve-chilled-cooled-water-system-efficiency/



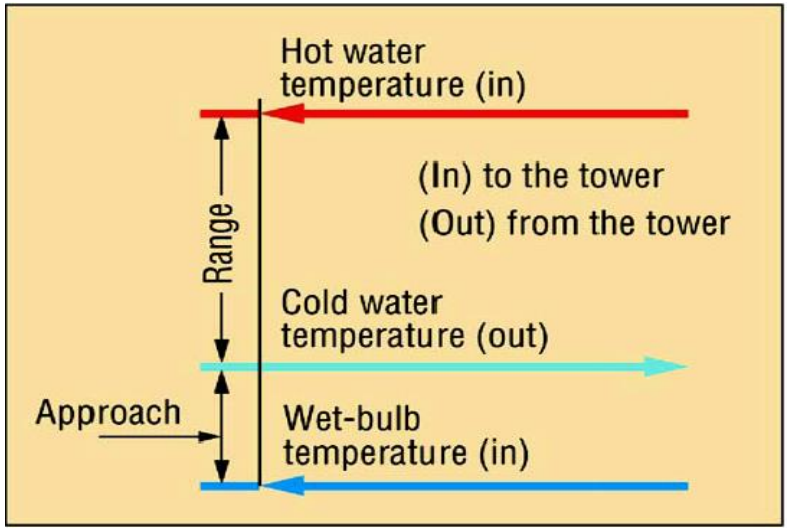
Condenser water pump

Image source: https://aircondlounge.com/how-to-calculate-chilled-water-pump-head/

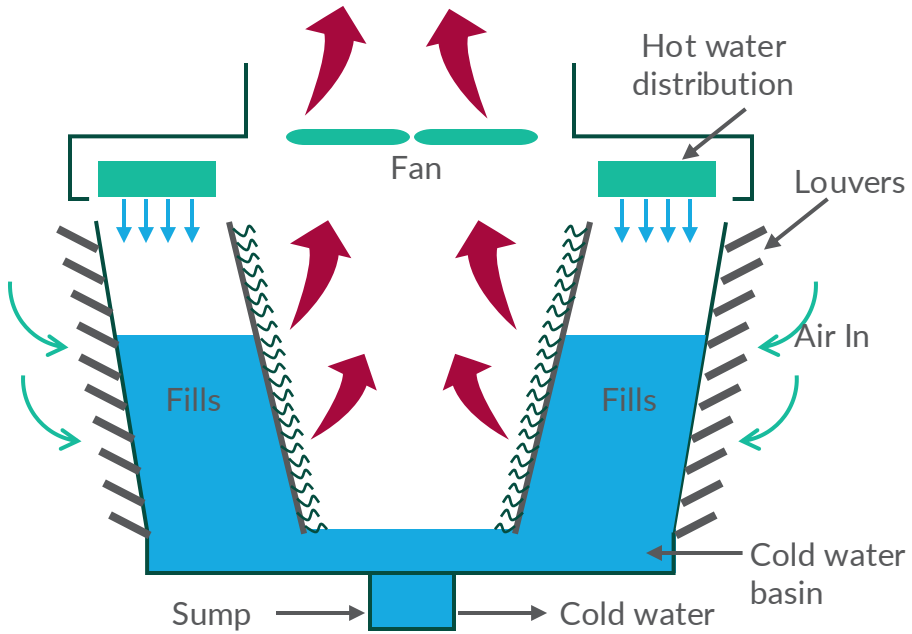
COOLING TOWER

Important parameters: Temperature range and temperature approach

Latent heat of condensation of the refrigerant vapor is transferred to the cooling water and rejected to the atmosphere by vaporization of water in the cooling tower, assisted by air flow



- **Range:** **Entering Water Temperature – Leaving Water Temperature**
- **Approach:** **Wet-bulb Temperature – Leaving Water Temperature**
- **Effectiveness:** **Range / (Range + Approach) {higher is better}**



Induced draft, double-flow crossflow tower

Source: Bureau of Energy Efficiency, Government of India, 2015

OVERALL SYSTEM EFFICIENCY

Including all components of the chilled water system.

- The combined central chilled water plant includes chillers, chilled water pumps, cooling water pumps and cooling tower fan (excluding air handling units)
- The figure of merit for assessing design system efficiency of central chilled water plant is defined as:

  (total installed motor capacity, kW) per (refrigeration capacity, kW_r)
- In India, the Energy Conservation Building Code 2017 defines this threshold as 0.26 kW / kW_r

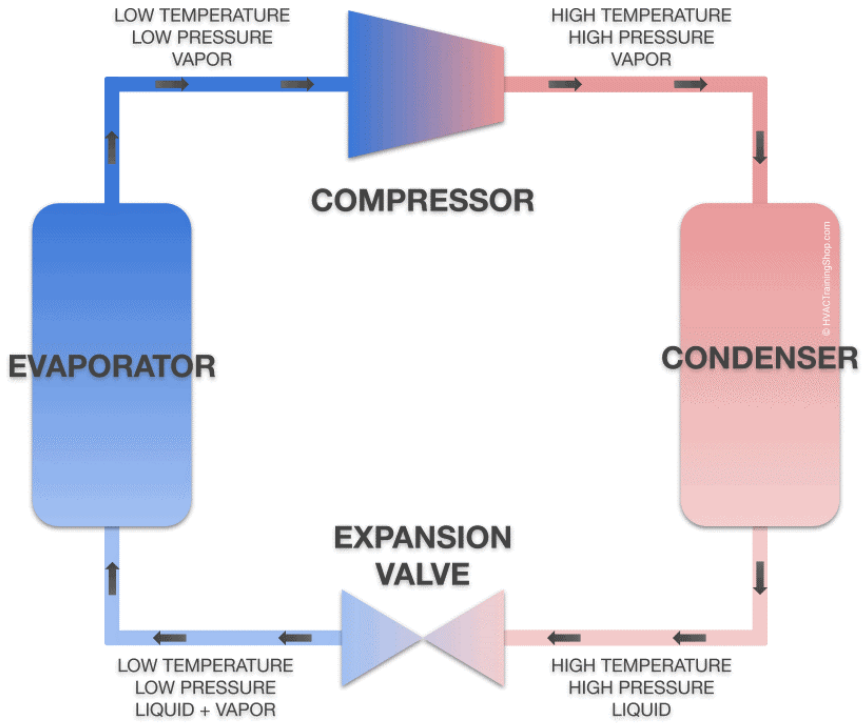


Image source: https://www.linkedin.com/pulse/how-chilled-water-system-works-muhammad-adnan-arshad/

LIGHTING

Basics and Commonly-used Systems



LIGHTING LUMINAIRES

Common indoor and outdoor luminaires





LIGHTING SYSTEMS

Performance parameters

- **Luminous flux** describes the quantity of light emitted by a light source. The most common measurement or unit of luminous flux is the **lumen (lm)**. The lumen rating of a lamp is a measure of the total light output of the lamp
- **Illuminance** is the quotient of the luminous flux incident on an element of the surface at a point of surface containing the point, by the area of that element. **Lux (lx)** is the metric unit of measure for illuminance of a surface
- **Luminous efficacy** is the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. It is a reflection of efficiency of energy conversion from electricity to light form (**unit: lumens per lamp watt (lm/W)**
- **Color Rendering Index (CRI)** is a measure of the effect of light on the perceived color of objects. It ranges from 0–100. A low CRI indicates that some colors may appear unnatural when illuminated by the lamp

$$E(Lux) = \frac{Lumens \times Design\ Factor}{Area}$$

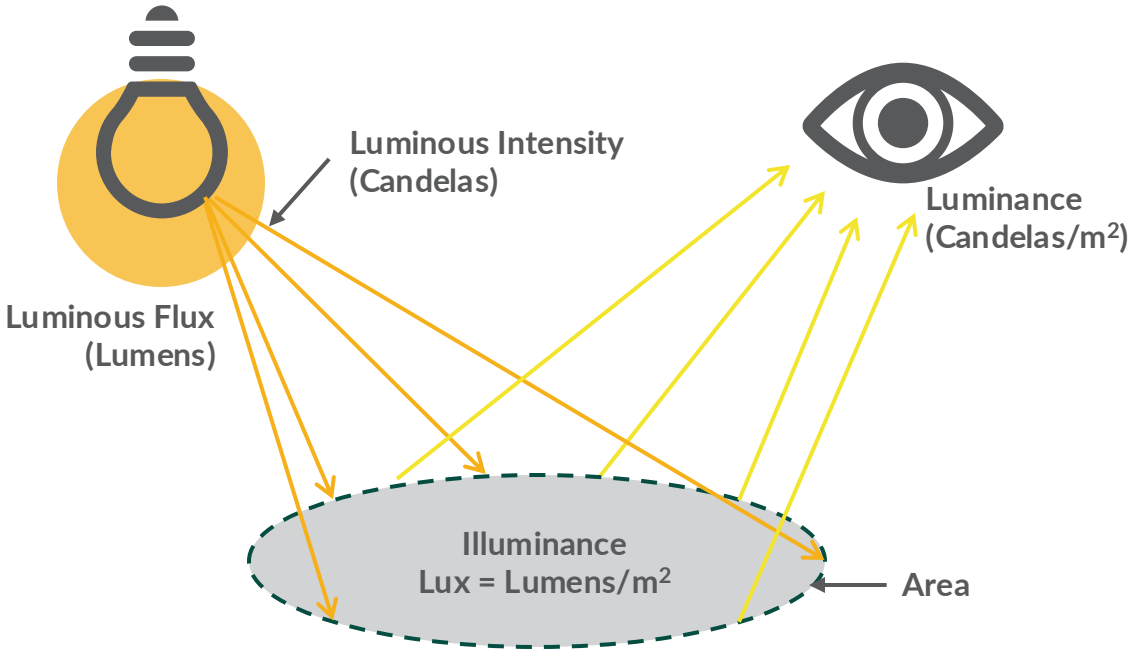


Image source: https://www.etaplighting.com/en/blog/lux-and-lumen-whats-difference

LIGHTING SYSTEMS

Commonly-used lamps

Conventional Lamps



Incandescent Lamp



Tubular Fluorescent Lamp

LED Lamps



Compact Fluorescent Lamp



LED Lamp



LED Tube Light

Lamps: Important Parameters

Type of Lamp	Life Span (in hours)	Lumens/ watt	Color Rendering Index (CRI)
Incandescent Lamp	1,000–2,000	8–18	100 (Excellent)
Compact Fluorescent Lamp (CFL)	12,000	40–70	85 (Very Good)
Tubular Fluorescent Lamp	25,000–40,000	46–60	67–77 (Good)
LED Tube Light/Bulb	50,000–100,000	50–130	80 (Very Good)

Source: Bureau of Energy Efficiency, Government of India, 2015

OTHER SERVICES

Commonly-used Equipment and Systems



Image source:

OTHER SERVICES

Efficiency metrics and minimum efficiency levels

- The system efficiency levels are prescribed at both international and national levels, and are updated at regular intervals
- Internationally, the minimum equipment efficiency values defined in **ASHRAE Standard 90.1** are well recognized and widely used. Meeting the prescriptions of the latest edition can ensure that selected systems will require lower operational energy
- At national levels, the local codes or standards will **supersede**; for example, in **India**, the **Energy Conservation Building Code (ECBC)** is applicable to both commercial and residential buildings. The minimum equipment efficiency values are prescribed with reference to the local conditions, available systems and future prescriptions on minimum performance levels
- The metrics for India's Star Labeling Program for appliances and equipment is referred to later in this module

SERVICE EQUIPMENT

With significant energy consumption: Ceiling fans and electric water heaters

PRESCRIBED PERFORMANCE PARAMETER

Service value is calculated as the ratio of air delivery (in cubic meters per minute) to power consumption (in watts)



PRESCRIBED PERFORMANCE PARAMETER

Standing loss is measured in kilowatt-hours per day (kWh/24 hours) for a temperature difference of 45°C. It indicates how much energy the water heater loses while maintaining the water temperature



SERVICE EQUIPMENT

With significant energy consumption: Pumps and elevators (lifts)

PRESCRIBED PERFORMANCE PARAMETER

Power consumption (kW) at specified head and flow



PRESCRIBED GUIDELINES

- **Compliance:** Guideline VDI 4707: Class 1–5 for energy efficiency of lifts
- **Type of motor:** Use of IE3 motor and above
- Use of variable voltage variable frequency drives and regenerative drives
- **Lumen efficacy of lamps in lifts: O**ver 85 lumen/W



Operational Energy Indices

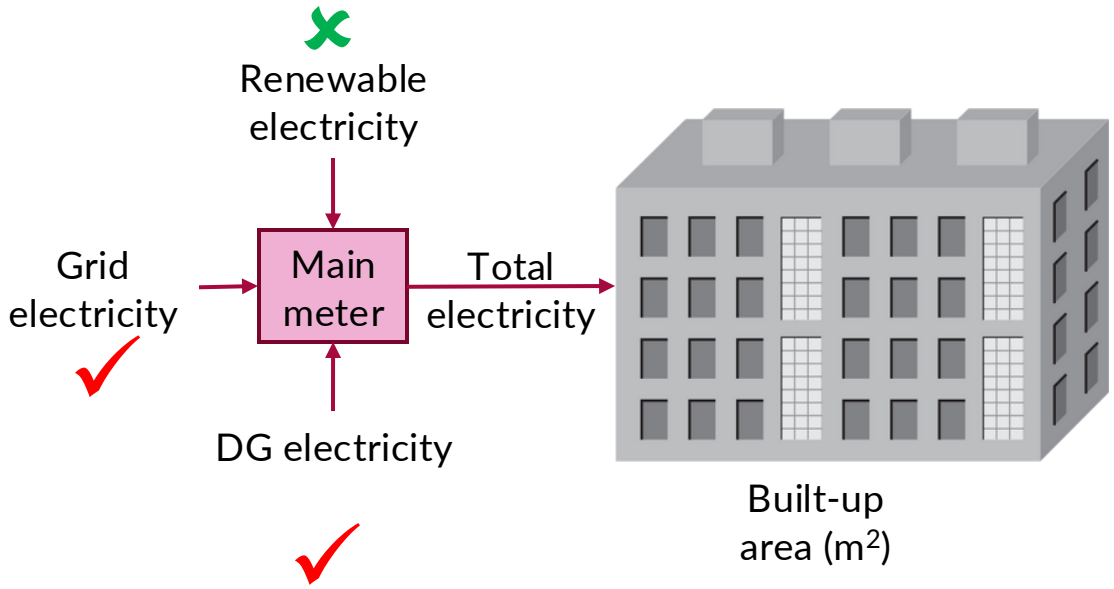


ENERGY PERFORMANCE INDEX (EPI)

Overall energy efficiency metric for buildings

- Definition: EPI is a metric used to measure the energy efficiency of a building or facility. It is typically defined as the total energy consumption per unit area, expressed in kWh/m² per year
- Purpose of EPI: EPI is crucial for assessing and comparing the energy efficiency of different buildings or urban areas. It helps identify opportunities for improvement and track energy conservation efforts over time
- EPI plays a key role in reducing operational costs, lowering carbon footprints, and contributing to sustainability goals. It is often used in compliance with energy efficiency regulations and certifications
- Formula:

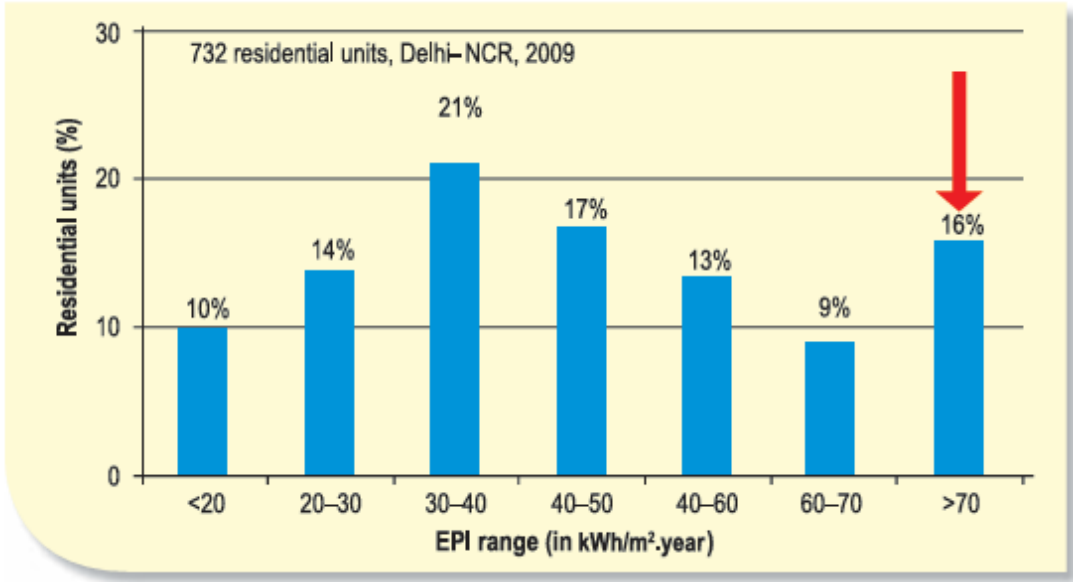
$$\text{EPI} = \frac{\text{Total Energy Consumption (kWh/year)}}{\text{Total Floor Area (m}^2\text{)}}$$



Sources: Bureau of Energy Efficiency, Government of India, 2022; Bureau of Energy Efficiency, Government of India, 2023b

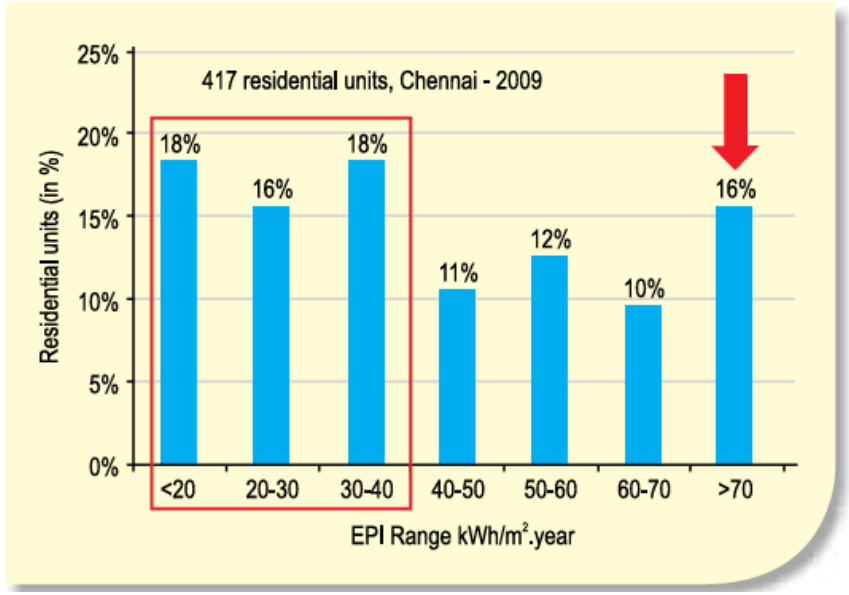
ENERGY PERFORMANCE INDEX (EPI)

For residential buildings



For **composite climate** in India, the average EPI, based on data collected from over 700 residential units for 2009 is **48 kWh/m².year**. The EPI does not include electricity consumption for common services

Over **16%** of the residential units have an EPI value **greater than 70 kWh/m².year**. Most of these residential units have three or more air-conditioners



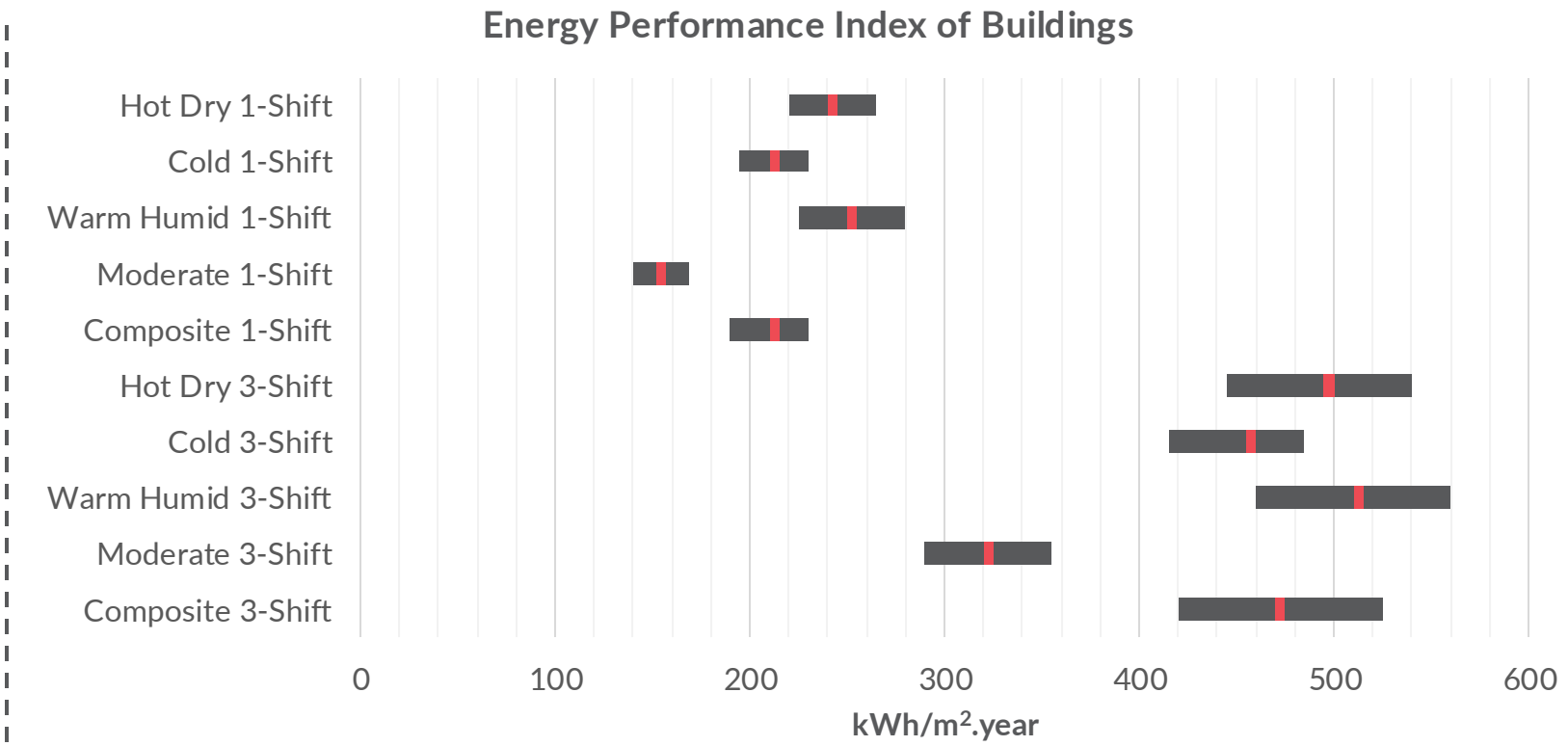
For **warm-humid climate** in India, the average EPI, based on data collected from over 400 residential units for 2009 is **44 kWh/m².year**. The EPI does not include electricity consumption for common services

ENERGY PERFORMANCE INDEX (EPI)

For buildings (1-shift and 3-shift operation)

A national survey for assessing the **EPI** of existing buildings in India was conducted in five climatic zones and two types of buildings:

- Daytime use
- 24 x 7 use



Source: CEPT University, Ahmedabad, & Shakti Foundation, New Delhi, "A stepped bundle approach to ECBC".

Energy Star Rating for Buildings



STAR RATING FOR BUILDINGS

For buildings (1-shift and 3-shift operation)

The star rating system is designed to evaluate and rate the energy efficiency of buildings on a scale, typically from 1 to 5 stars. It offers an easy-to-understand metric for homeowners, buyers and tenants to evaluate how energy efficient a property is.

Rating scale: A 1-star rating indicates poor energy performance, while a 5-star rating signifies excellent energy efficiency. Each additional star represents a higher level of energy efficiency:

- 1-Star: Basic compliance with local building codes; minimal insulation and little to no energy efficient systems
- 2-Star: Slight improvements over baseline requirements, with some energy efficient appliances and insulation
- 3-Star: Moderate energy efficiency with adequate insulation, and energy efficient HVAC and LED lighting
- 4-Star: Above-average energy efficiency, possibly including double-glazed windows, higher-quality insulation and efficient HVAC systems
- 5-Star: Top-tier energy efficiency with renewable energy sources, comprehensive insulation, advanced window glazing, smart home technology and low energy consumption throughout



Source: Bureau of Energy Efficiency, Government of India

RESIDENTIAL BUILDINGS

Star rating system

- The Star Rating System for Residential Buildings in India, established by the Bureau of Energy Efficiency (BEE), is a program that rates the energy efficiency of residential buildings on a **scale from 1 to 5 stars**
- **EPI calculation:**

  EPI for air-conditioned spaces (25% area) with 24°C as set point (E1) + EPI for other spaces (75% area) with natural ventilation (E2) set points defined by IMAC with air conditioner switched on
- EPI for other appliances: E3 (constant value)
- **Calculation of the EPI** is through a simulation-based tool to calculate the EPI of dwelling units. The user is required to feed-in information of the dwelling unit in the tool based on which the tool will automatically calculate the EPI

Residential Building Star Rating Plan				
Period: 14 December 2018 to 31 December 2024				
Star Rating	Energy Performance Index[1] (E1 + E2) of Dwelling Unit			
	Composite	Warm & Humid	Hot and Dry	Temperate
1-star	52 < EPI ≤ 60	58 < EPI ≤ 64	55 < EPI ≤ 67	28 < EPI ≤ 31
2-star	45 < EPI ≤ 52	49 < EPI ≤ 58	47 < EPI ≤ 55	24 < EPI ≤ 28
3-star	37 < EPI ≤ 45	39 < EPI ≤ 49	38 < EPI ≤ 47	21 < EPI ≤ 24
4-star	29 < EPI ≤ 37	30 < EPI ≤ 39	29 < EPI ≤ 38	17 < EPI ≤ 21
5-star	EPI ≤ 29	EPI ≤ 30	EPI ≤ 29	EPI ≤ 17

- **E1** and **E2** includes following systems: Building envelope characteristic; lighting system; and comfort system (AC)
- **E3** includes appliances such as: microwave oven, grinder, refrigerators, television, water pump, washing machine, etc.

Source: Bureau of Energy Efficiency, Government of India

OFFICE BUILDINGS

Star rating system

- The three building categories are based on built-up area (BUA) and in line with the categories in ECBC 2017
- The star rating band is formed by straight line equations in the form **y = (a*b) + c:**
  - 'y' denotes the EPI
  - 'a' denotes the coefficient in the table
  - 'b' denotes the percentage of AC area out of total built-up area

Star rating for office buildings

Climatic Zone	Building Category	1 Star	2 Star	3 Star	4 Star	5 Star
Composite	Large Office	y = 0.95x + 60	y = 0.9x + 50	y = 0.85x + 40	y = 0.8x + 30	y = 0.75x + 20
	Medium Office	y = 1.1x + 60	y = 1.05x + 50	y = x + 40	y = 0.95x + 30	y = 0.9x + 20
	Small Office	y = 0.65x + 60	y = 0.6x + 50	y = 0.55x + 40	y = 0.5x + 30	y = 0.45x + 20
Warm & Humid	Large Office	y = 0.9x + 65	y = 0.85x + 55	y = 0.8x + 45	y = 0.75x + 35	y = 0.7x + 25
	Medium Office	y = 0.9x + 65	y = 0.85x + 55	y = 0.8x + 45	y = 0.75x + 35	y = 0.7x + 25
	Small Office	y = 0.7x + 65	y = 0.65x + 55	y = 0.6x + 45	y = 0.55x + 35	y = 0.5x + 25
Hot & Dry	Large Office	y = 1.1x + 55	y = 1.05x + 45	y = x + 35	y = 0.95x + 25	y = 0.9x + 15
	Medium Office	y = 1.25x + 55	y = 1.2x + 45	y = 1.15x + 35	y = 1.1x + 25	y = 1.05x + 15
	Small Office	y= 0.75x + 55	y = 0.7x + 45	y = 0.65x + 35	y = 0.6x + 25	y = 0.55x + 15

Source: Bureau of Energy Efficiency, Government of India, 2023b

OFFICE BUILDINGS

Star rating system: Understanding the band for each star category

- **Star label bands**
  - Upper value of band: As per the equation given
  - Lower value of band: As per the equation of the next high rating (e.g., equation of the 2 star for a 1-star rating)

- **Example:** Any large office building in composite climatic zone, having 75% AC area (b=75)

  - For 1-star rating the upper value of band will be: 0.95*75 + 60 = **131.25 kWh/m²**
  - For 1-star rating the lower value of band will be: 0.9*75 + 50 = **117.5 kWh/m²**
  - For a building with 75% air-conditioned area, the **EPI band** for 1 star will be **117.5– 131.25 kWh/m²**

Star rating for office buildings

Climatic Zone	Building Category	1 Star	2 Star	3 Star	4 Star	5 Star
Composite	Large Office	y = 0.95x + 60	y = 0.9x + 50	y = 0.85x + 40	y = 0.8x + 30	y = 0.75x + 20
	Medium Office	y = 1.1x + 60	y = 1.05x + 50	y = x + 40	y = 0.95x + 30	y = 0.9x + 20
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Hot & Dry	Large Office	y = 1.1x + 55	y = 1.05x + 45	y = x + 35	y = 0.95x + 25	y = 0.9x + 15
	Medium Office	y = 1.25x + 55	y = 1.2x + 45	y = 1.15x + 35	y = 1.1x + 25	y = 1.05x + 15
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Source: Bureau of Energy Efficiency, Government of India, 2023b

Standards and Labeling

For Appliances



Image source: https://www.paiinternational.in/blogs/understanding-the-bee-star-rating-in-electronics-

STANDARDS AND LABELING (S&L)

For appliances

- In India, the S&L system provides consumers with an easy way to compare the energy use and operating costs of different products, encouraging the purchase of energy efficient models
- Rating scale: Appliances are rated from 1 star (least efficient) to 5 stars (most efficient)
- Energy consumption labeling: Each appliance label includes information about the product's energy consumption and an efficiency rating
- Product testing and standards: Appliances are tested against standards set by the Bureau of Energy Efficiency, which periodically updates the criteria to reflect advancements in technology
- Commonly-rated appliances: Refrigerators, air conditioners, ceiling fans, televisions, washing machines, water heaters, LED bulbs and tube lights
- Star rating criteria
  - Energy efficiency ratio (EER): Indicates efficiency for appliances like air conditioners and refrigerators
  - Annual energy consumption: Specifies the estimated annual electricity consumption in kilowatt-hours (kWh) for typical usage



S&L

Appliances covered – mandatory and voluntary

S NO	MANDATORY
1	Frost Free Refrigerator
2	Direct Cool Refrigerator
3	Deep Freezer
4	Room AC (Variable Speed)
5	Room AC (Fixed Speed)
6	RAC (Cassette, Floor Standing Tower, Ceiling Corner AC)
7	Light Commercial AC (Fixed Speed)
8	Stationary Storage Type Electric Water Heater
9	Tubular Fluorescent Lamp
10	LED Lamp
11	Ultra High Definition Television
12	Colour Television
13	Distribution Transformer
14	Ceiling Fan
15	Chiller
16	Washing Machine

S NO	VOLUNTARY
1	General Purpose Industrial Motor
2	Submersible Pump Set
3	Domestic Gas Stove
4	Computer
5	Ballast
6	Office Automation Product
7	Diesel Engine Driven Monoset Pump for Agricultural Purposes
8	Solid State Inverter
9	Diesel Generator Set
10	Microwave Oven
11	Solar Water Heater
12	Air Compressor
13	High Energy Li-Battery
14	Tyre
15	Multi Door Refrigerator
16	Pedestal Fan, Table Fan, Wall Fan
17	Induction Hob
18	Solar Photovoltaic

Thank you!

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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

3.4 Building Life Cycle Assessment (LCA)

Concept and Approaches

November 2024

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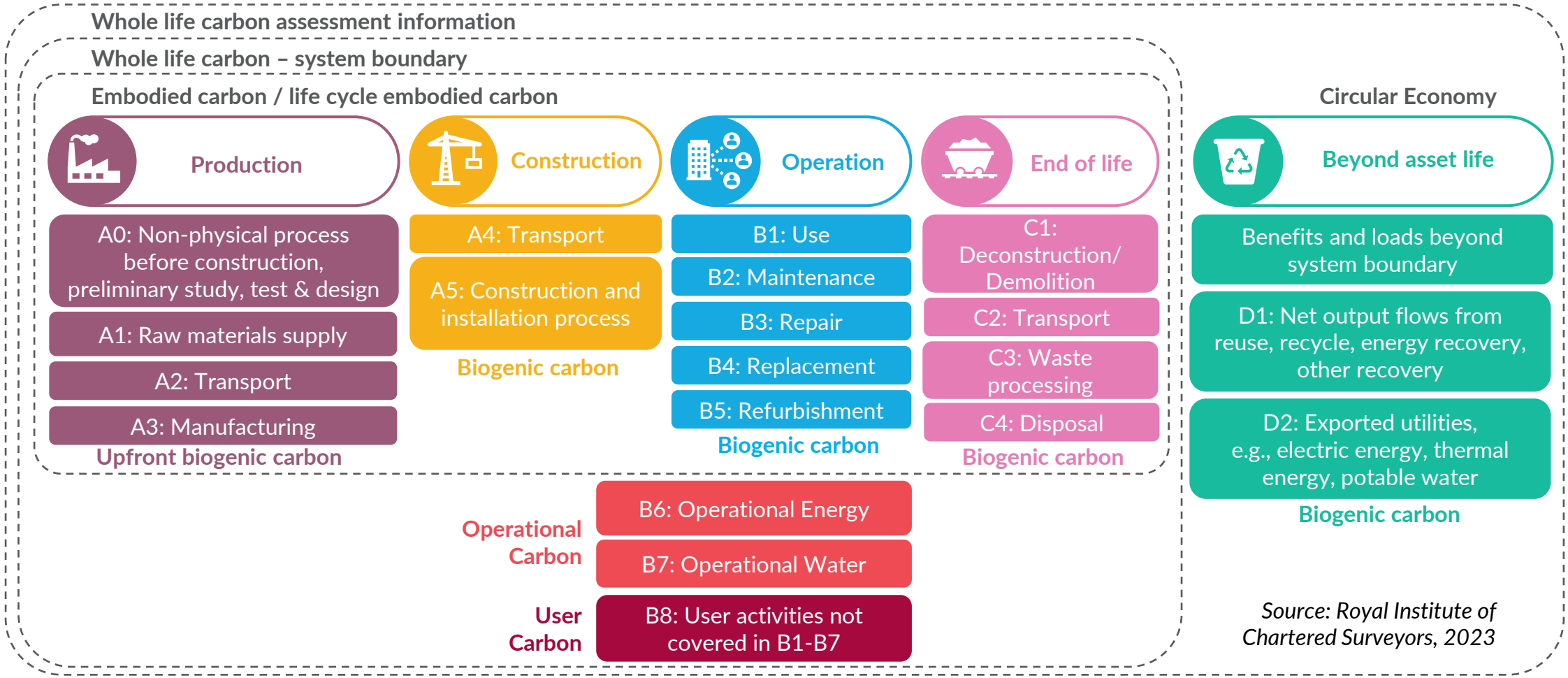
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WHOLE LIFE CARBON

Building life cycle stages



Source: Royal Institute of Chartered Surveyors, 2023

BUILDING LIFE CYCLE STAGES

Phases for embodied and operational carbon

Embodied carbon denotes carbon emissions associated with materials and construction processes throughout the whole life cycle of a building. This includes:[1]

- **Upfront carbon:** The emissions caused during the building material production and construction phases (A0–A5) of the building's life cycle before it is used. In contrast to other categories of emissions, these emissions have already been released into the atmosphere before the building is occupied or the infrastructure begins operation
- **Use stage embodied carbon:** Emissions associated with building materials and processes needed to maintain the building or infrastructure during use, such as for refurbishments (B1–B5). These are additional to operational carbon emitted due to heating, cooling and power etc.
- **End of life carbon:** The carbon emissions associated with deconstruction and demolition (C1), transportation from site (C2), waste processing (C3) and disposal (C4) phases of a building or infrastructure's life cycle which occur after its use

Operational carbon denotes the emissions associated with energy and water consumed (B6–B7) to operate the building over its life cycle[2]

[1] *Source: World Green Building Council, 2019*
[2] *Source: Royal Institute of Chartered Surveyors, 2023*

LIFE CYCLE ASSESSMENT

Scope of LCA

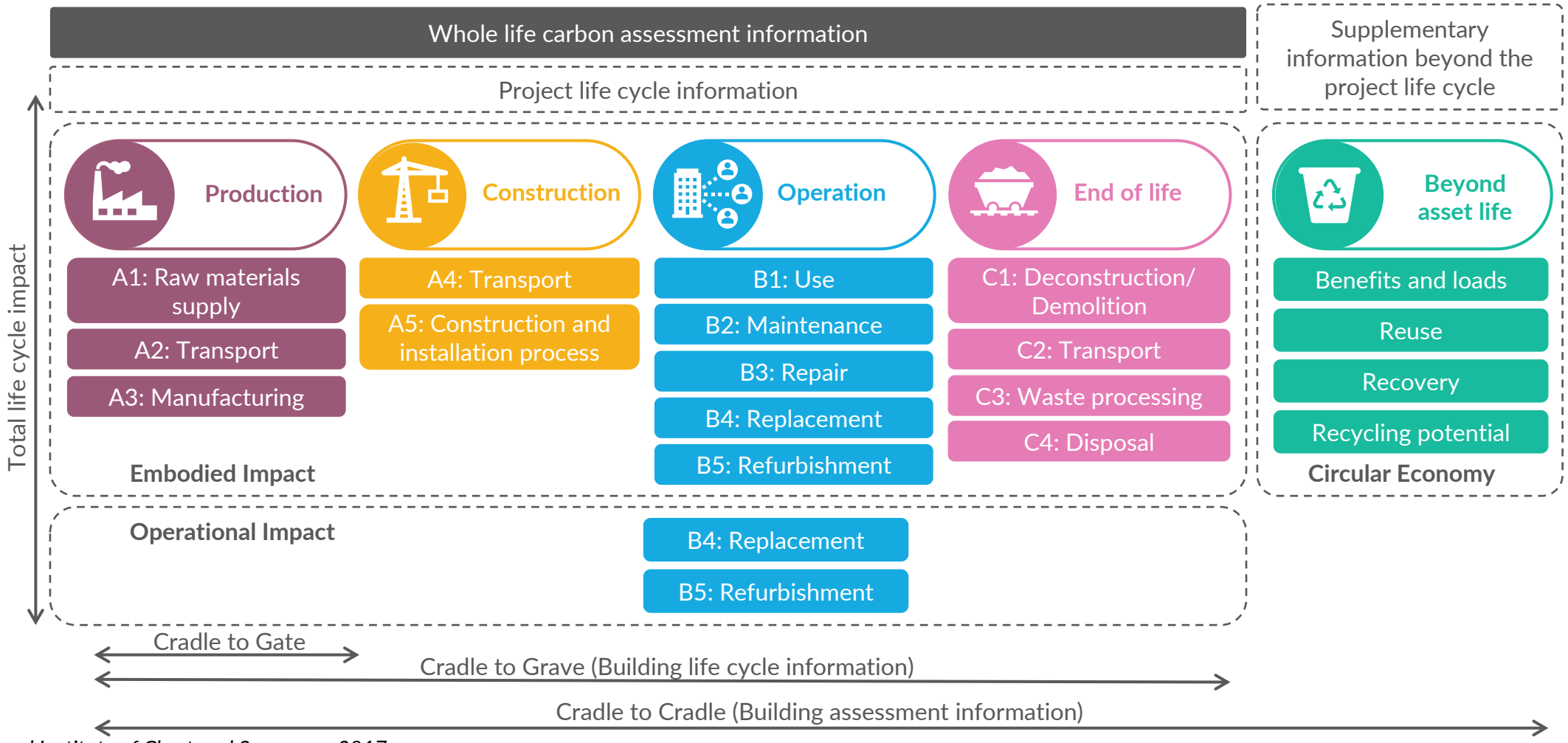
Life cycle assessment (LCA) is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a building, infrastructure, product or material throughout its life cycle (ISO 14040: 2006)[1]

Based on the scope of the LCA or stages for which data is available, one can choose to leave in or take out building life cycle stages. Thus, LCA could be of the following types:[2]

- **Cradle-to-gate** considers all activities starting with the extraction of materials from the earth (the cradle), their transportation, refining, processing and fabrication activities until the material or product is ready to leave the factory gate (A0–A3)
- **Cradle-to-practical completion (handover)** includes the cradle-to-gate results to just before building occupation and use (A0–A5)
- **Cradle-to-grave** includes the cradle-to-practical handover results plus the GHG emissions associated with the use of the material or product (maintenance) and the end of life (disposal, reuse, recycling) (A0–C4)
- **Cradle-to-cradle** goes beyond cradle to grave and conforms more to the model of the circular economy. In a cradle-to-cradle model, products would be designed in a way so that at the end of their initial life they can be reused or recycled, and therefore avoid landfill

[1] *Source: World Green Building Council, 2019*
[2] *Source: Royal Institute of Chartered Surveyors, 2017*

LCA SCOPES



Source: Royal Institute of Chartered Surveyors, 2017

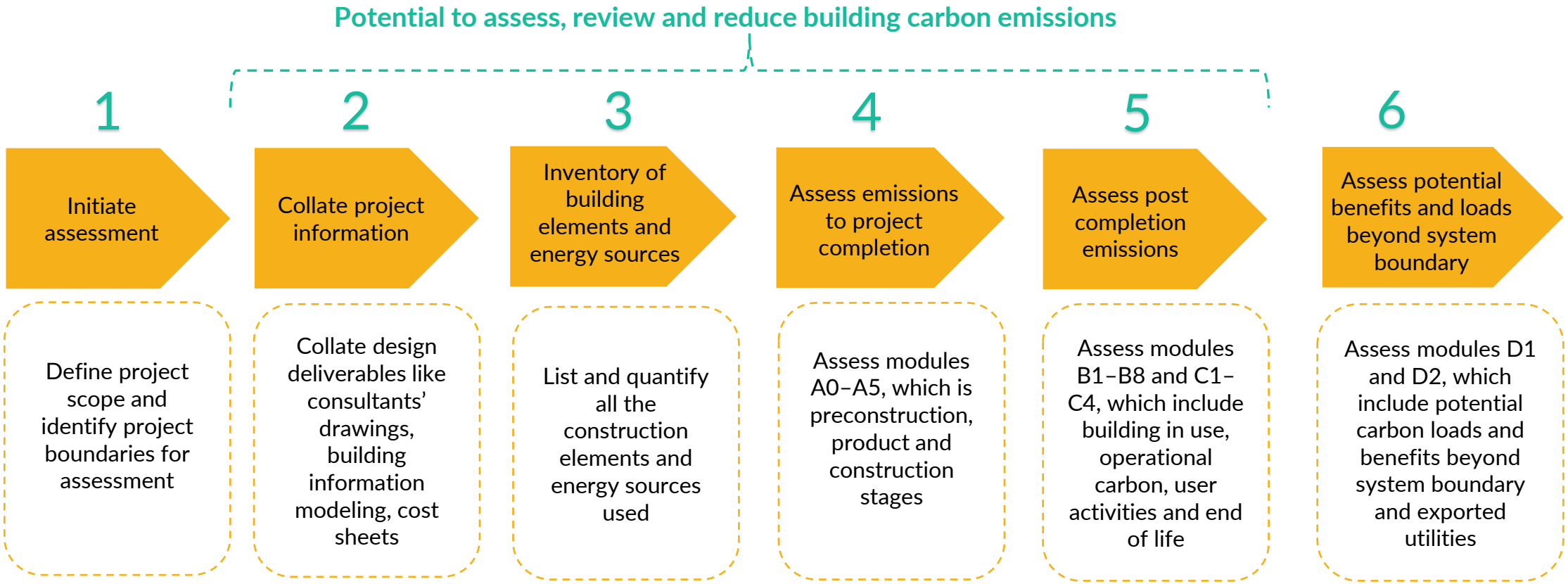
WHOLE LIFE CARBON ASSESSMENT

- **A whole life carbon assessment (WLCA)** is the calculation and reporting of the quantity of carbon impacts expected throughout all life cycle stages of a project and includes an assessment of the potential benefits and loads occurring beyond the system boundary.[1] **It is in effect a cradle-to-cradle LCA**
- All WLCAs follow a modular structure for carbon reporting, which breaks down the building life cycle into stages and modules
- A WLCA is intended to examine all carbon impacts from production of materials, construction, use and disposal of a built asset over its entire life cycle. This approach helps to mitigate the carbon at any stage of the life cycle

[1] *Source: Royal Institute of Chartered Surveyors, 2023*

WLCA METHODOLOGY

Steps for assessing WLCA

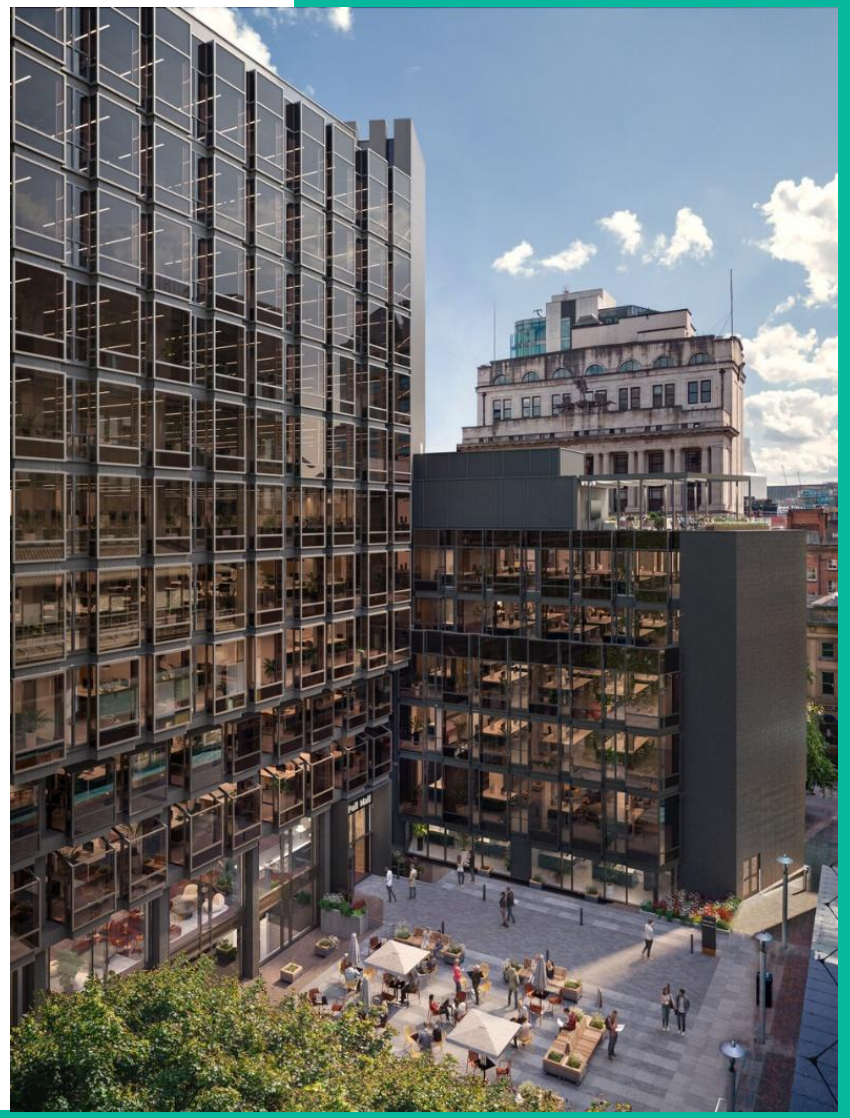


Source: Modified from Royal Institute of Chartered Surveyors, 2023

WLCA BUILDINGS

Retrofit case example: Pall Mall, Manchester, UK

- Pall Mall, built in 1969 and acquired by Bruntwood in 2021, is a property **of 85,000 sq. ft.** of office and hospitality spaces
- Whole life carbon was a driving factor for the decision to retain the building and undertake **a deep retrofit**
- **The WLCA revealed that deep retrofit is the most carbon-efficient solution** due to the proposed switch, away from gas heating to hybrid variable refrigerant flow, with an air source heat pump serving domestic hot water and air handling unit (AHU) coils



Source: Hollyman and Dodkin, 2024

WLCA BUILDINGS

Retrofit case example: Pall Mall, Manchester, UK (continued)

- The project, when completed in 2025, will achieve a **74% reduction in EUI** due to the deep retrofit
- The project will achieve a **higher energy performance rating (EPC), moving from G to A** (A+ being the highest; higher ratings being preferred by tenants)
- The project will achieve a **'very good' BREEAM rating with a 100% increase in rental value**

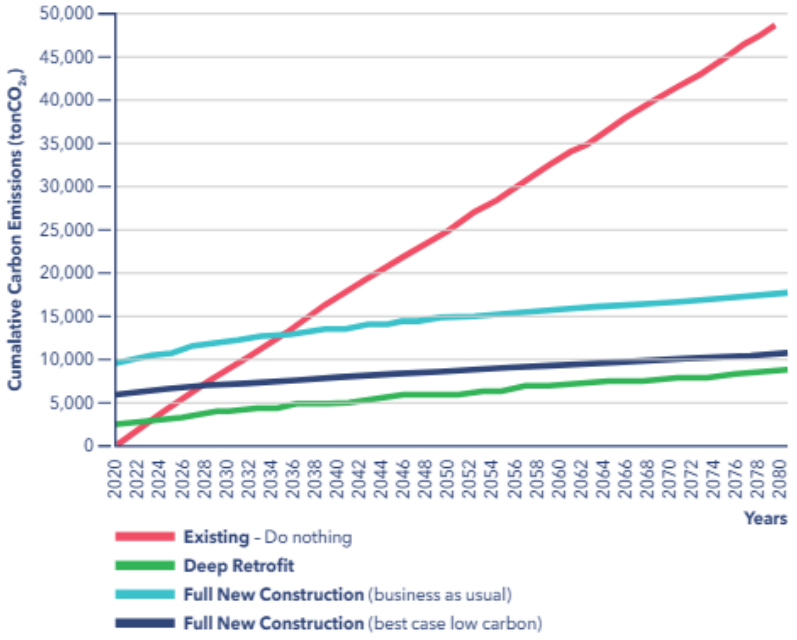


FIGURE 5:
Whole Life Carbon Timeline (in tons).

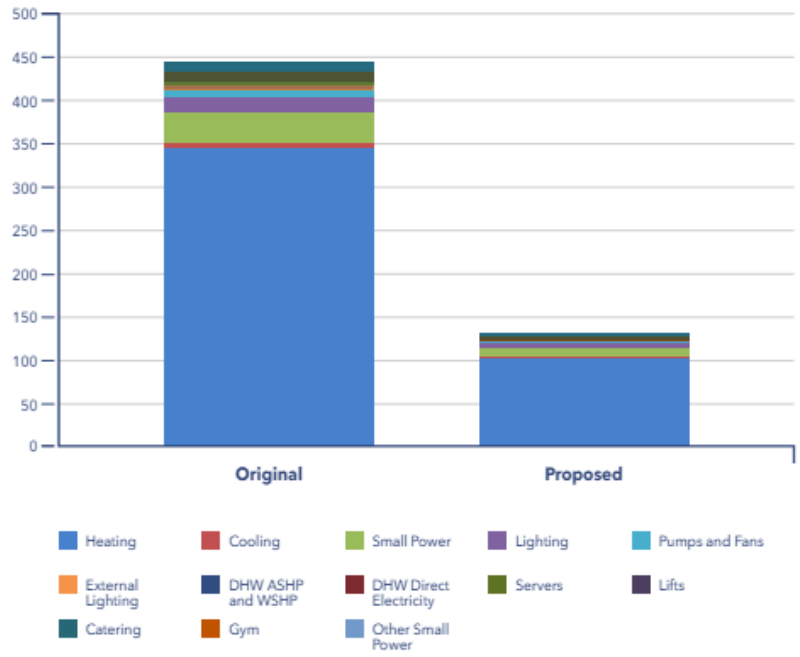


FIGURE 6:
Annual Energy Consumption of original and proposed building (kW/m²).

Source: Hollyman and Dodkin, 2024

WLCA BUILDINGS

Retrofit case example: Pall Mall, Manchester, UK (continued)

Other features of low carbon design:

- The fit out uses circular economy principles by **utilizing recycled and reclaimed furniture and materials for timber partitions and reclaimed raised access floors**
- The façade and glazing system designed reduces the need to cool the building

Bruntwood has **avoided 7,900 tons** of additional carbon by eliminating the need to rebuild (equivalent to around 16,000 flights from London to New York)





Source: Hollyman and Dodkin, 2024

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

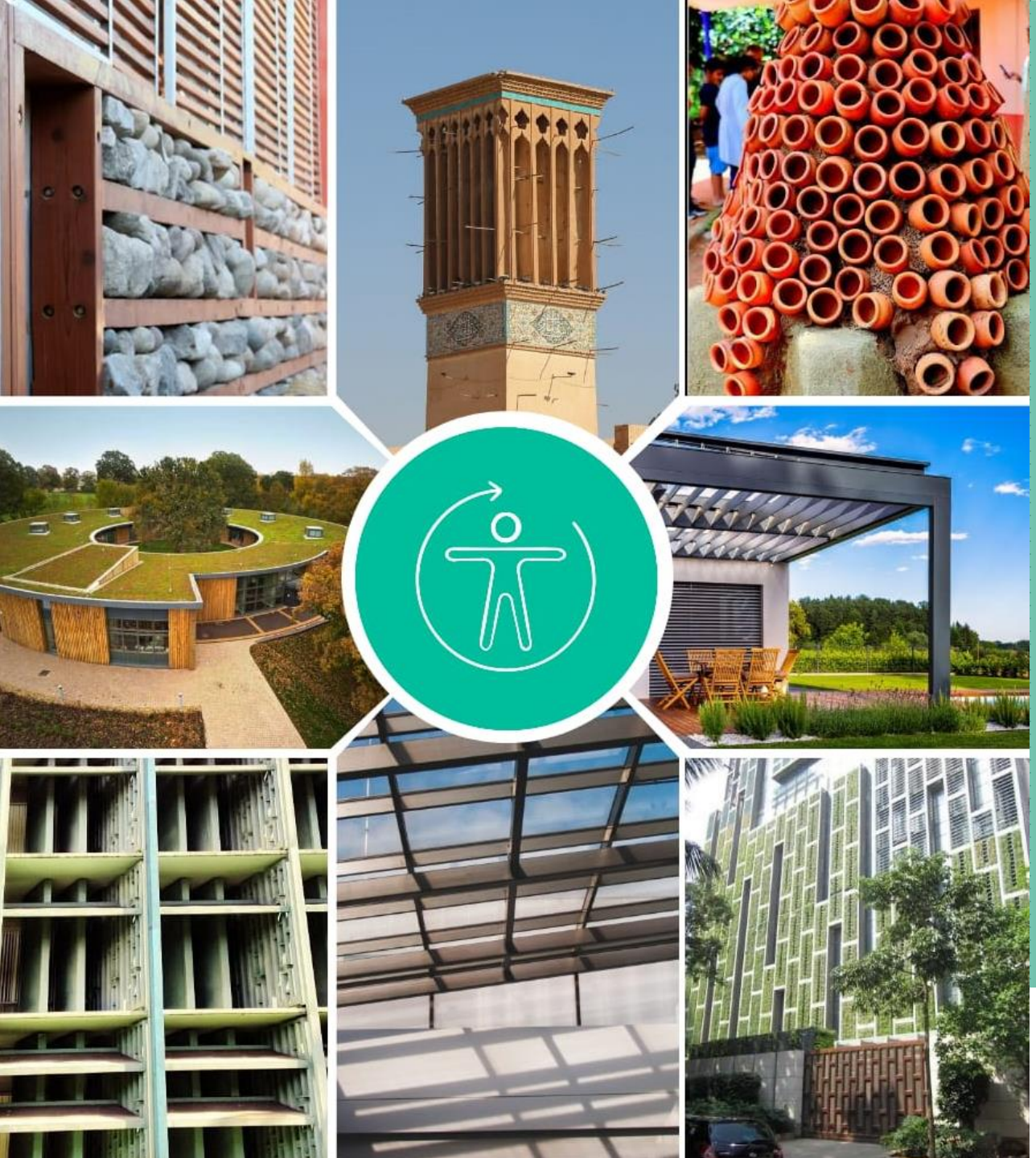
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Life Cycle Assessment for Transitioning to a Low-Carbon Economy

3.5 Low Carbon Building Assessment Tools

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WHAT WILL YOU LEARN?

01 **Carbon Assessment Tools for Buildings**

02 **Typical Internationally-used Carbon Assessment Tools: How it Works and Case Examples**

03 **ALCBT Carbon Tool: How it Works, Scope and Benefits**



CARBON ASSESSMENT TOOLS

Analytics for sustainable buildings

Carbon assessment tool provides analytics for:



CARBON ASSESSMENT TOOLS

Design-integrated tool



- Web-based tool
- Whole life carbon analysis
- Environmental product declaration (EPD) generation
- Licensed access
- Tailored for the construction sector

Source: Carbon Leadership Forum

CARBON ASSESSMENT TOOLS

Calculators

- Web-based tool
- Whole life carbon analysis
- Pre-fed cases
- Comparative energy and material efficiency measures
- Free access

- Embodied Carbon in Construction Calculator
- Access to building material EPDs
- Useful for selection and procurement
- More like a comparison tool
- Focuses on A1–A3 emissions
- Free access

Source: Carbon Leadership Forum

CARBON ASSESSMENT TOOLS

Other life cycle assessment (LCA) tools in construction sector



- Software application for LCA and green building certification
- Free access



- Software tool for assessing embodied and operational carbon (under development) in building sector

CARBON ASSESSMENT TOOLS

Other life cycle assessment tools targeting a range of industries: automotive, electronics, agriculture…



thinkstep
GaBi

- Whole life carbon analysis
- Licensed access
- Used mainly by industry professionals

SimaPro

- Paid service
- Whole life carbon analysis
- Used mainly by industry professionals

openLca

- EPD generation
- Free + paid datasets, popular in academia

Source: Carbon Leadership Forum

EC3 TOOL: EMBODIED CARBON CALCULATOR

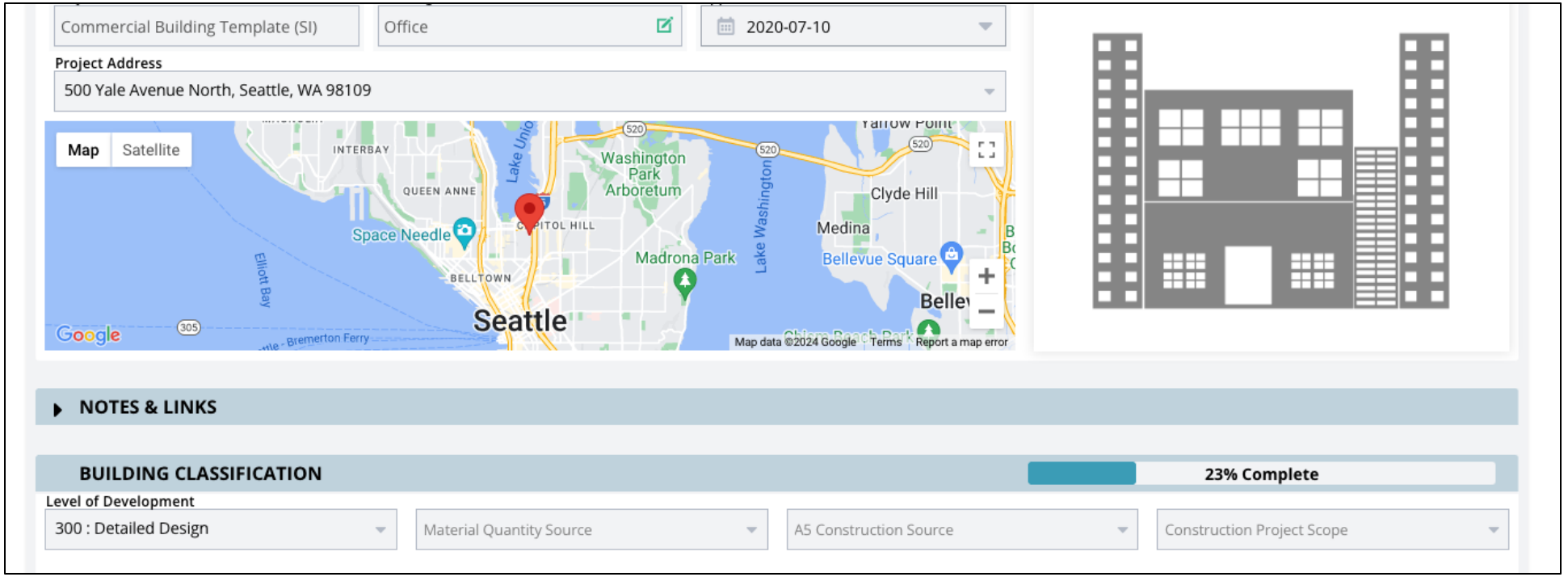
Life cycle assessment tool

- The Embodied Carbon Calculator EC3 is a free, open-access tool developed by Carbon Leadership Forum and Building Transparency. It covers LCA scope A1 to A3, and has a straightforward, easy-to-use interface for global application
- How:
  - Uses building material quantities from construction estimates (and/or information from BIM/REVIT)
  - Uses transparent, free-to-access database for EC of each material used consisting of **digital, third-party-verified EPDs**
  - This allows the user to directly specify which low carbon material should be procured for construction
- EC3 tool does not have a certification scheme, but helps certification programs, owners and policy-makers assess supply chain data (data granularity)
- EC3 tool is highly specific **to embodied carbon in materials** and this tool is ideal for architects and engineers focused on material choices

Source: Building Transparency

EC3 APPLICATION

Data entry screen

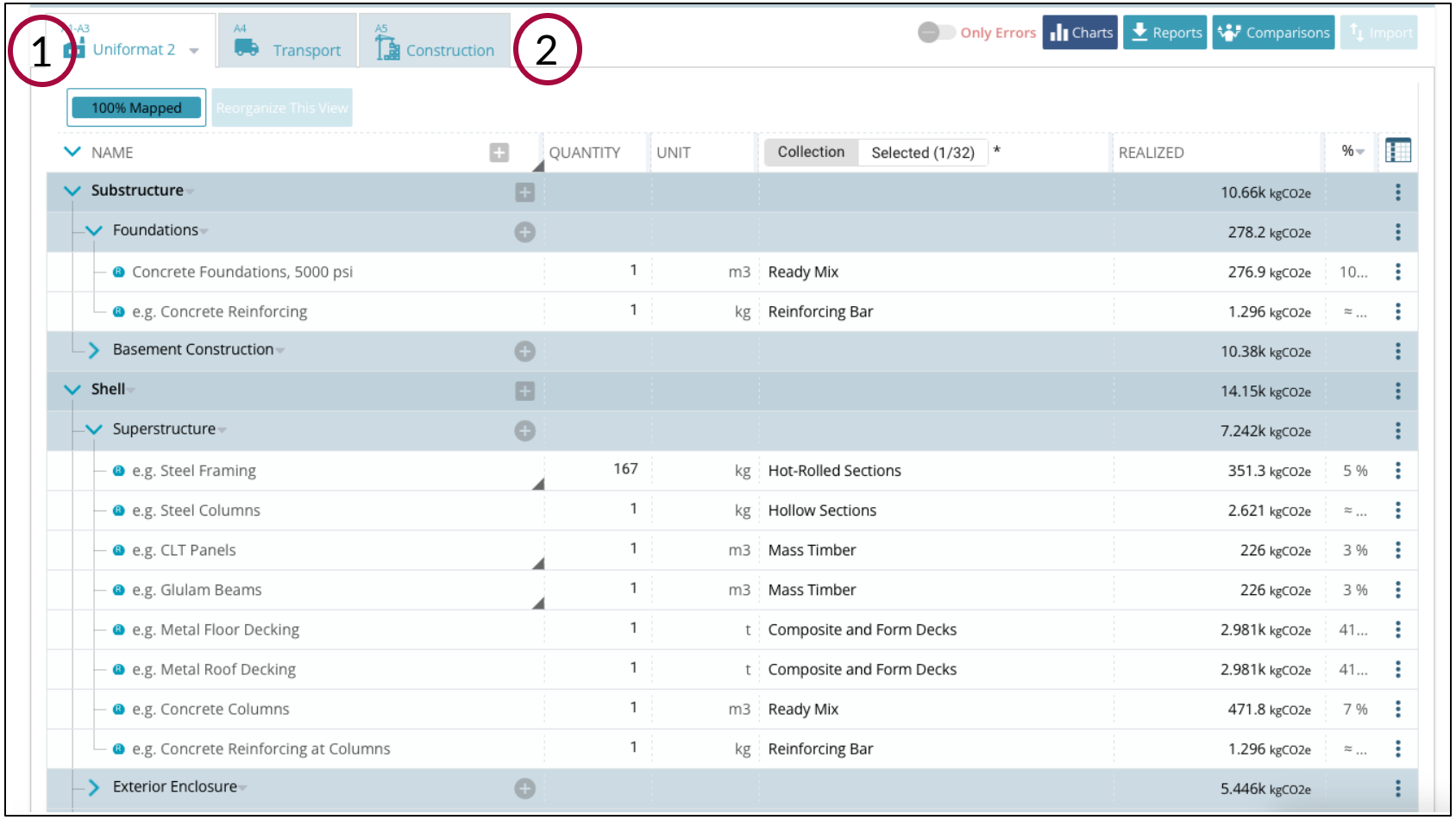


Choose the specific building type and location → Add additional data (floor area, natural gas/electricity consumption, etc.) → Start work in materials in the building

Source: EC3

EC3 APPLICATION

Substructure, shell and interior



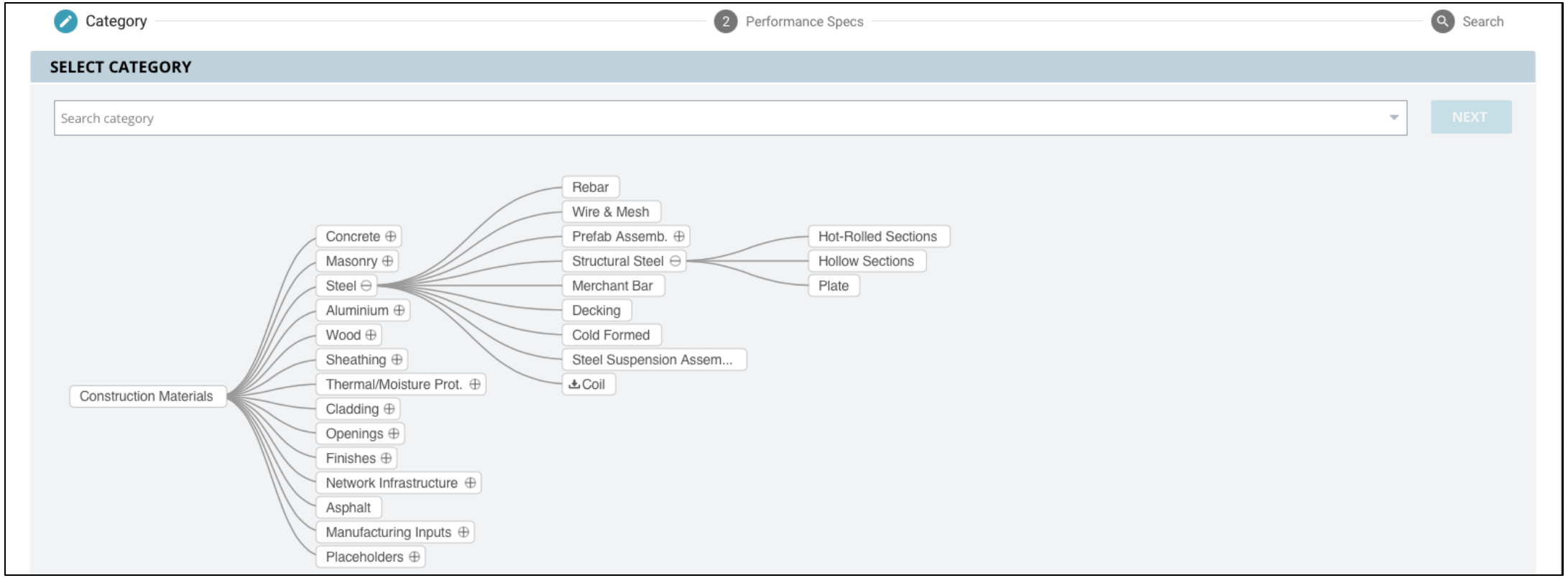
1. Subdivide into: e.g., substructure (foundations), shell (superstructure, exterior enclosure, roofing), and interior (insulation, ceiling tiles, carpet), …

2. Additional emissions for transport and construction can be added (see tabs at the top). The importance is to know: the quantity of each material and the distance/how materials are transported

Source: EC3

EC3 APPLICATION

Material workflow



Choose the specific construction material → Choose the specific requirements (e.g., compressive strength), distance from location → **Search and compare for relevant EPDs**

Source: EC3

EC3 APPLICATION

Find and compare materials

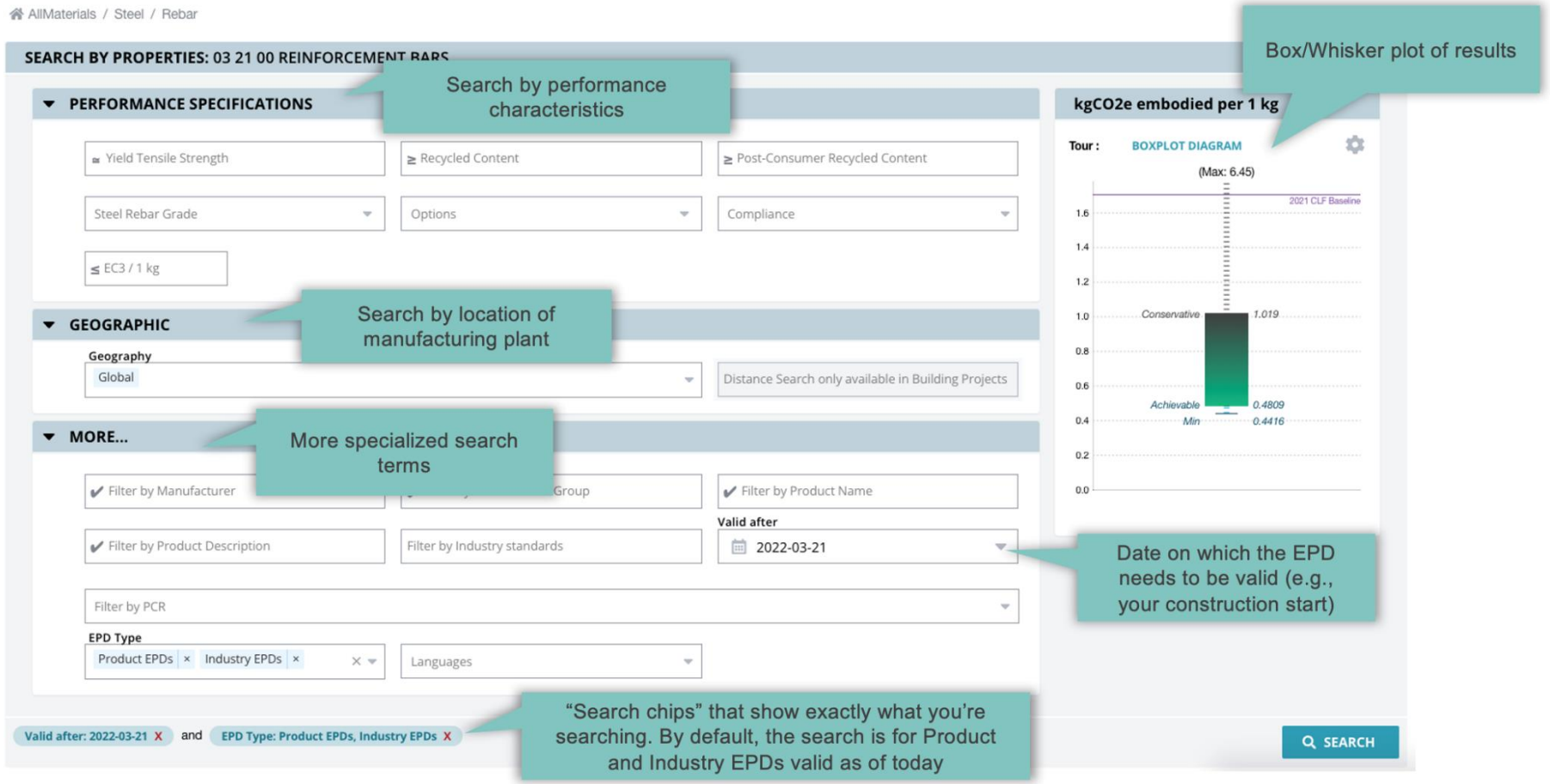


Image source: https://docs.buildingtransparency.org/ec3/main-features

EC3 APPLICATION

Plan and compare buildings

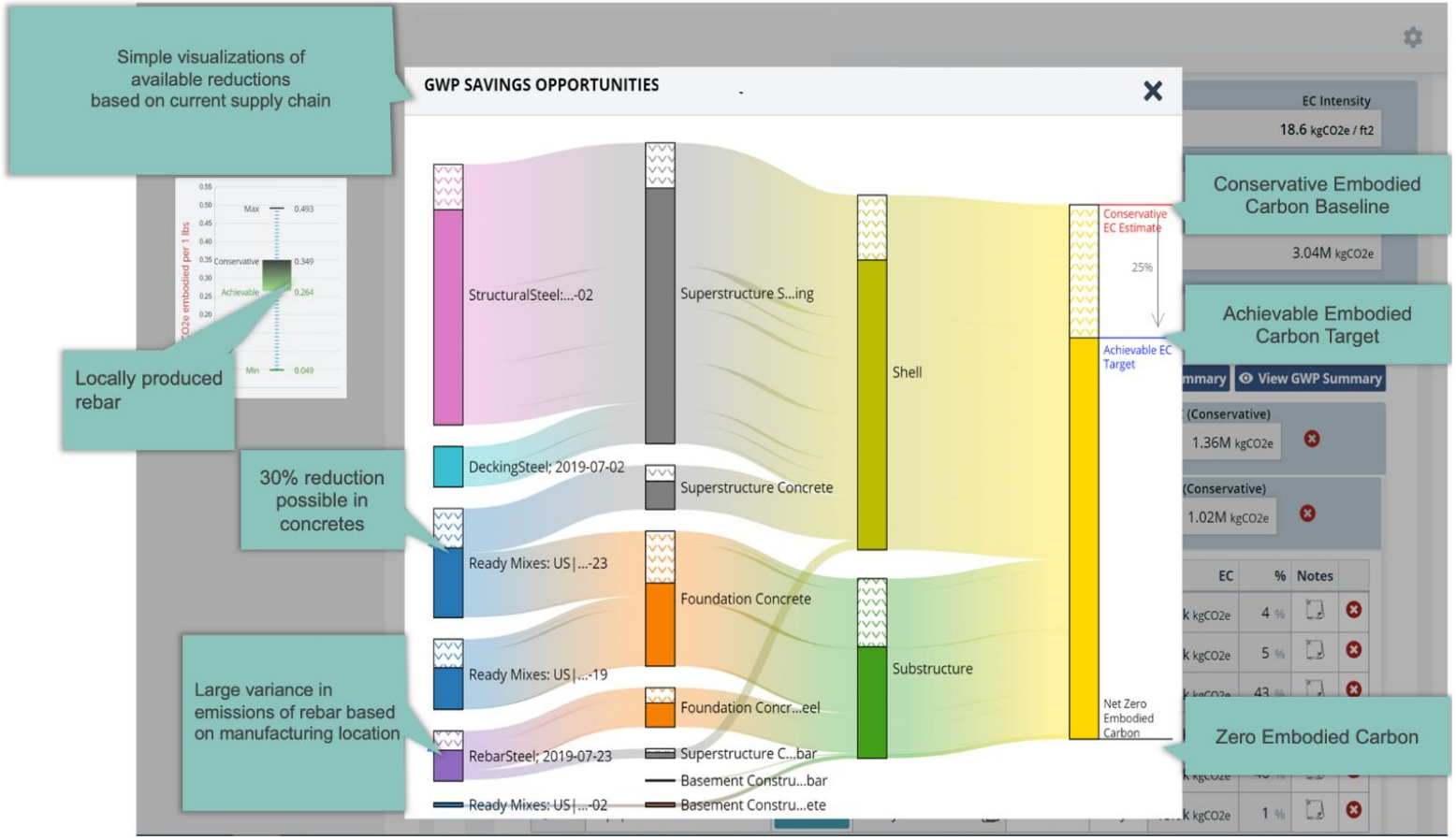


Image source: https://docs.buildingtransparency.org/ec3/main-features

EC3 APPLICATION

Results

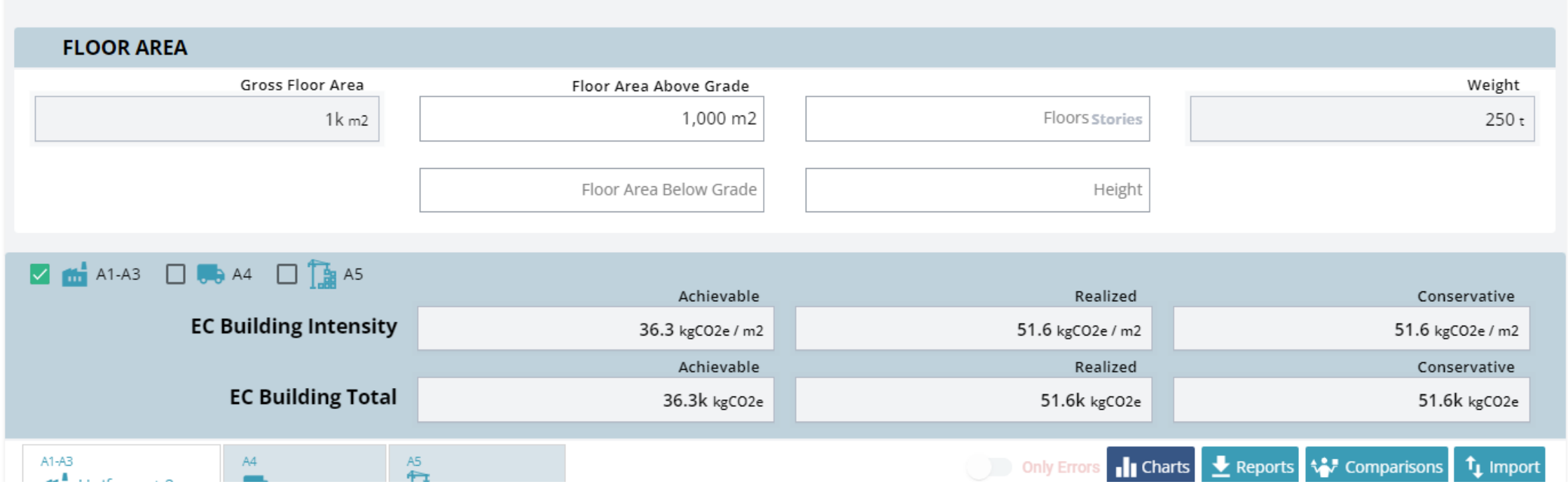


Image source: https://docs.buildingtransparency.org/ec3/main-features

EDGE APPLICATION

Life cycle assessment and certification tool

- EDGE is a green building certification system focused on making buildings more resource efficient. An innovation of IFC, a member of the World Bank Group, EDGE empowers emerging markets to scale up resource-efficient buildings in a fast, easy and affordable way
- EDGE enables developers and builders to quickly identify the most cost-effective strategies to reduce energy use, water use and embodied energy in materials. The strategies that are integrated into the project design are verified by an EDGE Auditor and certified by Green Business Certification Inc. (GBCI)
- EDGE is comprised of:
  - EDGE Software – The web-based EDGE App, available for free at edgebuildings.com, allows you to quickly determine the optimum combination of building design strategies for the best return on investment
  - Global Standard – EDGE requires a minimum projected reduction of 20% in energy use, water use and embodied energy in materials as benchmarked against a standard local building
  - Certification System – Certification by GBCI validates your achievements at a modest cost for nearly all building types, both new and existing

Source: US Green Building Council

EDGE APPLICATION

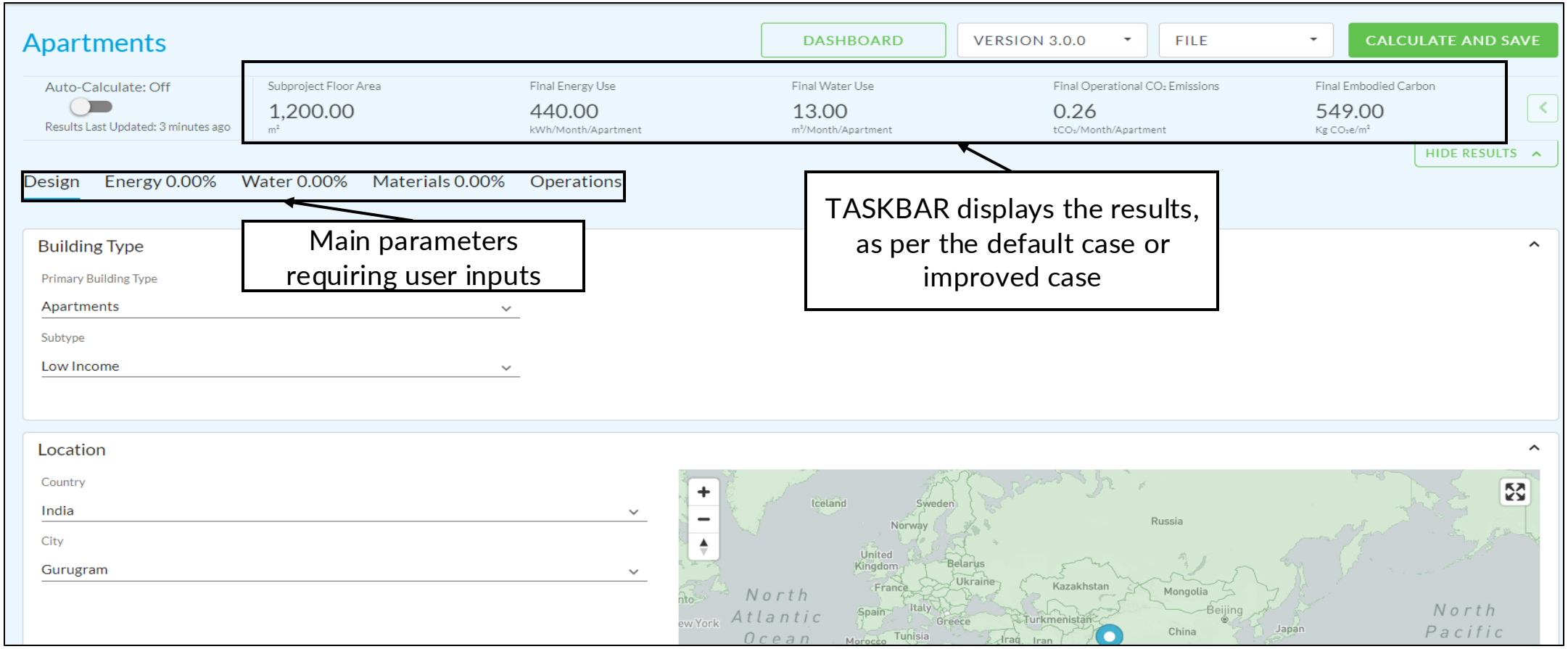
Life cycle assessment tool

- It is a comparative assessment tool, usually used for green building certification
- Based on location, typology and income group, pre-fed base case results are displayed:
  - Final energy usage
  - Final water use
  - Operational carbon
  - Embodied carbon
- The basic sections of the tool are:
  - Building design parameters
  - Energy efficiency measures
  - Water efficiency measures
  - Material efficiency measures
  - Operational energy

Source: EDGE

EDGE APPLICATION

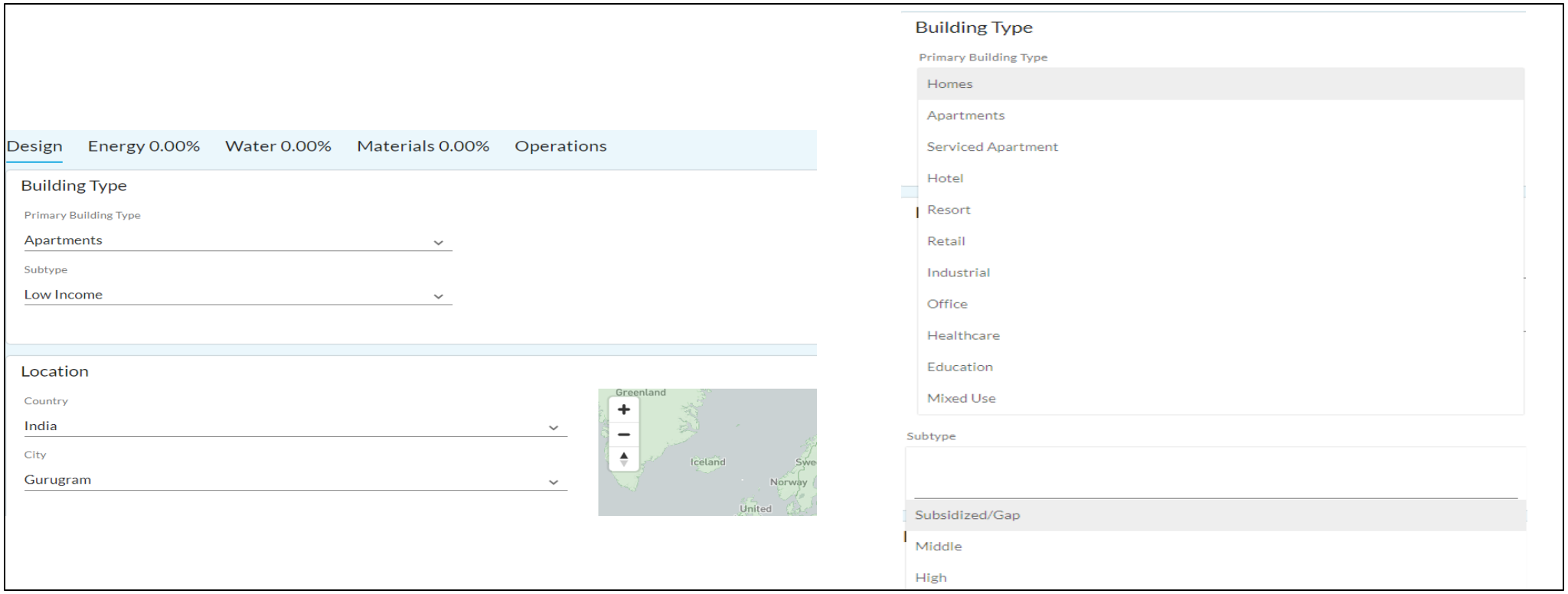
Data entry screen



Source: EDGE

EDGE APPLICATION

Data entry screen



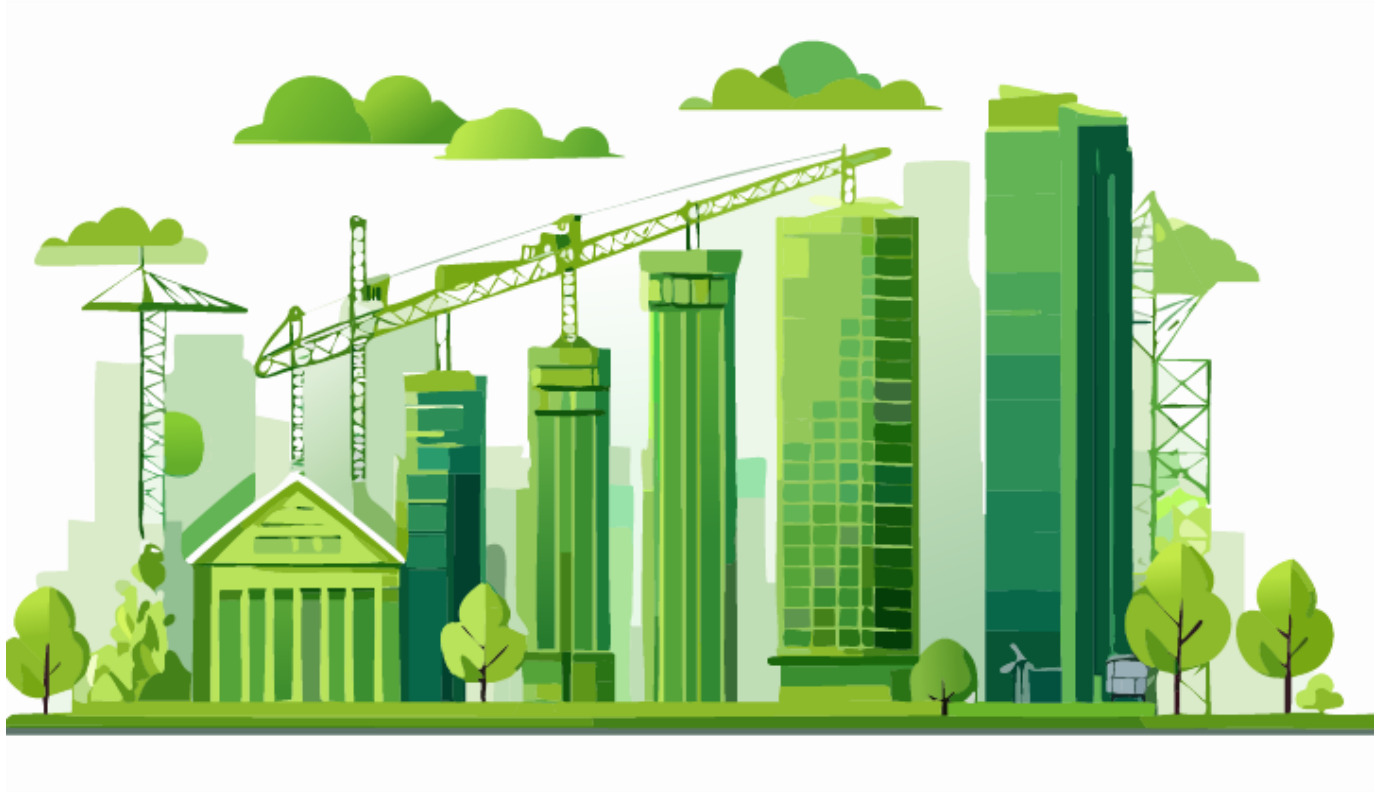
Base case values are governed by choosing building type, income group and location

Source: EDGE

BUILDING DESIGN PARAMETERS

User data entry

- User needs to input basic project details – name, organization, address, etc.
- Building data – number of apartments, floors above and below the grade, floor-to-floor height, etc.
- User can modify the typology according to project-specific details
- Building dimensions – building length in different directions
- HVAC system details
- Area and loads breakdown
- Fuel usage details (emissions factors of fuels can be customized)
- Climate data – elevation, annual rainfall, monthly average temperatures



Source: EDGE

ENERGY EFFICIENCY MEASURES

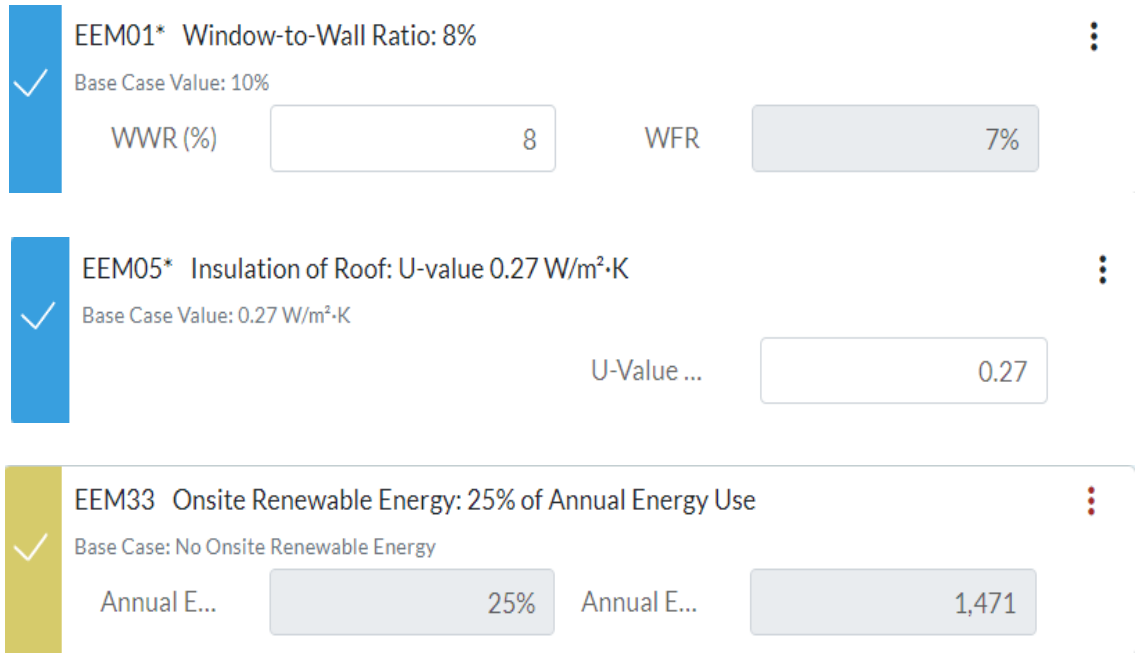
EDGE: List of measures available

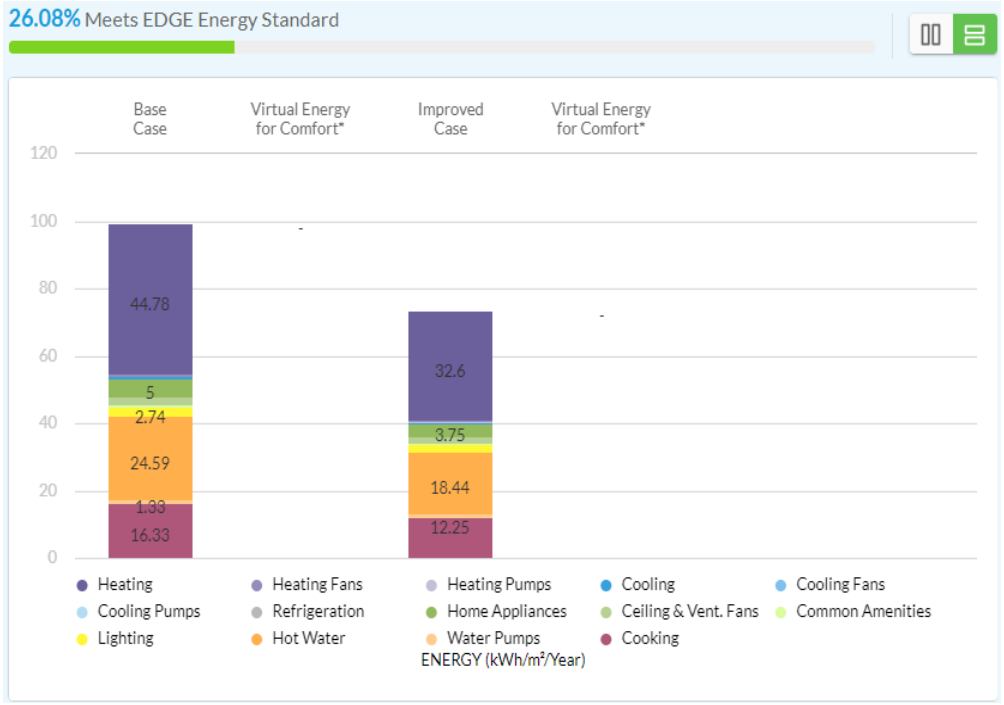
- Air infiltration of envelope
- Natural ventilation
- Ceiling fans
- Cooling system efficiency: COP
- Variable speed drives
- Fresh-air pre-conditioning system
- Space heating system efficiency
- Room heating controls with thermostatic valves
- Domestic hot water system
- Window-to-wall ratio
- Reflective roof: solar reflective index
- Reflective exterior walls: solar reflective index
- Insulation of roof: U-value
- Insulation of ground/raised floor slab: U-value
- Green roof
- Insulation of exterior walls: U-value
- Efficiency of glass: U-value, SHGC, VT
- Domestic hot water pre-heating system
- Economizers
- Demand control ventilation using CO_2 sensors
- Efficient lighting for internal areas
- Efficient lighting for external areas
- Lighting controls
- Efficient appliances
- Efficient smart meters and submeters
- Power factor corrections
- Onsite renewable generation
- Low impact refrigerants
- External shading devices: annual average shading factor

Source: EDGE

ENERGY EFFICIENCY MEASURES

Comparative analysis





After choosing some measures, improved case shows the respective changes in the energy numbers

Source: EDGE

MATERIAL EFFICIENCY MEASURES

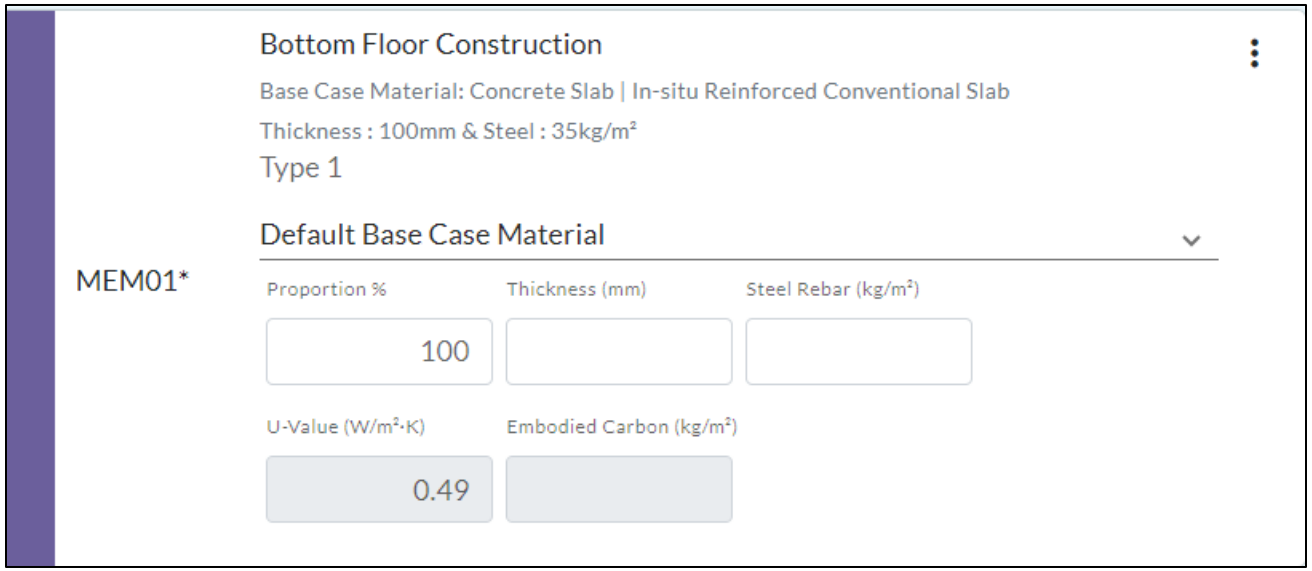
EDGE: List of measures available

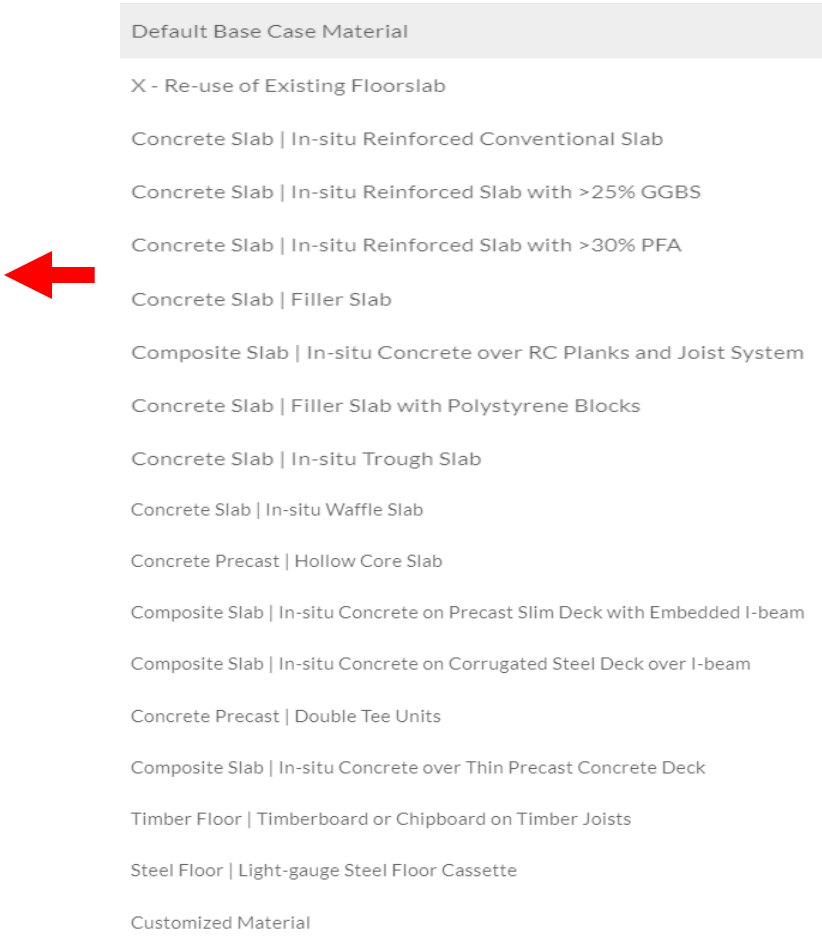
- Bottom floor construction
- Intermediate floor construction
- Floor finish
- Roof construction
- Exterior walls
- Interior walls
- Window frames
- Window glazing
- Roof insulation
- Wall insulation
- Floor insulation

Source: EDGE

MATERIAL EFFICIENCY MEASURES

EDGE: List of measures available



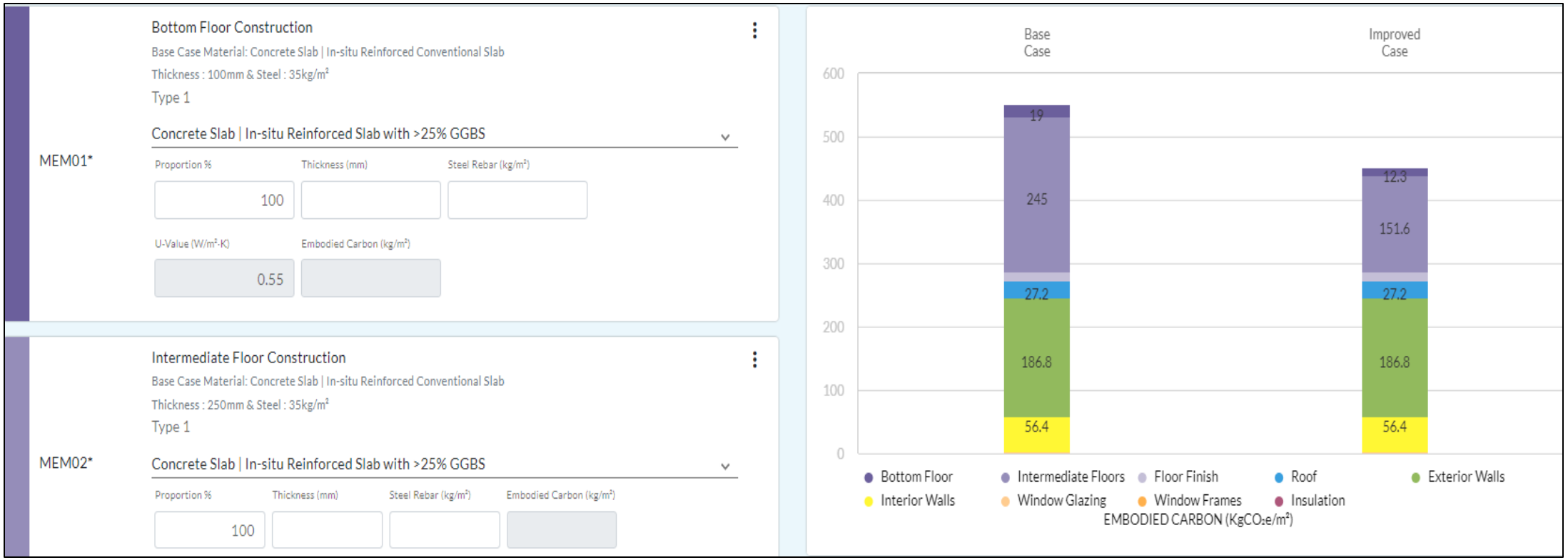


For every measure, there is a default case available. The user can change it to other available variants, as shown in the drop down menu on the right

Source: EDGE

MATERIAL EFFICIENCY MEASURES

Comparative analysis



After choosing the measures, improved case shows the respective changes in the embodied carbon numbers

Source: EDGE

OPERATIONAL ENERGY

User data entry

- User needs to input energy consumption data for all the months, the energy sources being:
  - Conventional electricity
  - Onsite renewable electricity
  - Offsite renewable electricity
  - Carbon offsets purchased
- For onsite non-renewable energy generation (if applicable), user can input fuel type and fuel consumption values for different months
- Outputs from the tool:
  - Total energy consumption
  - Onsite carbon emissions
  - Carbon mitigation from exported renewable energy
  - Net carbon emissions onsite
  - Total GHG offset
  - Net carbon emissions balance

Source: EDGE

EDGE

Case example: Residential home in Philippines

- Location: Philippines
- Energy measures: Window-to-wall ratio, LED lighting, solar photovoltaics
- Material measures: Corrugated zinc sheets for roof, in-situ reinforced wall for external walls, ferrocement wall panel for internal walls

GHG reductions: 0.4 tCO_2/year/home

SOLUTIONS		SAVINGS
Energy	► Reduced Window to Wall Ratio ► LED Lighting ► Solar Photovoltaics	42%
Water	► Low-Flow Showerheads ► Low-Flow Faucets for Kitchen Sinks ► Low-Flow Faucets for Washbasins	20%
Materials	► Corrugated Zinc Sheets for Roof ► In-Situ Reinforced Wall for External Walls ► Ferrocement Wall Panel for Internal Walls	26%
RESULTS		
Savings		
	Utility Bills ($/month/home)	11
	Energy (kWh/month/home)	135
	Water (kL/month/home)	2.4
	Embodied Energy (MJ/home)	1,320
Environmental Benefits		
	GHG Reductions (tCO_2/year/home)	0.4

Source: EDGE

EDGE

Case example: Commercial building in Mexico

- Location: Mexico
- Energy measures: Window-to-wall ratio, external shading, AC with water-cooled chiller, low E-coated glass, energy efficient lighting system, insulation of roof and wall
- Material measures: Concrete filler slab for floors and roof, medium-weight hollow concrete blocks, finished concrete flooring, uPVC window frames

GHG reductions: 497 tCO_2/year

SOLUTIONS	SAVINGS
Energy	**51%**
▸ Reduced Window to Wall Ratio ▸ External Shading ▸ Air Conditioning with Water-Cooled Chiller ▸ Low-E Coated Glass ▸ Energy-efficient Lighting System ▸ Insulation of Roof and Wall	
Water	**32%**
▸ Low-Flow Showerheads ▸ Dual Flush Water Closets ▸ Water-efficient Urinals	
Materials	**44%**
▸ Concrete Filler Slab for Floors and Roof ▸ Medium-weight Hollow Concrete Blocks ▸ Finished Concrete Flooring ▸ uPVC Window Frames	
RESULTS	
Extra Costs & Payback Time	
Green Solutions ($)	56,000
Payback (Yrs.)	0.6
Savings	
Utility Bills ($/month)	7,634
Energy (kWh/month)	90,028
Water (lt./room/night)	121
Embodied Energy (MJ/m²)	744
Environmental Benefits	
GHG Savings (tCO_2/year)	497

Source: EDGE

EDGE

Case example: Unlocking green buildings market for banks

- ProCredit is an international group of development-oriented commercial banks mainly active in South-Eastern and Eastern Europe
- ProCredit has been interested and engaged in financing green buildings for years but has had to develop an individual assessment approach for each country. This approach has posed a serious challenge due to the substantial additional workload involved, coupled with the difficulty of obtaining relevant information
- The group launched its first green loans in 2006 and gradually developed a green lending methodology and a green bonds framework to standardize its lending process and ensure specific environmental impacts are achieved. As of the end of 2020, the group's green loan portfolio amounted to almost EUR1 billion, representing 19% of its total loan portfolio
- Initially, the group has assessed green buildings against country baselines and according to country building codes. The process is intensive and often difficult to implement, owing to a lack of data or proper regulation in its countries of operation
- The situation changed when ProCredit integrated EDGE into the environmental impact assessments carried out for the head offices of its banks, where the benefits of EDGE were apparent: user-friendly application, availability of data, the possibility of preliminary assessment and recognized certification

Source: Polychroniadou, 2021

EDGE

Case example: Unlocking green buildings market for banks (continued)

- ProCredit decided to promote this certification further in its markets by using it as a tool in the assessment process for green buildings. The banks can now use EDGE instead of conducting individual analyses for the purpose of assessing a building's eligibility for a green loan
- ProCredit proposes conducting a preliminary assessment using the EDGE app to make an initial determination whether the project has potential for improved performance of 20% compared to the local baseline. This is done in partnership with Sintali-SGS, who offers EDGE Expert support through its partner network. EDGE Experts provide support in using the application and conducting initial analyses of ProCredit clients' projects
- This assessment is then submitted to the business committee of the bank for review and if approved, the client can benefit from preferential loan rates for the development of the green building project. A further requirement to be eligible for these loan rates is the actual completion of the EDGE certification process
- The use of EDGE data to define eligibility criteria enables the ProCredit banks to have a standardized and comparable approach across its markets, thus unlocking significant potential for building improvement and green finance. It also reduces the time required to conduct an initial eligibility analysis, as local baselines have already been calculated in the EDGE app
- By implementing green lending programs and leading by example through the certification of its own buildings, ProCredit is putting sustainability into action

Source: Polychroniadou, 2021

EC3 AND EDGE TOOLS

Comparison: Easy-to-use tools with different visions

EC3

Not a Certification Scheme

- Focuses on construction materials
- Uses EPDs
- Compares individual materials to be procured
- Ideal for architects and engineers focused on material choices



Perspectives: Granular Value Chain of Products (EC3) vs Financing/Policy (EDGE)



Current Focus: Developed Countries (EC3) vs Developing Countries (EDGE)

Edge

Certification Scheme

- Financial calculator
- Simplified compliance
- Reduced processing
- Cost effective
- Better suited for broader assessments and policy-making

ALCBT CARBON TOOL

Development of a low carbon assessment tool for the ALCBT project

The Tool

- The ALCBT Carbon Tool is a pivotal component of the Asia Low Carbon Buildings Transition (ALCBT) project
- It aims to address embodied and operational carbon in buildings in key Asian countries (Cambodia, India, Indonesia, Thailand, Vietnam)

The Objective

- Provide a scalable, user-friendly platform for assessing whole life carbon emissions in buildings
- Empower stakeholders to quantify and reduce carbon footprints
- Inform the development of a robust taxonomy and thresholds for green public procurement (GPP)

ALCBT CARBON TOOL

Overview



Comprehensive Carbon Assessment

Detailed Embodied Carbon for Structural and Non-structural Elements

Operational Carbon over Building Lifespan

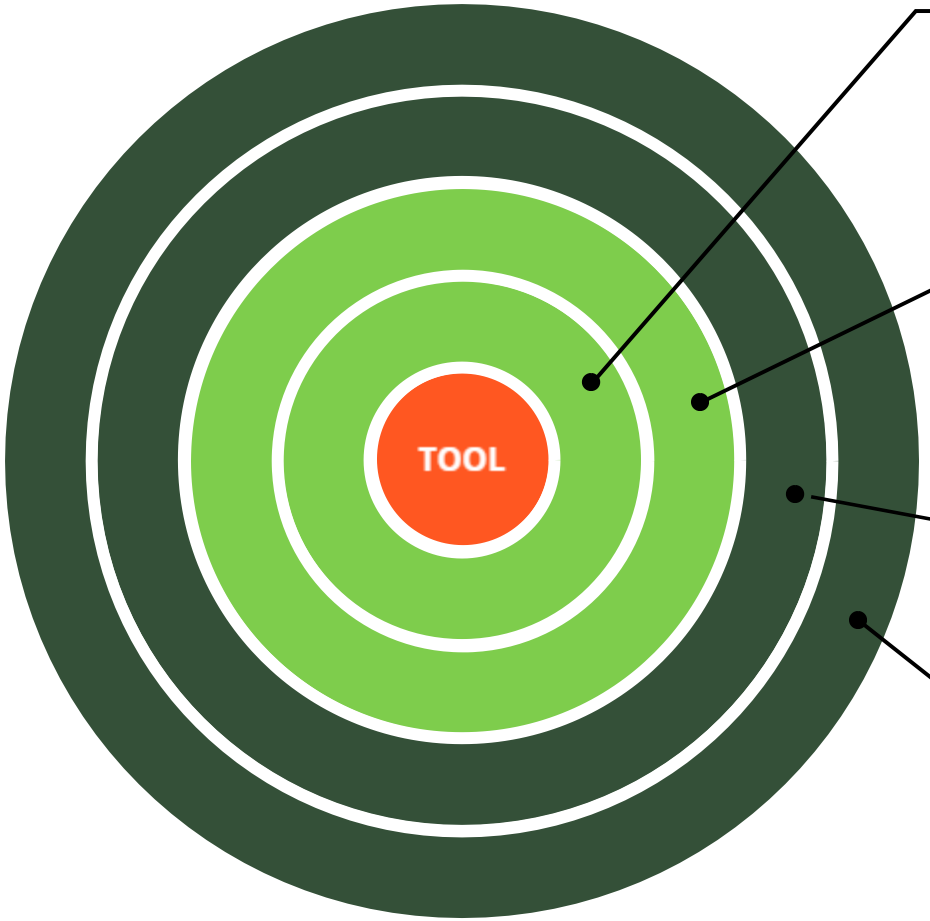
Data Capture from BIM Tools like REVIT for Accurate Material Quantification

Hierarchical EPD System: Site-specific>National>Regional>Global> Calculated LCA

Sensitivity Analysis for Material Choices and Design Alternatives

ALCBT CARBON TOOL

Design principles



Modular structure

Allows for updates and expansion

Comprehensive built-in material and EPD database and interface

Initially for India, later expandable to all ALCBT countries

Adaptive functionality

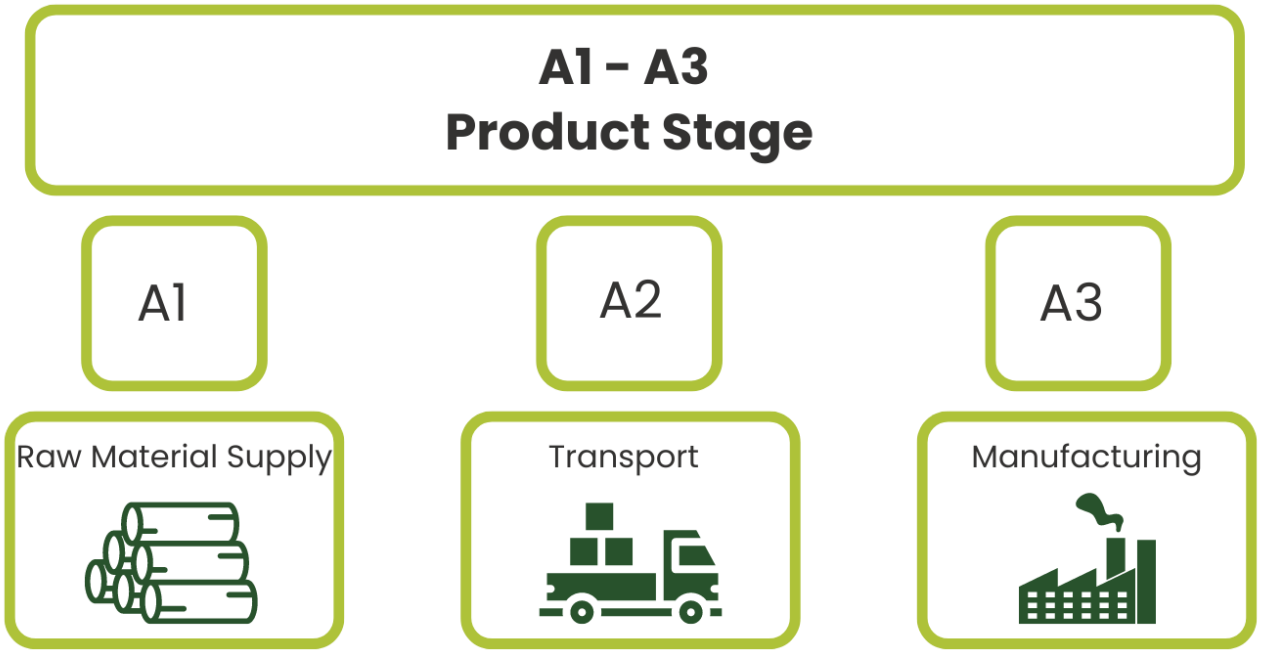
Accommodates limited data availability in certain regions

Full transparency

In calculations and data sources to ensure credibility and trust

ALCBT CARBON TOOL

Current LCA scope



ALCBT CARBON TOOL

Specific features

QUANTIFICATION

- Measure carbon emissions
- Track construction activities
- Monitor material impact

CARBON HOTSPOTS

- Identify high-impact areas
- Analyze intensity levels
- Target improvements

DESIGN ALTERNATIVES

- Compare options
- Evaluate impacts
- Optimize choices

COMPLIANCE

- Meet standards
- Drive benchmarks
- Facilitate certification

ALCBT CARBON TOOL

Overview of user interactions

TAB 1: Data Entry: Building Information

TAB 2: Modeling Elements

TAB 3: Modeling Items

TAB 4: Results + Analysis

ALCBT CARBON TOOL

Data entry requirements

Building characteristics and information – type, location, climate zone, gross floor area, year of construction, etc.

Building elements – structural and non-structural, e.g., exterior walls, floors, thickness of each layer, etc.

Material categories and groups, e.g., components of windows and curtain walls, declared units

Material-specific data – EPDs, PCRs, embodied carbon factors, etc.

Operational energy use – annual electricity consumption, energy audit report, heating, cooling usage

Life cycle considerations – scope of LCA (A1–A3), end of life use, etc.

ALCBT CARBON TOOL

Modeling elements

Element Definition

Name: Exterior Walls

Type: Residential Wall Assembly

Layers Breakdown

Layer 1: Outside Cladding
Material: Laminated Timber
Thickness: 5 cm

Layer 2: Insulation
Material: Perlite 0–3
Thickness: 10 cm

Layer 3: Structural Layer
Material: Softwood Lumber
Thickness: 10 cm

Calculation

Volume = Thickness × Area

Mass = Volume × Density

Environmental Impact = Mass × GWP/PENRT Factors

ALCBT CARBON TOOL

Calculation example

Table 1: Outer Wall Structure LCA Data

Layer	Material	Thickness (mm)	Bulk Density (kg/m³)	GWP A1-A3 (kg CO2-eq)	PENRT A1-A3 (MJ)
1	Material A	250	800	12.5	50
2	Material B	100	600	7.0	30

Table 2: Roof Structure LCA Data

Layer	Material	Thickness (mm)	Bulk Density (kg/m³)	GWP A1-A3 (kg CO2-eq)	PENRT A1-A3 (MJ)
1	Material C	300	900	15.0	60
2	Material D	150	700	8.0	35

Table 3: Summary of LCA Results

Structural Element	Total GWP (kg CO2-eq)	Total PENRT (MJ)
Outer Wall	19.5	80
Roof	23.0	95

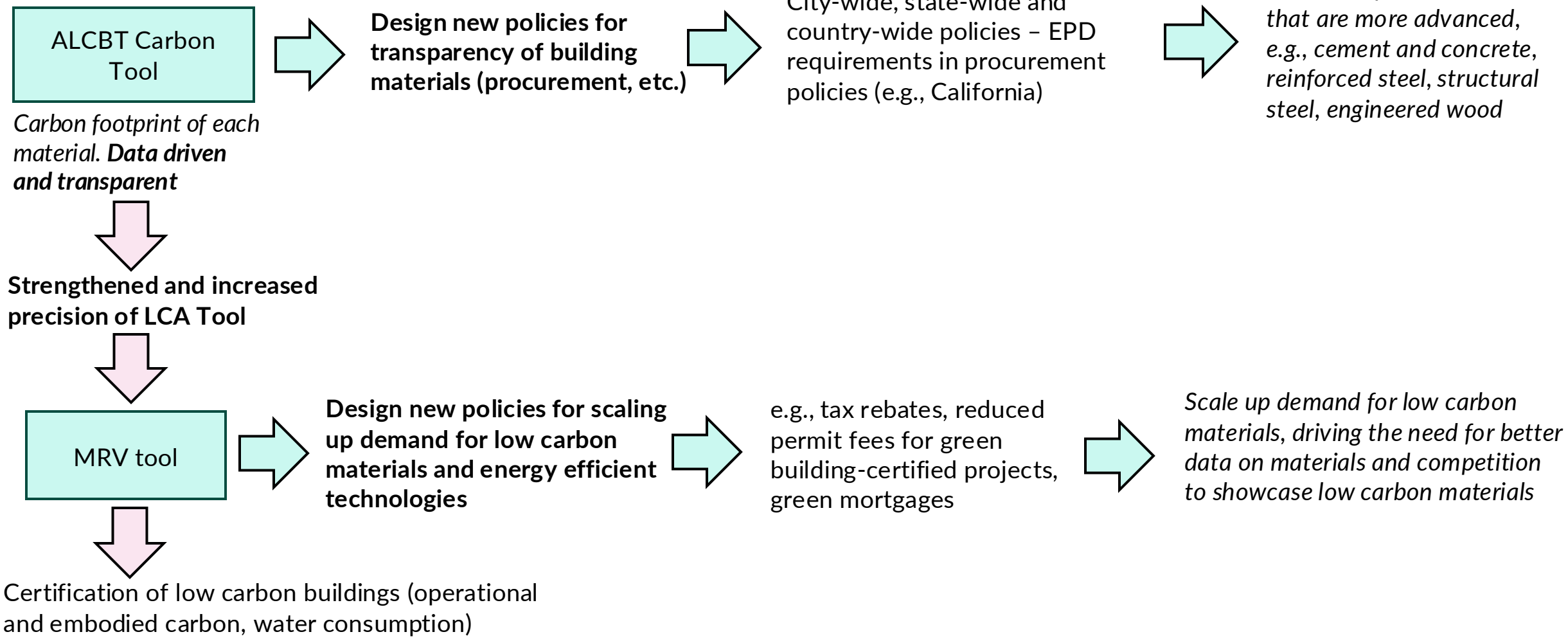
MRV CONCEPTS

Distinction between MRV and ALCBT tool

- The ALCBT Carbon Tool helps to **create a baseline for a building stock** from ALCBT countries. This will help to feed in entry data for the monitoring, reporting and verification (MRV) tool
- The MRV tool **calculates or estimates emissions under different future scenarios** by allowing users to change selected factors that impact projected emissions from the building sector at given time periods, including any significant actions such as regulations and policies, or introduction of efficient and low carbon solutions at specific periods, alone or in combination
- The MRV tool supports large-scale modeling of buildings, building populations, and future pathways, scenarios and baselines. **This tool enables policy-makers to set national targets in NDCs and LT-LEDS**
- The ALCBT Carbon Tool can provide both quick and detailed modeling of whole life carbon of a building. This tool helps to define baselines for city- and country-specific buildings, and design new policies for scaling up the demand for low carbon materials and energy efficient technologies

SCALING UP BUILDING LCA

Potential pathway



Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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Supported by:
Federal Ministry for Economic Affairs and Climate Action
IKI INTERNATIONAL CLIMATE INITIATIVE
on the basis of a decision by the German Bundestag



ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

4.1 Financing Low Carbon Buildings

November 2024

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?



- Low carbon buildings: Additional cost implications
- Building sector green finance opportunity and market size



- Financial and fiscal instruments for funding



- European Union taxonomy
- Blended finance
- Assessing risks and opportunities associated with energy efficiency investments



- Beneficial financing terms to developers and buyers
- Green loans
- Green mortgages
- Loans for retrofit and renovation of buildings



- Case examples

FINANCING LOW CARBON BUILDINGS

Issues and concerns

Financing of business-as-usual conventional buildings is traditionally well established. However, attracting finance for low carbon buildings can be a challenge due to the following reasons:

- **Lack of awareness about the concept of low carbon buildings**
- **Lack of confidence among stakeholders about low carbon technologies and building features delivering the claims of energy and cost savings**
- **Insufficient information about the extent of higher capital investment demanded by low carbon buildings**
- **Apprehension of builders about losing market share due to higher premiums for low carbon buildings, especially since the major financial benefit over the lifetime of the building is to the buyer and not to the builder**
- **Reluctance of prospective buyers to pay premiums for low carbon buildings due to lack of awareness about operational savings**
- **Buyer interest in energy savings reduces when buildings are not self-occupied, and the benefits of energy cost savings go to the tenants**
- **Absence of government incentives to at least partially offset the higher cost of low carbon (green) buildings**
- **Doubts about the market size that prevent banks and financial institutes evolving robust 'off-the-shelf' loan products for financing low carbon buildings and other sustainability projects**

LOW CARBON BUILDINGS

Cost implications

Green Residential Building

Reduces utility bills, waste output and maintenance costs

- Lowers operating expenses
- Improves resource efficiency

Saves more than 20% on energy and water consumption



Average 15%–20% reduction in utility bills for homeowners

Green buildings that incorporate recycling can reduce waste output by 90% and use 30% less energy, equating to a 5% increase in net operating income compared to traditional buildings

18%–37% lower operating costs than traditional buildings

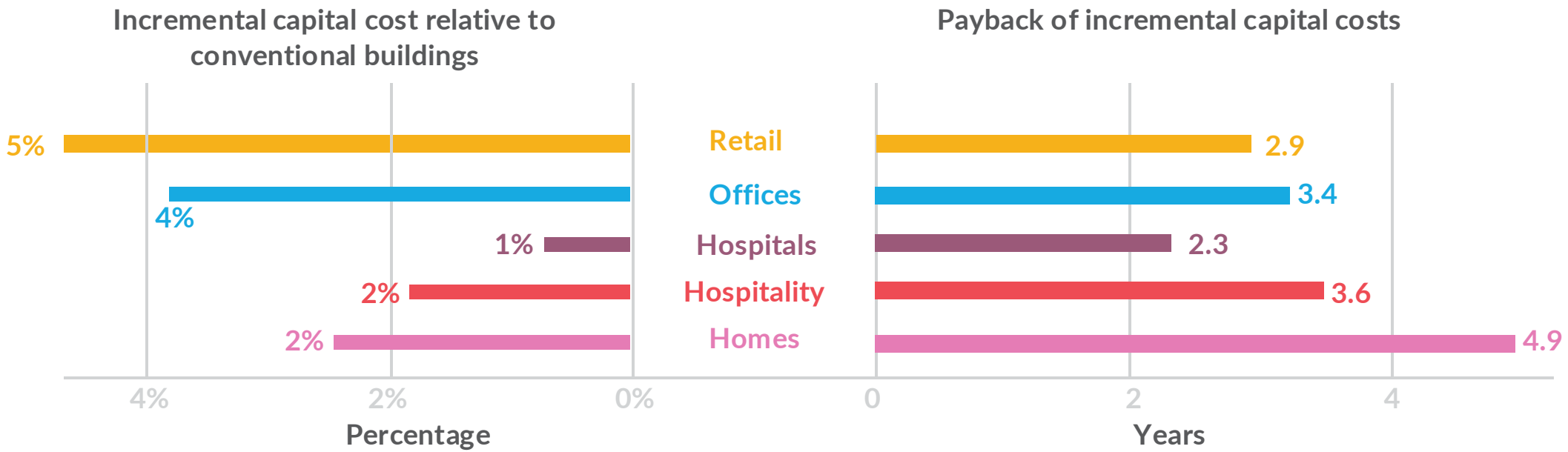
Green Commercial Building



Source: International Finance Corporation, 2019

LOW CARBON BUILDINGS

Cost implications



The incremental costs in the range of 1% to 5% has payback periods in the range of 2.3 years to 4.9 years

Note: Incremental capital costs are the ratio of incremental cost over typical construction costs

Source: International Finance Corporation, 2023

LOW CARBON BUILDINGS

Case example: Additional cost and payback

In Indonesia, the EDGE-certified Citra Maja Raya development reported the additional cost of green measures to be **4.7%, with a payback period of 1.8 years**

The green measures included:

- **Optimum window sizing**
- **External shading**
- **Insulation of roof and external walls**
- **Natural ventilation**
- **Energy and water efficient systems**

The utility savings per year amount **to 30%**. Some residents reported that their monthly **utility bill decreased from an equivalent of USD55 in previous non-green housing to USD14**



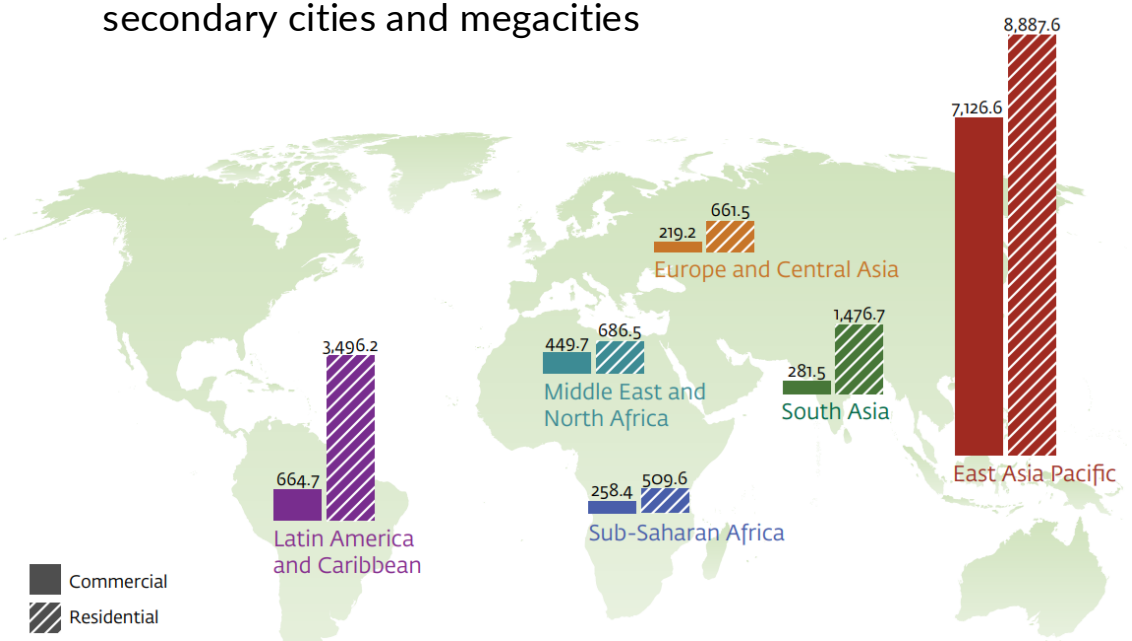
Citra Maja Raya Housing Estate, Indonesia

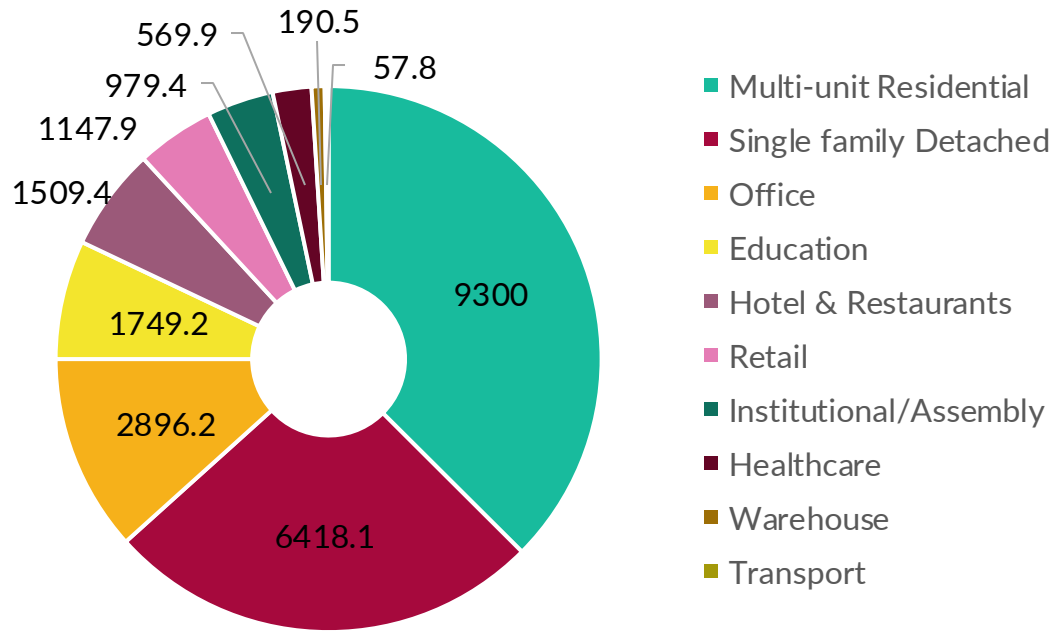
Image: https://www.kokogiovanni.com/2018/11/rumah-murah-cluster-sanur-persembahan-citra-maja-raya.html

MARKET POTENTIAL

Global projections for green buildings

- The market potential for green buildings is estimated to reach USD24.7 trillion by 2030 across emerging market cities with populations exceeding half a million, with the residential sector representing USD15.7 trillion of this opportunity
- The East Asia Pacific region alone presents a green building investment opportunity of USD16 trillion, accounting for over half of the total opportunity across all emerging markets
- South Asia holds a USD1.8 trillion investment potential in green buildings, primarily driven by rapidly growing secondary cities and megacities





Source: International Finance Corporation, 2019

FINANCING LOW CARBON BUILDINGS

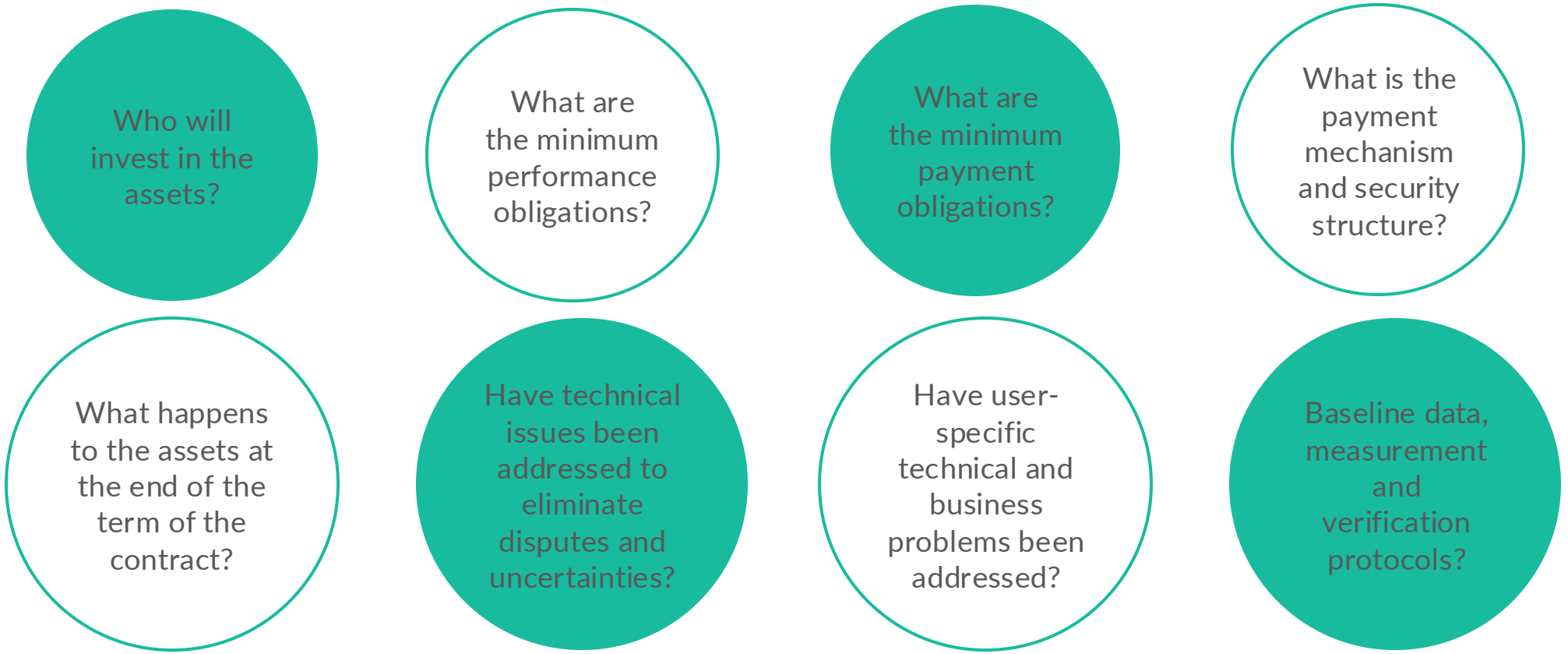
Need of the hour: Innovative green financing for the building sector

- Banks and financial institutes play an important role in mobilizing funds to achieve climate change goals. Innovative financial products supporting the transition to a low carbon economy are being developed and gaining acceptance
- Presently, green financing in most countries is primarily focused on renewable energy, electric mobility, industrial energy efficiency, water and agriculture. Low carbon green buildings have yet to attract significant attention
- *Green bonds* appear to be gaining traction in the financial markets of both developed and emerging economies, and are expected to be the way forward for funding sustainability projects
- *Blended finance*, where investors with different risk tolerances participate in the same project, offers an effective way to secure capital for sustainability projects



FINANCING LOW CARBON BUILDINGS

Clarity on project transactions



Clarity on the above issues is a prerequisite for successfully implementing business models

FINANCING LOW CARBON BUILDINGS

Essentials for a contract

Energy efficiency projects are medium-term contract-driven businesses. Standard formats for energy services agreements help streamline business models, provide minimum safeguards to honor obligations and resolve disputes. Some of the prerequisites are:

- Precise definition of scope of services
- Clear delineation of responsibilities for all parties involved
- Establishment of baselines
- Enforce minimum and guaranteed performance standards
- Determine measurement and verification protocols
- Enforce minimum and guaranteed payment obligations
- Devise payment and security structure for suitable collateral and delayed payment risk
- Evolve clear-cut energy services billing procedures
- Put in place termination valuation formulas
- Take or pay protection for lenders
- Address potential areas of dispute

FINANCIAL INSTRUMENTS

Categories

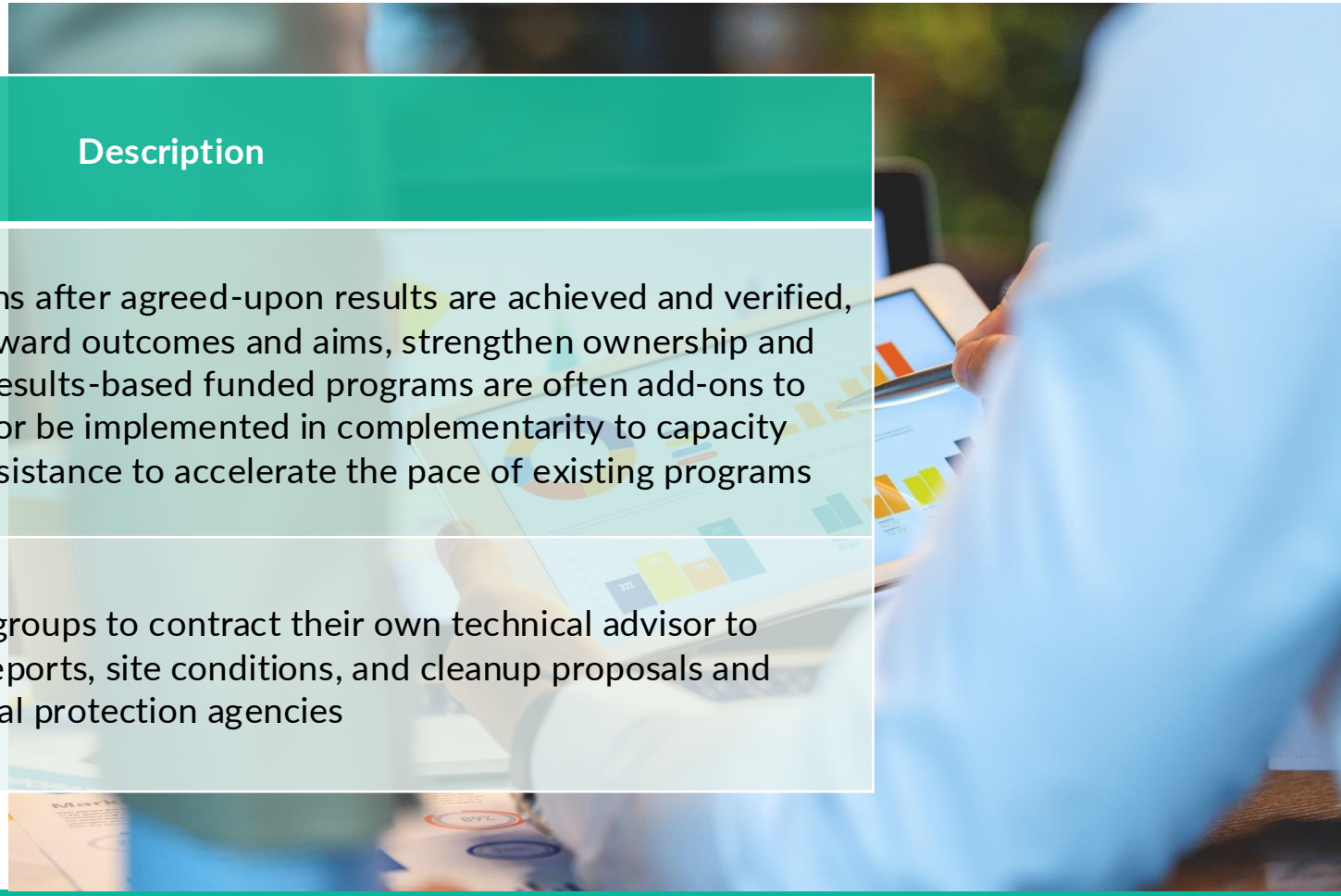
- The financial sector offers various instruments, both traditional and specialized, which can be categorized into grants, debts, equities, structured finance models, risk mitigation models, asset finance models and other innovative models packaged to meet the demands of the global sustainability drive
- Additionally, government bodies are offering incentives and disincentives through fiscal instruments
- Not all instruments have the same role in the net zero buildings transition. Some can only be used in certain contexts while others only allow for a subset of building improvement measures
- Overall, there is no one financial instrument that covers all the needs of a net zero transition. Reaching net zero in the buildings sector requires all building types, all technical elements, and all recipients to be served. Rarely will a standard financial instrument be able to address all issues adequately
- Considering the specific demands of sustainability projects, there is scope for innovation and customization of financial instruments. This modules gives an overview of financial and fiscal instruments that can be considered, depending on the customization required, with reference to the specific demands of the project

Source: LaSalle et al., 2022

FINANCIAL INSTRUMENTS

Grants from international bilateral agencies

Instrument	Description
Result-based grant	Rewards individuals or institutions after agreed-upon results are achieved and verified, which helps to shift the focus toward outcomes and aims, strengthen ownership and provide incentives to perform. Results-based funded programs are often add-ons to other programs and can include or be implemented in complementarity to capacity building activities or technical assistance to accelerate the pace of existing programs
Technical assistance grant	Provides funding to community groups to contract their own technical advisor to interpret and explain technical reports, site conditions, and cleanup proposals and decisions issued by environmental protection agencies

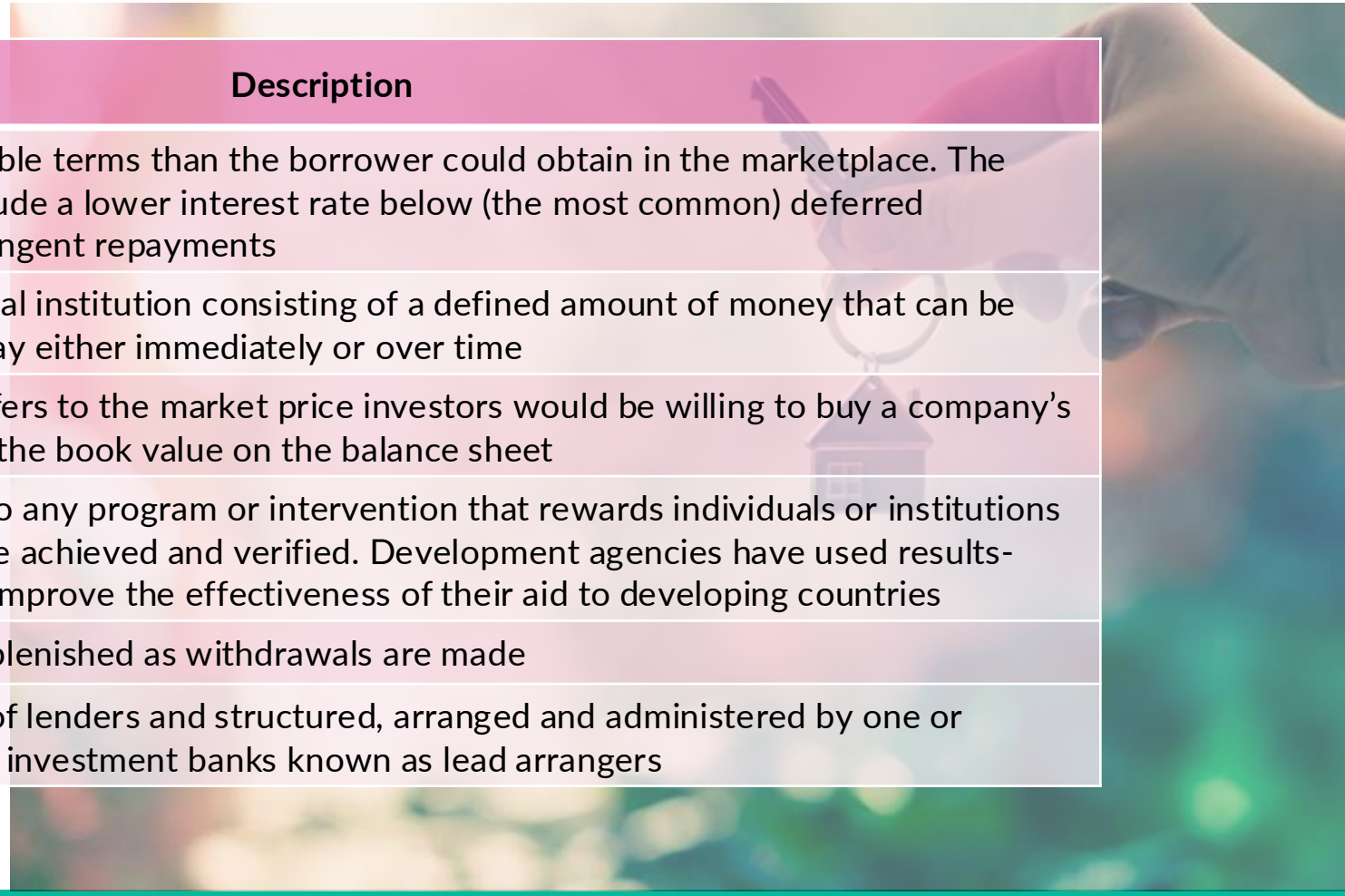


Source: Purnomo et al., 2024

FINANCIAL INSTRUMENTS

Debt financing

Instrument	Description
Concessional loan	A loan made on more favorable terms than the borrower could obtain in the marketplace. The concessional terms may include a lower interest rate below (the most common) deferred repayments or income-contingent repayments
Credit line	A flexible loan from a financial institution consisting of a defined amount of money that can be accessed as needed and repay either immediately or over time
Market-rate debt	The market value of debt refers to the market price investors would be willing to buy a company's debt for, which differs from the book value on the balance sheet
Results-based loan	An umbrella term referring to any program or intervention that rewards individuals or institutions after agreed-upon results are achieved and verified. Development agencies have used results-based financing as a tool to improve the effectiveness of their aid to developing countries
Revolving fund	A fund that is continually replenished as withdrawals are made
Syndicated loan	A loan provided by a group of lenders and structured, arranged and administered by one or several commercial banks or investment banks known as lead arrangers



Source: Purnomo et al., 2024

FINANCIAL INSTRUMENTS

Debt financing

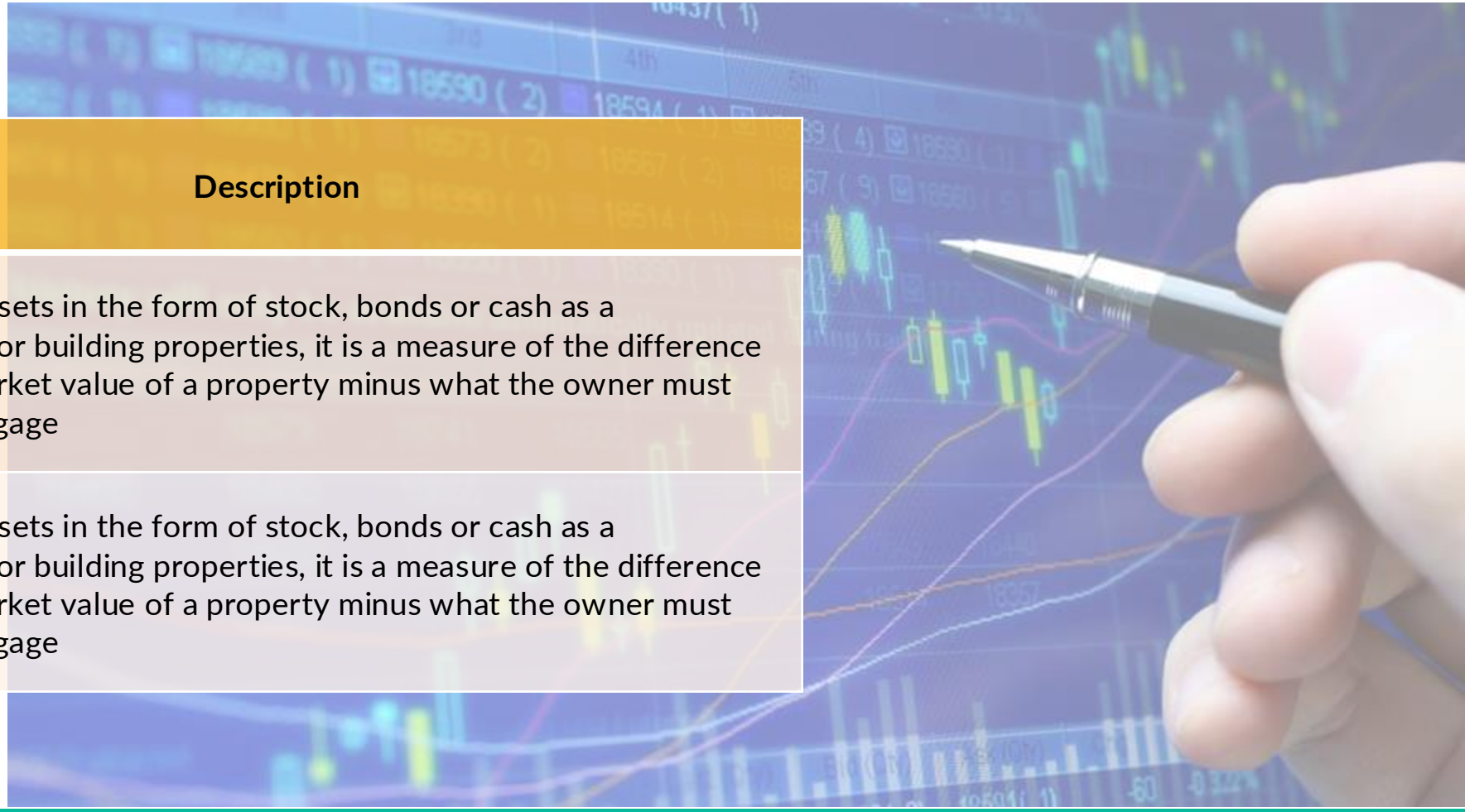
Instrument	Description
Green mortgage	A mortgage specifically targeted at green buildings. As an incentive for the borrower to either buy a green building or renovate an existing one to make it greener, the bank would offer either a lower interest rate or an increased loan amount
Catastrophe bond / insurance pool	Risk-linked securities that transfer a specified set of risks from a sponsor to investors
Green corporate / obligation bond	A green bond is differentiated from a regular bond in that it signifies a commitment to exclusively use the funds raised to finance or refinance green projects, assets or business activities
Green project / municipal bond	Any type of bond instrument where the proceeds will be exclusively applied to finance or refinance in part or in full new and/or existing eligible projects that provide clear environmental benefits, which are assessed and quantified by the issuer where feasible
Green sukuk	The green label indicates that the sukuk is compliant with green bond standards, principles and framework. The proceeds of green bonds are used to finance climate change mitigation, climate change adaptation and environmental projects

Source: Purnomo et al., 2024

FINANCIAL INSTRUMENTS

Equities

Instrument	Description
Private equity	Ownership of assets in the form of stock, bonds or cash as a ‘shareholding’. For building properties, it is a measure of the difference between the market value of a property minus what the owner must pay on the mortgage
Public equity	Ownership of assets in the form of stock, bonds or cash as a ‘shareholding’. For building properties, it is a measure of the difference between the market value of a property minus what the owner must pay on the mortgage



Source: Purnomo et al., 2024

FINANCIAL INSTRUMENTS

Structured finance

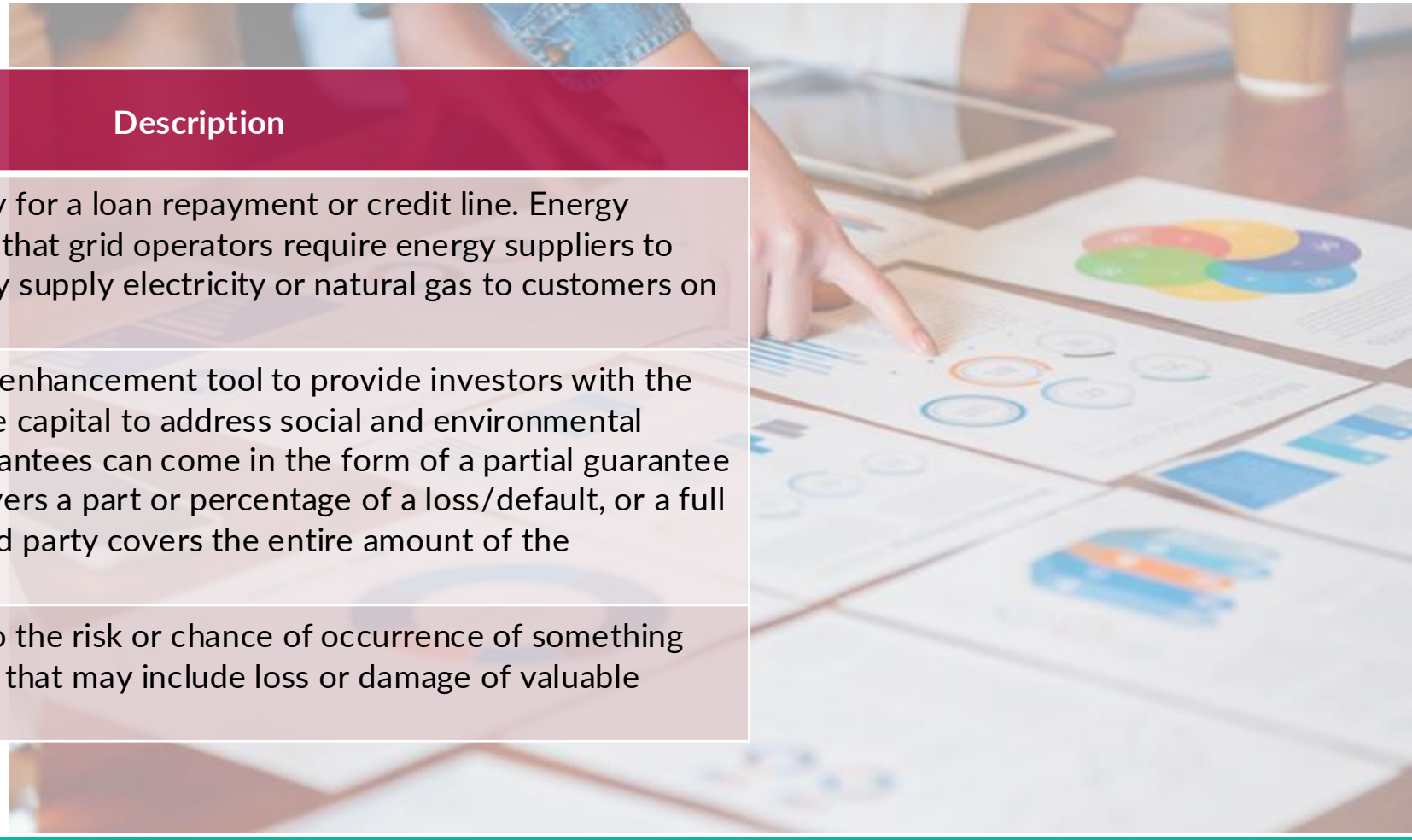
Instrument	Description
Aggregation platform	Platform for a group of companies or local institutions to partner together to buy energy from a single developer or multiple developers at smaller volumes while retaining the economic advantages of a high-volume purchase
Land banking / land readjustment	An effective tool in allowing local governments to take on regeneration projects through increased land values while engaging and involving the original residents and landowners as stakeholders
Pooled procurement for green financial product or building	Combines financial and other resources of purchasing authorities to improve efficiency and create greater purchasing power for green financial products or buildings
Securitization / Asset-backed securities (ABS)	A type of financial investment that is collateralized by an underlying pool of assets – usually one that generates a cash flow from debt, such as loans, leases, credit card balances or receivables

Source: Purnomo et al., 2024

RISK MITIGATION INSTRUMENTS

From banks and financial institutes

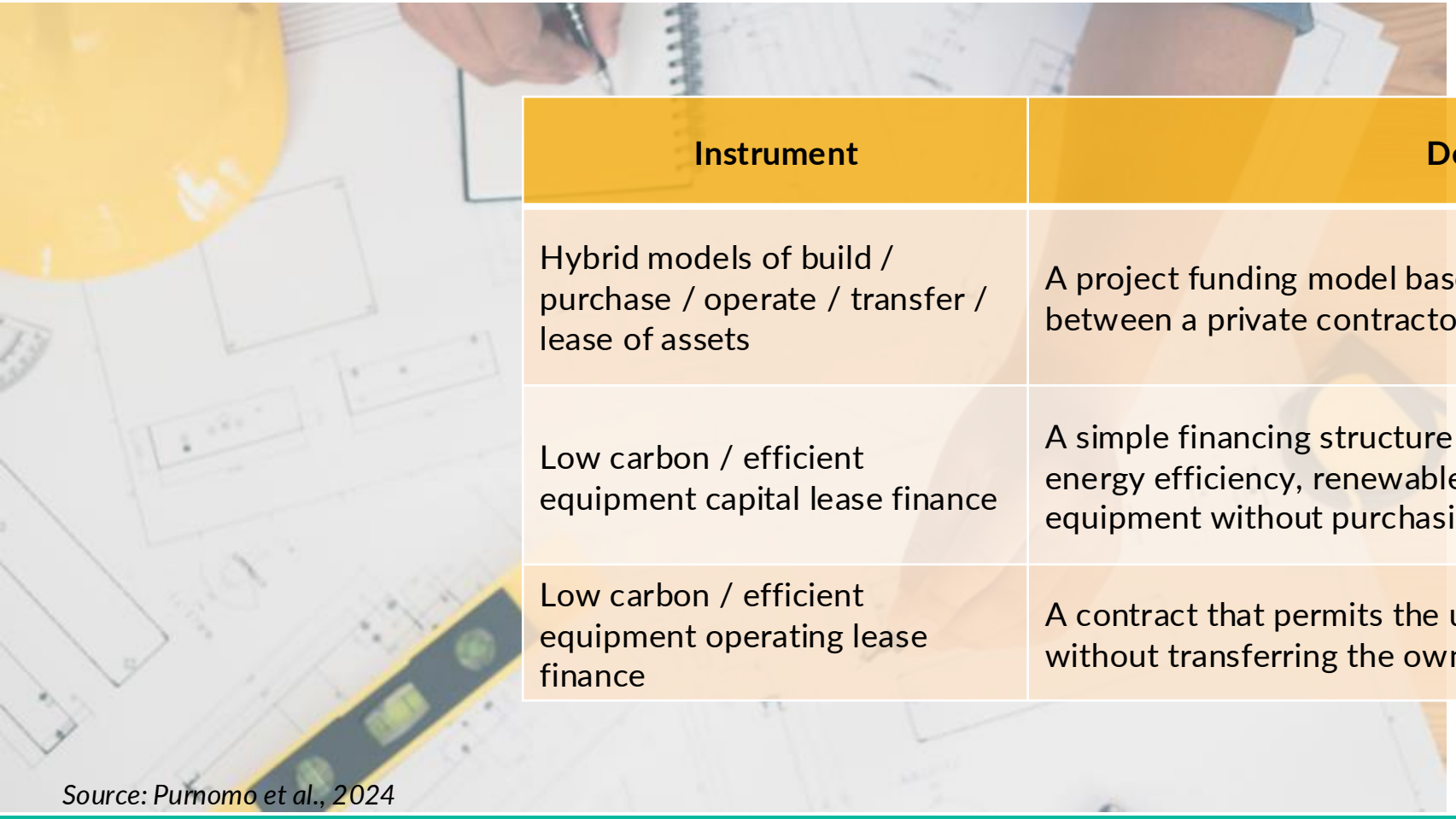
Instrument	Description
Collateral	Pledge to offer security for a loan repayment or credit line. Energy collateral is the money that grid operators require energy suppliers to post in order to actively supply electricity or natural gas to customers on that grid
Full or partial credit guarantee	A guarantee is a credit enhancement tool to provide investors with the ability to leverage more capital to address social and environmental challenges. Credit guarantees can come in the form of a partial guarantee where a third party covers a part or percentage of a loss/default, or a full guarantee where a third party covers the entire amount of the loss/default
Risk insurance product	Risk insurance refers to the risk or chance of occurrence of something harmful or unexpected that may include loss or damage of valuable assets



Source: Purnomo et al., 2024

ASSET FINANCE MODELS

Between customers and solution providers



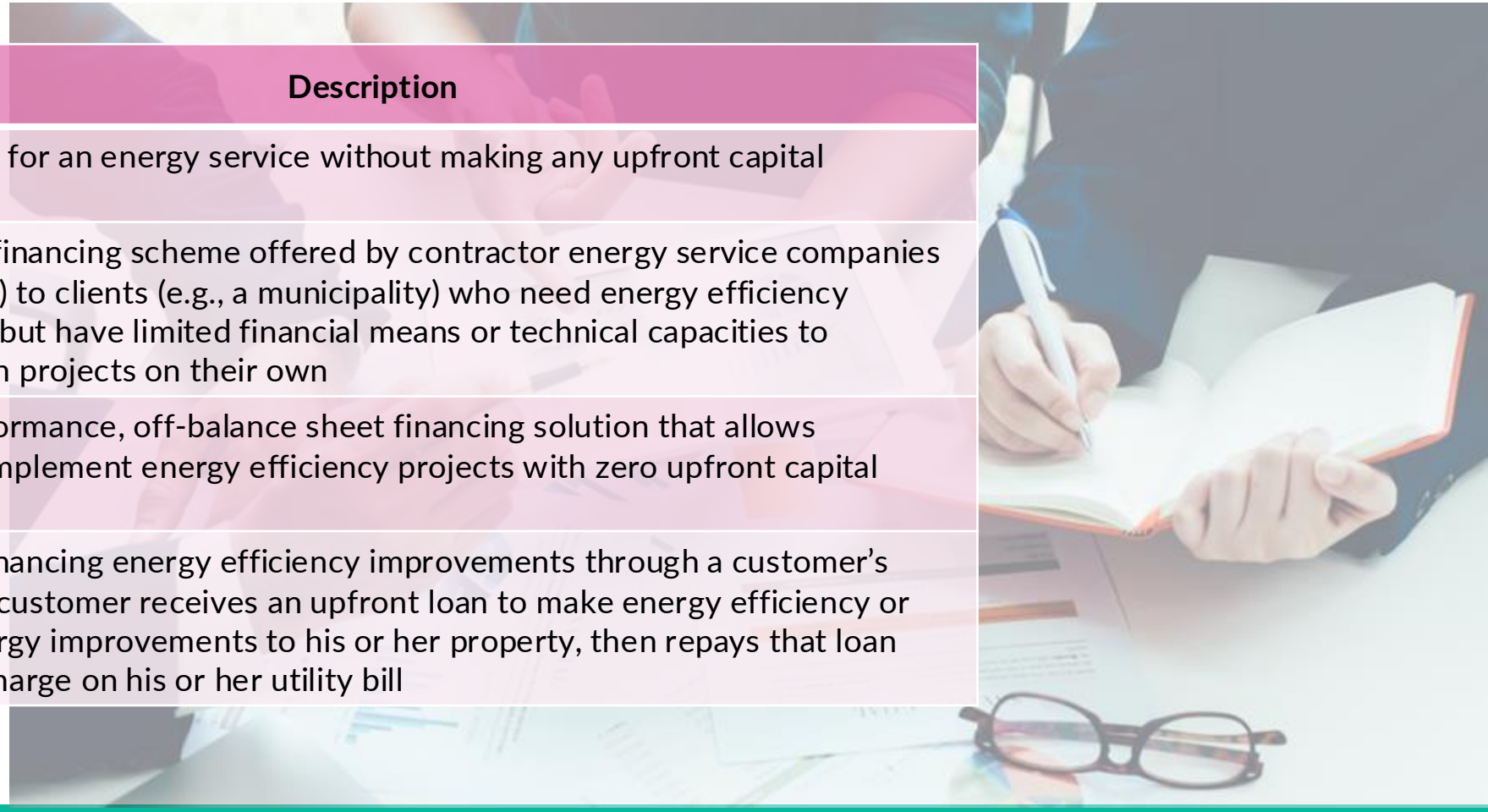
Instrument	Description
Hybrid models of build / purchase / operate / transfer / lease of assets	A project funding model based on a financial agreement between a private contractor and a public organization
Low carbon / efficient equipment capital lease finance	A simple financing structure that allows a customer to use energy efficiency, renewable energy or other generation equipment without purchasing it outright
Low carbon / efficient equipment operating lease finance	A contract that permits the use of an energy efficient asset without transferring the ownership rights of said asset

Source: Purnomo et al., 2024

OTHER INNOVATIVE MODELS

Between customers and solution providers

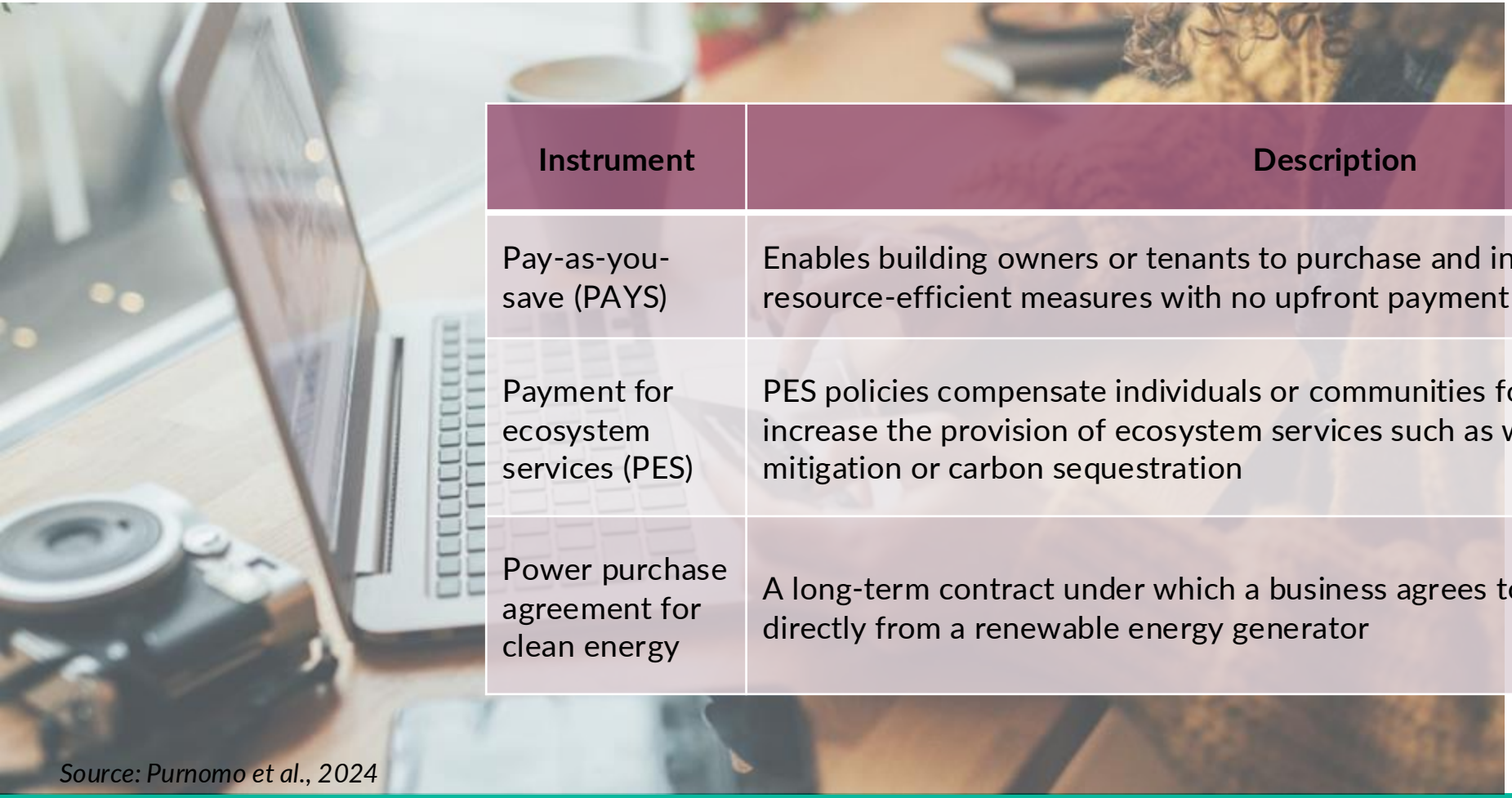
Instrument	Description
As-a-service model	Customers pay for an energy service without making any upfront capital investment
Energy performance contract (EPC) and ESCOs	An innovative financing scheme offered by contractor energy service companies (usually ESCOs) to clients (e.g., a municipality) who need energy efficiency improvements but have limited financial means or technical capacities to implement such projects on their own
Energy service agreement (ESA)	A pay-for-performance, off-balance sheet financing solution that allows customers to implement energy efficiency projects with zero upfront capital expenditure
On-bill financing (OBF) and repayment (OBR)	A method of financing energy efficiency improvements through a customer's utility bill. The customer receives an upfront loan to make energy efficiency or renewable energy improvements to his or her property, then repays that loan through a surcharge on his or her utility bill



Source: Purnomo et al., 2024

OTHER INNOVATIVE MODELS

Between customers and solution providers



Instrument	Description
Pay-as-you-save (PAYS)	Enables building owners or tenants to purchase and install money-saving resource-efficient measures with no upfront payment and no debt obligation
Payment for ecosystem services (PES)	PES policies compensate individuals or communities for undertaking actions that increase the provision of ecosystem services such as water purification, flood mitigation or carbon sequestration
Power purchase agreement for clean energy	A long-term contract under which a business agrees to purchase electricity directly from a renewable energy generator

Source: Purnomo et al., 2024

FISCAL INSTRUMENTS

With government bodies

Instrument	Description
Capital cost subsidy	A subsidy that covers a share of the upfront capital cost of an asset (e.g., a solar water heater)
Carbon credits and markets	A mechanism to reduce greenhouse gas (GHG) emissions by creating a market in which companies can trade in emissions permits
Energy / carbon tax	A type of penalty that businesses must pay for excessive GHG emissions
Feed-in-tariff	A payment made to households or businesses generating their own electricity using methods that do not contribute to the depletion of natural resources, proportional to the amount of power generated
Financial penalty	The obligation to pay a sum of money on conviction of a criminal or administrative offense
Property Assessed Clean Energy (PACE)	PACE initiatives allow local governments to support building owners carry out energy efficiency retrofits or install renewable energy in their properties. This entails conducting special assessments for eligibility and providing upfront funding for the improvement, which is paid back through property tax bills

Source: Purnomo et al., 2024

FISCAL INSTRUMENTS

With government bodies



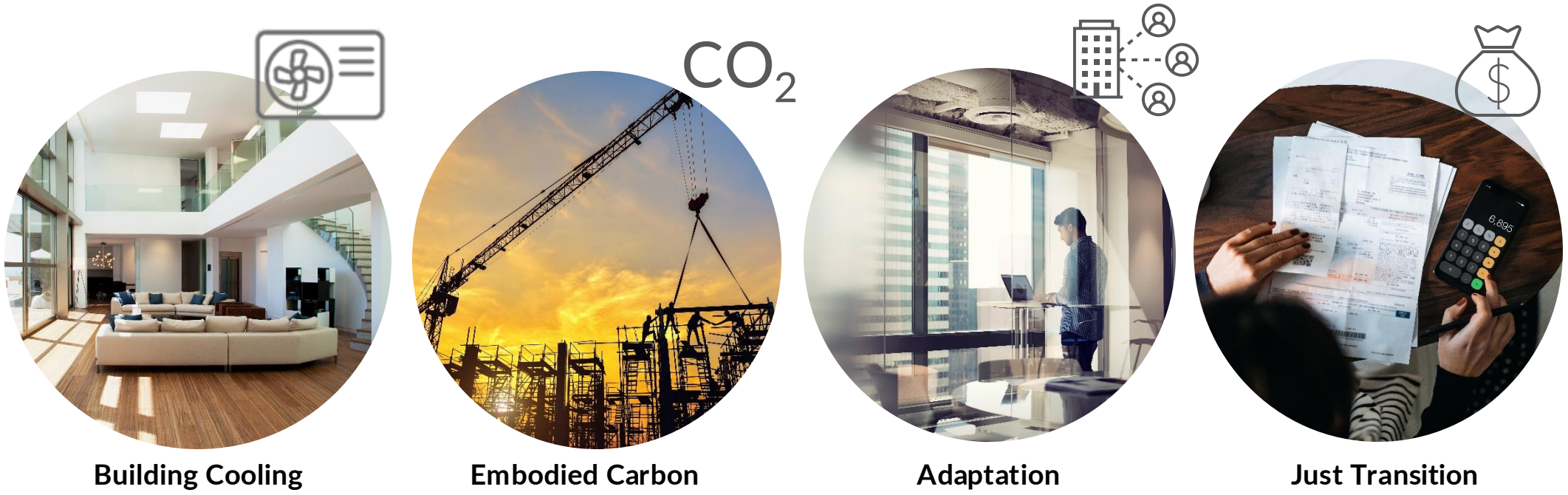
Instrument	Description
Service subsidies	Include payments, tax breaks or other forms of economic support given to individuals and industries. The subsidies are designed to promote infant industries, achieve universal access objectives (health, education and sanitation), and encourage more sustainable patterns of production and consumption (energy and transport), as well as respond to market failures and their potentially undesirable social and developmental consequences
Tax incentives	Include credits, rebates, reductions and exemptions for property owners to install energy-saving equipment and renewable energy systems, and meet green building certification standards. Tax incentives can be based on specific low embodied-carbon criteria such as energy efficiency building codes or green building certification standards
Tax or fee-based land-value capture (LVC)	The value of privately-held land often increases due to public investments in the area. LVC methods usually seek to harness a portion of these unearned rents to help finance public infrastructure or improvement projects. Betterment taxes can be implemented to levy tax on total land value or on the incremental value in the neighborhood of the public investment

Source: Purnomo et al., 2024

FINANCIAL INTERVENTIONS

High-impact thematic focus areas

To make significant impact in the buildings sector, financial instruments should address the following four thematic areas



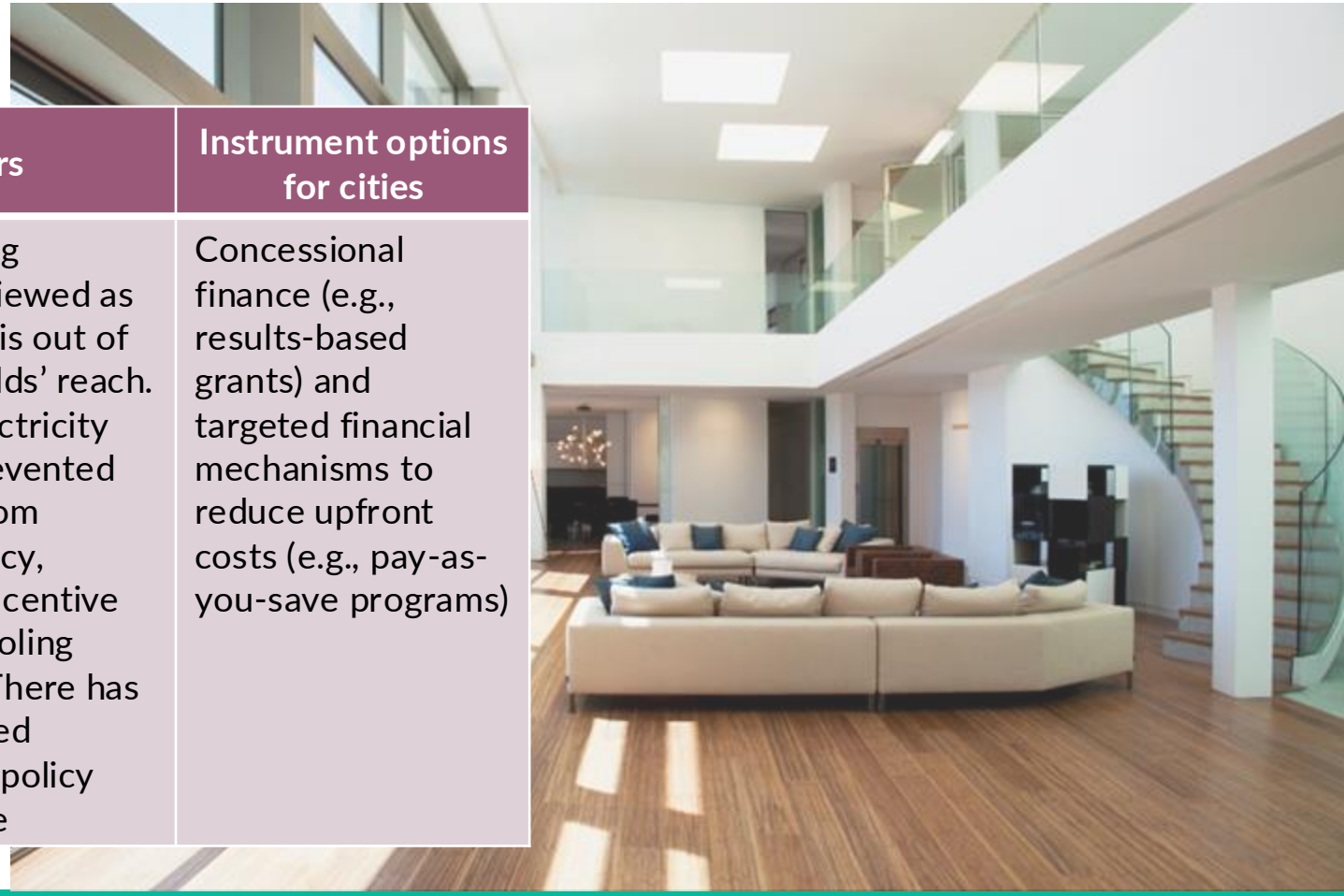
Building Cooling | **Embodied Carbon** | **Adaptation** | **Just Transition**

Source: Micale et al., 2023

FINANCIAL INTERVENTIONS NEEDED

Thematic area: Building cooling

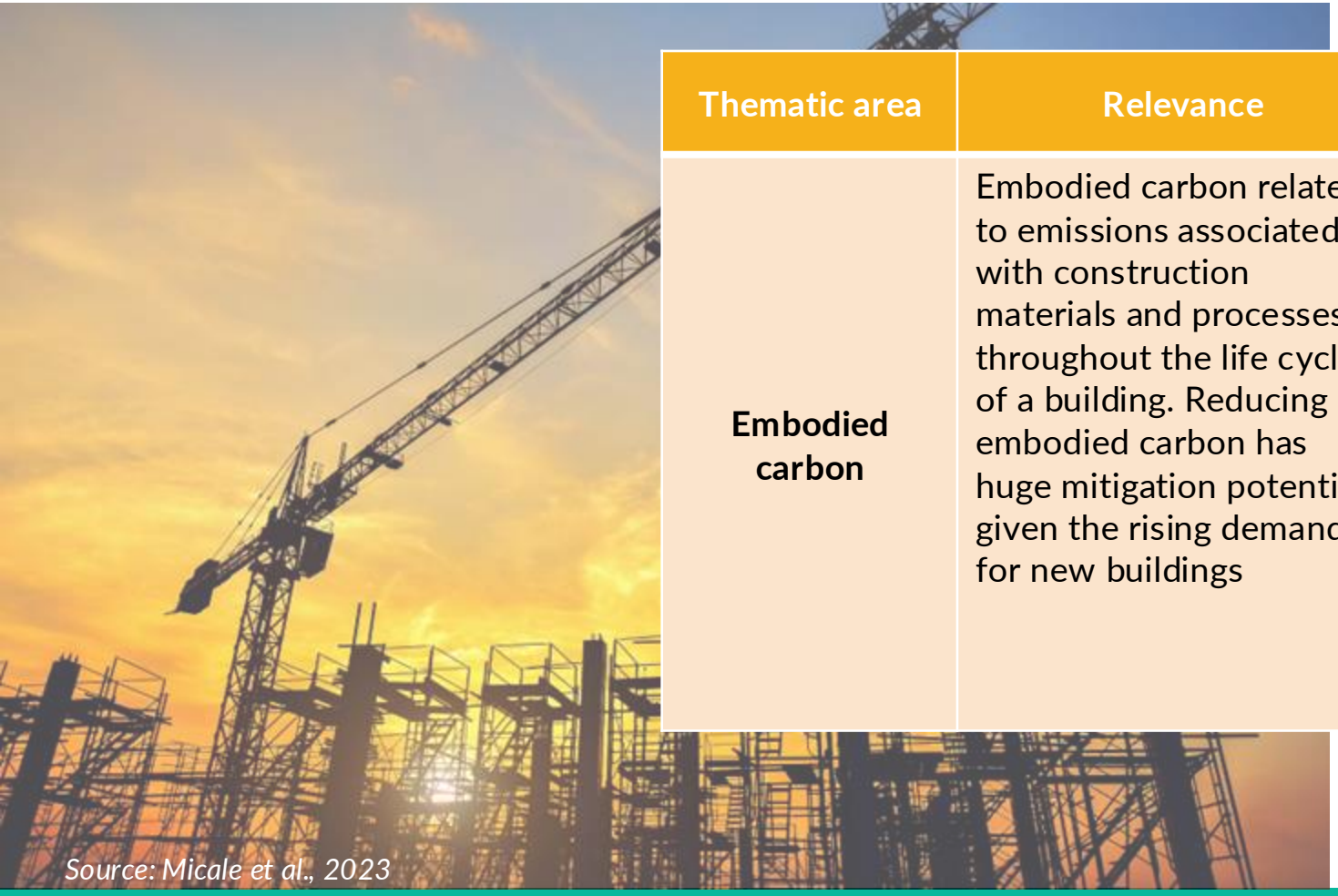
Thematic area	Relevance	Barriers	Instrument options for cities
Building cooling	Building cooling is the fastest-growing energy use in buildings. Meeting cooling energy demand without increasing emissions requires efficient cooling equipment, as well as thermal envelope and passive designs	Efficient cooling equipment is viewed as expensive and is out of many households' reach. Fluctuating electricity prices have prevented cost savings from energy efficiency, becoming an incentive for efficient cooling technologies. There has also been limited regulation and policy support to date	Concessional finance (e.g., results-based grants) and targeted financial mechanisms to reduce upfront costs (e.g., pay-as-you-save programs)



Source: Micale et al., 2023

FINANCIAL INTERVENTIONS NEEDED

Thematic area: Embodied carbon



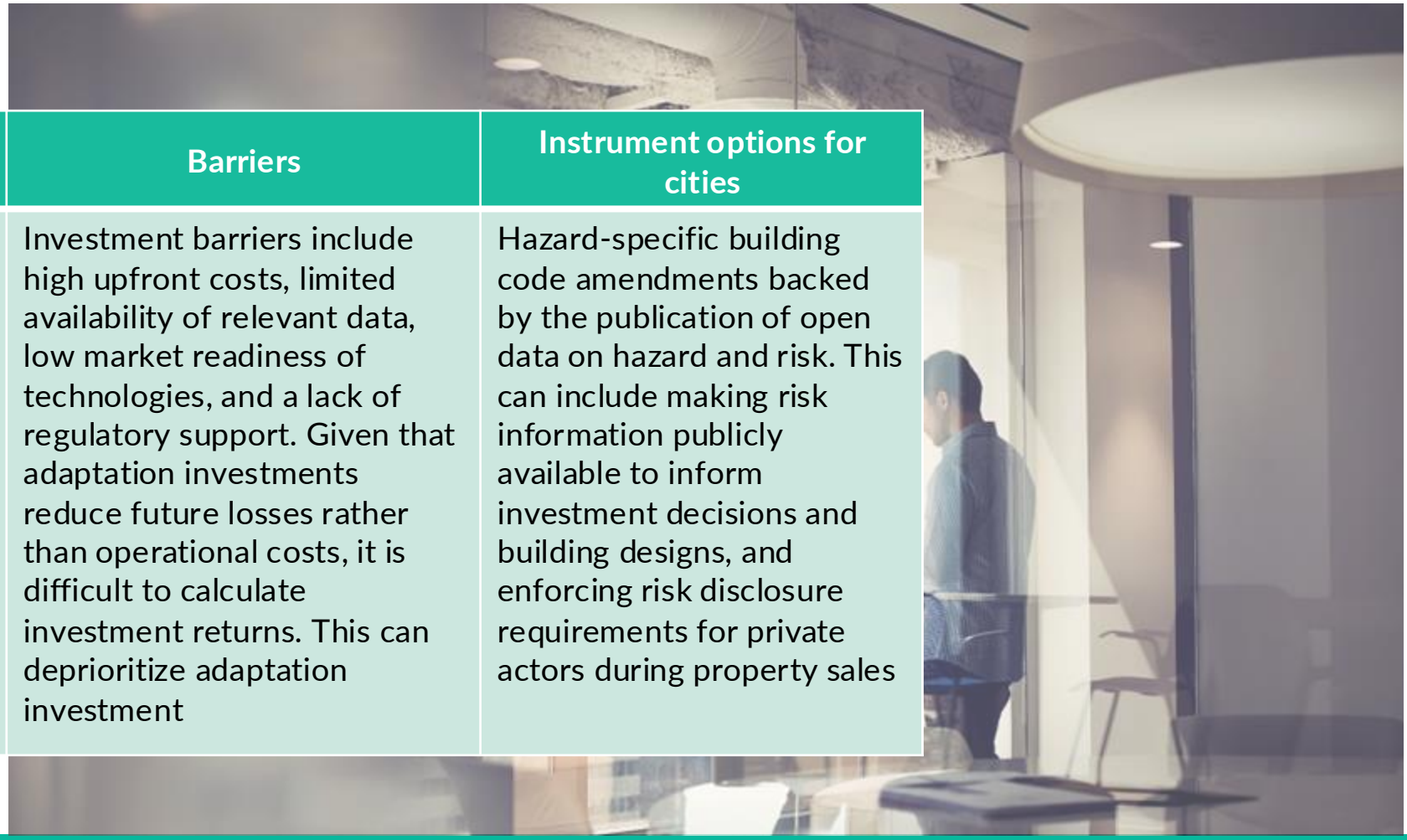
Source: Micale et al., 2023

Thematic area	Relevance	Barriers	Instrument options for cities
Embodied carbon	Embodied carbon relates to emissions associated with construction materials and processes throughout the life cycle of a building. Reducing embodied carbon has huge mitigation potential, given the rising demand for new buildings	Embodied carbon reduction is hindered by a lack of scalable, low carbon technical solutions, lack of awareness and expertise on existing solutions, and lack of performance data and examples of regulatory support for existing solutions	Skills development via workforce training, data benchmarks achieved through life cycle carbon calculation, and effective mandates such as embodied carbon building codes and reporting requirements

FINANCIAL INTERVENTIONS NEEDED

Thematic area: Adaptation for climate resilience

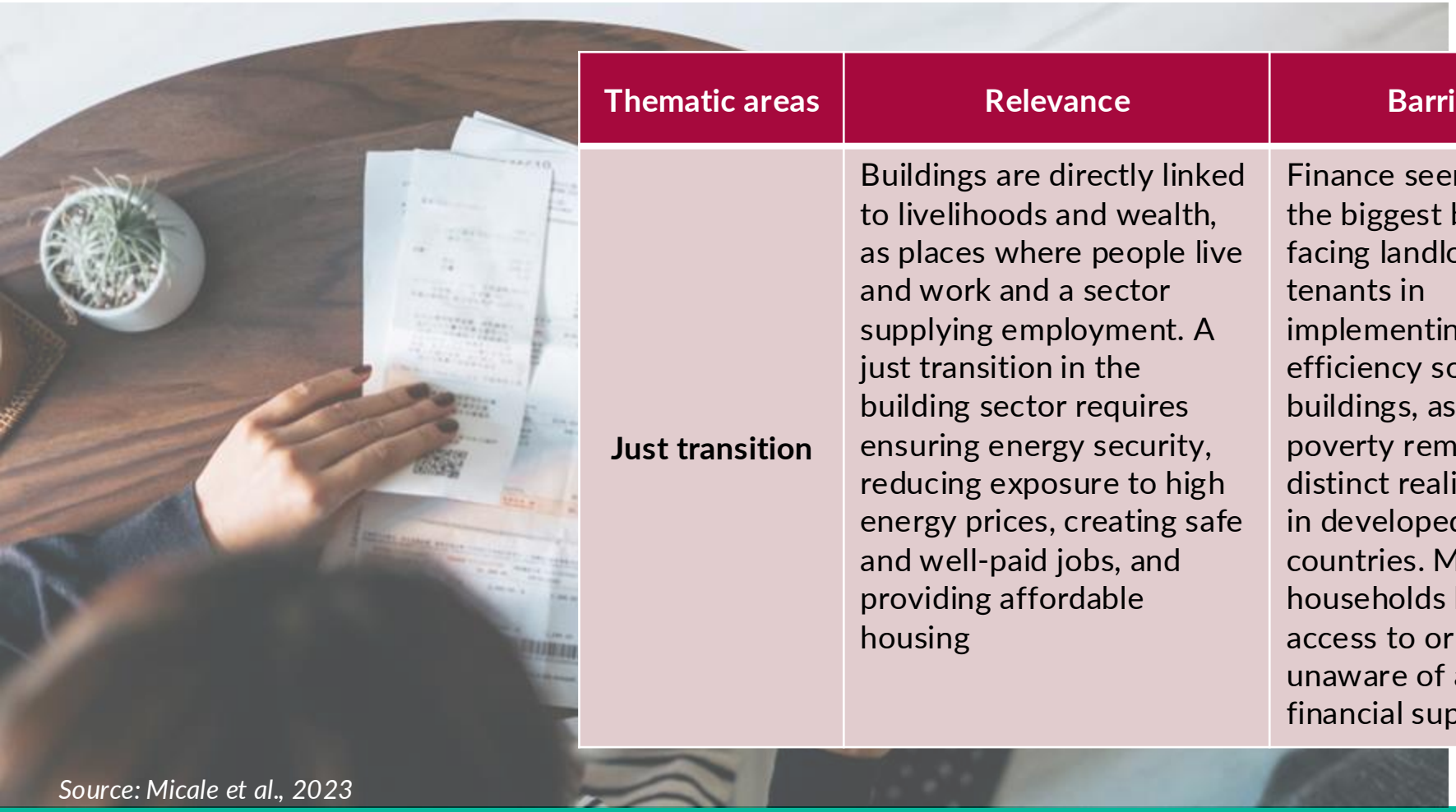
Thematic area	Relevance	Barriers	Instrument options for cities
Adaptation	Adapting buildings to become more climate resilient safeguards people, communities and economies	Investment barriers include high upfront costs, limited availability of relevant data, low market readiness of technologies, and a lack of regulatory support. Given that adaptation investments reduce future losses rather than operational costs, it is difficult to calculate investment returns. This can deprioritize adaptation investment	Hazard-specific building code amendments backed by the publication of open data on hazard and risk. This can include making risk information publicly available to inform investment decisions and building designs, and enforcing risk disclosure requirements for private actors during property sales



Source: Micale et al., 2023

FINANCIAL INTERVENTIONS NEEDED

Thematic area: Just transition ensuring energy security and decent livelihood



Thematic areas	Relevance	Barriers	Instrument options for cities
Just transition	Buildings are directly linked to livelihoods and wealth, as places where people live and work and a sector supplying employment. A just transition in the building sector requires ensuring energy security, reducing exposure to high energy prices, creating safe and well-paid jobs, and providing affordable housing	Finance seems to be the biggest barrier facing landlords and tenants in implementing energy efficiency solutions in buildings, as energy poverty remains a distinct reality, even in developed countries. Many households lack access to or are unaware of affordable financial support	Effectively designed subsidies to make low carbon projects financially viable. Subsidy pilot projects can help identify and test pro-poor solutions and eventually cut costs

Source: Micale et al., 2023

FINANCING LOW CARBON BUILDINGS

Financial barriers and impacted thematic areas

Barrier type	Barrier description	High-impact thematic focus			
		Cooling	Embodied carbon	Adaptation	Just transition
Financial barriers	Lack of access to affordable finance				
	Lack of awareness of funding options				
	Limited supply of dedicated financing instruments				
	Inability to pay for upfront cost				

Source: Micale et al., 2023

FINANCING LOW CARBON BUILDINGS

Investment risk and opportunity barriers and impacted thematic areas

Barrier type	Barrier description	High-impact thematic focus			
		Cooling	Embodied carbon	Adaptation	Just transition
Investment risk and opportunity barriers	Asset class has insufficient project scale				
	High investment costs compared to alternatives				
	Low or fluctuating energy prices				
	Long payback on investment				
	Perceived technical performance risk				
	Split incentive between landlords and tenants				
	Low priority investment				
	Lack of awareness and appropriate information on opportunity				
	Lack of performance data				
	High or uncertain maintenance and operation costs				

Source: Micale et al., 2023

FINANCING LOW CARBON BUILDINGS

Market readiness barriers and impacted thematic areas

Barrier type	Barrier description	High-impact thematic focus			
		Cooling	Embodied carbon	Adaptation	Just transition
Market readiness barriers	Limited experience with technical solutions		■	■	
	Lack of expertise and skills		■	■	
	Limited supply of technical products		■	■	

Source: Micale et al., 2023

FINANCING LOW CARBON BUILDINGS

Regulatory barriers and impacted thematic areas

Barrier type	Barrier description	High-impact thematic focus			
		Cooling	Embodied carbon	Adaptation	Just transition
Regulatory barriers	Lack of building regulations support				
	Lack of standard technologies				
	Lack of information on standards and labeling				
	Long processes for application of permits and access to land				
	Social risk and community opposition				

Source: Micale et al., 2023

EU TAXONOMY

European Union's objectives for investments in sustainability projects

- The EU taxonomy for sustainable activities is a classification system that helps investors and companies understand which economic activities are environmentally sustainable
- The EU taxonomy is an element of the EU Renewed Sustainable Finance Strategy that aims to push the financial and industrial sectors toward more investments for climate neutrality in the EU. The objective of the EU taxonomy is to establish a classification framework to facilitate sustainable investment across six environmental objectives
- For investors, this provides the basis to identify which investments are sustainable and can be marketed as such, increasing transparency. Following the enacting of this regulation through the EU and its member states, only investments that comply with technical screening criteria for one of the six environmental objectives, five do-no significant harm standards (see next slide), as well as a set of common minimum social safeguards, can be communicated as sustainable
- Financial institutions are progressively expected to disclose to what extent their portfolios are taxonomy-aligned

Objectives

1. Climate change mitigation
2. Climate change adaptation
3. Sustainable use and protection of water and marine resources
4. Transition to a circular economy
5. Pollution prevention and control
6. Protection and restoration of biodiversity and ecosystems

Source: Programme for Energy Efficiency in Buildings, 2021

EU TAXONOMY

Implications for the building sector

- Technical screening criteria have been developed for economic activities in the building sector
- Other economic activities relevant to the building sector covered by the taxonomy are installation, maintenance and repair of renewable energy technologies, as well as instruments and devices for measuring, regulation and controlling of energy performance of a building. Manufacturing and mining criteria for other economic activities and environmental objectives will equally affect supply chains in the buildings sector
- The five accompanying do-no-significant harm standards concern: (i) minimum water use criteria for installations; (ii) circular economy elements such as re-use, recycling or material recovery of construction waste; (iv) pollution minimization; (v) and biodiversity protection through environmental impact assessments and, in the case of new construction, no construction on arable land, forest land or greenfield land of high biodiversity

Type of economic activity	Technical screening criteria
Construction of new buildings	• Primary energy demand of new construction is at least 10% lower than nearly zero energy building requirements in national measures • Energy performance certified by energy performance certificate • For buildings > 5000m²: life cycle global warming potential calculated, and level of performance is tested post-construction, both disclosed to investors and clients
Renovation of existing buildings	• As applicable in national regulations for major renovations • Reduction of primary energy demand of at least 30%
Acquisition and ownership	• Buildings built before 12/2020: at least Energy Performance Certificate (EPC) Class A, or within top 15% of national building stock expressed in primary energy demand • Buildings built after 12/2020: meet criteria for construction of new buildings • Large non-residential building with HVAC output >290 kW: operated efficiently through energy performance monitoring and assessment

Source: Programme for Energy Efficiency in Buildings, 2021

BLENDED FINANCE

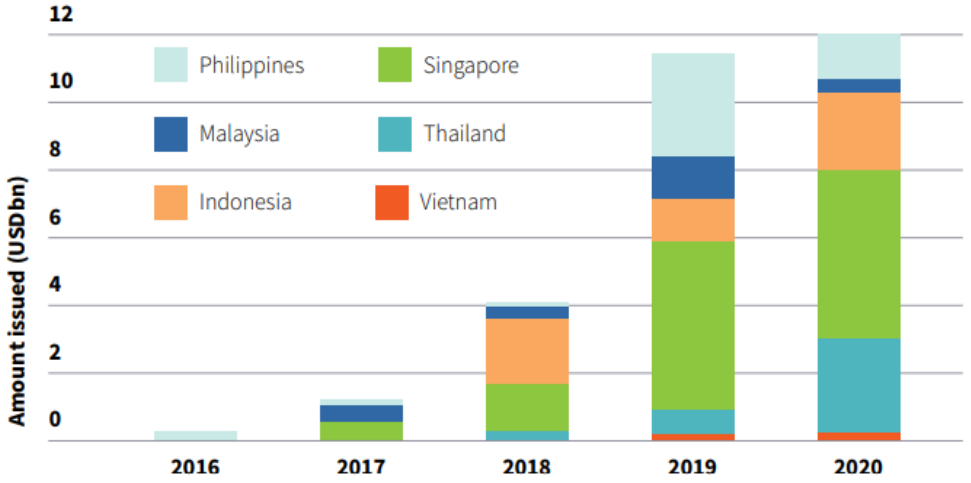
Financial risk mitigation for investors

- Blended finance lets investors choose different risk tolerances while participating in the same project. Often used in real estate transactions, it is proving to be an effective way to get capital to critical, but hard-to-fund projects. The approach can bring together philanthropy, government funding and private sector investors with different risk and return expectations. Those willing to take more risk can act as a capital cushion for investors who need to take less risk but are interested in financing high-impact projects
- Institutional investors (banks, insurers, asset managers, etc.) invest the major portion of the capital for profitable risk adjusted returns
- Concessionary investors (public development assistance and foundations) invest lesser amounts, accepting higher risk of loss or earn below market rate of return
- Finance domain specialists, often sponsored by development banks and private institutions, help match projects with investment capital
- Deserving projects receive finance and apply it to sustainable development programs
- Governments and central banks can work toward easing the access of blended finance to banks, financial institutes, and developers and builders with the specific mandate to provide green finance to low carbon buildings and meet the climate goals of the building sector

GREEN BONDS AND LOANS

The way forward

- Green bonds and loans are debt instruments used to finance projects, assets and activities that support climate change adaptation and mitigation, issued by governments, municipalities, banks and corporates. The green bond label can be applied to any debt format, including for example private placement, securitization, covered bond and sukuk
- Global best practices suggest that bonds and loans be issued in line with Green Bond Principles (GBP), Green Loan Principles (GLP), Climate Bonds Taxonomy and Standard, ASEAN Green Bond Standards, and country-specific guidelines. The key is that the use of proceeds (UoPs) is ring-fenced to only finance green assets, projects and activities
- While there is no single set of global definitions for eligible projects to be funded with green bond and loan proceeds, the Climate Bonds Initiative uses the Climate Bonds Taxonomy, which features eight UoP categories: energy; buildings; transport; water; waste; land use; industry; and information and communications technology



Growth in issuance of sustainability bonds in ASEAN countries, 2016–2020

Indonesia has issued green bonds (sukuks) in the form of:

- Sovereign national bonds
- Municipal bonds

Sources: Nguyet et al. 2021; Purnomo et al., 2024

GREEN MORTGAGES

Case example: Romania

- The Romania Green Building Council (RoGBC) created the SMARTER Finance for Families Program to convince banks to introduce green mortgages
- The program argues that green mortgages can deliver a triple win for developers, banks and home buyers
- A participating developer builds a more expensive green home on the condition that a participating bank will provide a larger loan to a green home buyer to cover the extra cost of building green. The bank books a larger and less risky loan, earning a higher return. The home buyer benefits with a lower monthly ownership cost for a superior home through a combination of preferential mortgage terms and utility savings
- Two participating banks, Raiffeisen Bank and Alpha Bank, offered a green mortgage discount of 75 and 50 basis points, respectively, on the conventional mortgage rate of 5.25%



Image source: https://greenhomes.solutions/news/10-000-green-homes

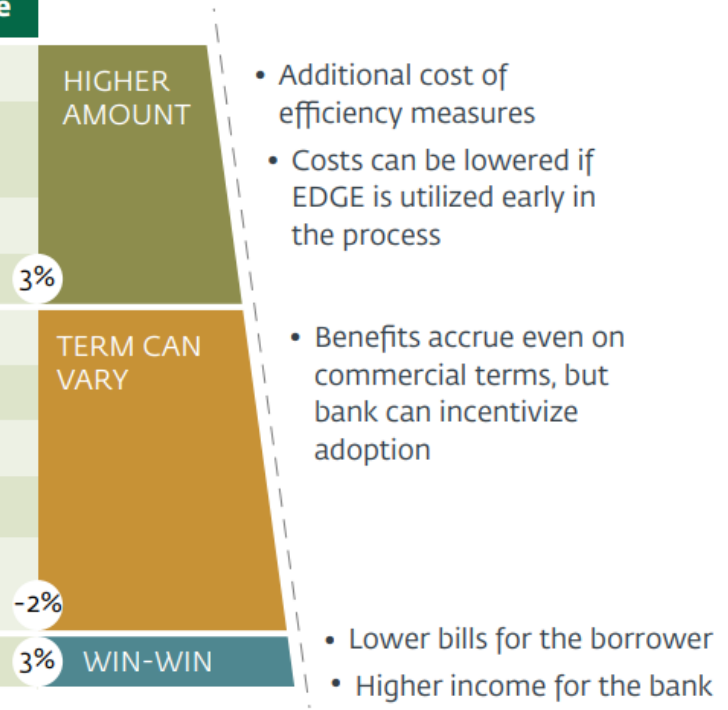
Source: International Finance Corporation, 2019

GREEN MORTGAGES

Comparison with standard mortgages

Green mortgages compare favorably with standard mortgages, despite higher initial costs. The utility savings result in a reduction in the monthly cost of ownership, benefiting both customers and banks – a win-win situation

	Standard building: Standard mortgage	Green building: Green mortgage
Base purchase cost	50,000	50,000
Green measures (3% higher costs)		1,500
20% down payment	(10,000)	(10,300)
Loan amount	40,000	41,200
Rate	11%	11%
Term	20 yrs	20 yrs
Monthly payment	$413	$425
Utility savings (20%)		(20)
Cost of monthly ownership	$413	$405
Bank income (yr 1)	4,371	4,502



Source: International Finance Corporation, 2019

VIETNAM

A glimpse of green credit programs

Proponents	Amount	Intended customers	Participants	Results
State Bank of Vietnam (SBV)	Approximately USD100m	SMEs with green projects	Vietcombank, BIDV, Agribank and Sacombank	• 26 projects: renewable energy, waste management and organic agriculture • The interest rates applicable to SMEs is 1%–3% lower than market interest rates • Banks participating in the program are refinanced from SBV at interest rates 1% lower than usual
Agribank and Vietnam Development Bank (VDB)	60% of the required capital (about USD18m)	Solar Power Plant TTC Phong Dien in Hue province	Agribank and Vietnam Development Bank	• Construction was from 2017 to 2018 • Agribank Thua Thien-Hue and Agribank Gia Lai branches will finance 30% of the total investment, while VDB Thua Thien-Hue and VDB Quang Tri will cover the rest
Vietcombank and Japan International Cooperation Bank (JICB)	USD200m	Solar and wind power projects in Vietnam	Vietcombank and Japan international Cooperation Bank	Limited results so far, as the cooperation agreement between Vietcombank and JICB was signed in May 2019
Agribank and Central Power Corporation (EVNCPC)	VND735bn	Central Power Solar Project in Khanh Hoa province	Agribank	The power plant was completed and put into operation in late May 2019

The focus is on small and medium-sized enterprises (SMEs), and solar and wind power plants. **The buildings sector is yet to attract any significant green funds**

Source: Davidson et al., 2020

INDONESIA

Case example: Green and affordable housing program

- Supported by the International Finance Corporation (IFC), the Ministry of Housing and Public Works aims to build 10,000 new houses with green certification across Sumatra, Java and Sulawesi (Indonesia's most populous islands) by 2024. This is part of IFC's Excellence in Design for Greater Efficiencies (EDGE) initiative, focusing on renewable energy and waste management for buildings
- The initiative provides grants for assessment based on climatic conditions, usage patterns, technology, and typical buildings in a given area to demonstrate the amount of energy and water savings achievable by implementing sustainable technologies
- The grants fund the assessment costs to calculate the savings and financing needs for green buildings. However, there is room to improve the deployment of grant-based instruments. First, data accuracy in relation to results-based grants remains a challenge, especially in generating evidence-based energy performance. Second, there is a lack of awareness of available grant facilities for green buildings, and a lack of understanding of the best options to use such grants



Source: Purnomo et al., 2024

Image source: https://ruangkantorku.com/ruang-kantor/altira-office-tower-sunter-jakarta-utara/

INDONESIA

Case example: Intervention by Central Bank

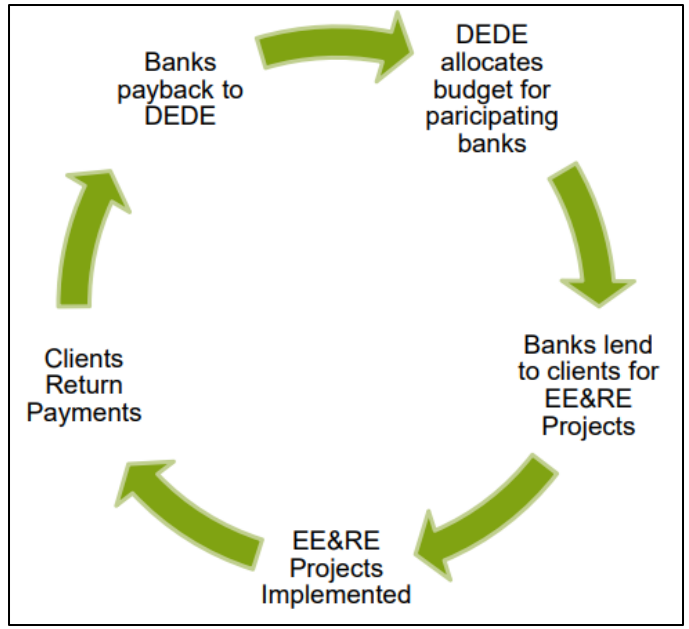
- The Indonesian Financial Services Authority (OJK) and the Central Bank of Indonesia have created a sustainable finance roadmap aimed at increasing green finance portfolios, including for buildings. This is designed to support banks in financing green buildings in their portfolios and also greening their own operations, including their office buildings. This regulation can support the development of the green building sector in major cities like Jakarta, where large commercial banks have started applying green standards in their office buildings
- The OJK Sustainable Finance Roadmap, adopted in 2021, contains guidance and policy directions for sustainable finance development in Indonesia, and is a realization of cooperation between OJK and the government, particularly the Ministry of Environment and Forestry. The objectives are to:
  - Ensure financial institutions operate sustainably, by obligating them to report emissions reductions pertaining to energy consumption as part of their annual mandatory sustainability reporting. This mandate, enforced under POJK 51/2017 has triggered major banks to invest in green building retrofit projects and invest in energy efficiency
  - Encourage capital market participants to raise funds through green-labeled instruments, regulated under POJK 60/2017. The OJK includes green buildings as among the projects eligible to access funds from green bond issuance. The OJK also provides clear regulations for local governments to issue municipal bonds

Source: Purnomo et al., 2024

THAILAND

Case example: Energy efficiency (EE) revolving fund for banks

- Launched in 2003, the general principle of the EE Revolving Fund (EERF) is that the revenue generated via repaid loans is made available for issuing new loans – hence the term revolving. This fund structure is sustainable in that it ensures a consistent inflow and outflow of monies for funding EE measures
- The EERF started as a partnership between the government and six participating banks (PBs), which later expanded to 11 banks. The EERF is managed by the Planning Division of the Department of Alternative Energy Development and Efficiency (DEDE)
- Initially, the EERF provided PBs with zero interest credit lines to jumpstart projects. When financing higher-volume projects, PBs used their own funds and mixed accordingly. The interest was subsequently set at 0.5% to cover administrative costs. Interest for on-lending to borrowers was set at a ceiling of 4% per annum. Although many of the PB borrowers requested higher amounts, the maximum loan amount was THB50 million (~USD1.4 million) per project in order to fund as many medium-sized projects as possible
- During 2003–2011, the EERF financed 294 projects totaling THB15,959 million (with THB7,232 million from the EERF and THB8,727 million from commercial banks). The impact assessment indicated reduction in oil imports of 320 KTOE/year and GHG emissions reduction of 0.98 million tCO_2eq.



Source: Grüning, 2012

POLICY INTERVENTIONS

Case example: Green building code implementation in Columbia

- In 2015, the Colombian government enacted the first mandatory green building code in Latin America. This includes minimum requirements for the construction of new residential and commercial buildings aimed at ensuring lower energy and resource consumption than conventional buildings. By establishing clear direction for public policy, the government raised awareness in the industry and successfully unleashed a wave of private sector investment in green buildings totaling USD9 billion to date, according to IFC estimates
- Policies included tax incentives for green technologies and certified green projects. This enabling environment gave banks confidence to launch green construction finance and green mortgages. In 2016, Bancolombia became the first bank in Latin America to finance green buildings by raising USD400 million in three bond issuances. In 2017, the Colombian Chamber of Construction (CAMACOL) started an aggressive educational program with its members to promote EDGE certification. By 2021, five banks were offering green building finance products—mainly green mortgages: Bancolombia, Davivienda, BBVA, Banco Bogotá and Caja Social
- In 2021, about 20% of Colombian new construction was certified as green, from virtually no green buildings in 2017. CAMACOL is now pushing members toward zero-carbon construction. Banks meanwhile are increasing their product offerings for green construction: BBVA, for instance, plans to launch preferential financing for EDGE Advanced buildings (higher resource efficiency)

Source: International Finance Corporation, 2023

GREEN CONSTRUCTION FINANCE

Case example: Concessional finance in Costa Rica

- In 2016, Costa Rican bank, Banco Promerica, obtained a USD30 million loan from the Dutch development bank, FMO, to launch a green construction finance and green mortgage program. Before the bank could launch a green mortgage program, it had to build a sufficient pipeline of certified green properties
- To incentivize developers to build green, the bank offered a discount on green construction finance. It charged 8.75% (instead of 9.25%), offered a 0.75% front-end fee (instead of 1%), and provided a four-year term (instead of three years). Depending on the project, the discount on the front-end fee covered most of the cost of the upfront requirement of green certification
- Promerica succeeded in building a sufficient supply of green properties to start offering green mortgages. It offered qualifying home buyers a 30-year fixed rate that was slightly higher than the market rate for 30-year variable-rate mortgages in the country. It aims to expand its mortgage portfolio, which is currently 10% of its business. To finance this expansion, the bank plans to securitize its green mortgage portfolio once it reaches USD20 million to USD30 million in size

Source: International Finance Corporation, 2019

LOW CARBON BUILDING FINANCING

Barriers



Financial Barriers

- Lack of access to affordable finance
- Lack of awareness of funding options
- Limited supply of dedicated financing instruments
- Inability to pay for upfront costs



Regulatory Barriers

- Lack of building regulation support
- Lack of technology standards
- Long processes for application of permits and access to land
- Social risk and community opposition



Market Barriers

- Limited experience with technical solutions
- Lack of expertise and skills
- Limited technical product supply



Investment Risk and Opportunity Barriers

- Asset class has insufficient project scale
- Higher investment costs compared to alternatives
- Long payback on investment
- Perceived technical performance risk
- Split incentive between landlords and tenants
- Low priority investment
- Lack of awareness and appropriate information on opportunity
- Lack of performance data
- High or uncertain maintenance and operation costs

Source: Purnomo et al., 2024

LOW CARBON BUILDING FINANCING

Opportunities for innovation in government policies

- Low carbon buildings are expected to be 5%–10% more expensive than conventional buildings
- The three main stakeholders involved in monetary transactions in the building sector are: (i) developers and builders; (ii) banks and financial institutes; and (iii) buyers. Banks and financial institutes are unlikely to have any issues in giving a 5%–10% higher loans to credit worthy developers and builders for low carbon buildings. However, the developers and builders need to be convinced that buyers will pay a higher price for the green features. There is a need for well-publicized demonstration projects in different parts of the country of low carbon commercial and residential buildings that can convince all stakeholders of the benefits of low carbon buildings. A compendium of recommended measures to make buildings compliant should be made available to developers, builders and architects
- Governments should consider policy initiatives to enable urban local bodies (ULBs) to provide higher 'floor area ratio' (FAR) (permissible total built-up area divided by the total area of the plot) as an incentive to developers and builders to compensate for the 5%–10% higher investment. This may enable builders to sell their low carbon buildings at the same price as conventional buildings. Higher FAR incentive can be very transformative, motivating more developers and builders to move away from constructing conventional buildings to low carbon buildings. Higher FAR will also enable ULBs to generate more revenue from building owners through property taxes
- Governments can reduce property registration duty for low carbon buildings as an incentive for property buyers. Since property registration duties constitute a significant portion of the total property cost, offering a discount can serve as a powerful motivator for property buyers to shift to low carbon buildings

LOW CARBON BUILDING FINANCING

Opportunities for policy interventions by central banks and government

- Unless green loans are available to developers, builders and property buyers as a standard product through normal banking channels, it is difficult to envisage proliferation of low carbon buildings on the scale required to achieve climate goals. Real scale-up may happen if all major banks offer concessional green loans and mortgages as standard off-the-shelf products to builders and developers. Access to blended finance can help ensure the competitiveness of these innovative loan and mortgage products
- Central banks should treat energy efficient green buildings as a priority sector for concessional loans, in the same way as it treats micro, small and medium-sized enterprises. A directive from central banks to commercial banks can help evolve options for green loans and mortgages in all major banks. This can also make banks active marketing agents for promoting energy efficient green buildings with developers and builders being presented with both options when they approach banks for credits and loans
- Central banks should explore the possibility of government-sponsored Super ESCOs offering a package along with loans from banks and financial institutes to cover additional investment of 5%–10% in low carbon buildings. The empaneled energy auditors (under the Super ESCO) can provide technical support and confirm the implementation of recommended measures for low carbon buildings
- Governments must work toward strict enforcement of energy efficiency and green building codes for all new constructions and promote retrofits in existing buildings, using carrot and stick policies with incentives and disincentives. Urban local bodies (ULBs) should make energy efficiency and green building features mandatory before approval of construction plans, and competent juries will have to be appointed in ULBs

Thank you!

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Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy | PROJECT

4.2 ESCO Business Models

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

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WHAT WILL YOU LEARN?

01 Concept of Energy Saving Companies (ESCOs)

02 ESCO Market Potential in the Building Sector

03 ESCO Business Models

04 Energy Performance Contract

05 Demand Aggregation and Bulk Procurement

06 Case Studies on ESCO Projects

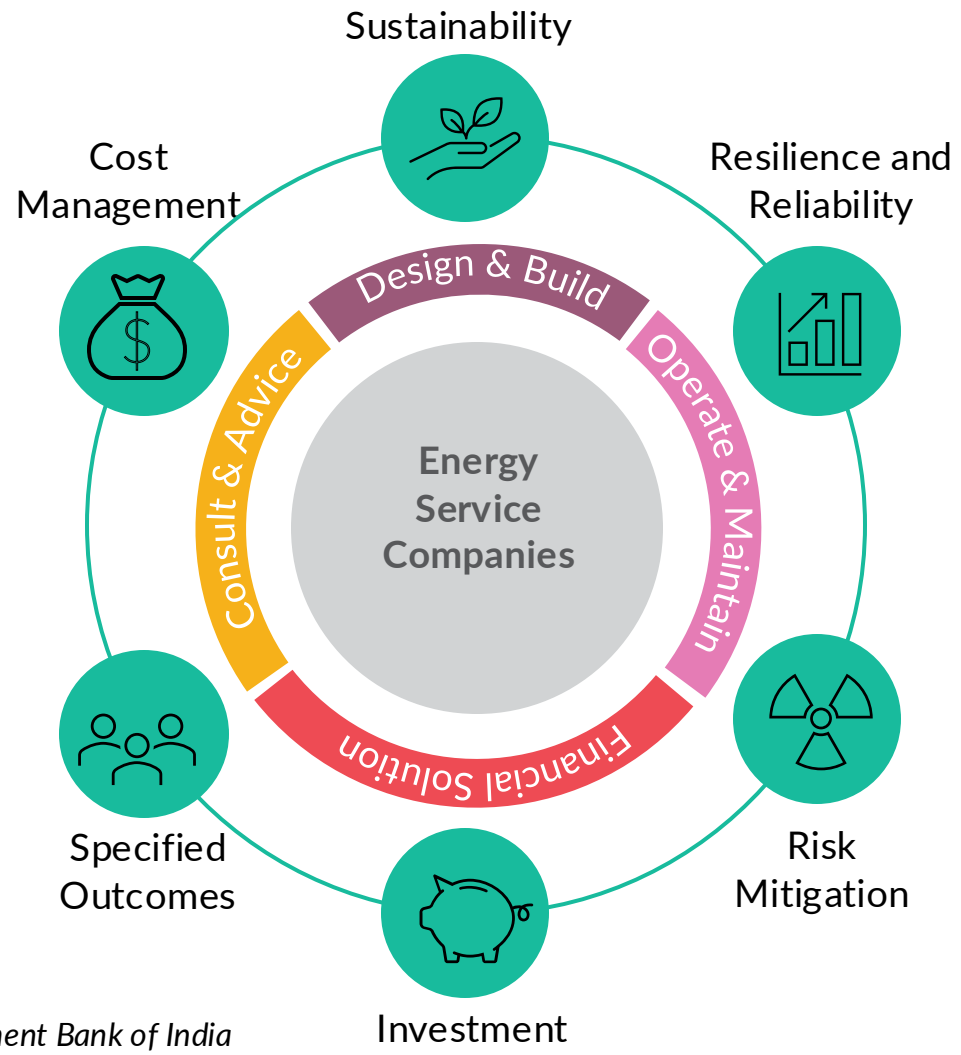
07 Opportunities, Challenges and Risks



ENERGY SERVICE COMPANIES

ESCOs: The concept and operating principles

- Energy service companies (ESCOs) develop, design, build and arrange financing for projects that save energy, reduce energy costs, and decrease operations and maintenance costs at their customers' facilities
- In general, ESCOs act as project developers for a comprehensive range of energy conservation measures and assume the technical and performance risks associated with a project
- ESCOs are distinguished from other firms that offer energy efficiency improvements in that they use the performance-based contracting methodology. When an ESCO implements a project, the company's compensation is directly linked to the actual energy cost savings
- The substantial energy efficiency retrofits and renewable energy technologies inherent in energy savings performance contract (ESPC) projects typically require a large initial capital investment and may have a relatively long payback period. Debt payments are tied to the energy cost savings guaranteed for the project, so the agency pays for the capital improvements of the ESPC project with the money saved by the project



Source: Small Industries Development Bank of India

MARKET POTENTIAL

For energy efficiency in buildings in Southeast Asia

- The percentage of primary energy used in buildings is estimated to be 37% in Cambodia, 38% in Indonesia, 15% in Thailand and 22% in Vietnam, which is an indicator of the market potential for energy efficiency improvement in buildings
- Like other markets around the world, the ESCO industry is still nascent across ASEAN countries. Many ESCOs suffer from a lack of scale and balance sheet strength, and a lack of contractual confidence for their services, such that many financially viable energy efficiency projects do not get financed
- Vietnam is proposing that the Vietnam Electricity (EVN) be made a Super ESCO
- Cambodia is in the process of discussions for developing a legal and regulatory framework for ESCOs

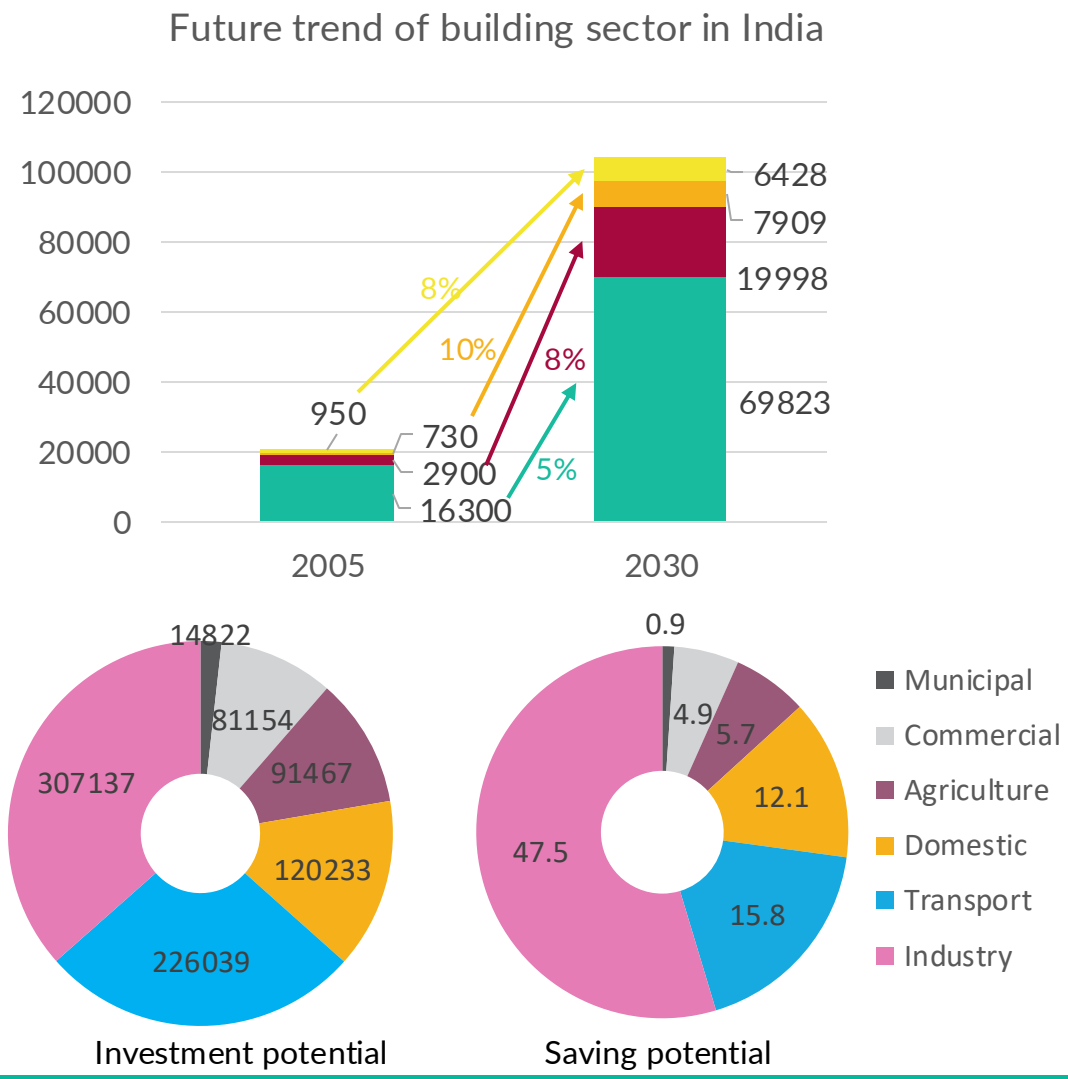
Country	Population '000s (2019)	Total final energy consumption Mtoe (2019)	Energy use per capita toe (2019)	% of primary energy used in buildings
Cambodia	16,250	6.6	0.4	37%
Indonesia	270,626	174.0	0.6	38%
Thailand	69,428	98.9	1.4	15%
Vietnam	95,545	64.1	0.7	22%

Source: Lister et al., 2020

MARKET POTENTIAL

For energy efficiency in buildings in India

- In 2019–2020, the primary energy demand was 810 Mtoe. The estimated energy saving potential is 47.5 Mtoe and 80 billion kWh of electricity
- The EE investment potential is estimated to be USD73 billion by 2031
- The overall constructed area is expected to increase by about 5 times from 21 billion square feet (2005) to approximately 104 billion square feet by 2030 at a CAGR between 5% and 10%
- Building energy consumption accounts for over 30% of electrical energy consumption in the country and is rising annually at 8%
- The ESCO ecosystem in India has received a boost due to the proactive measures of the government. However, it is yet to mature into a preferred option for financing of energy efficiency projects

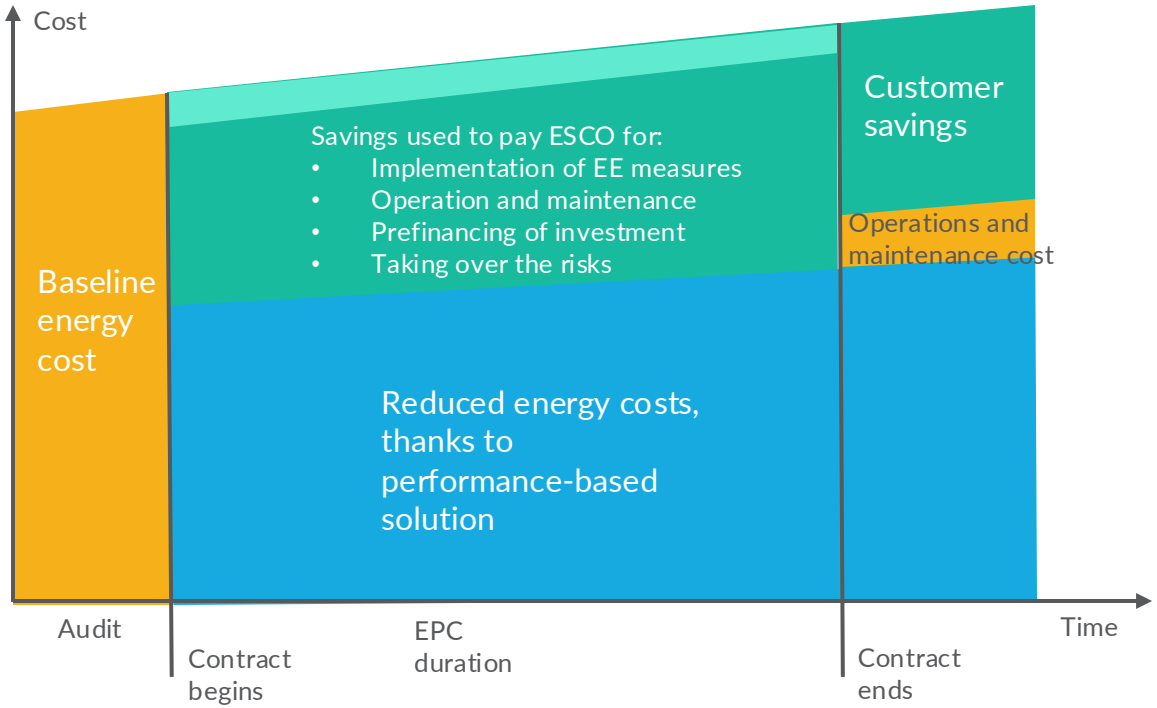


Sources: Garnaik, 2023; Energy Efficiency Services Limited

ESCO CONTRACT

Energy performance contract models

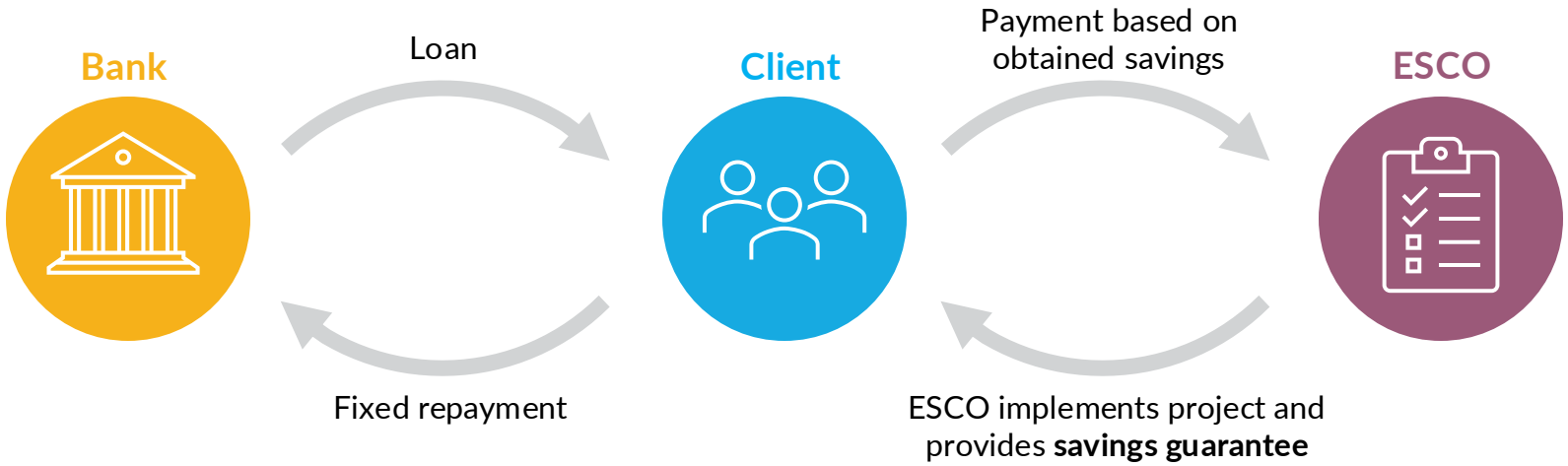
- Most agreements between customers and ESCOs are underpinned by energy performance contracts (EPCs). The EPC commits the ESCO to installing the necessary equipment, provides a performance guarantee and establishes the terms of any upfront or ongoing payments, which are intended to be less than the financial savings realized by the project. The two most common types of EPCs are: (i) guaranteed savings model or (ii) shared savings model
- The EPC provides the customer with a guaranteed level of energy savings and the ESCO with a reliable source of revenue. EPCs typically last from two to 20 years, depending on the measures implemented. Depending on the customer's preference and access to capital, the customer, the ESCO, or a combination of the two can be responsible for securing the finance for the project. A direct loan agreement with a third-party lender is an option for both parties



Source: International Energy Agency

ESCO CONTRACT

Guaranteed savings model

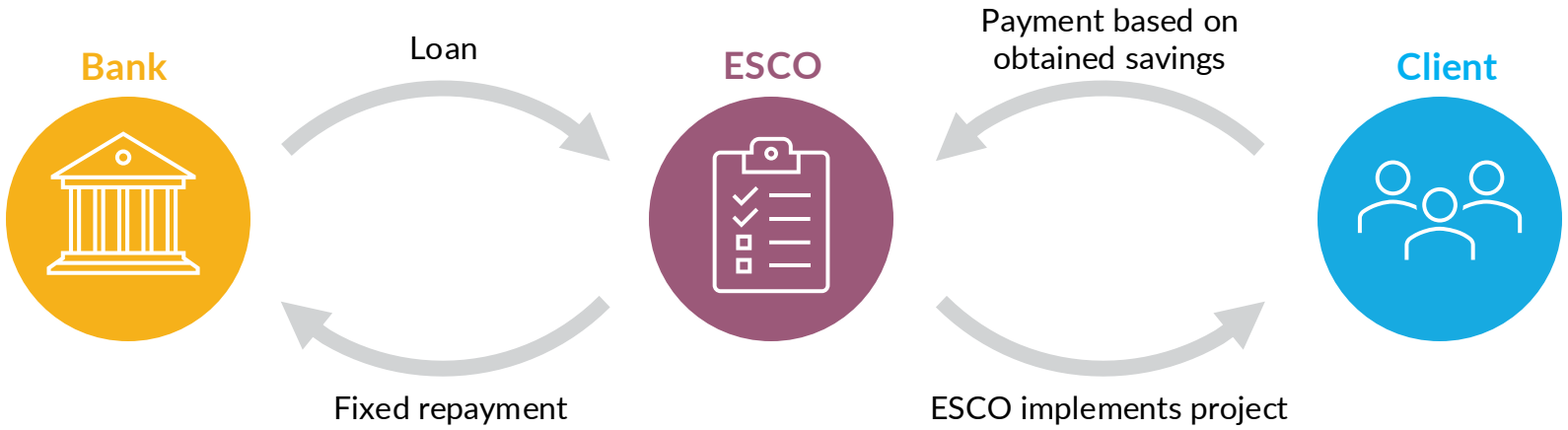


The ESCO takes on the technical risk. The client obtains a bank loan, or uses their own equity, to pay contractually-determined fees to the ESCO and the bank and keeps the difference

Source: International Energy Agency

ESCO CONTRACT

Shared savings model

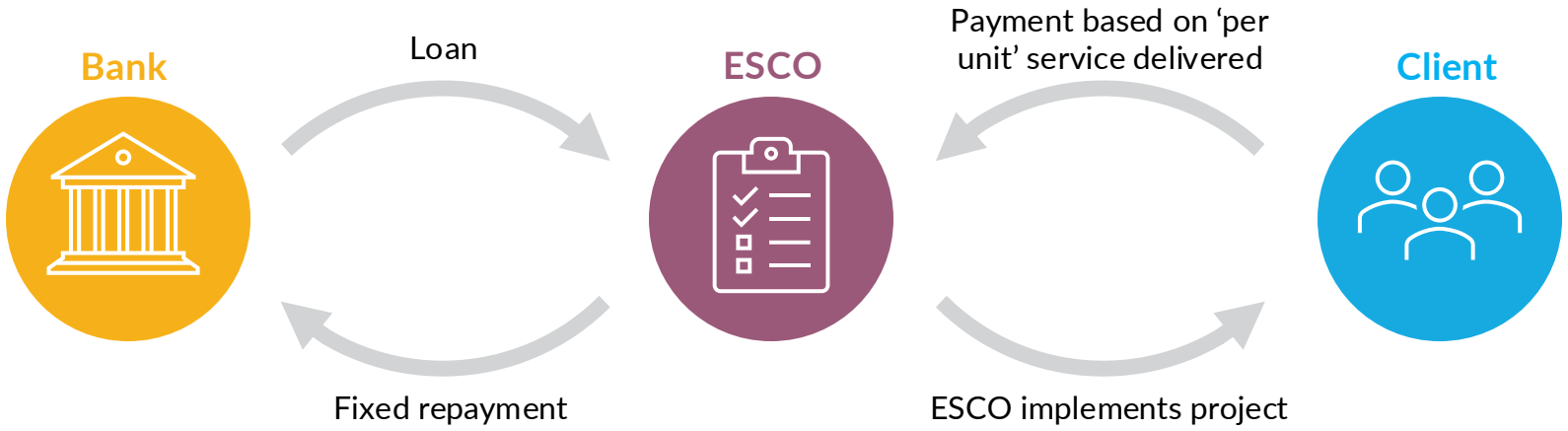


The ESCO can provide financing, as well as project development and implementation costs, with the energy savings shared between the ESCO and the client over the contract period. This model requires the ESCO to have the capacity to borrow and to have projects with revenue streams that will ensure the loans can be repaid

Source: International Energy Agency

ESCO CONTRACT

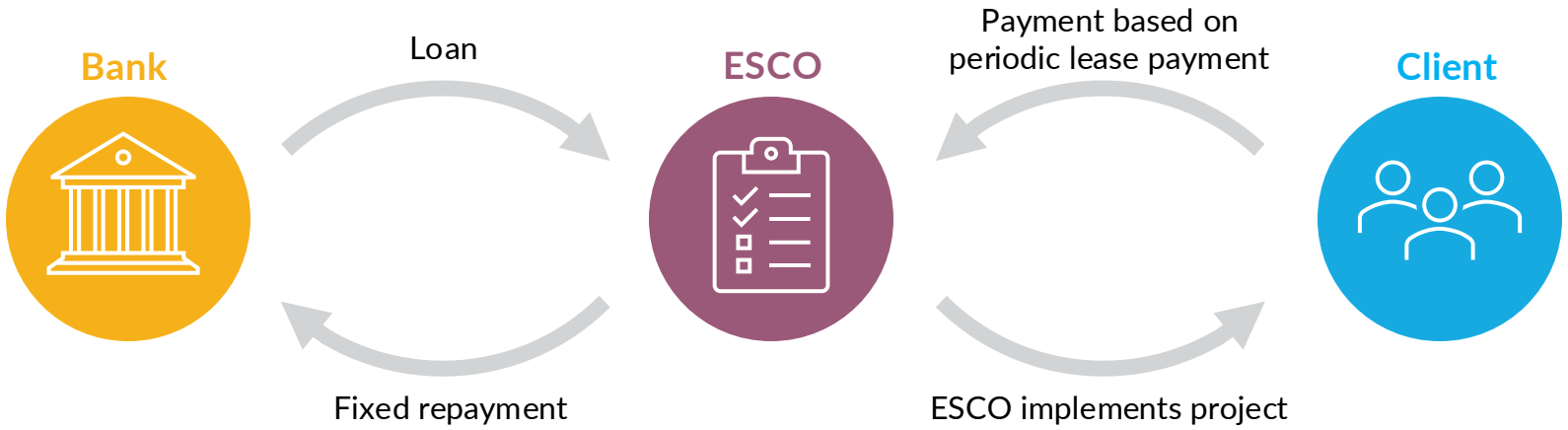
Energy supply contracting or service model



The ESCO can provide financing, as well as project development and implementation costs, with the ESCO receiving payment for 'per unit' service delivered to the client over the contract period. This model requires the ESCO to have the capacity to borrow and to have projects with revenue streams that will ensure the loans can be repaid

ESCO CONTRACT

Leasing and purchase model



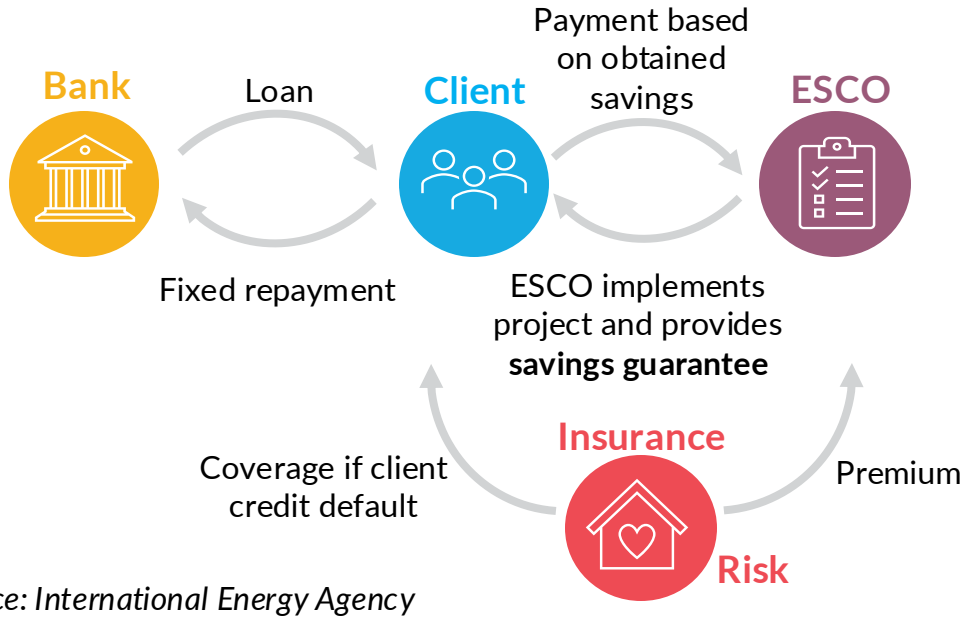
The ESCO can provide financing, as well as project development and implementation costs, with the ESCO leasing the equipment to the client and receiving periodic lease payment from the client over the contract period. At the end of contract period, the client buys the equipment

Source: Wijaya et al., 2021

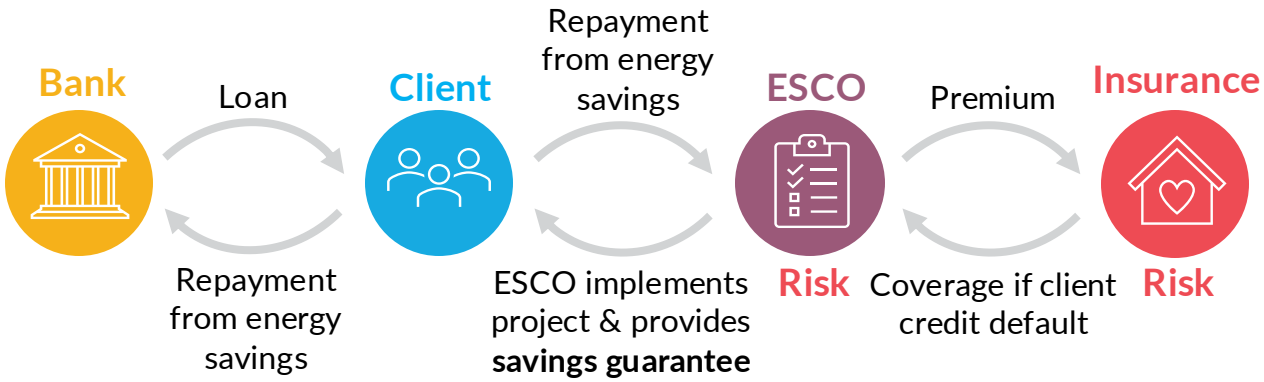
ESCO CONTRACT

Energy savings insurance and credit risk guarantee

Uncertainty associated with the performance of efficiency measures inhibits third-party energy efficiency financing globally. In response, energy savings insurance has emerged as a solution offered by a small number of financial institutions, private companies and insurance companies, to reduce the risk of an energy efficiency project



Source: International Energy Agency



Typically, there are two types of insurance packages offered by insurers – technical and credit:

- In the technical package, the insurance provider covers the ESCO or technology provider in the event that promised energy savings are not achieved, assuming the technical risk associated with efficiency projects
- In the credit package, the insurance provider assumes the credit risk of a project, thereby ensuring that repayments owing to the ESCO can continue to be made, in the case of customer credit default

ESCO REPAYMENT MODELS

Popular models

- **Upfront payment model**: This is the common 'sales model' where 100% payment is received by the ESCO from the end-user after supply of the technology. This model works if the ESCO offered price is less than the retail market price for the same technology (due to bulk procurement by the ESCO)
- **On-bill financing (OBF) model**: The consumer pays the ESCO through equated monthly instalments (EMIs), thus, reducing the upfront payment burden for the end-user. The EMIs are usually collected by electricity utility (distribution) companies through their monthly electricity bills on behalf of the ESCO through an agreement between the ESCO and the utility. The OBF model may require necessary approvals from country's regulatory authorities. The OBF is attractive when the EMI is less than the energy cost saving
- **Pay-as-you-save (PAYS) model**: The entire upfront investment of the project cost is borne by the ESCO. The project investment cost is recovered from the end-user in suitable instalments through a deemed energy saving approach. To ensure the repayment by the end-user, an ESCROW account is maintained, or alternatively a bank guarantee is taken
- **Engineering, procurement and commissioning (EPC) model**: The ESCO takes the responsibility of project design, procurement and commissioning of the project and gets 80%–90% of the project cost (technology cost and project management fees) after commissioning; and the balance is paid during the warranty period
- **Service model**: The ESCO charges a 'per unit' price of the delivered service (like electricity, steam, chilled water, electric vehicle, smart meter etc.). To ensure regular periodic repayment, the end-user is required to open an ESCROW account to be replenished by the client

M&V PROTOCOL

Quantification of energy cost savings

- The quantification of energy saving is important for success of the ESCO model. In the shared savings model, any disagreements between the client and ESCO on the quantum of savings will lead to failure of the model
- A measurement and verification (M&V) protocol is imperative for success of the ESCO model and should be part of the energy savings performance contract (ESPC)
- The M&V protocol should be simple and transparent, avoiding complex empirical calculations and assumptions
- Quantification based on measurements by site instrumentation is encouraged, although it may increase the initial cost of the project
- Any subjective corrections in the quantified energy savings and cost values should be by mutual agreement and be a part of the ESPC
- An independent verifier is encouraged to quantify the saving as per the M&V protocol

DEEMED SAVING APPROACH

Avoids the need for an M&V protocol

- A deemed saving approach, in which a fixed savings is agreed upon, irrespective of the utilization of the equipment, is a simple method, which can be adopted for standard, reliable technologies like energy efficient appliances
- In this approach, the quantum of energy savings is agreed upon based on previous test results following procedures recommended by equipment standards or star rating schemes for equipment, and assumed realistic operating hours
- The deemed saving approach is useful for mass promotion of energy efficient products as the end-user knows the fixed periodic payouts that must be made to the ESCO
- The deemed saving approach is also useful for the ESCO to explore demand aggregation and mass procurement of energy efficient products to reduce the cost of technology to the end-user

REDUCING COST OF TECHNOLGY

Demand aggregation and bulk procurement

- Affordability of proven and reliable technologies is key to generating market demand for energy efficient products
- Demand aggregation and bulk procurement have proven to reduce the cost of standard energy efficient technologies and enable speedy market transformation. They also have the potential to create a huge supply chain of the products and provide job opportunities
- The following are some of the attributes of successful demand aggregation and bulk procurement programs:
  - **Government ownership**: Governments can announce consumer-centric schemes for mass promotion of energy efficient products through public outreach programs with time-bound milestones and targets
  - **Promotion of standard technologies**: Standard and reliable technologies that can be promoted without the need for monitoring and verification, such as LED lamps, BLDC fans and air conditioners, are suitable
  - **Bulk procurement**: Public energy utilities or government-sponsored Super ESCOs are preferable for implementing the program through ESCO or non-ESCO models. Multiple suppliers are desirable to maintain price competitiveness and reliability of supplies. A fair assessment of the market demand is important to avoid being overburdened with unsold inventory

ESCO PROJECT IN HOTELS

Case example: Heat pumps for hot and chilled water

- In a reputed luxury hotel chain in India, water chillers operating at 7°C were being used for room cooling, and diesel-fired boilers were being used for generating hot water at 55°C for bathing, laundry and kitchen use
- The installation of eight heat pumps of differing capacities in four hotels on an ESCO basis led to the decommissioning of diesel-fired boilers and simultaneous reduction in load on the water chillers used for air conditioning
- The total annual energy cost savings were USD192,000 per year
- The total investment for the heat pumps were USD311,000
- The economics of heat pumps will vary at different locations, depending on the relative price of fuels and electricity



Heat pumps



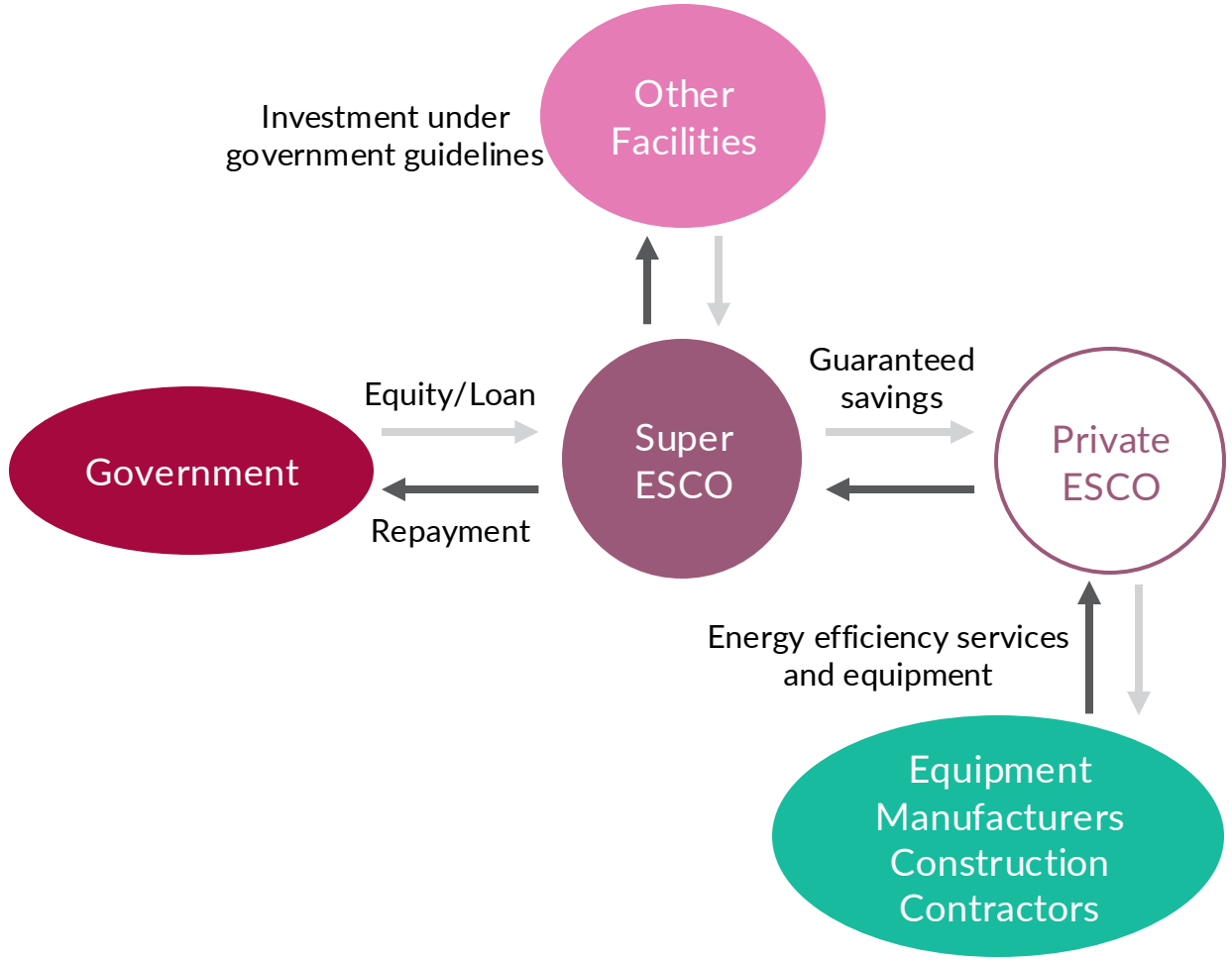
Associated storage tanks for hot and chilled water

Source: SEE-Tech Solutions, Nagpur, India

SUPER ESCOs

Government-sponsored entities

- Super ESCOs are governmental entities created to serve the public sector, develop the capacity of private ESCOs and facilitate project financing
- Super ESCOs are useful because existing programs designed to engage clients with ESCOs, such as energy audits programs, rebates, direct install programs, demand side management bidding or standard offer approach, rarely provide the full amount of funding required to cover implementation costs such as engineering, procurement and installation costs
- Clients may have the means to finance energy efficiency projects, but experience has shown that energy efficiency projects are not an imperative investment priority for many businesses. Easing access to external financing increases EE project implementation rate



Sources: International Energy Agency; Lütken et al., 2024

SUPER ESCOs

Initiatives around the globe

The US Federal Energy Management Program (FEMP)

Initiated in the 1990s, it is one of the earliest examples of a public institutional model close to the Super ESCO concept. The FEMP promotes energy efficiency and the use of renewable energy resources at federal sites

India's Energy Efficiency Services Limited (EESL)

EESL, led by the Ministry of Power, Government of India, was established in 2009 to implement large-scale energy efficiency programs in India under the National Mission on Enhanced Energy Efficiency (NMEEE) through innovative business models. EESL has completed building energy efficiency projects in 10,344 buildings, including railway stations. EESL has so far saved over 50 billion kWh of electricity in India. EESL also has a presence in Bangladesh, Malaysia, Myanmar, Thailand and Vietnam

Saudi Arabia's National Energy Services Company (NESCO)

Saudi Arabia's Public Investment Fund created the National Energy Services Company (NESCO), also known as Tarshid, in October 2017, with an initial capitalization of over USD500 million to increase the energy efficiency of government and public buildings, public streetlighting, etc.

Croatia's HEP ESCO

The World Bank supported the creation of the HEP ESCO within Hrvatska Elektroprivreda d.d. (HEP is the national power utility). The objective is to develop, finance and implement energy efficiency projects on a commercial, for-profit basis, using local businesses as key delivery agents. A niche market has been established in Croatia for financing energy efficiency projects in public buildings of local authorities (administration buildings, schools, etc.), hospitals and universities, and streetlighting

SUPER ESCOs

Initiatives around the globe (continued)

Belgium's FEDESCO:
FEDESCO is a 100% subsidiary of the Federal Participation and Investment Corporation, founded in 2005, to facilitate and finance energy efficiency projects in federal government buildings throughout Belgium. With a capital investment of EUR6.5 million and an additional EUR10 million in state guarantees, FEDESCO implements projects exclusively with the Federal Building Agency and enters into EPC contracts with public facilities without competition, using either internal funds or financing from commercial banks (with a state guarantee)

United Arab Emirates' Etihad ESCO:
Etihad ESCO was established in 2013 by the Dubai Electricity and Water Authority as a Super ESCO to make Dubai's built environment a leading example of energy efficiency for the region and the world. Etihad ESCO aims to develop energy efficiency projects targeting more than 30,000 buildings in Dubai with a goal of 1.7 TWh in energy savings by 2030. Etihad ESCO is fostering a viable ESPC market for ESCOs by executing building retrofits, increasing the penetration of district cooling, building the capacity of local ESCOs and facilitating access to project finance

Super ESCO of India

EESL's Success Story



ENERGY EFFICIENCY MARKET IN INDIA

Unlocking national potential for energy efficiency (UNNATEE)

Primary Energy Demand

810 million toe (2019-20)

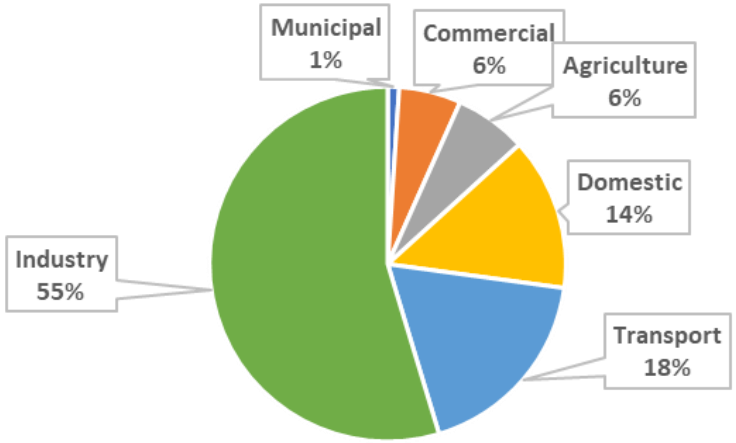
Energy Saving Potential

47.5 million toe and **89** billion units of electricity by 2031

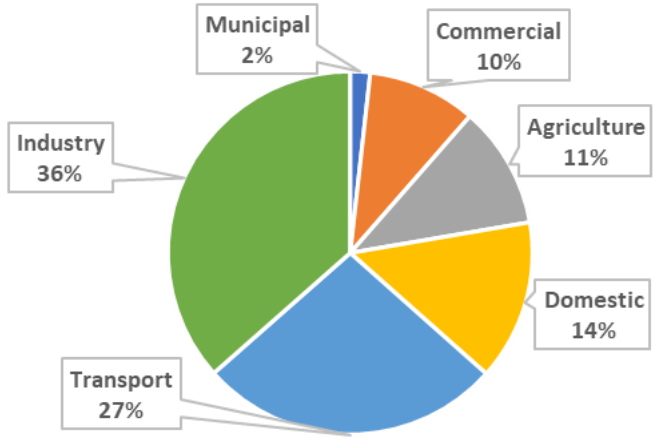
EE Investment Potential

73 billion USD by 2031

Saving Potential

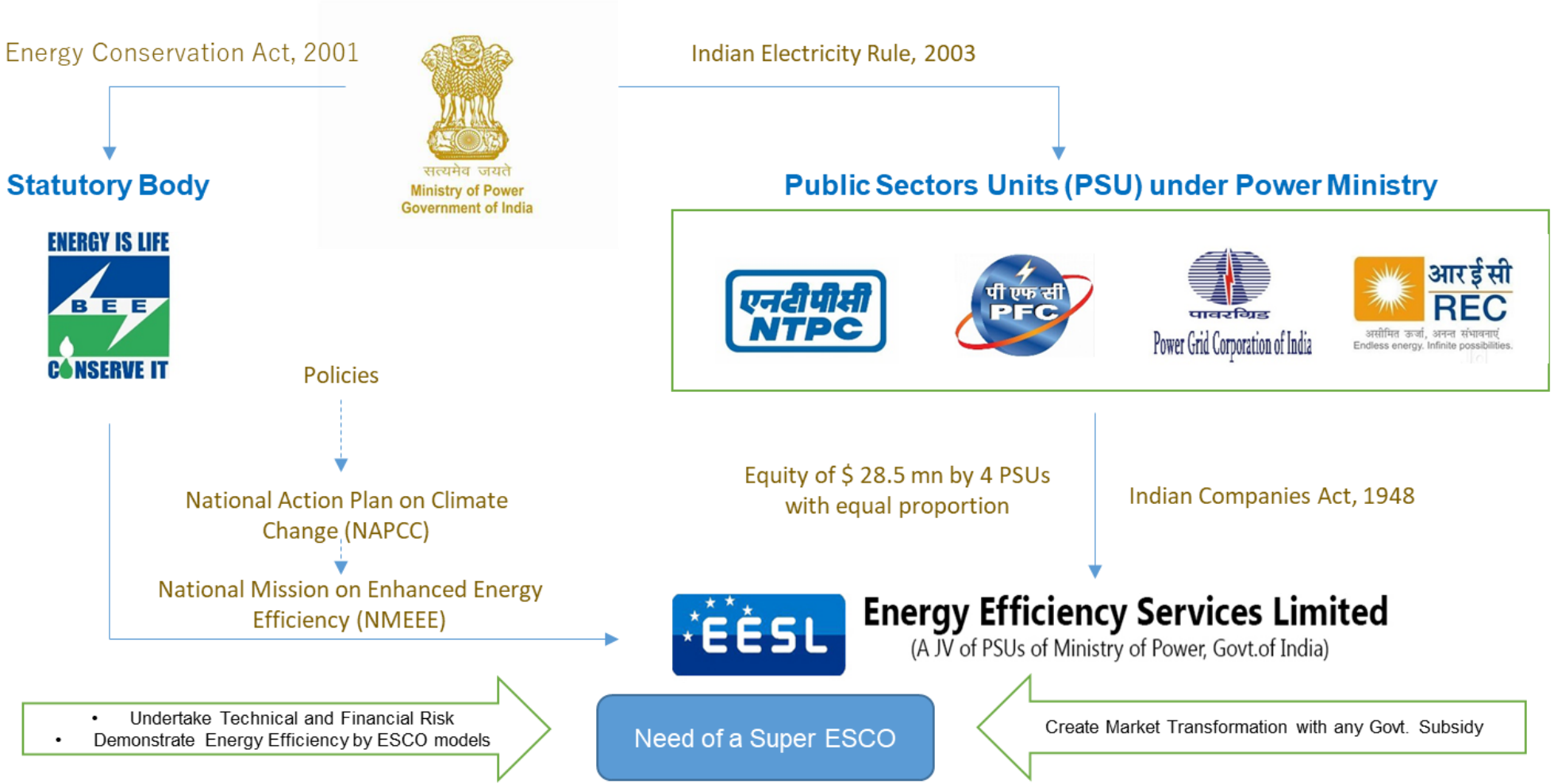


Investment Potential



INCEPTION OF EESL

Year 2009



INDIA'S SUPER ESCO

EESL's achievements (as of April 2023)

Founded in 2009, under the National Mission on Enhanced Efficiency (NMEEE)

India's Super ESCO

Estimated monetary savings of over

USD 2,800 million

Joint venture of 4 public sector enterprises and the Ministry of Power, Government of India



Estimated energy savings from EESL's interventions

54 billion kWh

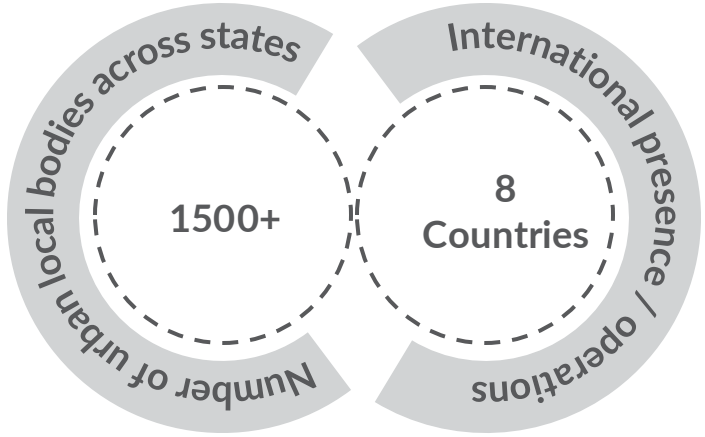
per year with avoided peak demand of 10,740 MW

Estimated carbon footprint reduction

44 million ton

of CO_2 per year



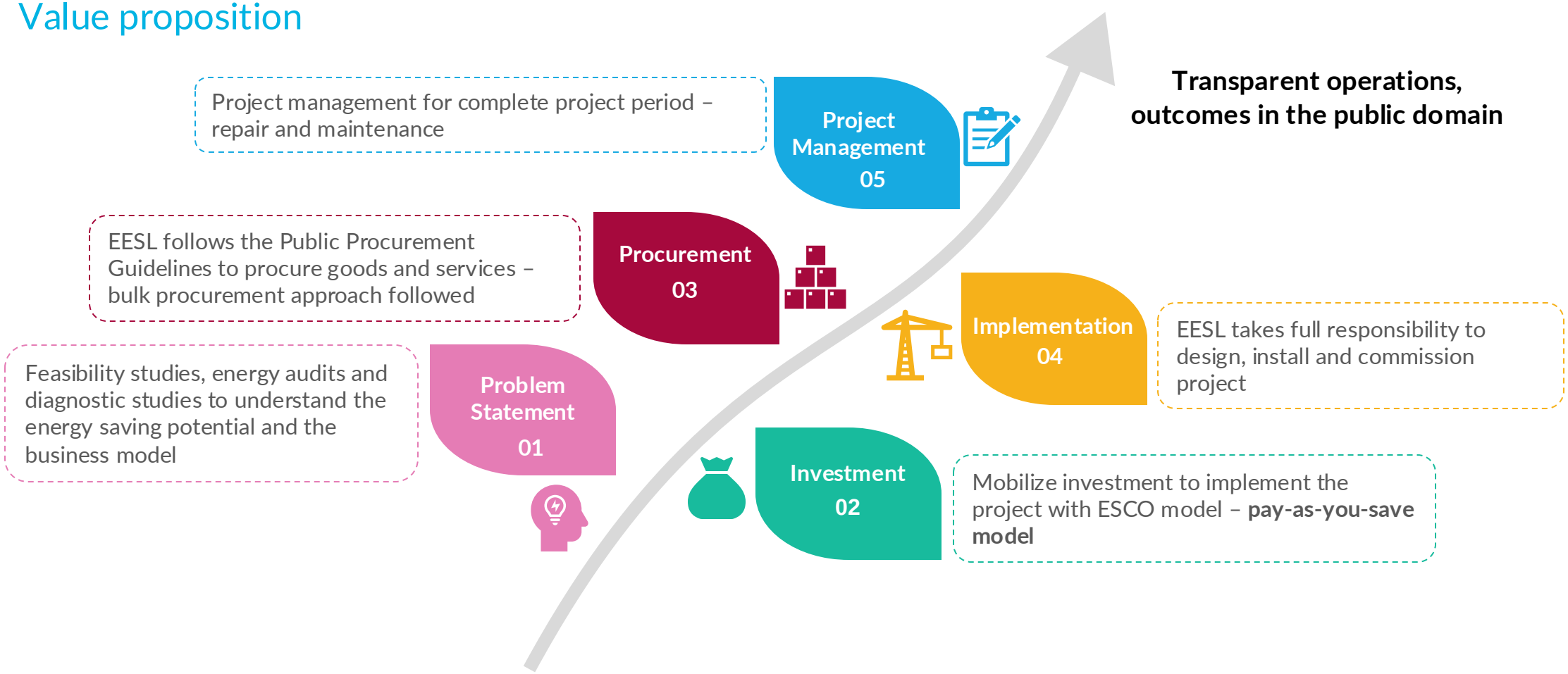




Source: Garnaik, 2023

EESL, INDIA

Value proposition

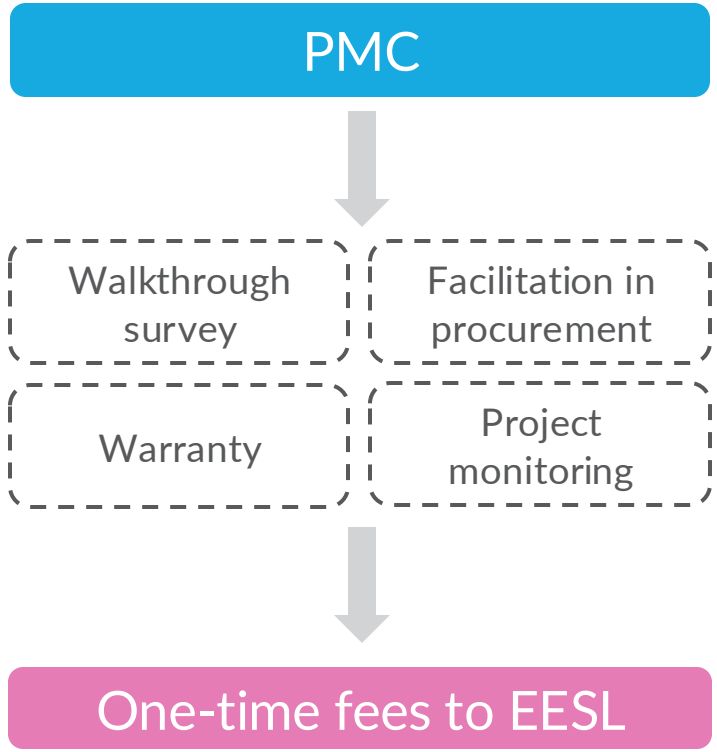


Source: Garnaik, 2023

EESL'S BUSINESS MODELS

Model 1: Project management cost (PMC) model, investment by client

- Clients express interest to purchase a particular energy saving equipment
- EESL aggregates the demand from many clients and negotiates a discounted price from reputed vendors
- EESL facilitates procurement and deployment of the equipment
- Clients pay 100% upfront cost with additional 10%–12% as EESL's PMC cost
- Warranty period is typically 3 to 5 years
- Typically, this model is used for demand aggregation, procurement and deployment of LED lights, fans, electric motors and unitary air conditioners

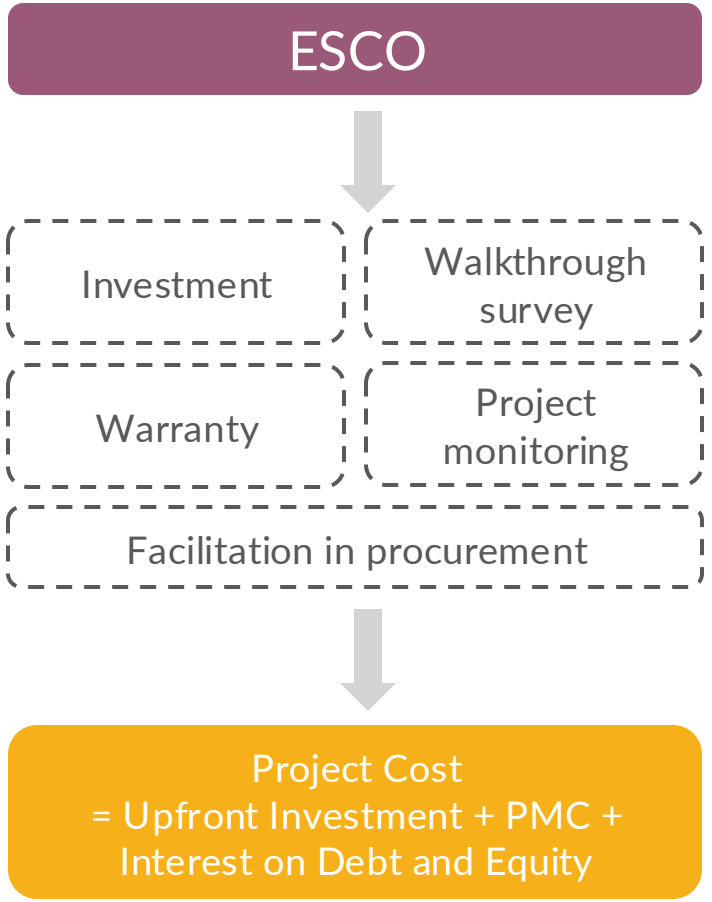


Source: Garnaik, 2023

EESL'S BUSINESS MODELS

Model 2: Investment by EESL

- Clients express interest to purchase a particular energy saving equipment
- EESL aggregates the demand from many clients and negotiates a discounted price from reputed vendors
- EESL facilitates procurement and deployment of the equipment
- Clients pay 100% upfront cost with additional 10%–12% as EESL's PMC cost, and interest on debt and equity
- Warranty period is typically 3 to 5 years
- Typically, this model is used for demand aggregation, procurement and deployment of LED lights, fans, electric motors and unitary air conditioners

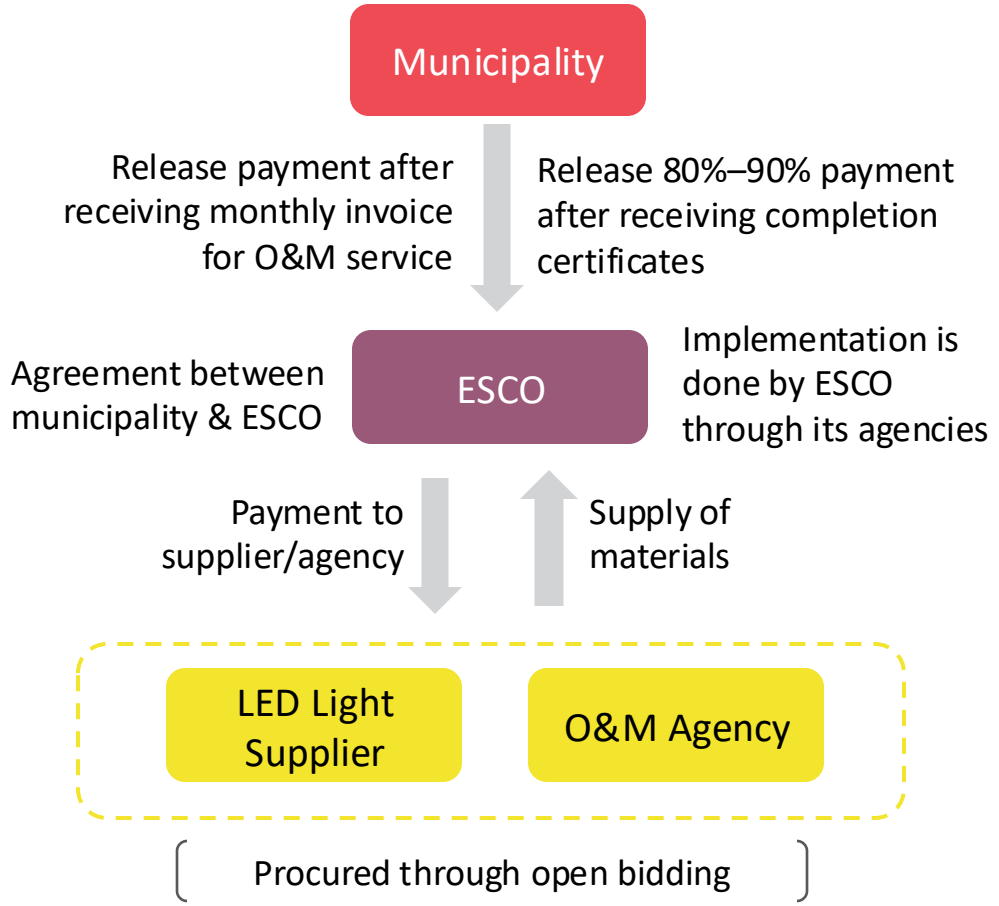


Source: Garnaik, 2023

EESL'S BUSINESS MODELS

Model 3: CapEx and OpEx model for streetlighting in urban local bodies (ULB)

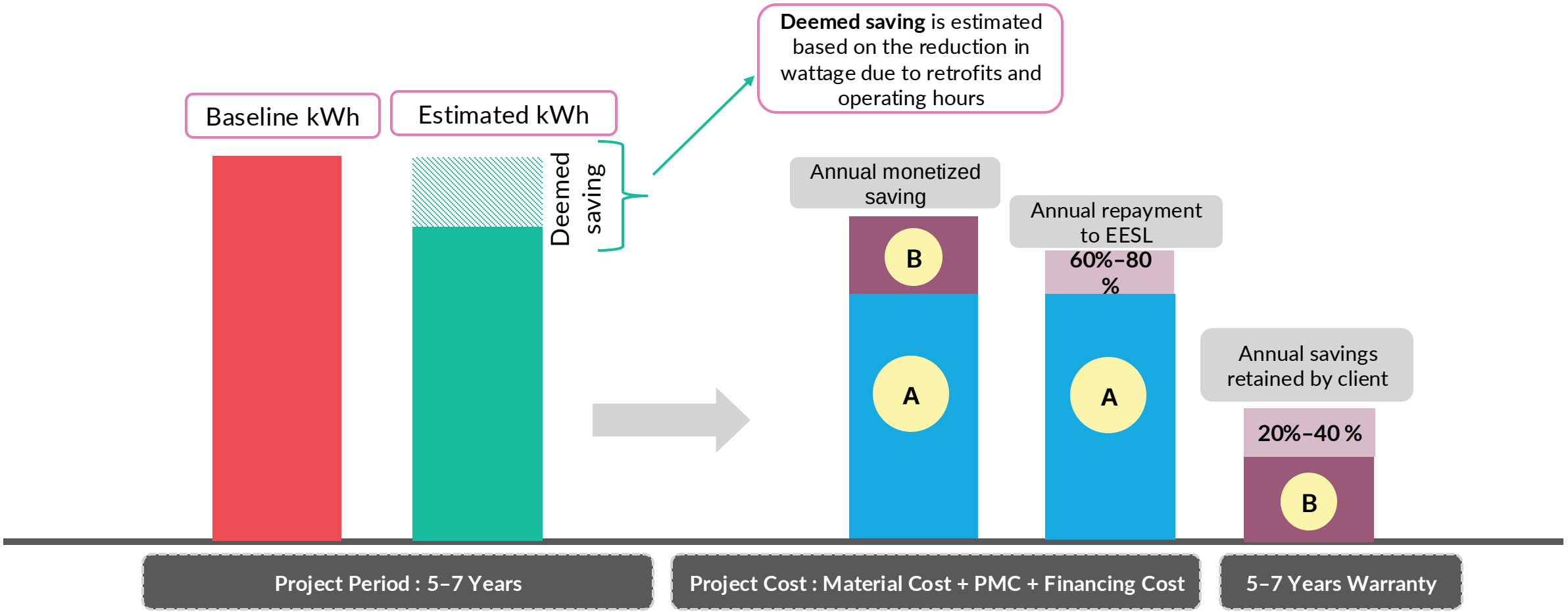
- Supply of materials (LED, CCMS and IDC) , installation and maintenance by EESL
- EESL enters into an agreement with ULB
- **Payment terms:**
  - 100% of light cost and IDC after price discovery and issuance of LoA to suppliers
  - 1% of materials cost as PMC
  - AMC as 1% of the material cost and 10% increment per year up to project period
  - AMC to be paid on monthly basis
  - Payment period is 45 days from invoicing
  - Provision of ESCROW account
- Warranty period is 7 years
- Supply and installation period is 6 months
- ULB financials only security of payments



Source: Garnaik, 2023

EESL'S BUSINESS MODELS

Model 4: Shared, deemed saving model



Source: Garnaik, 2023

UJALA

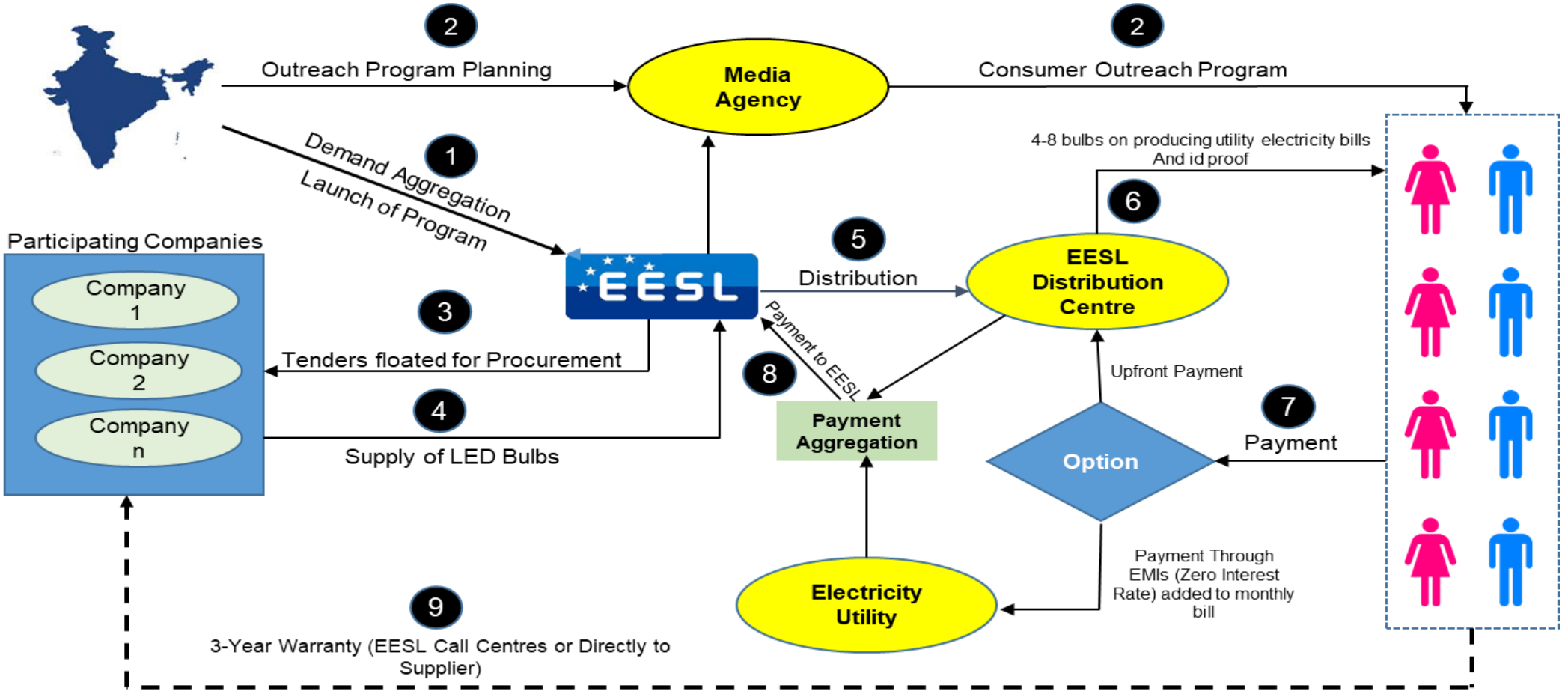
India's Domestic Efficient Lighting Program



Source: Garnaik, 2023

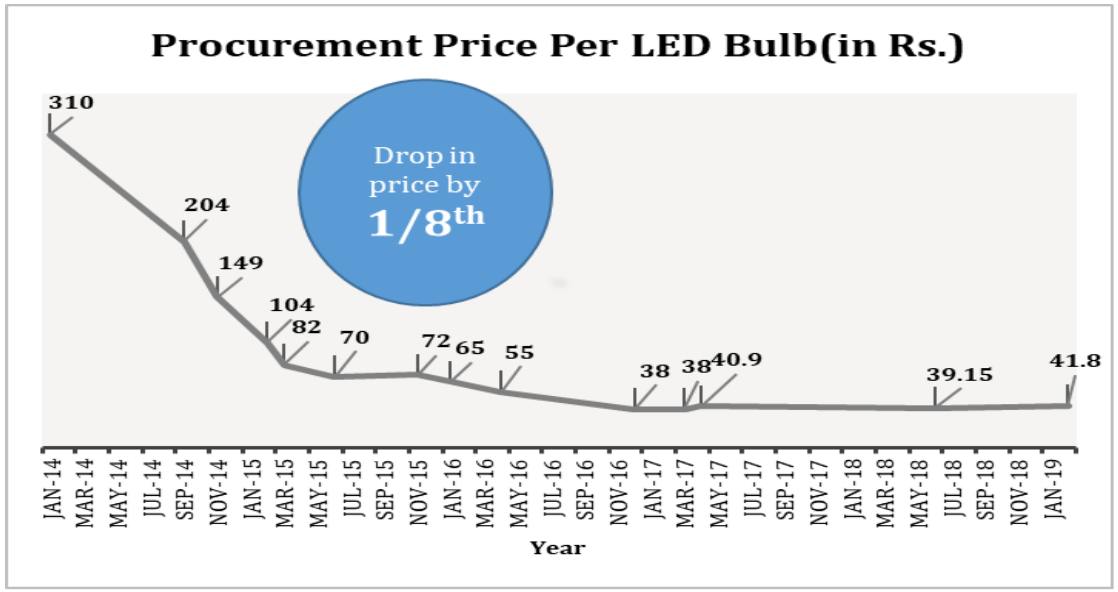
UJALA

Operating model of India's Domestic Efficient Lighting Program

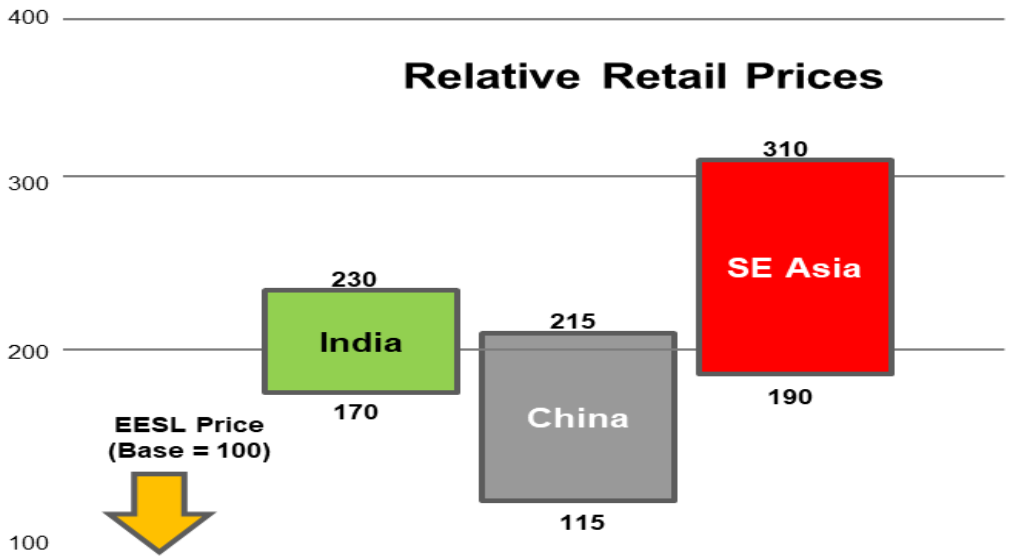


UJALA

Huge cost reduction with the same product quality!!!



- Investment done : $ **300** mn



EESL's price is much lower than the Retail Price in SE Asian Region

BULK PROCUREMENT OF LED LAMPS

Aggregation of demand and deployment by deemed saving approach

50-70 %

Energy Saving

Energy Saving is calculated on "Deemed Saving" approach by considering baseline wattage and hours of operation.

20-25%

Price Reduction

EESL adopts open public bidding process for Bulk Procurement

10-14%

Project Management Cost

EESL Project Management Cost depends upon the Project size, extent of involvement



More than 4 Million Lights have been deployed in Industries and Buildings by EESL worth 85 million USD

EESL provides various ranges of LED lights from 9 Watts to 190 Watts with 3-5 years warranty period. Typical supply period is one month to three months. Deployments of LED lights have been done in **10400 Buildings, 100 PSUs/Industries, 800 Railway Stations, 64 Airports** and **1200 Bank ATMs** across the country.

DEEMED SAVING APPROACH

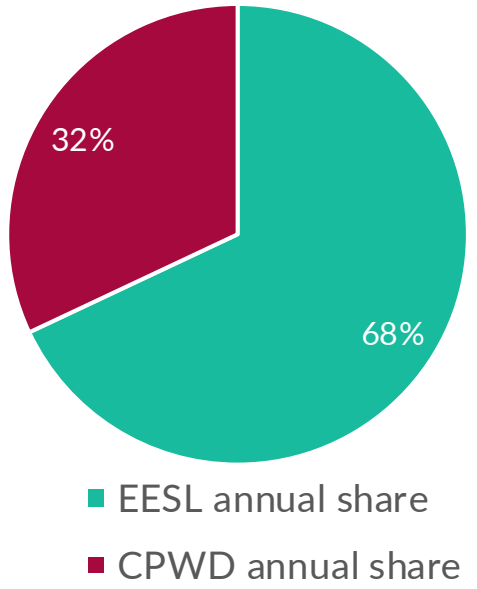
Promising energy saving products for bulk procurement

Technology	Application	Baseline	New Technology	Estimated Deemed Saving
LED Light	Domestic	100 W	9 W	91 W
	Streetlight	250 W	120 W	130 W
		400 W	190 W	210 W
		150 W	70 W	80 W
		70 W	35 W	35 W
BLDC Ceiling Fan	Buildings	80 W	30 W	50 W
Energy Efficient Air Conditioners	Buildings	1,800 W	1,050 W	750 W

EESL'S BUILDING PROJECT

Case example: ESCO model at CGO Complex, New Delhi, India

Particulars	Unit	Value
Estimated energy savings	kVAh	2,139,636
Fixed tariff	INR per kVAh	10
Estimated annual cost savings	INR per year	21,396,357
Investment	INR	48,475,430
EESL PMC fee	INR	4,483,977
Estimated capital cost	INR	52,959,408
Contract period	Years	5
Annual payout to EESL	INR	14,632,670
EESL Share	%	68
EESL quarterly repayment	INR	3,658,168
Number of quarterly repayments		20



Source: Energy Efficiency Services Limited

SUPER EFFICIENT AC PROGRAM

Case example: EESL's intervention for sustainable cooling

EESL ENERGY EFFICIENCY SERVICES LIMITED
A JV of PSUs under the Ministry of Power

ISEER 5.4
40% more efficient than 3-Star ACs

INR 39990
Price equivalent to 4-Star ACs

Cool: How EESL is meeting India's cooling needs in a sustainable manner

20-25%
Energy Saving

100000+ ACs
Deployed

gef ADB ASIAN DEVELOPMENT BANK UN environment

3-7 days
Delivery time in Tire-1 and Tire-2 cities





- About **30%** reduction in price in comparison to retail price
- Consumers could save about **INR2,000 and INR3,000 per year** compared to 5-star AC and 3-star AC, respectively
- **Hassle-free** service with complaint redressal support during program life, with **buyback option**
- Unlike conventional ACs, there is **no derating** of the cooling capacity even at high ambient temperatures, as high as 43°C
- Supports **India Cooling Action Plan** and **NITI Aayog @75** vision on energy savings and CO_2 emissions reduction
- Opportunity to scale up and create **manufacturing base** for more efficient products
- Optimizes investment on power infrastructure and synergizes with the ongoing demand side management program

STREETLIGHT NATIONAL PROGRAM

Case example: EESL's projects with urban local bodies (ULBs) for streetlighting





- Installation of **12.1 million** streetlights in over 1,600 ULBs in 20 states and 13,000 *gram panchayats* (village councils) in 3 states has transformed illumination in over **300,000 km** of roads in India with LED lights
- **7.8 billion units** of electricity saving and **1,355 MW** of peak demand reduction
- Energy cost saved by ULBs is about **USD750 million**
- Uptime of streetlights increased to **more than 95%**
- Reduction in price from **USD2.5/Watt to USD0.6/Watt** in six years due to bulk procurement of LED lamps
- **Eight-fold increment** in industrial production of LED lamps (that is from about 5,000 per day to 40,000 per day)
- Increase of sales of streetlights from less than 0.10 million lamps per month to more than **1 million lamps per month** in six years
- Improved **safety** on roads due to better illumination
- Significa stem

EESL created professional partnerships with ULBs and states

IMPACT OF BULK PROCUREMENT

Case example: ESCO market transformation in India (2016–2021)

Program	Outcome (by 2021)	Energy Saving Model	Approach	Business Model	Impact	
					Investment (million USD)	Technology Pricing (from base)
UJALA	360 million	Deemed Saving	Bulk Procurement	Upfront Payment	300	12%
Super Efficient AC	100,000	Star Rating / Deemed Saving	Bulk Procurement	Upfront Payment	72	75%
National Motor Replacement Program	12,000	Deemed Saving	Bulk Procurement	Upfront / EMI	6	80%
Streetlight National Program	12 million	Deemed Saving	Bulk Procurement	Annualized Payment	640	65%
MSME Program	24 Technologies	Measured Saving	Bulk Procurement	Upfront / EMI	8	75%–85%

EESL's INITIATIVES

Electricity savings achieved

360 million
LED Bulbs
UJALA

7.2 million
LED Tube Lights
UJALA

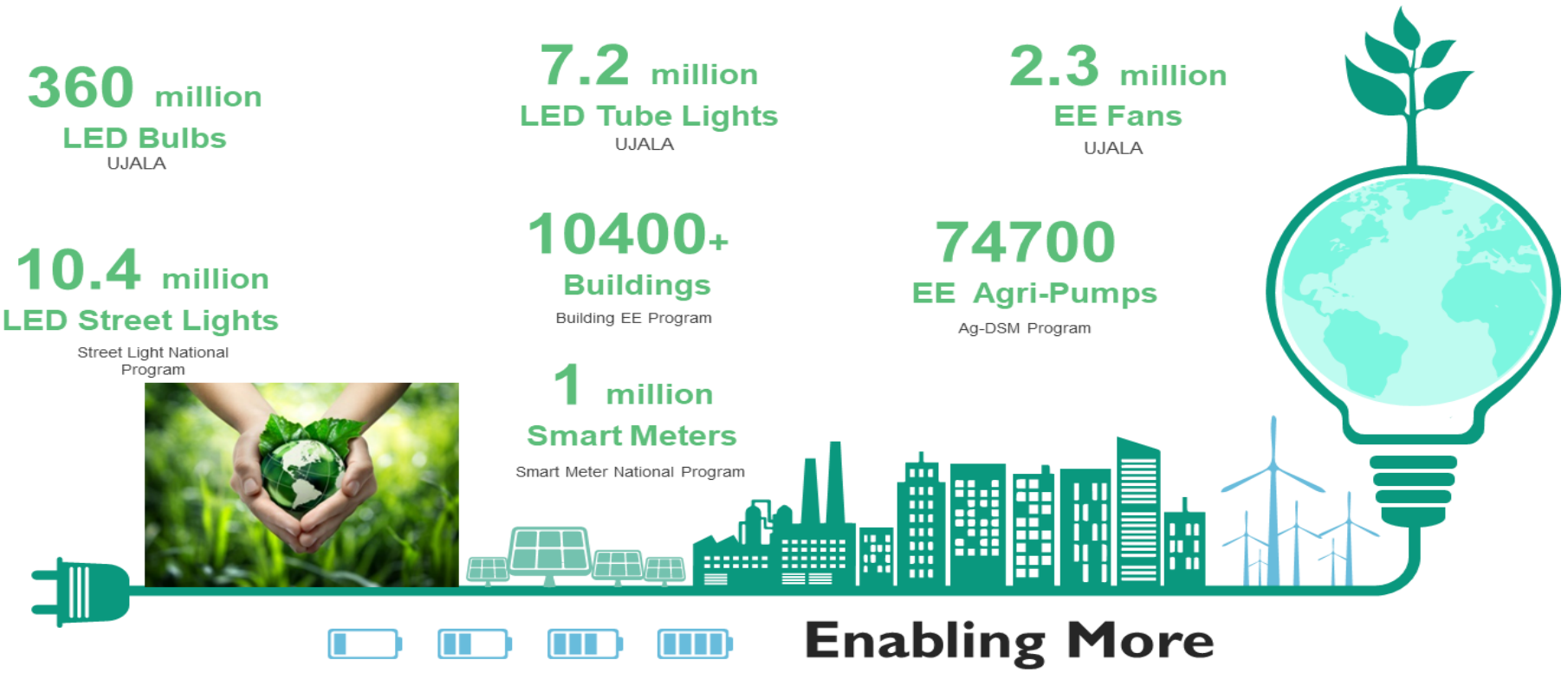
2.3 million
EE Fans
UJALA

10.4 million
LED Street Lights
Street Light National Program

10400+
Buildings
Building EE Program

74700
EE Agri-Pumps
Ag-DSM Program

1 million
Smart Meters
Smart Meter National Program



Energy Efficiency Business has resulted Electricity saving of over 45 billion kWh per annum

GGGI's INTERVENTIONS IN SE ASIA

Thailand: To reduce barriers to energy efficiency investment in SMEs

GGGI launched a project jointly with the Provincial Electricity Authority (PEA) called the Thai Auto Parts Supply Chain Development through Energy Efficiency (TAPEE) Program, targeting Thai auto-parts SMEs

The major activities are:

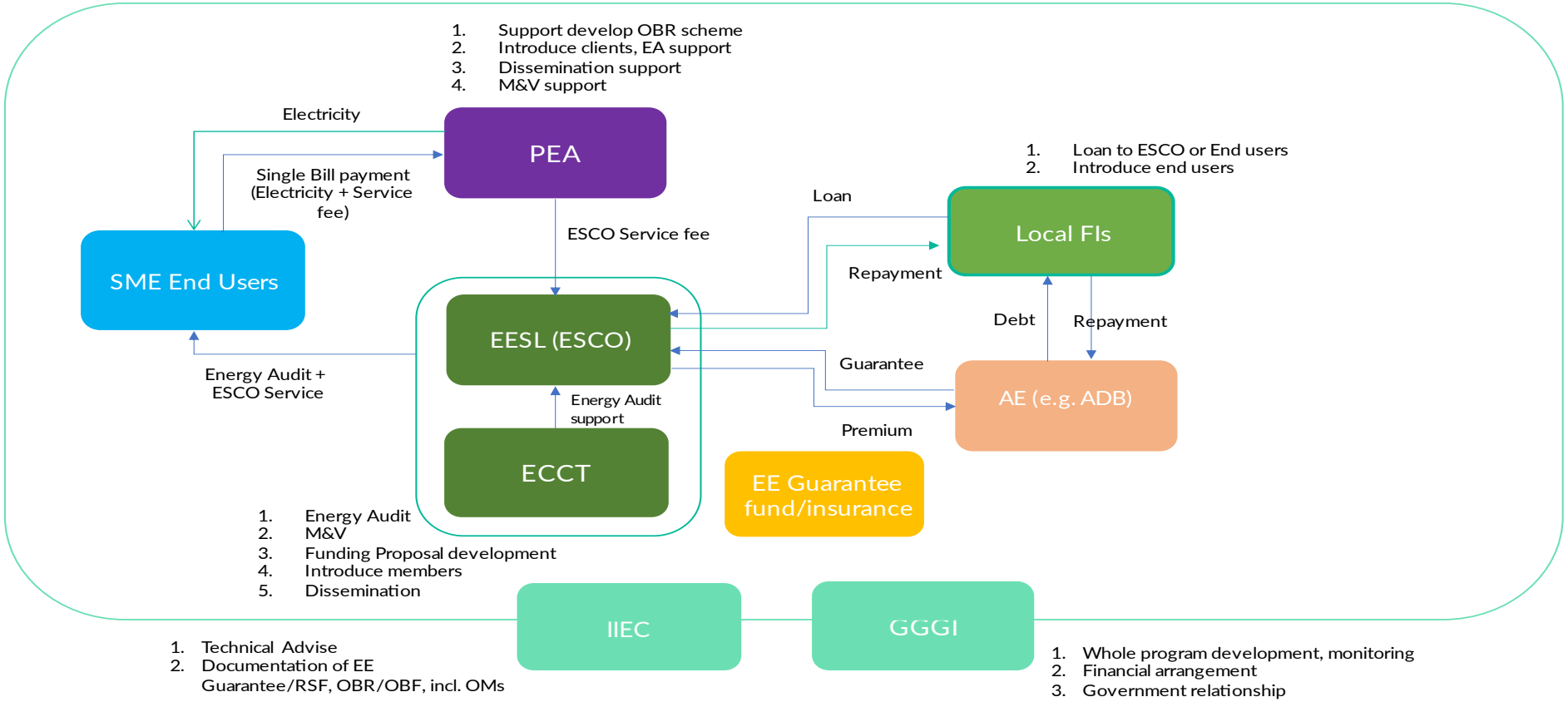
- Identification of 20 mid-to-large units and 200 small units for baseline data collection and energy audit
- Energy audit of selected SME units for identification of energy saving opportunities
- Collaboration with EESL, industry association, the Office of Natural Resources and Environmental Policy and Planning (ONEP) and PEA for energy audit work and demand assessment activities
- Identification of EE technologies with highest energy saving and replication potential – hence good investment opportunity
- Development of EE proposal with projected cost savings from EE upgrades
- Suggest mechanism for operationalizing on-bill financing (OBF) model to be adopted by PEA
- Development of guidelines, and support PEA in monitoring report of electricity bills, conducting M&V of projects and quantifying energy savings
- Mobilize ESCOs (domestic and international) to invest in EE projects of Thai auto-parts SMEs

Source: Kumar et al., 2017

GGGI's INTERVENTIONS IN SE ASIA

Thailand: To reduce barriers to energy efficiency investment in SMEs (continued)

Suggested Business model for TAPEE program



Source: Kumar et al., 2017

GGGI's INTERVENTIONS IN SE ASIA

Thailand: To reduce barriers to energy efficiency investment in SMEs (continued)

Outcomes

- Energy audit in 220 SMEs conducted
- Five standard technologies identified as replicable technologies with simple payback period of 1–3 years: IE3 motor, LED light, air compressor, energy efficient AC and VFD
- Draft OBF mechanism proposed to PEA
- Investment opportunities of over USD2 million identified
- EESL, the public ESCO of India committed to invest USD2 million in Thailand. EESL subsequently sensitized the local ESCO Association
- The program was announced by PEA on May 23, 2019 in a joint ceremony with GGGI, EESL and ECCT



Announcement of TAPEE Program in Bangkok, Thailand

Source: Kumar et al., 2017

ESCO BUSINESS

Challenges and risks

- **Energy efficiency not a priority:** Limited energy efficiency policy, lack of adequate enforcement at the state and municipal levels, absence of good governing practices, such as the provision of energy-related data in the public domain and support for the operation of ESCOs in different states, limit the widespread adoption of the ESCO model
- **Technological risks associated with energy conservation measures:** Technological risks associated with newer technologies like low-grade heat recovery is usually high when compared to mature and simple technologies such as LED lighting and pumps and motors – management buy-in becomes difficult in such cases
- **Challenges in baselining and M&V:** The main barrier in baselining is the lack of sufficient data. It is also very time consuming and means an upfront cost for ESCOs. Often, ESCOs do not budget sufficiently for long-term operations of the facility. M&V is heavily tied to baselining. An inadequate metering infrastructure is a significant challenge in the ESCO ecosystem and deserves urgent attention
- **Managerial attitudes toward ESCO operations:** Although funds are usually allocated for energy conservation projects in large industries, decisions pertaining to investments in energy efficiency are usually made at multiple thresholds – engineering, finance and others. Obtaining the buy-in from the engineering department is difficult at times, and the finance department may not fully understand energy conservation measures from a technical viewpoint. The poor flow of information leads to long delays in approvals. ESCO contracts are usually very detailed (to circumvent any disputes in M&V, sharing savings) – this also hinders contract approvals

Source: Kumar et al., 2017

ESCO BUSINESS

Challenges and risks (continued)

- **Preference for very short payback periods:** Pricing disincentives for energy efficiency investments, energy subsidies and price distortions impede the ESCO industry. If input energy costs are already quite low, end-users are not particularly motivated to install energy conservation measures that could reduce their energy bills through energy efficiency. The most preferred payback period is 1–3 years. This severely restricts the penetration of projects with longer paybacks
- **Ambiguous definition of ESCOs and lack of legal framework:** ESCOs do not have a standard definition. The ecosystem suffers from ambiguity in roles and capabilities of market actors. The lack of legal framework for the ESCO business adds to the risk in financial transactions and ownership of assets
- **A disconnect between ESCOs and end-users' preferred business model:** ESCOs have not experimented much with new ESCO models for project implementation. Shared savings is the most widely used ESCO model in the market today. ESCOs finance projects on their own balance sheets to mitigate financial risks, hindering the implementation of many projects
- **Lack of trust in the ESCO ecosystem:** There is a general feeling of mistrust among end-users and financiers who prefer to remain within the confines of small projects with conservative and safe returns instead of scaling up projects. They also prefer working with established ESCOs with proven track records, which often makes it difficult for new and deserving ESCOs to build their portfolios
- **Difficulty in availing financing:** ESCOs continue to be constrained by financial reasons. While large vendor ESCOs are better placed to finance shared savings projects, small ESCOs, with weak assets and collateral support, struggle to secure financing – bankers are uninterested in small-size projects and sometimes skeptical about ESCOs' non-standardized solutions. Bankers are reluctant to transition from traditional asset-based financing to future cash-flow-based financing, which is an important feature of international ESCO businesses. Financial schemes such as the partial risk guarantee fund (PRGF) are not being used to their fullest potential because of poor awareness of EE financing and heavy transaction costs

Source: Kumar et al., 2017 (with minor adaptation on the legal framework)

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

IKI Independent Complaint Mechanism

Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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IKI INTERNATIONAL CLIMATE INITIATIVE
on the basis of a decision by the German Bundestag



GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy | PROJECT

4.3 Sustainable Public Procurement

November 2024

ASEAN CENTRE FOR ENERGY ACE

EESL

HEAT

Supported by:

Federal Ministry for Economic Affairs and Climate Action

IKI INTERNATIONAL CLIMATE INITIATIVE

on the basis of a decision by the German Bundestag

WHAT WILL YOU LEARN?

01 Need for sustainable public procurement guidelines

02 Understanding standards, labels, certifications and environmental product declarations for sustainable equipment, appliances, building materials, etc.

03 Progress of sustainable procurement activities in ALCBT partner countries



SUSTAINABILITY

Four pillars of sustainability

ENVIRONMENTAL

- Environmental resource management
- Urban planning
- CO_2 reduction
- Alternative energies
- Water management
- Sustainable agriculture
- Marine resources management
- Protection of ecosystems
- Pollution and waste management
- Clean drinking water

SOCIAL

- Human rights
- Ethical supply chain
- Cultural and indigenous empowerment
- Food security
- Fair pay and labor law protections
- Local skills and employability development
- Anti-child labor and forced labor laws
- Fair trade
- Health and safety
- Gender equality including universal education, women-owned business
- Child mortality and maternal health
- Healthy lives and well-being for all

ECONOMIC

- Economic regeneration
- Sustainable economic development
- Emerging markets
- Development of small and medium-sized enterprises
- Total cost of ownership and life cycle costing
- Value for money
- Supply chain capacity development
- Poverty reduction

INSTITUTIONAL

- Business ethics
- Sustainable institutional development
- Governance and management
- Quality of teaching and learning
- Relations with the community
- Equality
- Encouraging strengthening systems
- Organization for Economic Co-operation and Development (OECD) MAPS assessment
- MAPS – sustainable public procurement module
- Use of country systems
- Policies and targets

Source: Asian Development Bank, 2021

SUSTAINABLE PROCUREMENT

United Nations sustainable procurement indicators

For a tender to qualify as sustainable procurement, it must meet the requirement of at least one indicator in each of the three pillars: environmental, social and economic

Pillar		Sustainable procurement Indicator	Examples of tender requirement
Environment 	1	Environment	Environmental management system, corporate environmental policy, waste management, policy on hazardous materials and chemicals
	2	Sustainable resource use	Ecolabels, circular design, energy-saving recycling, bulk packaging
	3	Climate change mitigation and adaptation	Energy efficiency, renewable energy purchasing, greenhouse gas reporting, offsetting, clean transportation and logistics, resilient infrastructure
	4	Protection of the environment, biodiversity and restoration of natural habitats	Ecolabels, sustainable or organic agriculture, forestry, fishing
Social 	5	Human rights and labor issues	Universal Declaration of Human Rights, International Labour Organization core conventions, freedom of association and collective bargaining, elimination of child and forced labor and discrimination at work, health and safety, fairly-traded goods
	6	Inclusion of persons with disability	Inclusion of disadvantaged groups such as persons with disabilities, inclusiveness and accessibility considerations in design, disability-inclusive suppliers

Source: Asian Development Bank, 2021

SUSTAINABLE PROCUREMENT

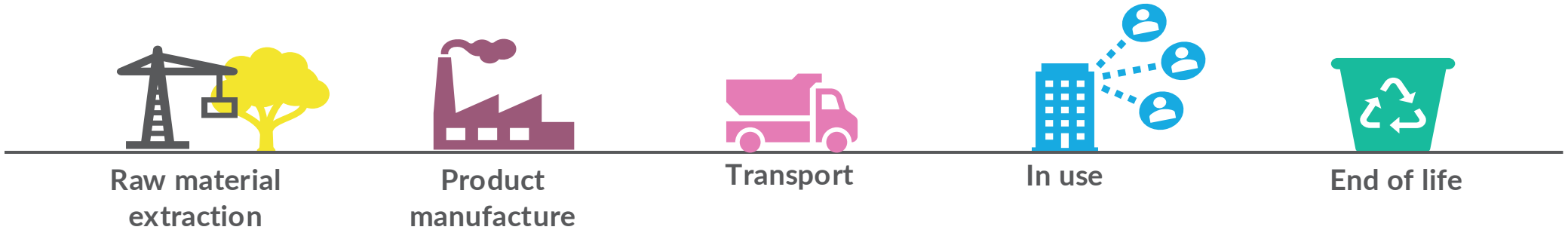
United Nations sustainable procurement indicators (continued)

Pillar		Sustainable procurement Indicator	Examples of Tender Requirement
Economy 	7	Gender equality and women`s empowerment	Gender mainstreaming, reserved procurement for women-owned businesses
	8	Social health and well-being	Avoidance of hazardous chemicals, labeling of chemicals
	9	Whole life cycle cost	Total cost of ownership, life cycle costing
	10	Local communities and small and medium-sized enterprises	Reserved labor for local communities, local materials and services, local micro, small and medium-sized enterprises
The following two indicators only serve for informational purposes and do not factor toward the classification of a sustainable procurement tender			
General 	11	Promoting sustainability throughout the supply chain	Extend sustainability requirements to tier-2 suppliers, identify and approve primary subcontractors
	12	Global compact	Considerations promoting vendors' participation in the UN Global Compact
	13	Suppliers' monitoring and auditing	Contract conditions and/or key performance indicators that stipulate verification of suppliers' environmental and social claims through spot checks and audit provisions

Source: Asian Development Bank, 2021

PRODUCT LIFE CYCLE

Five stages in the life of a product



- Every product consumes energy and water, and generates solid, liquid and/or gaseous waste products during the process of raw material extraction, product manufacturing, transportation, product utilization, and finally, during disposal of product at the end of its life, thus impacting the environment
- Preferring products with minimal impact on the environment is the way forward for sustainable development. This implies using products that consume less virgin raw materials, less energy and less water, and generate less solid, liquid and gaseous waste products during manufacturing; less carbon emissions during transportation and product distribution; less energy and water demand during utilization of the product; and finally, have minimal environmental impact during disposal at the end of its life – ideally the products should be reusable or recyclable

Source: Asian Development Bank, 2021

PUBLIC PROCUREMENT

Traditional procurement

1. Procuring agency defines specifications and requirements → 2. Tender is floated and bids are received → 3. Technical evaluation based on specifications → 4. Financial evaluation (selection based on initial cost)

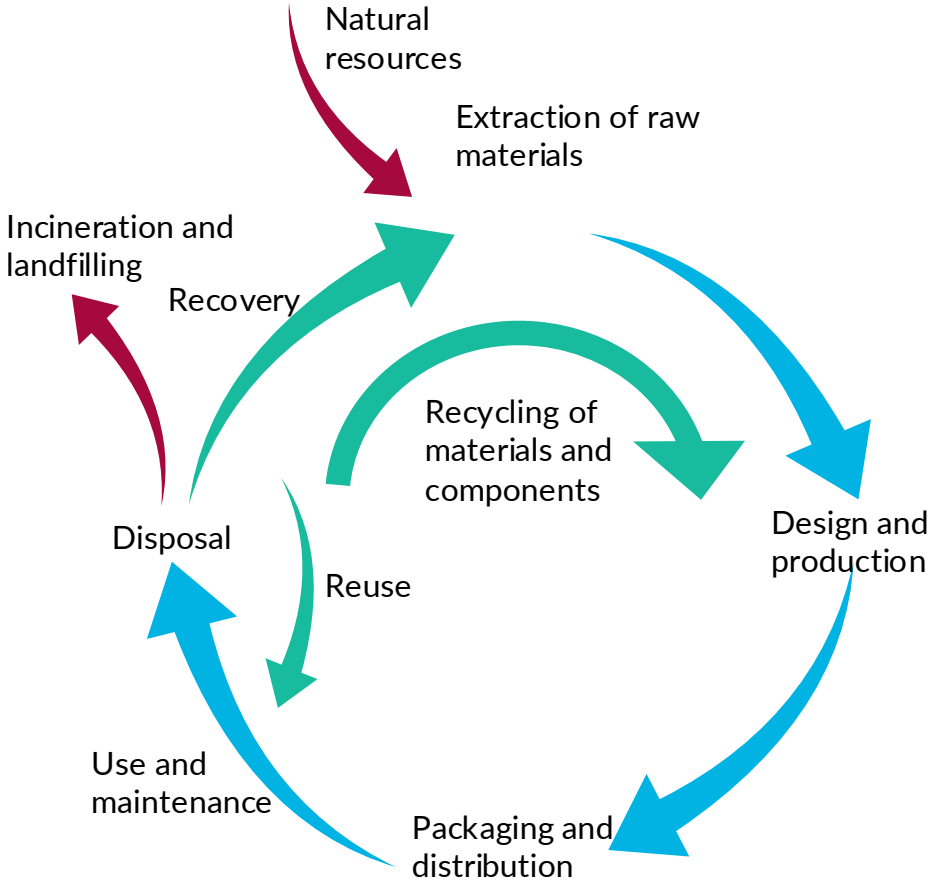
Traditional procurement has typically focused on cost and efficiency considerations. It does not usually factor in environmental, social, economic and institutional impact of the project, including the effects of the materials and processes used, on the community at large

Image source: https://sustainabledevelopment.in/wp-content/uploads/2020/06/1592393377Sustainable-Public-Procurement.pdf

SUSTAINABLE PUBLIC PROCUREMENT

Definition and implications

- Public procurement refers to the process by which public authorities, such as line ministries, departments and state-owned enterprises, purchase goods, works and services from the private sector
- Sustainable public procurement (SuPP) is a purchasing and investment process that considers the economic, environmental, social and institutional impacts of the entity's spending
- Procuring in a sustainable way involves looking beyond short-term needs and considering the longer-term impacts of each project and procurement. Organizations practicing SuPP meet their needs for goods, services, utilities and works not on a private cost–benefit analysis, but with a view to maximizing net benefits for themselves and the wider world
- SuPP allows governments to meet their needs for goods, services, utilities and works in a way that achieves value for money on a whole-life basis in terms of generating benefits not only for the organization, but also for the society and economy, while remaining within the carrying capacity of the environment



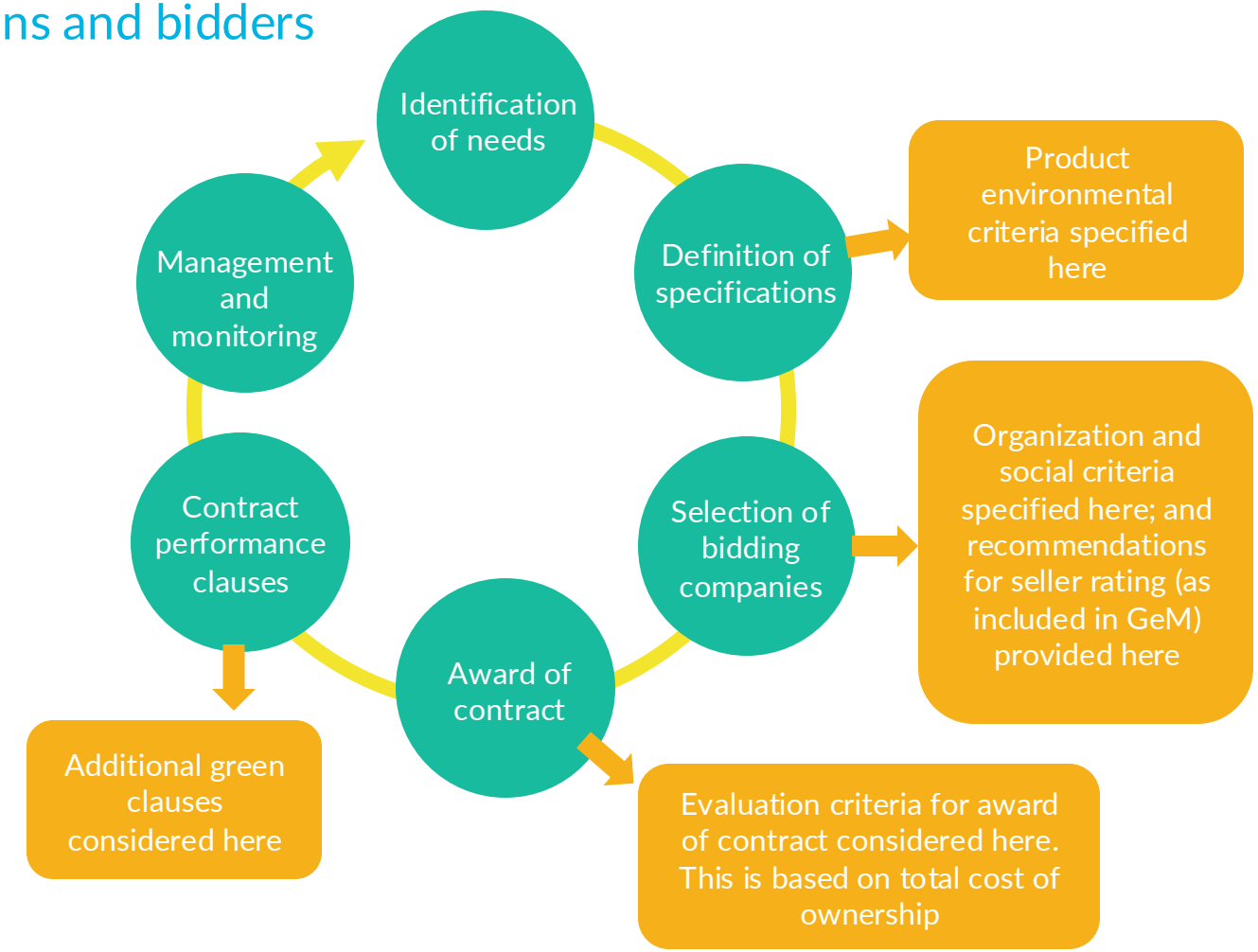
A typical product life cycle diagram

Sources: United Nations Environment Programme, 2021b; Asian Development Bank, 2021

SUSTAINABLE PUBLIC PROCUREMENT

Steps for critical assessment of solutions and bidders

- Assess the quality of proposed sustainable solutions
- Assess bidders' sustainability credentials and track records
- Assess and compare whole-life costs
- Select the most advantageous bid



Source: Asian Development Bank, 2021

Image source: https://sustainabledevelopment.in/wp-content/uploads/2020/06/1592393377Sustainable-Public-Procurement.pdf

SUSTAINABLE PUBLIC PROCUREMENT

Large canvas of benefits

Countries making a commitment to invest their time, human and financial resources, and funding to SuPP implementation will have the opportunity to:

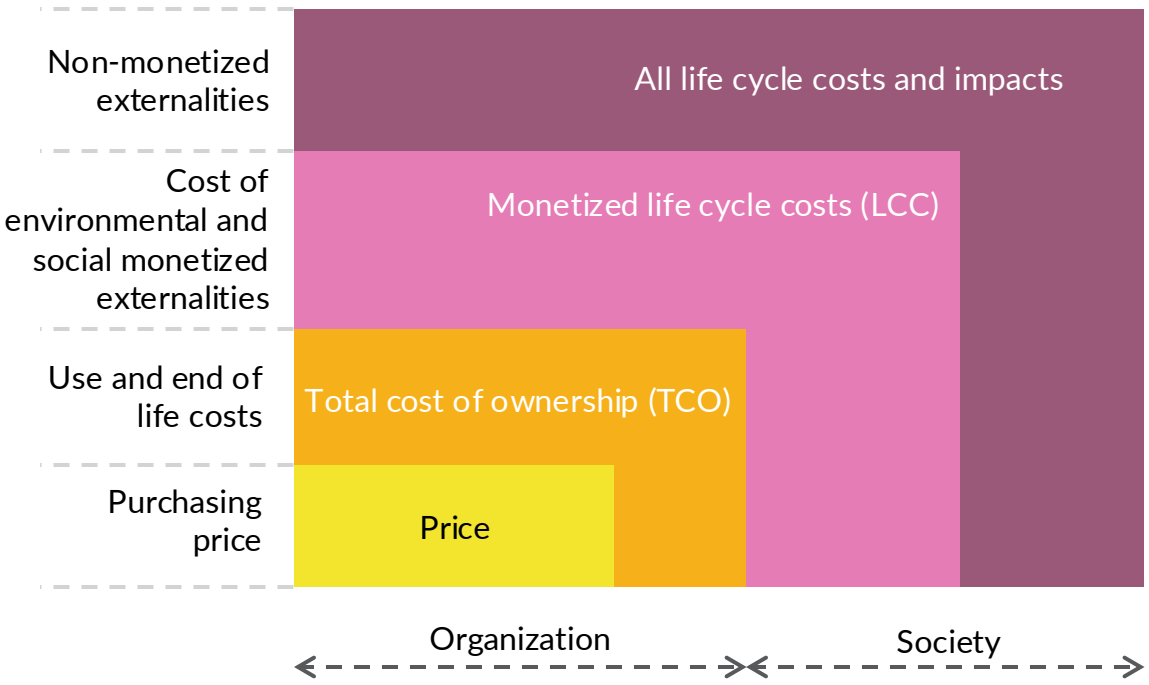
- Contribute to the delivery of the Sustainable Development Goals
- Contribute to national sustainable development objectives
- Improve environmental performance
- Contribute to a circular economy
- Deliver financial benefits
- Develop markets for more sustainable products and services
- Foster innovation
- Contribute to social equity
- Promote gender equality
- Bring political benefits



SUSTAINABLE PUBLIC PROCUREMENT

Life cycle assessment and life cycle costing

- Life cycle assessment (LCA) refers to the sustainability impacts during a life cycle that varies from product to product. A full assessment requires detailed data that is often not available
- Life cycle costing (LCC) is an economic assessment considering all agreed projected significant and relevant cost flows over a period of analysis expressed in monetary value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety and availability
- LCC considers all the costs that will be incurred during the lifetime of the product, work or service. They include:
  - Purchase price and all associated costs (delivery, installation, insurance, etc.)
  - Operating costs, including energy, fuel and water use, spares, and maintenance
  - End-of-life costs (such as decommissioning or disposal) or residual value (i.e., revenue from the sale of a product)



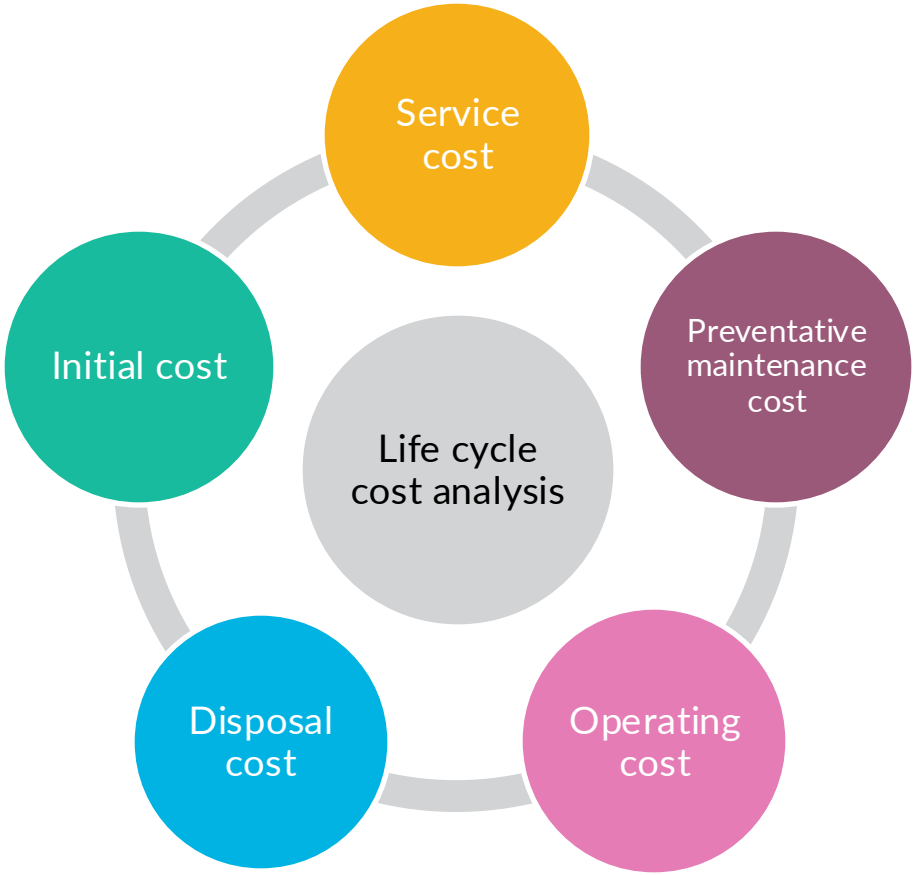
Source: United Nations Environment Programme, 2021b

Image source: UN Environment, ISO 20400

SUSTAINABLE PUBLIC PROCUREMENT

Life cycle costing

- LCC makes good sense regardless of a public authority's environmental objectives
- By applying LCC, public purchasers are accounting for the costs of resource use, maintenance and disposal, which are not reflected in the purchase price
- Often, this will lead to win-win situations whereby a greener product, work or service is also cheaper overall
- The main potentials for savings over the life cycle of a good, work or service are:
  - Savings on the use of energy, water and fuel
  - Savings on maintenance and replacement
  - Savings on disposal costs



Source: United Nations Environment Programme, 2021b

SUSTAINABLE PUBLIC PROCUREMENT

Financial benefits

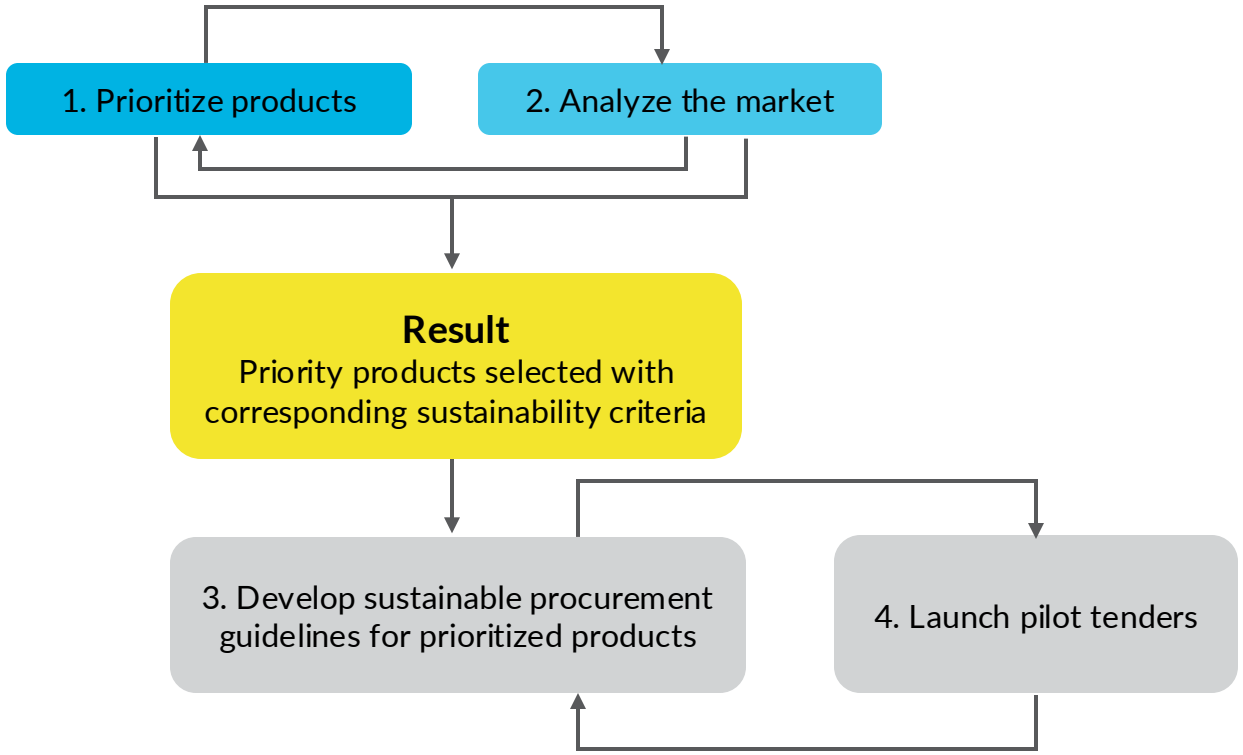
SuPP helps reduce total operating costs by procuring more efficient and sustainable goods, works or services that:

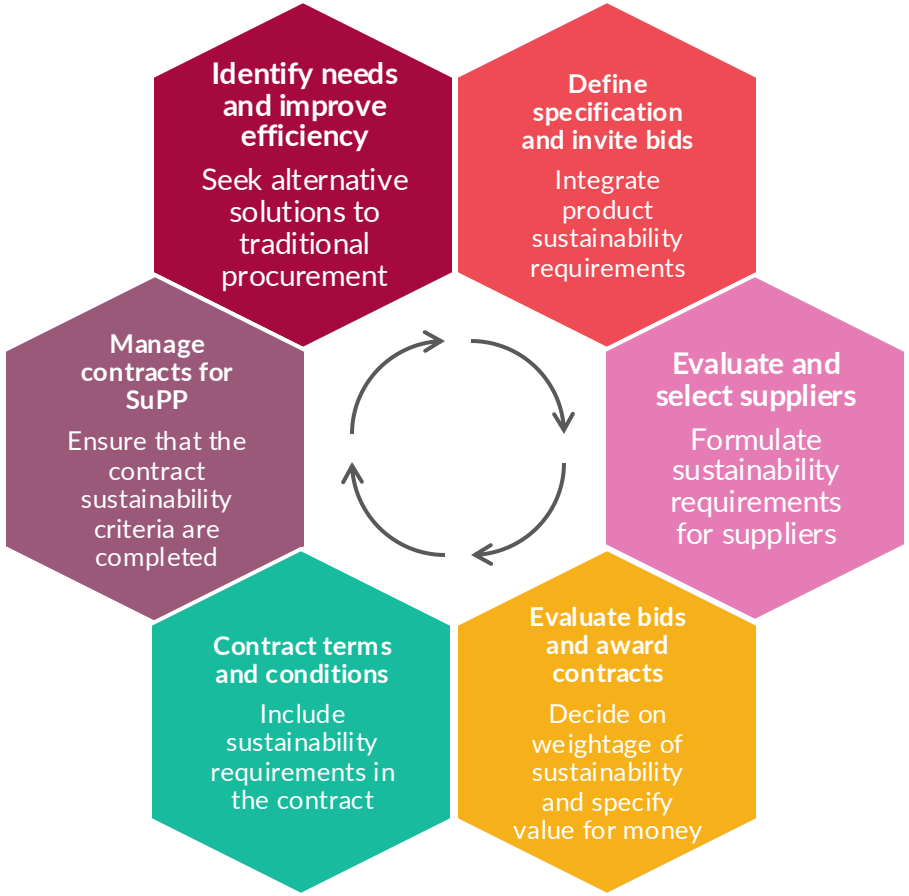
- Develop the market's capacities to deliver sustainable solutions
- Increase demand for sustainable solutions, which in turn increases market competitiveness
- Strive for innovative and more sustainable outcomes
- Lead to cost savings on a long-term basis by applying LCC and operation and maintenance considerations
- Minimize disposal costs and sustainable impacts of products at their end of life

Source: Asian Development Bank, 2021

SUSTAINABLE PUBLIC PROCUREMENT

Prioritizing products, investigating the market and developing guidelines

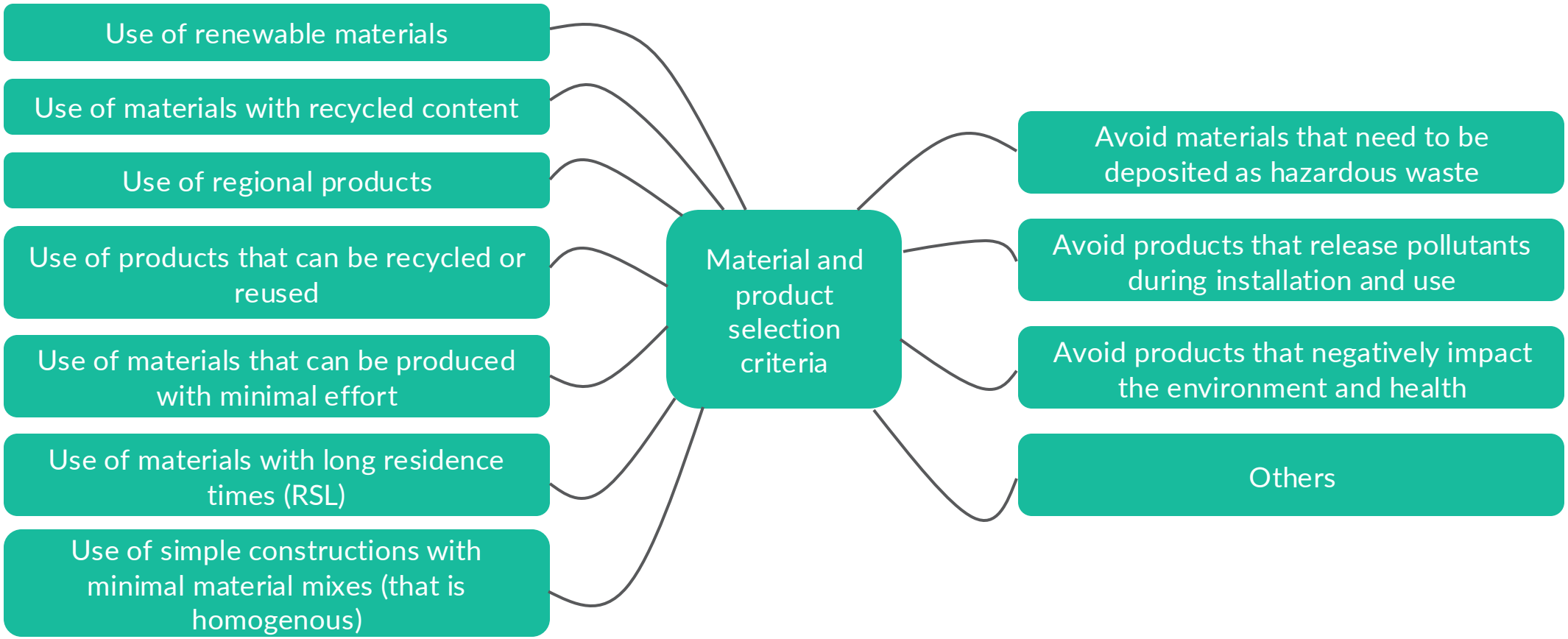




Source: United Nations Environment Programme, 2021b

BUILDING MATERIALS

Sustainability: Material and product selection criteria

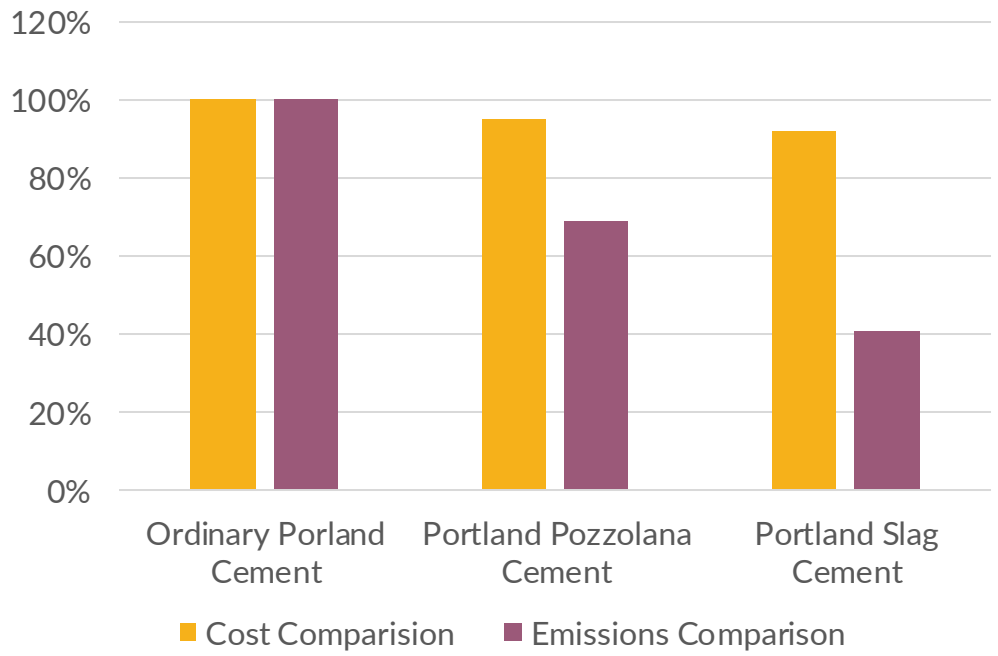


Source: SAICM Secretariat, 2023

CEMENT

Case example: India – Options, market penetration, emissions and comparative costs

Cement type	Description	Market penetration	Emissions intensity ($kgCO_2$/tonne)
Ordinary Portland Cement (OPC)	Regular cement made with a mix of clay or shale and limestone or chalk (to produce clinker) and gypsum	27%	740
Portland Pozzolana Cement (PPC)	Blended cement made with clinker mixed with fly ash	65%	511
Portland Slag Cement (PSC)	Blended cement made with clinker mixed with slag	7%	340



Sources: Global Cement and Concrete Association, 2022; Xynteo, 2024

GREEN PROCUREMENT INITIATIVES

International initiatives and benchmarks for green steel, cement and concrete

- The Industrial Deep Decarbonization Initiative (IDDI), an initiative under UNIDO, launched the Green Public Procurement Pledge in September 2022 to encourage governments to report environmental data and use low-emissions and near-zero emissions cement, concrete and steel in their construction projects. So far, nine countries have joined IDDI
- World Economic Forum's First Movers' Coalition (FMC), a public-private partnership launched in 2021, includes 65 global companies, which have committed to use their purchasing power to create markets in at least one of seven key sectors. So far, 18 companies have committed to the steel sector target. At COP27, the coalition launched cement and concrete as its latest sector with five companies as initial signatories
- The Climate Group's SteelZero and ConcreteZero initiatives are corporate partnerships with 25 and 22 companies, respectively that have committed to using net-zero steel and low- and net-zero emissions concrete. SteelZero, launched in 2020, is a partnership with ResponsibleSteel. ConcreteZero, launched in 2022, is a partnership with WBCSD and WorldGBC

Source: Gangotra et al., 2023

GREEN PROCUREMENT INITIATIVES

International initiatives and benchmarks for green steel, cement and concrete

Initiative/Policy	Type	Definitions and Benchmarks	Targeted Share of Purchases
FMC	Public-Private	Near zero emissions steel: 100–400 kg Co_2e/t Near zero emissions cement: 184kg CO_2/t Near zero emissions concrete: 70–144 kg CO_2/m^3	10% by 2030
IDDI	Public	Near zero emissions steel: 50–400 kg CO_2e/t Low emissions steel: 800–2,400 kg CO_2e/t Near zero emissions cement: 40–125 kg CO_2e/t Low emissions cement: 250–750 kg CO_2e/t	Signatories to decide
SteelZero	Private	Low emissions steel: 200–1,400 kg CO_2e/t Net zero steel: As close to zero as possible	50% low emissions by 2030 100% net zero by 2050
ConcreteZero	Private	Low embodied carbon concrete: 100–270 kg CO_2/m^3 Net zero concrete: As close to zero as possible with at least 90% mitigation	30% low carbon by 2025 50% low carbon by 2030 100% net zero by 2050
GSA Buy Clean	Public	Low embodied carbon concrete: 242–414 kg CO_2/m^3	100%
Buy Clean California Act	Public	Global warming potential limit for concrete reinforcing steel, hot-rolled steel, hollow structural steel, steel plate: 890–1,490 kg CO_2e/t	100%

Note: Range for steel, cement and concrete depends on scrap share, clinker ratio and concrete compressive strength, respectively

Source: Gangotra et al., 2023

SUSTAINABILITY STANDARDS AND LABELS

Internationally-recognized certifications

- ISO 14001 on Environmental Management Systems is the most common international standard providing assurances that environmental impacts are being measured and improved. More specific standards such as ISO 14020:2000 on Environmental Labels and Declarations, ISO 45001:2018 on Occupational Health and Safety Management, and ISO 20400:2017 on Sustainable Procurement establish guiding principles for the development and use of sustainable procurement practices and management
- SA800035 on Social Accountability from Social Accountability International and OHSAS 45001 on Occupational Health and Safety Management are increasingly being used for application of social sustainability criteria
- Other international sustainability standards and certifications include the Leadership in Energy and Environmental Design (LEED), Forest Stewardship Council (FSC) and the Marine Stewardship Council (MSC)
- The Global Ecolabelling Network (GEN) is a non-profit association for third-party environmental performance recognition and certification

Source: Asian Development Bank, 2021

SUSTAINABILITY

Ecolabeling: Industry standards and verification

Standard for Sustainable and Resilient Infrastructure

This is a global voluntary standard that integrates key criteria of resilience and sustainability into infrastructure development, taking into consideration governance, social and environmental factors. It is currently developed under International Social and Environmental Accreditation and Labelling (ISEAL) guidelines by the Swiss Global Infrastructure Basel Foundation (GIB) and the French bank Natixis. GIB and Natixis launched the SuRe standard on December 9, 2015

Health and Safety Management (OHSAS 18001)

OHSAS 18001 is one of the international standards for occupational health and safety management systems. It provides a framework for the effective management of occupational health and safety, including all aspects of risk management and legal compliance. It addresses occupational health and safety rather than any specific product safety matters

Environmental Management (ISO 14001)

ISO 14001 sets out the criteria for an environmental management system. It maps out a framework that a company or organization can follow to set up an effective environmental management system.
Designed for any type of organization regardless of its activity or sector, ISO 14001 can provide assurance to company management and employees as well as external stakeholders that environmental impact is being measured and improved

Eco-Management and Audit Scheme

This is a voluntary environmental management instrument, which was developed in 1993 by the European Commission. It enables organizations to assess, manage and continuously improve their environmental performance. The scheme is globally applicable and open to all types of private and public organizations. To register with EMAS, organizations must meet the requirements of the EU EMAS- Regulation. Currently, more than 4,600 organizations and more than 7,900 sites are EMAS-registered

Source: Asian Development Bank, 2021

ECOLABELING

ISO classification type I

Type I Ecolabels (ISO 14024:1999)

- Only independent and reliable labels that consider the life cycle impact of products and services are called ecolabels, even if this term is commonly used in a broad and not always correct way
- This type of ecolabel is the most useful for procurement professionals. The ecolabels are based on ambitious criteria of environmental quality, and they guarantee that the awarded products respect the highest environmental standard in that market segment. The criteria are usually developed through the involvement of a large number of stakeholders and awarded after an independent process of verification
- Ecolabels take into account all adverse environmental impacts of a product throughout its life cycle, including energy and water consumption, emissions and disposal



ISO type I ecolabels

Source: Asian Development Bank, 2021

Image source: https://dldxedu.com/education-tips/3-types-eco-labels-know/

ECOLABELING

ISO classification type II

Type II Ecolabels – Self-Declared Environmental Claims (ISO 14021:1999)

- Labels belonging to this group do not share some of the usual characteristics of environmental labels, the main difference being that they are not awarded by an independent authority. These labels are developed internally by companies and can take the form of a declaration or a logo referring to a company's product
- Companies have developed their own environmental label or claim as consumers and procurement professionals are increasingly attentive to the environmental impact of what they procure. Therefore, providing information on the environmental performance of products and services is becoming a commercially interesting option for many firms. The self-declaration that a company voluntarily makes refers to an environmental aspect of a product, to a component of the product, or to its packaging; and/or is made on the product, on product packaging, in product literature, or in advertisement
- This kind of producer declaration can provide useful information for procurers, if all green claims are accurate and true. If the information conveyed in claims is vague, misleading or inaccurate, the consequence can be loss of trust in claims and labels in general



ISO type II ecolabels

Source: Asian Development Bank, 2021

ECOLABELING

ISO classification type III

Type III Ecolabels – Environmental Impact Labels (ISO 14025:2006)

- Type III ecolabels consist of qualified product information based on life cycle impacts. Environmental parameters are fixed by a qualified third party and then companies compile environmental information into the reporting format, which is independently verified. The impacts are expressed in a way that makes it easy to compare different products and sets of parameters for public procurement purposes
- Type III ecolabels do not assess or weigh the environmental performance of the products they describe. This type of environmental labels only shows the objective data, and their evaluation is left to the procurer. Type III ecolabels require exhaustive life cycle data sheets called environmental product declarations



ISO type III ecolabels

Source: Asian Development Bank, 2021

ECOLABELING

ECO LABEL: Criteria for building material and product certification

- Raw material extraction
  - Extraction management (only for natural products)
  - Extraction management (for all hard coating products)
- Raw material selection (for all hard coating products)
  - Absence of risk phrases on raw materials
  - Limiting the presence of certain substances in additives (only for glazed tiles)
  - Limiting the presence of asbestos and polyester resins in materials
- Finishing operations (only for natural products)
- Production process (for processed products only)
  - Energy consumption
  - Water consumption and use
  - Emissions to air
  - Emissions to water
  - Cement

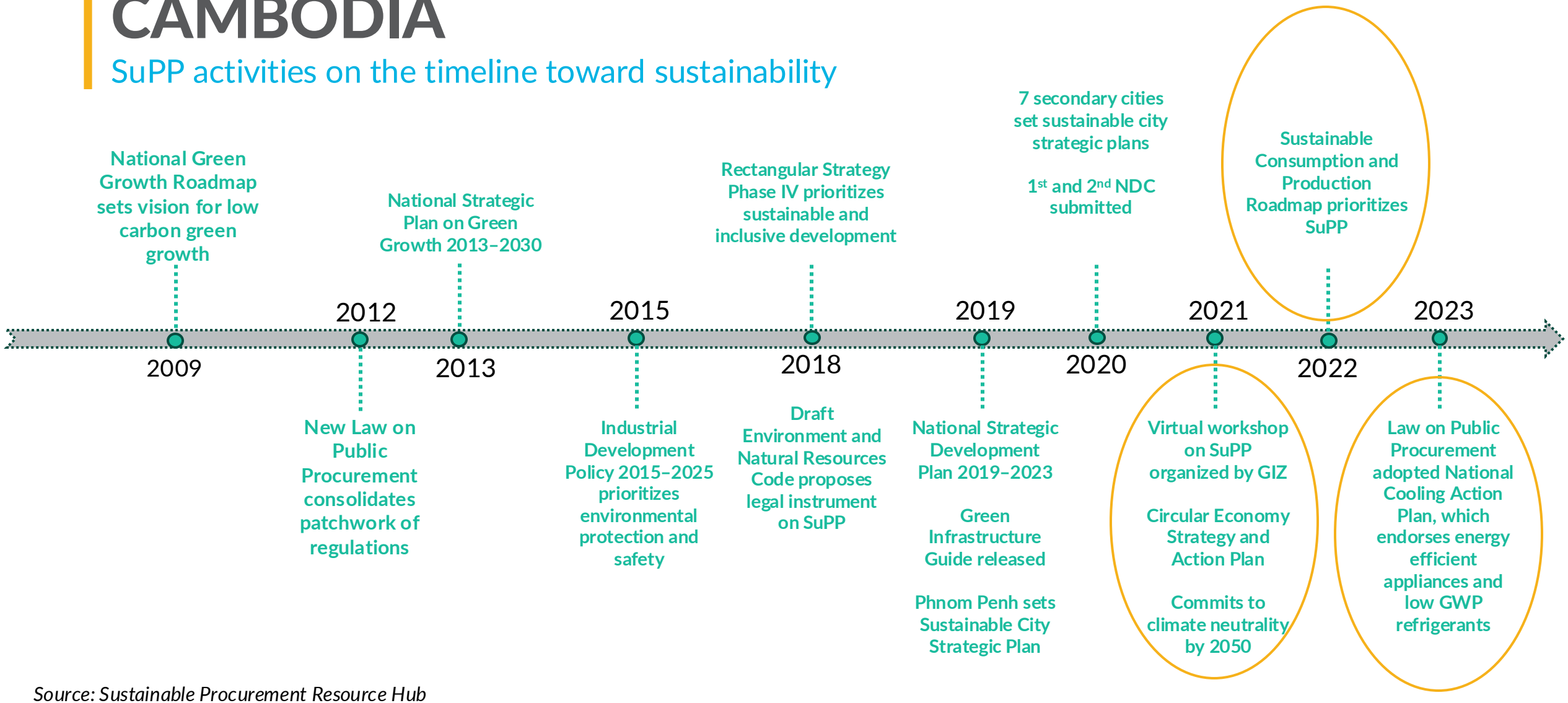
ECO LABEL certification from Ecological Certification Institute is based on ISO 14024 standard used in European Union countries, based on type 1 ecolabel. It is an optional environmental label, based on detailed life cycle analysis. Among the sectors available for certification, building construction materials is also included

- Waste management
  - Waste management (only for natural products)
  - Recycling of waste (only for processed products)
- Use phase
  - Release of hazardous substances (glazed tiles only)
- Packaging features
- Suitability for use
- Consumer information

Source: ECO LABEL

CAMBODIA

SuPP activities on the timeline toward sustainability



Source: Sustainable Procurement Resource Hub

CAMBODIA

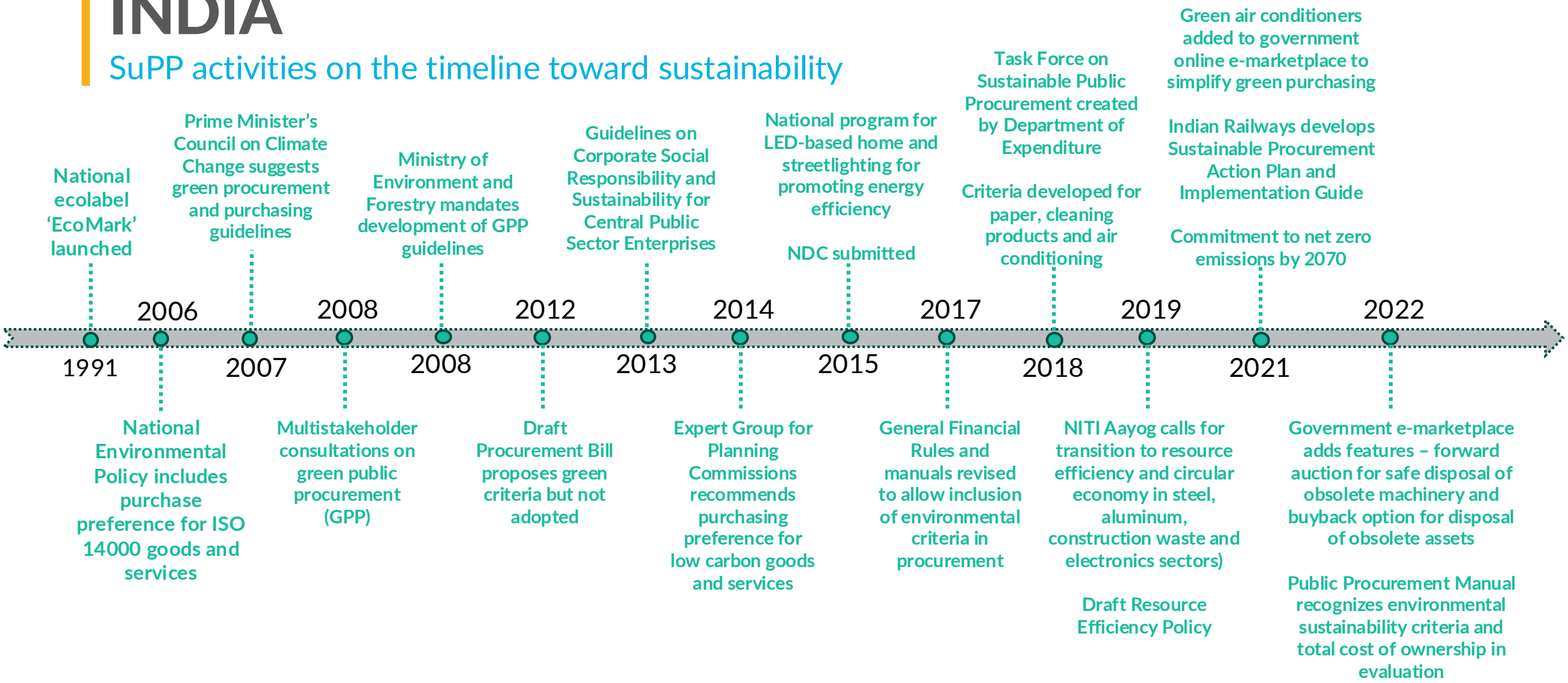
Progress on implementation of SuPP

- SuPP is recognized in Cambodia's Sustainable Consumption and Production Roadmap 2022–2035 as a key strategy to promote ‘sustainable investment’ - one of the roadmap's five key pillars. The roadmap calls for the set up of a sustainable (green) procurement standard under the National Council for Sustainable Development (NCSD) and Ministry of Economy and Finance, and design of environmental criteria and performance requirements for priority products and services
- A new Environment and Natural Resources Code has been adopted in May 2023, with a detailed section on ‘sustainable public procurement’. The code outlines a proposed mechanism for the design of green tenders that depends on the development of environmental standards and ecolabels. The NCSD is currently designing an ecolabeling program in Cambodia, in collaboration with relevant line ministries, with support from GIZ
- The NCSD is an interministerial body that is leading the implementation of SuPP in Cambodia. The adoption of the Public Procurement Law in May 2023, which includes provisions aligning public procurement with sustainable principles demonstrates Cambodia’s commitment to SuPP. However, results may only be visible after increasing awareness generation among stakeholders, ensuring effective cooperation between ministries and developing an e-procurement portal for greater transparency

Source: Sustainable Procurement Resource Hub

INDIA

SuPP activities on the timeline toward sustainability



Source: Sustainable Procurement Resource Hub

INDIA

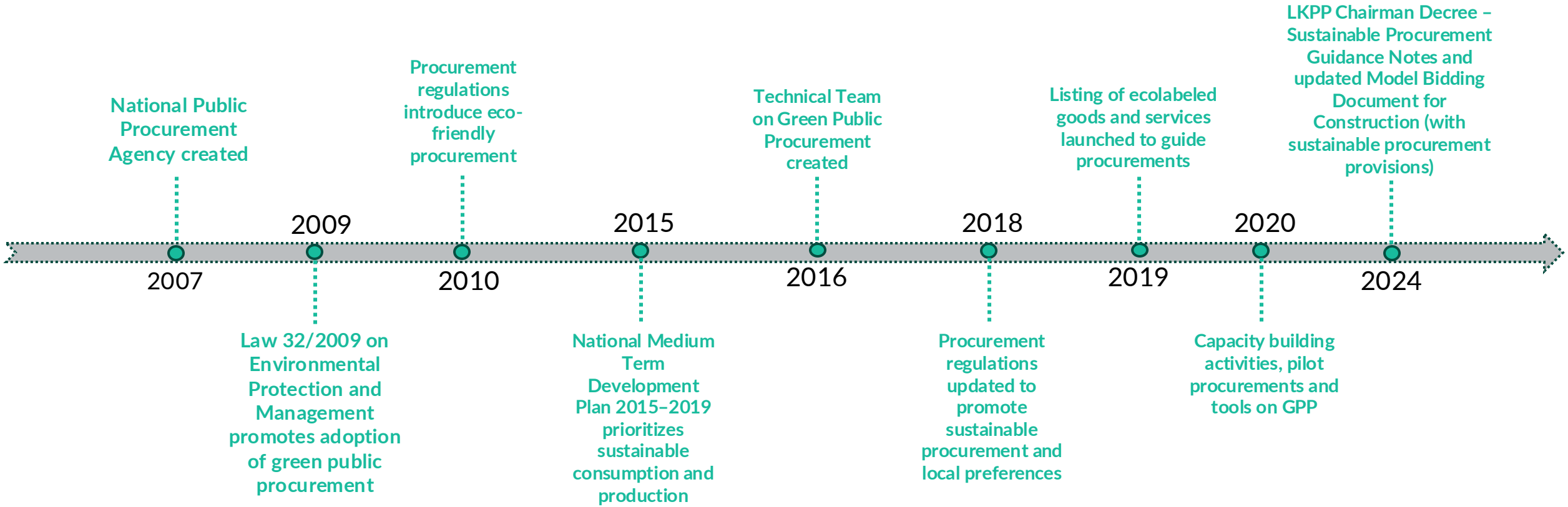
Progress on implementation of SuPP

- General Financial Rules and Manual opened the door for SuPP in the absence of procurement law reform
- Indian Railways and few other public agencies implemented SuPP over the past decade without central procurement support
- Task Force on Sustainable Public Procurement created in 2018 has seven priority spend categories to pilot SuPP implementation
- 2017 Public Procurement (Preference to Made in India) Order encourages inclusion of preferences in public procurements for domestic suppliers
- Government e-Marketplace includes sustainable products and services, making it simple for procuring entities to buy green and local. Presently, major building construction materials are not included
- GreenPro is a type 1 ecolabel for sustainable products, materials and technologies for the construction, operation and maintenance of buildings. Over 1,500 products have obtained GreenPro certification
- Introductory training modules on SuPP available since 2020

Source: Sustainable Procurement Resource Hub

INDONESIA

SuPP activities on the timeline toward sustainability



Source: Sustainable Procurement Resource Hub

INDONESIA

Progress on implementation of SuPP

- Green public procurement was first introduced in Law 32/2009 on Environmental Protection and Management, Articles 42(2)c and 43(3)a. The law identified procurement of environmentally sound goods and services as an 'economic instrument of the environment' to promote sustainable consumption and production (complementary to environmental taxes, levies, subsidies, permitting, labels, etc). The use of ecolabels are encouraged to identify environmentally-friendly goods and services
- In 2013, the 10-Year Framework of Sustainable Consumption and Production launched quick-win programs designed to advance SuPP
- Public procurement is now governed by Presidential Regulation 16/2018 as amended in No. 12/2021. It outlines SuPP as a core procurement objective (Articles 4,5). Article 19 requires the procuring entity to maximize the use of green industrial products and green criteria in technical specifications and terms of reference (TOR). Articles 19(1).d and 19(4) also clearly mention that the Commitment Making Officer (PPK) shall, in preparing technical specifications and TOR for goods and services, prefer ecolabeled products
- Ministerial Regulation No. 5 on the Procedure for Application of Eco-friendly Labels for Green Public Procurement (GPP) was adopted by the Ministry of Environment and Forestry in 2019. The regulation requires that procurements be made based on a list of ecolabeled goods and services in priority product categories: office paper, plastic files, wood for furniture, medical waste treatment equipment and air conditioners (as specified in Circular Letter No.16/2020). The list of products are to be updated annually and gradually expanded to other product categories with time. Three product categories were added in 2021: processed wood for construction, cement and eco-friendly concrete

Source: Sustainable Procurement Resource Hub

THAILAND

SuPP activities on the timeline toward sustainability



Source: Sustainable Procurement Resource Hub

THAILAND

Progress on implementation of SuPP

- Since 2005, Thailand has established a vision that the government sector should be a leader in green procurement in order to create a proper market of products and services that are environmentally friendly. This vision was pronounced in multiple policy documents, including the 20-Year National Strategy, 10th–13th National Economic and Social Development Plans, Environmental Quality Management Plan, and Pollution Control Plan. The green procurement concept aligns with the 'sufficiency economy philosophy' that underpins the country's development pathway toward green growth
- Over the years, the GPP Promotion Plan has expanded in its second (2013) and third phases (2017) to promote green purchasing more broadly, to all governmental units at national and local levels, universities, the private sector and the general public
- The National Roadmap for Sustainable Consumption and Production (SCP) 2017 sets a vision of Thailand as the leader in ASEAN on sustainable consumption and production by adopting the sufficiency economy concept and mobilizing through integration of social innovation by 2036. Ecolabeling and sustainable procurement are seen as key implementation tools to achieve the nation's ambitious SCP goals
- Public procurements in Thailand are regulated by the Public Procurement and Supplies Administration Act 2017, an act that specifically promotes green and social procurement. Procurements must obtain optimal benefits to the state agency conforming to the principles of value for money, efficiency and effectiveness, and accountability. Section 65 allows procurers to consider non-price criteria, including life cycle costs and suppliers promoted by the states, which include those 'creating innovation' or 'conserving energy or the environment'

Source: Sustainable Procurement Resource Hub

THAILAND

Progress on implementation of SuPP (continued)

- Since 2009, a green public procurement ‘recognition award’ has been given to best performing agencies based on results submitted to the Pollution Control Department (PCD)
- To access public procurement contracts, suppliers in Thailand are invited to qualify for recognized ecolabels or register on government procurement websites. There are two major platforms for green products in Thailand:
  - Green Basket, managed by PCD, that lists suppliers in 40 product categories to simplify green purchasing for government agencies
  - Thai Eco-Products Directory, operated by the Federation of Thai Industries. It was launched in 2022 to act as the central hub for green products and services in Thailand. The directory compiles data from 18 different Thai ecolabels in 13 product and service categories
- Green public procurement in Thailand is made simple by allowing procurers to choose from listings of verified green vendors. Ecolabels have a longstanding basis in the country. The Thailand Business Council for Sustainable Development (TBCSD) initiated the Thai Green Label, a type I ecolabel scheme in October 1993
- When the Government of Thailand started actively promoting GPP in 2005, the Green Cart was developed as a list for green public procurement products covering 17 products and 5 service categories. The Green Cart is both a catalogue and a set of criteria based on the Thai Green Label (for products) and the Green Leaf (for hotels). By 2018, the coverage of the Green Cart was expanded to 22 product and 6 service categories. Procuring agencies can check whether procuring products satisfy the Green Cart criteria

Source: Sustainable Procurement Resource Hub

THAILAND

Progress on implementation of SuPP (continued)

- The TBCSD and Thailand Environment Institute manage several ecolabels in the country:
  - Green Label for products and services based on a life cycle assessment
  - Carbon reduction labels granted to products or services with low emissions production processes, or buildings with low carbon emissions operations
  - Green Industry Mark for the manufacturing sector based on the concept of environmental management systems and cleaner technology
  - Green Leaf as a standard of environmental management systems for hotels based on existence of a green policy, green product procurement, energy management and local participation in environmental conservation activities at the area of the hotel's location
  - Private sector self-claimed ecolabels in the building materials sector, such as SCG Eco Value and Green Heart developed by the Siam City Cement Public Company Limited in 2017
  - Coolmode for textile companies that produce climate-friendly textile and garments that are cool, comfortable and easy to clean

Source: Sustainable Procurement Resource Hub

VIETNAM

Progress on implementation of SuPP

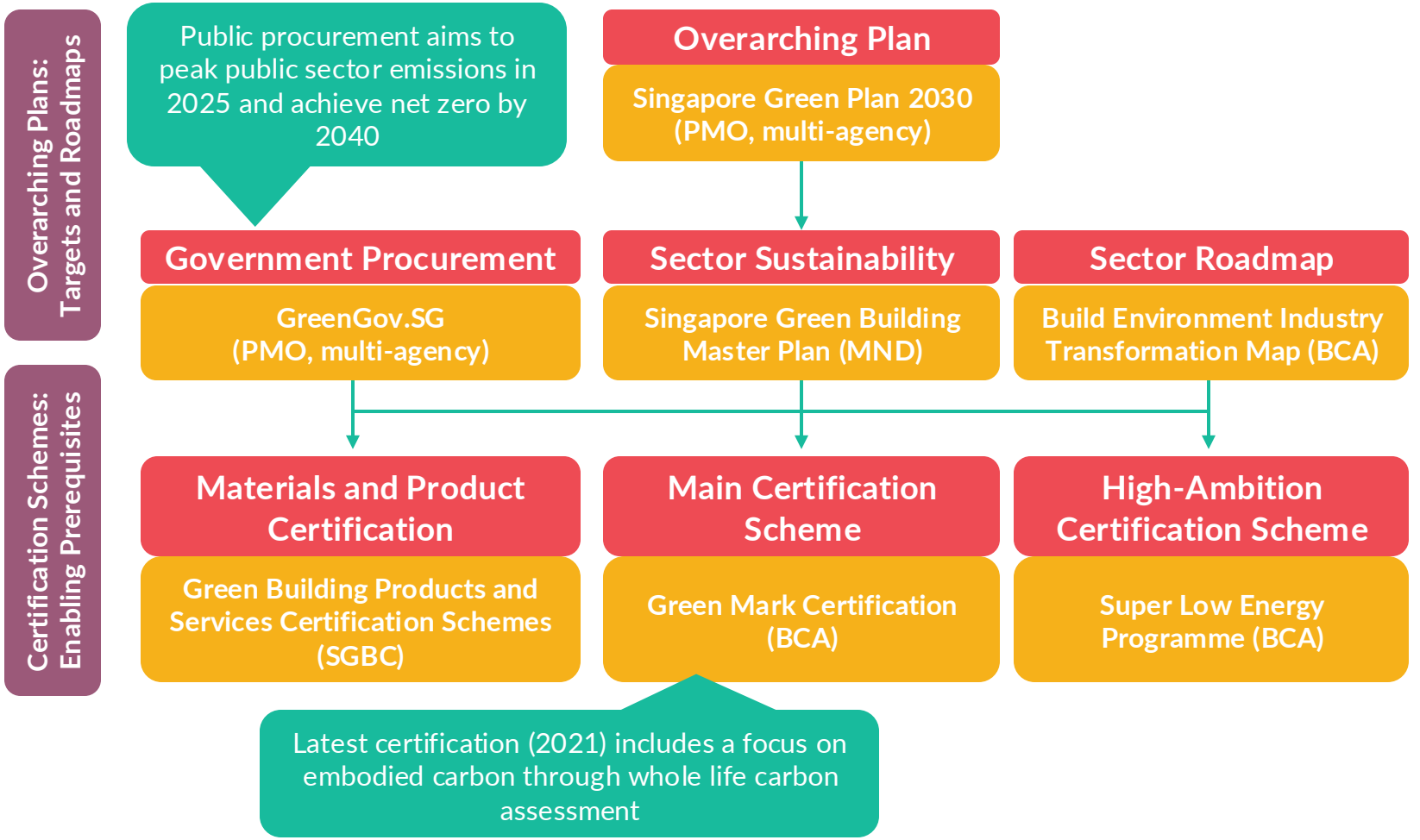
- Vietnam has only recently begun its official journey toward sustainable public procurement. The legal and regulatory frameworks are still being formulated
- Vietnam continues to adopt and adapt international best practices on public procurement reform, and it is active in discerning and complying with the good practices as suggested by more experienced countries. This includes establishing the legal framework for S/GPP to introduce practices in sustainability as one of the objectives for public procurement
- Various developments in legal applications are being proposed such as sub-decrees and guidelines on the implementation processes, which will enable S/GPP to reach its target of 35% of total public procurement by 2035, and 50% of total public procurement by 2050
- Sustainability is integrated into the general legal framework, but it is not yet a core principle or key objective of public procurement. The primary goal of public procurement in Vietnam is still focused on achieving the lowest cost in general, with commodity prices being the main consideration for decision-making. Currently, these financial factors involving low commodity costs, heavily influence estimates of public procurement and often dictate the approval of such procurements
- However, Article 10 of the recent Law on Bidding clearly enunciates the inclusion of sustainability into certain stages of the procurement cycle. The various elements of sustainability include: (i) Environment – environmental pollution prevention, environmental protection, sustainable resource use, and minimization and adaptation to climate change; (ii) Social – health, social welfare and occupational safety; and (iii) Economic – Sustainability throughout the supplier's supply chain, life cycle costs of services or goods, and other criteria

Source: SWITCH-Asia, 2024

MODEL SPP

Case example: Singapore

- Singapore presents a consolidated public procurement strategy involving multiple government ministries and enabling infrastructure, including an overarching roadmap, certification schemes and an embodied carbon calculator
- The targets for public procurement are more ambitious than targets for the wider industry



Source: Xynteo, 2024

ALCBT Project Countries: Progress on implementation of SuPP

- While legislations have been passed for SuPP, the implementation has been weak in all ALCBT project countries, except Thailand to some extent. In 2023, Cambodia has taken important steps by adopting the Public Procurement Law (with emphasis on sustainability) and the Environment and Natural Resources Code, has defined an institutional structure, and is currently designing an ecolabeling program
- The coverage of products and services in sustainable procurement programs is still too small to make a significant impact. Many energy and carbon intensive products must be added, supported by appropriate ecolabeling. Energy and carbon intensive building construction materials like cement and steel are yet to be included
- With reference to ISO 14024:1999, voluntary type II ecolabeling of more energy and carbon intensive products should be encouraged and supported
- Scoring methodology for tender evaluation should be improved to favor green products and services
- Mandates may be required for minimum green products and services procurement, as part of the total annual procurement by government agencies

Source: SWITCH-Asia, 2024

Thank you!

For more information, visit us at https://ALCBT.GGGI.ORG or scan the QR code below

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Any person who believes they may be harmed by an IKI project or who wish to report corruption or the misuse of funds, can lodge a complaint to the IKI Independent Complaint Mechanism at IKI-complaints@z-u-g.org. The IKI complaint mechanism has a panel of independent experts who will investigate the complaint. In the course of the investigation, we will consult with the complainant so as to avoid unnecessary risks for the complainant. More information can be found at https://www.international-climate-initiative.com/en/about-iki/values-responsibility/independent-complaint-mechanism/.

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GGGI

ASIA LOW CARBON BUILDINGS TRANSITION PROJECT

Life Cycle Assessment for Transitioning to a Low-Carbon Economy

4.4 Carbon Trading

Cambodia, India, Indonesia, Thailand and Vietnam

November 2024

Supported by:

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WHAT WILL YOU LEARN?

01 What are Carbon Markets and Key Milestones

02 Article 6 of the Paris Agreement and its Relationship to NDCs

03 Types of Carbon Markets

04 Carbon Pricing Instruments

05 Carbon Taxation and Carbon Credit Trading

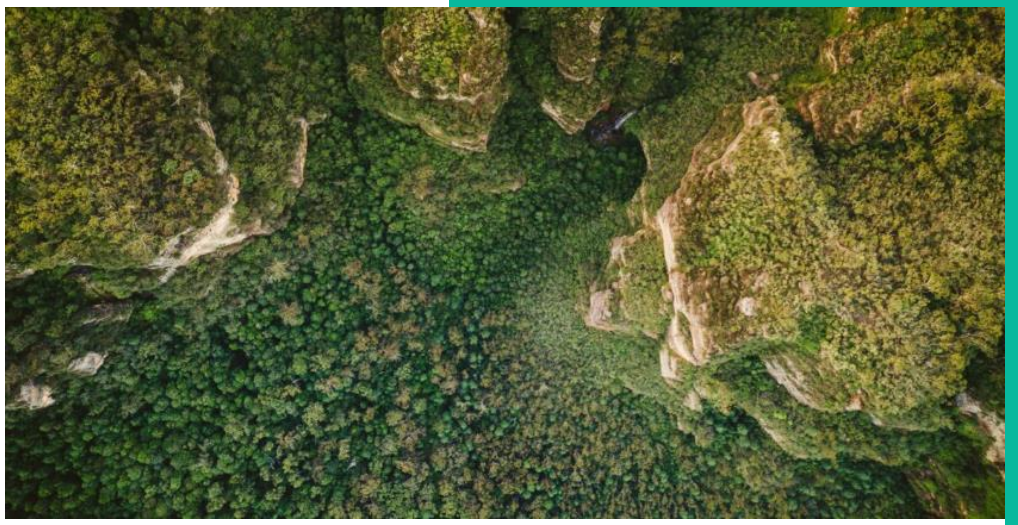
06 CDM, Standards and MRV

07 Government Initiatives for Carbon Trading

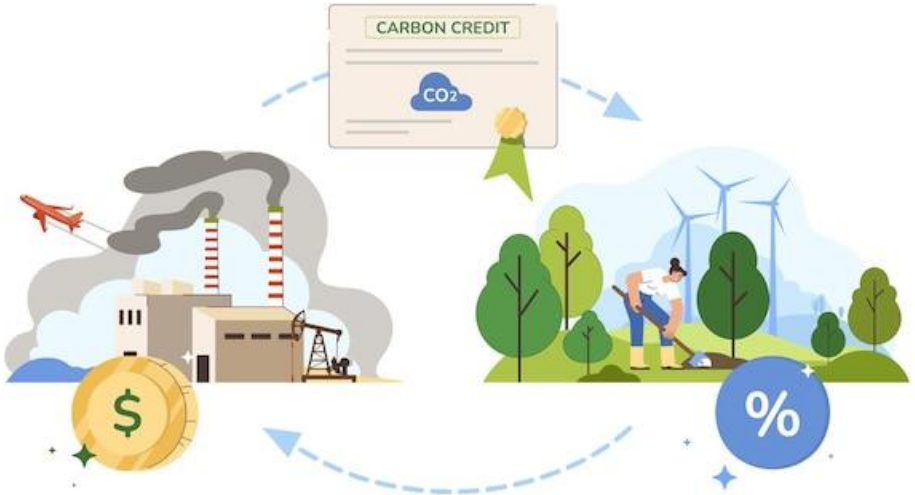


CARBON MARKETS

Introduction to carbon markets



- Carbon markets are ***carbon pricing mechanisms*** enabling governments and non-state actors to trade greenhouse gas (GHG) emissions credits
- ***Carbon markets turn emissions reductions and removals into tradeable assets*** *(Credits are generated from emissions reduction projects, such as energy efficiency and clean energy projects)*
- Carbon markets ***mobilize resources, reduce costs and incentivize climate action*** by enabling countries and companies to **trade carbon credits** through reduction and removal of GHG emissions and thus ***transition toward net zero emissions***



OVERVIEW OF CARBON MARKETS

Key milestones



Kyoto Protocol

- 37 industrialised economies and the EU commit to an average 5% reduction in GHG compared to 1990 levels over a 5-year period (2008-2012)

Doha Amendment

- Kyoto second commitment period (not fully ratified): reduce GHG emissions by at least 18% below 1990 levels over an 8-year period (2013-2020)

Paris Agreement

- All signatories - not just industrialised - committed to national carbon reduction targets
- Article 6 permits the sale of carbon credits by countries meeting targets to nations falling short

COP26 Glasgow

- 153 countries adopt 2030 targets: Nationally Determined Contributions (NDCs)
- Carbon 'rulebook' (Article 6) breakthrough
- New rules for carbon accounting, transfer mechanism and plans for a global carbon market

COP27 Egypt

- Move from planning to implementation
- Launch of the African Carbon Markets Initiative

CARBON MARKETS

Its relation to NDCs and Article 6 of Paris Agreement

Significant components of Article 6:

Article 6.2

Creates the ***basis for trading in GHG emissions reductions*** (or mitigation outcomes) across countries

Article 6.4

Establishes a ***mechanism for trading GHG emissions reductions*** between countries under the supervision of the COP

Article 6.8

Recognizes non-market approaches to promote mitigation and adaptation. It introduces ***cooperation through finance, technology transfer and capacity building***, where no trading of emissions reductions is involved

Article 6 Paris Agreement:

- *Allows countries to voluntarily cooperate with each other to achieve emissions reduction targets set out in their NDCs*
- *Countries will be able to transfer carbon credits earned from the reduction of GHG emissions to help one or more countries meet climate targets*

ARTICLE 6, PARIS AGREEMENT

How it supports carbon markets

- Corresponding adjustment requirements ***may extend beyond compliance markets to the voluntary carbon markets***, where demand is driven by the private sector's voluntary commitments to reduce emissions
- ***In 2023, 143 of 154 Parties stated in their NDCs that they plan to or will possibly use carbon credits from cooperative approaches under Article 6 as a means to finance climate action and achieve national targets***
- Thus, Article 6 ***establishes an international carbon market*** with **multilateral governance under the UNFCCC** setting ***common global standards and guidance for development and trading in emissions reductions and Internationally Transferred Mitigation Outcomes***

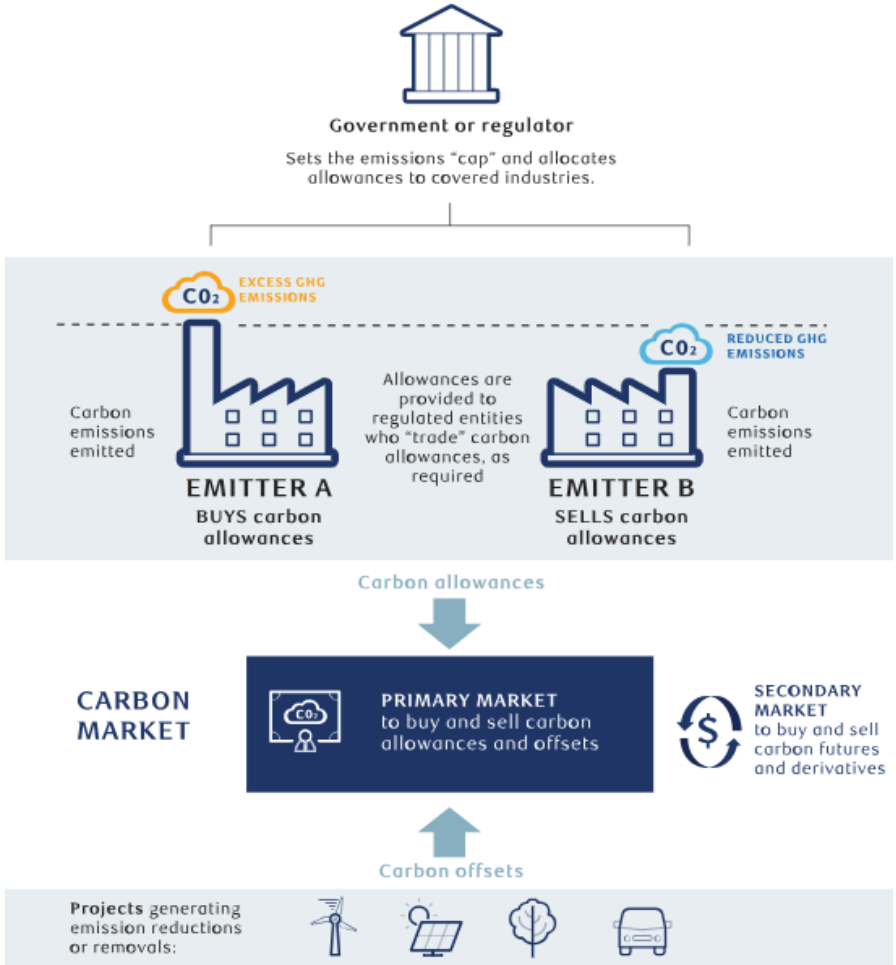
Article 6 Paris Agreement:

- *Article 6 pertains to the establishment of international compliance carbon markets governed by the rules of the Paris Agreement where countries can trade carbon credits*
- *The agreement on Article 6 established an accounting mechanism known as 'corresponding adjustment' to ensure that double counting does not occur*

CARBON MARKETS

Compliance and voluntary carbon markets

- Currently there exist two types of carbon markets: **compliance markets and voluntary markets**
- A compliance market is a market for **carbon offsets created by the need to comply with a regulatory act**. In a cap-and-trade emissions reductions market, actors buy and sell carbon offsets to comply with the cap or limit imposed on their emissions
- Some of the mechanisms are:
  - **Emissions Trading Schemes (ETS)**
  - **Clean Development Mechanism (CDM)**
  - **Joint Implementation (JI)**
  - **Carbon Tax**



Compliance carbon markets, cap and trade program

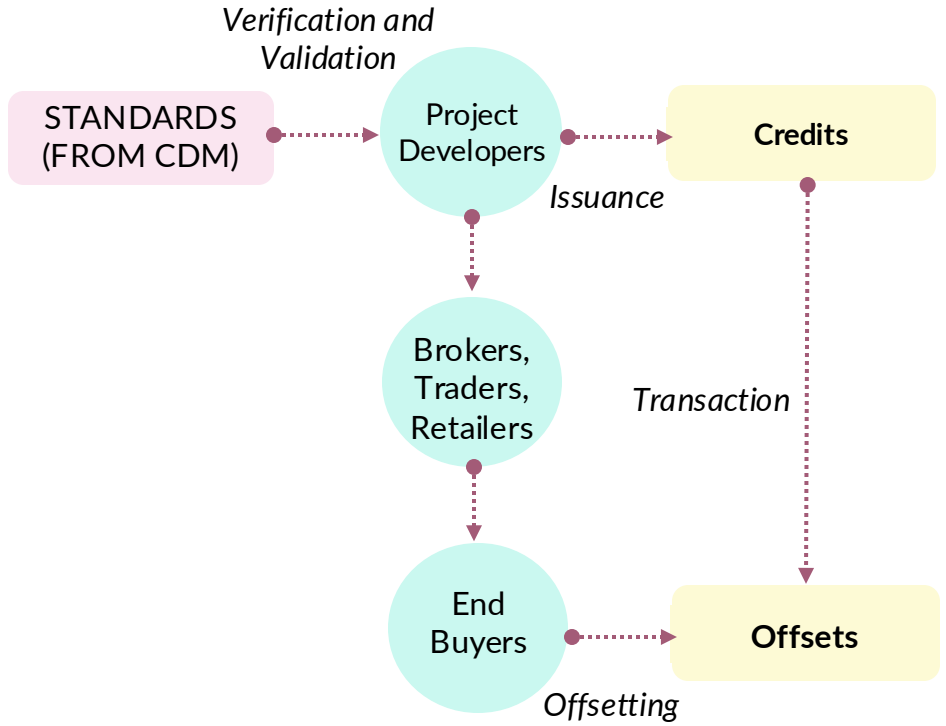
Source: The Carbon Market, a Green Economy Growth Tool, Ministère de l'Environnement et de la Lutte contre les changements climatique.;Quebec, Canada; https://www.environnement.gouv.qc.ca/changementsclimatiques/marche-carbone_en.asp

Image: Carbon markets are growing: Here's what you need to know https://www.rbcwealthmanagement.com/en-eu/insights/carbon-markets-are-growing-heres-what-you-need-to-know

CARBON MARKETS

Compliance and voluntary carbon markets (continued)

- The voluntary carbon market is a ***decentralized market where private actors voluntarily buy and sell carbon credits*** that represent certified removals or reductions of GHGs in the atmosphere
- Each carbon credit corresponds to ***one metric ton of reduced, avoided or removed CO_2 or equivalent GHG.*** It can be used by a company or an individual to compensate for the emissions of one ton of CO_2 or equivalent gases, becoming an offset. It is moved to a register for retired credits, or retirements, and it is no longer tradable
- Compliance markets are currently limited to specific regions. Voluntary carbon credits are significantly more fluid, unrestrained by boundaries set by nation states or political unions. ***Voluntary carbon credits also have the potential to be accessed by every sector of the economy instead of a limited number of industries***



Structure of the voluntary carbon market

Source: S&P Global Platts

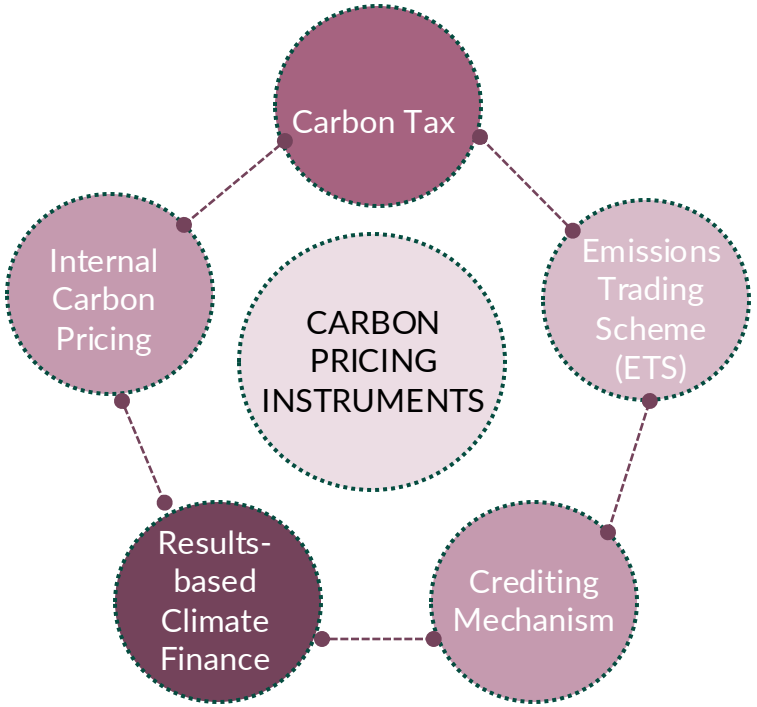
CARBON PRICING

The necessity for carbon pricing

Carbon pricing is an approach to reduce carbon emissions (also referred to as greenhouse gas or GHG emissions) that uses market mechanisms to pass the cost of emitting on to emitters – ***"Polluter Pays"***

Why price carbon?

- Can be an **effective policy to spur innovation**, create lasting economic growth and help nations foster a low carbon economy
- Can provide an **economically efficient means of reducing GHG emissions**
- **Sends a price signal** that could **influence** widely dispersed **economic decisions**



Carbon pricing instruments

Source: Carbon Pricing Leadership Coalition

CARBON TRADING INSTRUMENTS

Carbon pricing

Carbon Tax

Puts a ***direct price on GHG emissions*** for every ton of carbon pollution emitted. It thus creates a financial incentive to lower emissions by switching to more efficient processes or cleaner fuels (i.e., less pollution means lower taxes)

Emissions Trading Scheme (ETS)

Also known as a **cap-and-trade system**—sets a limit ('cap') on total direct GHG emissions from specific sectors and sets up a market where the rights to emit (in the form of carbon permits or allowances) are traded

Results-based Climate Finance (RBCF)

Entities receive funds when they meet pre-defined climate-related goals, such as emissions reductions

Internal Carbon Pricing

Governments and firms assign their own internal price to carbon use to factor this into their investment decisions

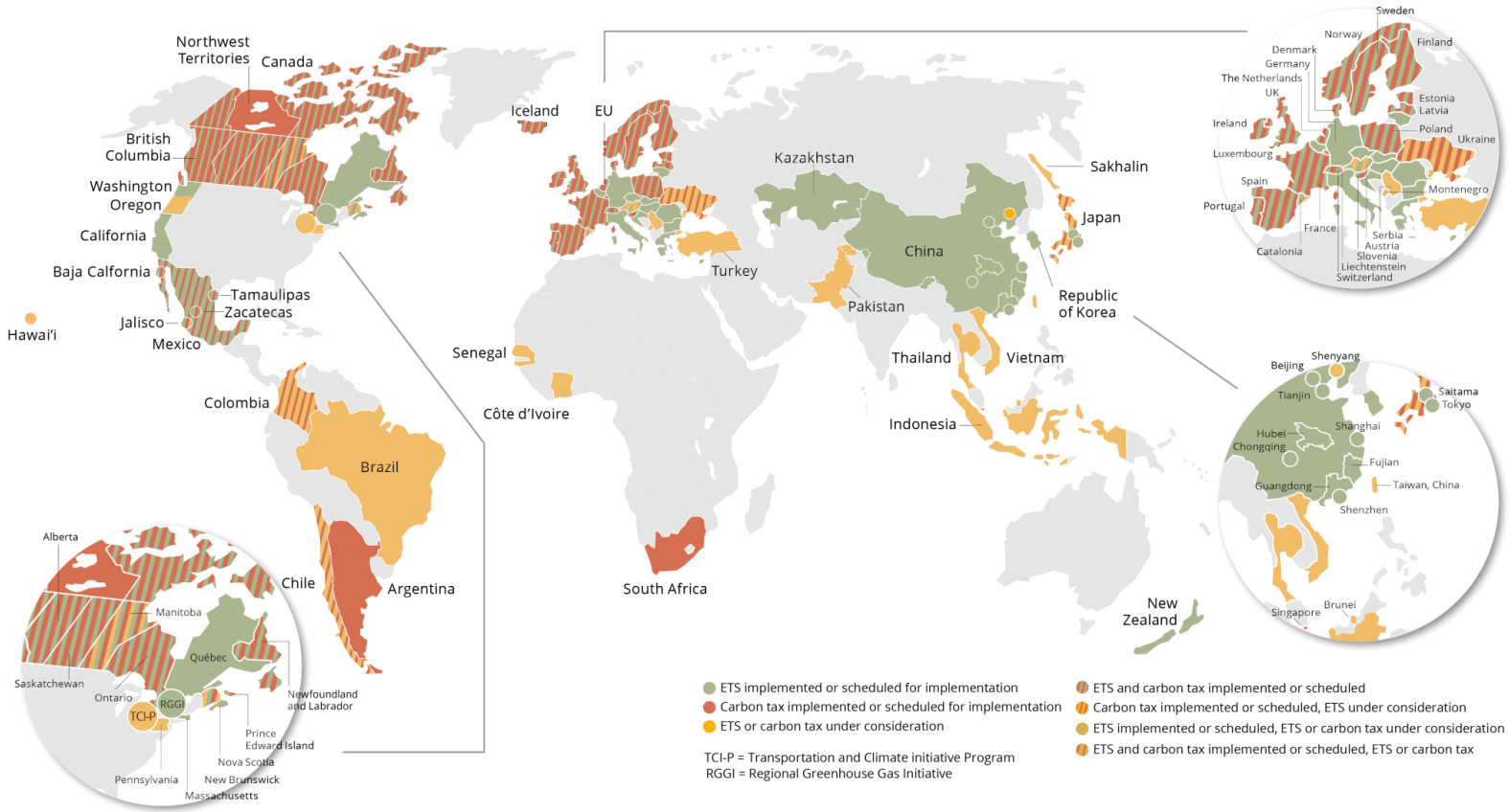


Image source: Unsplash

CARBON TAXATION

Global pricing initiatives

Carbon pricing initiatives are considered 'scheduled for implementation' once they have been formally adopted through legislation and have an official start date and 'under consideration' if the government has announced its intention to work toward implementation



Source: World Bank, 2023

CARBON TAXATION

International norms and examples

The main idea behind taxation schemes is to incentivize emitters to invest in more sustainable technologies

The abatement costs are hard to quantify, setting the right carbon tax is challenging

*Almost **one-third** of the carbon tax systems were introduced in the 1990s **by Scandinavian countries***

***Smaller countries**, including Estonia, Latvia, Liechtenstein, Switzerland, Iceland and Ireland **followed by 2010** and **Japan followed in 2012** as the first non-European country*

***In the last five years**, national taxation schemes have been implemented in Canada, Singapore and South Africa*



Canada: *Nationwide tax on oil, coal and gas*



UK: *Carbon tax has led electric utilities to switch away from coal*



Singapore: *Tax targeting GHG emissions from all fossil fuels used by facilities from the industry and power sector*

Source: Pérez and Rhode, 2020

CARBON CREDIT TRADING

Standards and measurement, reporting and verification (MRV)

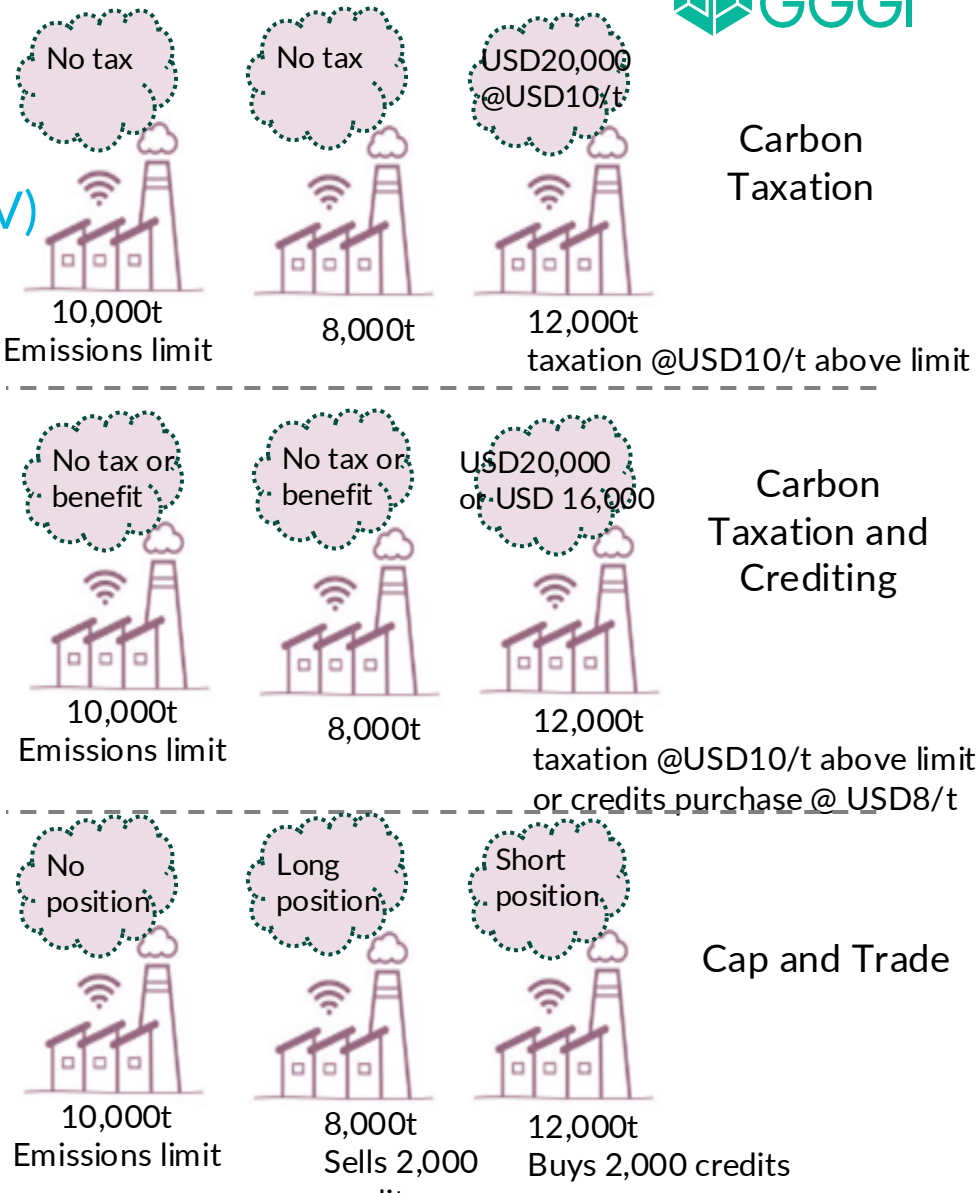
TIME PERIOD
Globally-agreed obligations or individual commitments
Paris Commitment – 2030
EU ETS Phase 4 2040

Units of CO_2e (Carbon Dioxide Equivalent)

- 1 ton CO_2 = 1 credit
- 1 ton CH_4 = 28 credits
- 1 ton N_2O = 265 credits
- 1 ton SF_6 (sulphur hexafluoride) = 23,500 credits

Standards

- UNFCCC for CDM
- EU for EU Trading Scheme
- Japanese Government for Joint Crediting Mechanism
- California Resources Board for California's Cap and Trade Program
- Verra and Gold Standards for Voluntary Carbon Markets



Source: Garnaik

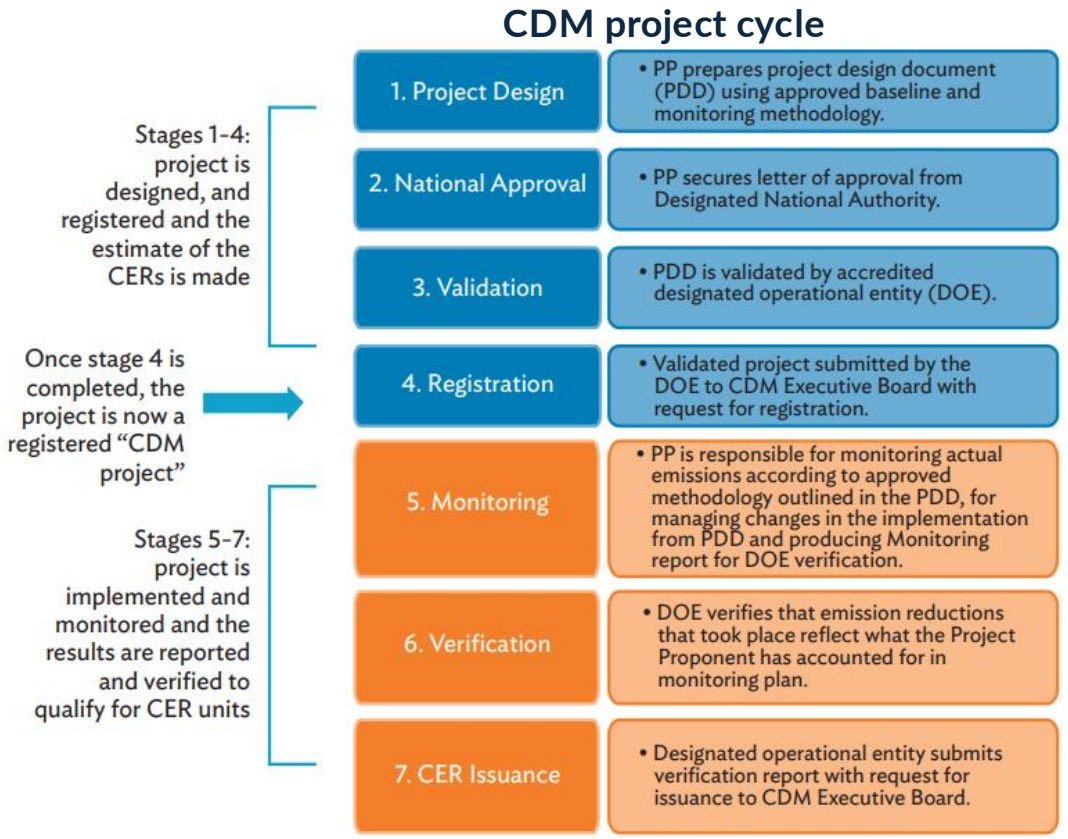
CLEAN DEVELOPMENT MECHANISM

Standards and MRV

Eligible CDM project types:

- Energy Industries (Renewable / Non Renewable
- Energy Distribution
- Energy Demand
- Manufacturing Industries
- Chemical Industries
- Construction
- Transport
- Mining / Mineral Production and Solvent Use
- Fugitive Emissions from Fuel (Solid, Oil, Gas)
- Waste Handling and Disposal
- Reforestation / Afforestation
- Agriculture and Metal Production

Source: Asian Development Bank, 2016



CER – certified reductions; CDM – Clean Development Mechanism; PP – Project Participants
Note: the CDM project cycle can be broken in two main sections

Source: UNFCC, 2014, What is CDM; http://cdm.unfcc.int/about/index.html

GOVERNMENT INITIATIVES

Cambodia: Initiatives for carbon trading

Cambodia enacted regulations on December 14, 2023, to implement Article 6 of the Paris Agreement within its borders

These include:

Article 6 Operations Manual

This manual provides a framework for issuing and transferring Internationally Transferred Mitigation Outcomes (ITMOs), which are referred to as authorized Greenhouse Gas Emissions Reductions (GHG ERs)

Positive List Inclusion

Projects must align with the updated Nationally Determined Contributions (NDCs)

Source: Ministry of Environment, Government of Cambodia, 2024

Criteria for GHG ER projects



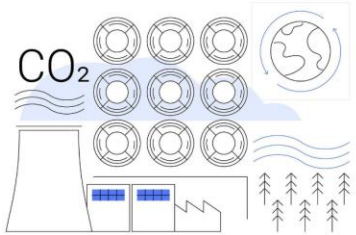
Positive list inclusion



Domestic use preservation



Authorization period



Eligible carbon mechanisms



Verification and additionality



Environmental integrity



Alignment

GOVERNMENT INITIATIVES

Cambodia: Initiatives for carbon trading (continued)

Various initiatives to reduce carbon emissions and achieve neutrality

Asia's Low Carbon Building Transition Project (ALCBT)

Launched in May 2024, this project aims to transition Cambodia's building sector to low carbon buildings. The goal is to reduce energy consumption and GHG emissions

REDD+ Program

The government has developed the REDD+ Program in several provinces to help reduce emissions from deforestation and forest degradation

Decarbonization

Cambodia is decarbonizing its transport and power sector



Source: Ministry of Environment, Government of Cambodia, 2024

Image source: earth journalism.net

GOVERNMENT INITIATIVES

India: Initiatives for carbon trading

Carbon Credit Trading Scheme (CCTS)

Finalized in June 2023 and scheduled to begin in 2025–2026, this scheme aims to trade GHG emissions using carbon credit certificates. The CCTS has two mechanisms – compliance mechanism and offset mechanism

Perform, Achieve and Trade Scheme (PAT)

Launched in 2012, the scheme covers 13 energy-intensive sectors with *1,333 designated customers*

Renewable Energy Certificates (RECs)

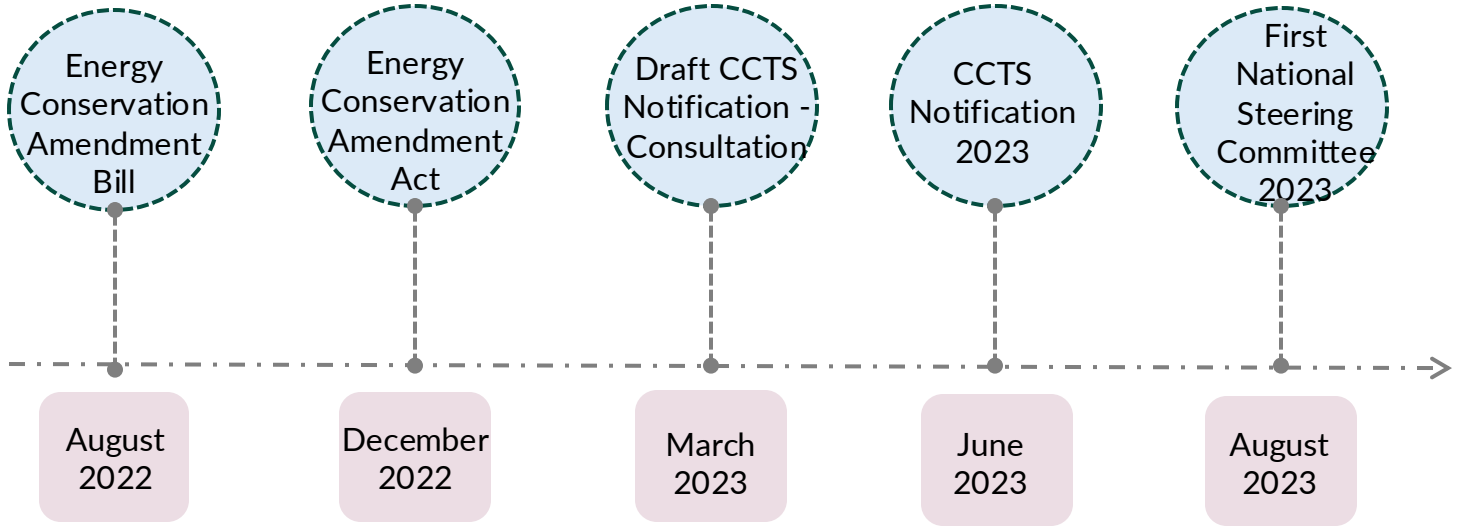
Launched in 2010, it covers 13 sectors including distribution licensees, captive consumers and open access users. *A total of 1,117 projects registered (~5,607MW)*

Green Hydrogen Energy and Battery Energy Storage System (BESS)

This is an accelerated movement to create an enabling environment through policy, research and market transformation

GOVERNMENT INITIATIVES

India carbon markets: Key milestones



Current Approach under PAT

$$SEC = \frac{\text{Total Energy Input to the Plant Boundary (TOE)}}{\text{Equivalent Product or Output (t)}}$$

Transition

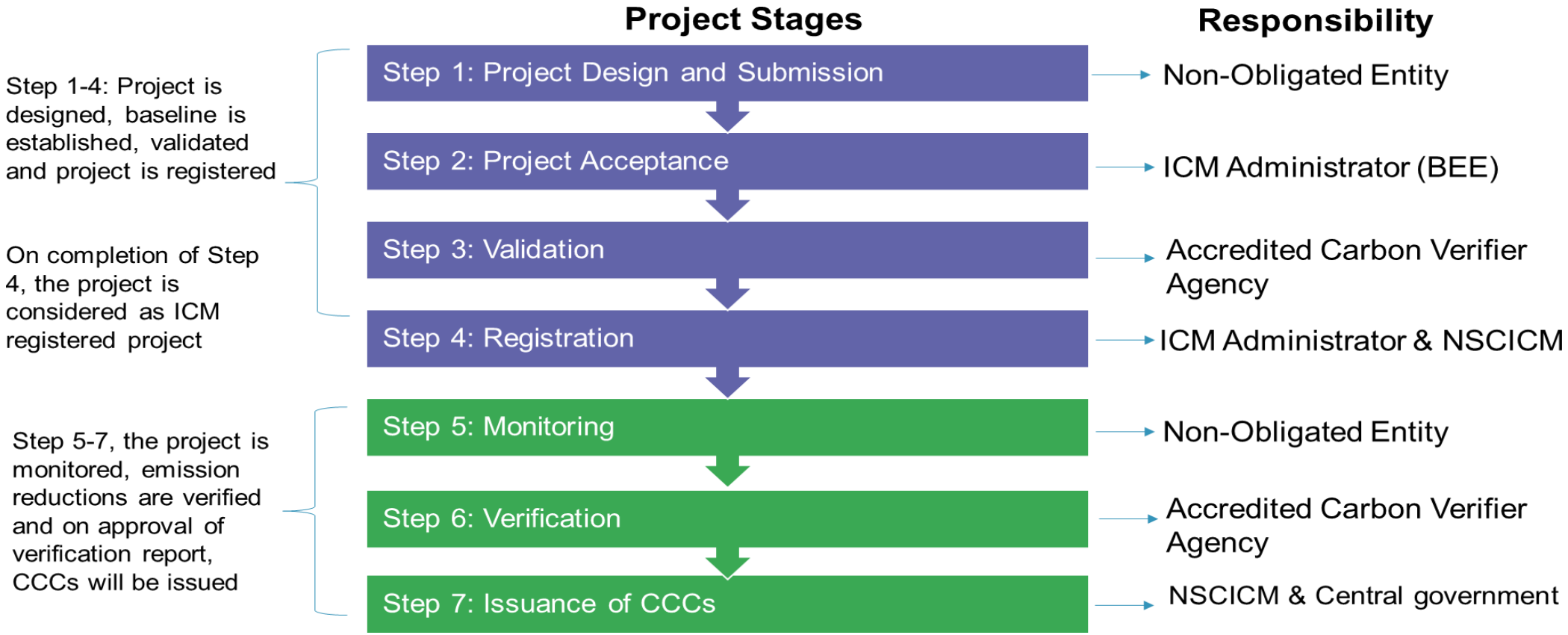
Proposed for Compliance Mechanism Approach under CCTS

$$SGE = \frac{\text{Total GHG Emissions from DCs } (tCO_2eq)}{\text{Equivalent Product or Output (t)}}$$

Source: Garnaik

CARBON MITIGATION PROJECTS

India: Project stages and responsible agencies



Source: Garnaik

GOVERNMENT INITIATIVES

Indonesia: Initiatives for carbon trading

Presidential Regulation on Carbon Pricing and Indonesia Carbon Exchange (IDX Carbon)

On September 26, 2023, the Indonesian Stock Exchange launched the Indonesia Carbon Exchange to achieve the NDC and GHG emissions control in national development

Indonesian Economic Value of Carbon Trading Scheme

In February 2023, the Ministry of Energy and Mineral Resources launched the Indonesian Economic Value of Carbon (NEK) Trading Scheme. This mandatory, intensity-based ETS is for the power sector and targets coal-fired power plants connected to the Perusahaan Listrik Negara (PLN) grid

GOVERNMENT INITIATIVES

Indonesia: Initiatives for carbon trading (continued)

Issuing PTBAE-PUs

PTBAE-PUs are emissions allowance for the energy and forestry sector. This is applied to the power plant subsector in the energy sector, and mangrove and peat land located within or outside the forest area in the forestry sector. In January 2023, to kickstart carbon trading, the Ministry of Energy and Mineral Resources issued PTBAE PUs for the power plant subsector to 99 coal power plants consisting of 42 power producers

Indonesia's Voluntary Carbon Markets

In 2022, Indonesia launched a voluntary carbon market that allows companies to trade carbon credits. Projects that generate credits include renewable energy, energy efficiency, and land-use changes, including forest conservation (REDD+)

GOVERNMENT INITIATIVES

Thailand: Initiatives for carbon trading

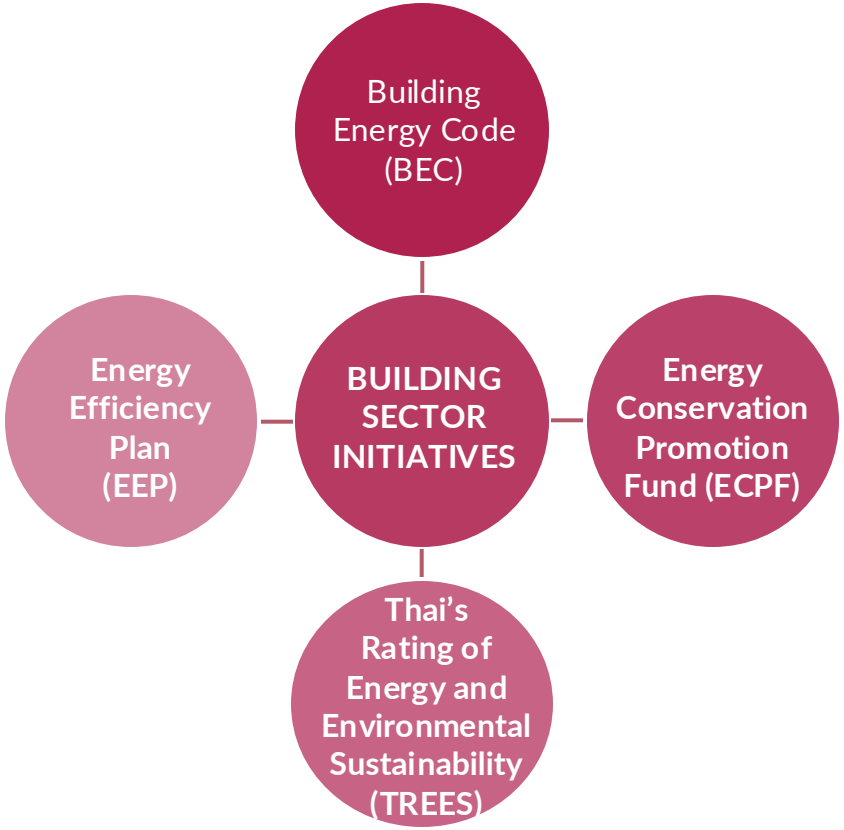
The Thailand Greenhouse Gas Management Organization (TGO) has developed the ***Thailand Voluntary Emissions Trading System*** (Thailand V-ETS) to promote GHG emissions reduction under the domestic voluntary carbon market

Thailand Carbon Offsetting Program

Organizations can offset their carbon emissions by purchasing carbon credits generated by approved ***Thailand Voluntary Emissions Reduction*** (T-VER) projects

Thailand Emissions Trading Scheme *(under development)*

A national carbon trading system to align with its commitment to carbon neutrality by 2050 is being developed. The framework is expected to be like the EU ETS, where emitters trade emissions permits to meet the cap



GOVERNMENT INITIATIVES

Vietnam: Initiatives for carbon trading

Carbon Credit Management Mechanism

On May 7, 2024, Prime Minister Pham Minh Chinh issued a directive to establish a carbon credit management mechanism. The directive aims to help businesses understand the carbon market and meet their NDC targets

Vietnam's National Carbon Market

Vietnam is working on **establishing a national carbon market**, which is expected to be operational by 2027, under the management of the **Ministry of Natural Resources and Environment.** The government has been developing a legal framework to support emissions trading, starting with pilot projects in the energy and industrial sectors. This will **eventually extend to the building sector, especially for large commercial and residential buildings**

GOVERNMENT INITIATIVES

Vietnam: Initiatives for carbon trading (continued)

Vietnam Voluntary Carbon Market

Vietnam is developing a **voluntary carbon market to encourage businesses and organizations** to reduce their emissions and trade carbon credits. Renewable energy projects, forest conservation and energy efficiency in the built environment can generate carbon credits that can be traded in this market

Joint Crediting Mechanism (JCM)

Vietnam participates in the Joint Crediting Mechanism with Japan, where both countries collaborate on low carbon projects. In this mechanism, **Vietnam earns carbon credits through energy-saving projects, including in the building sector**, which can be traded or used to meet emissions targets

National Carbon Credit Exchange

Vietnam plans to establish a national carbon credit exchange that will begin operations in 2028. Before the full rollout, the government will run a pilot carbon trading platform starting in 2025

Thank you!

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