Energy Efficient Buildings

ME 613 Term paper presentation
2024-2025 I

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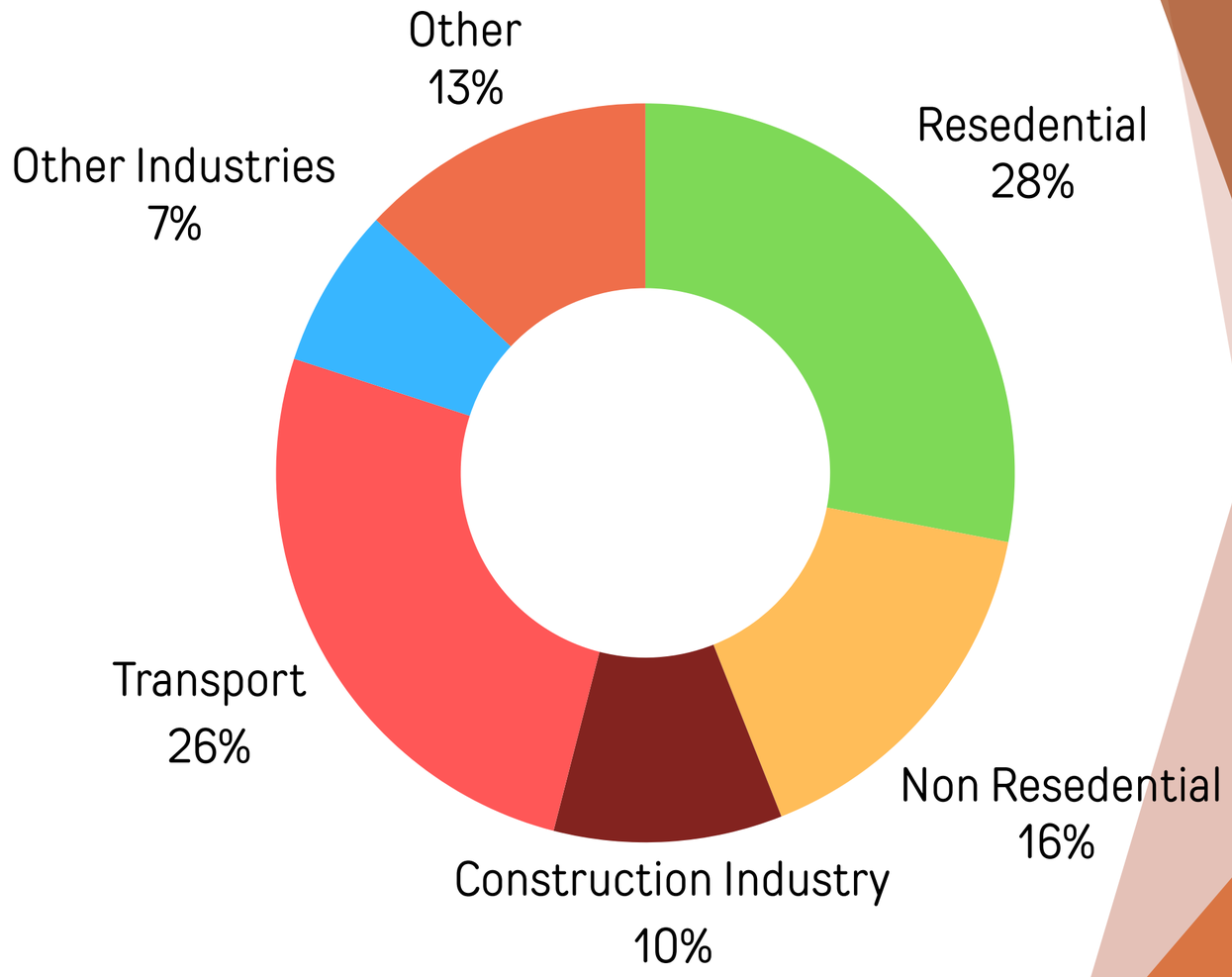
Background

The Building Sector's Energy Challenge: Rising Consumption and Emissions

Have you ever considered which sector consumes the majority of the world's energy production?



Source : UNEP

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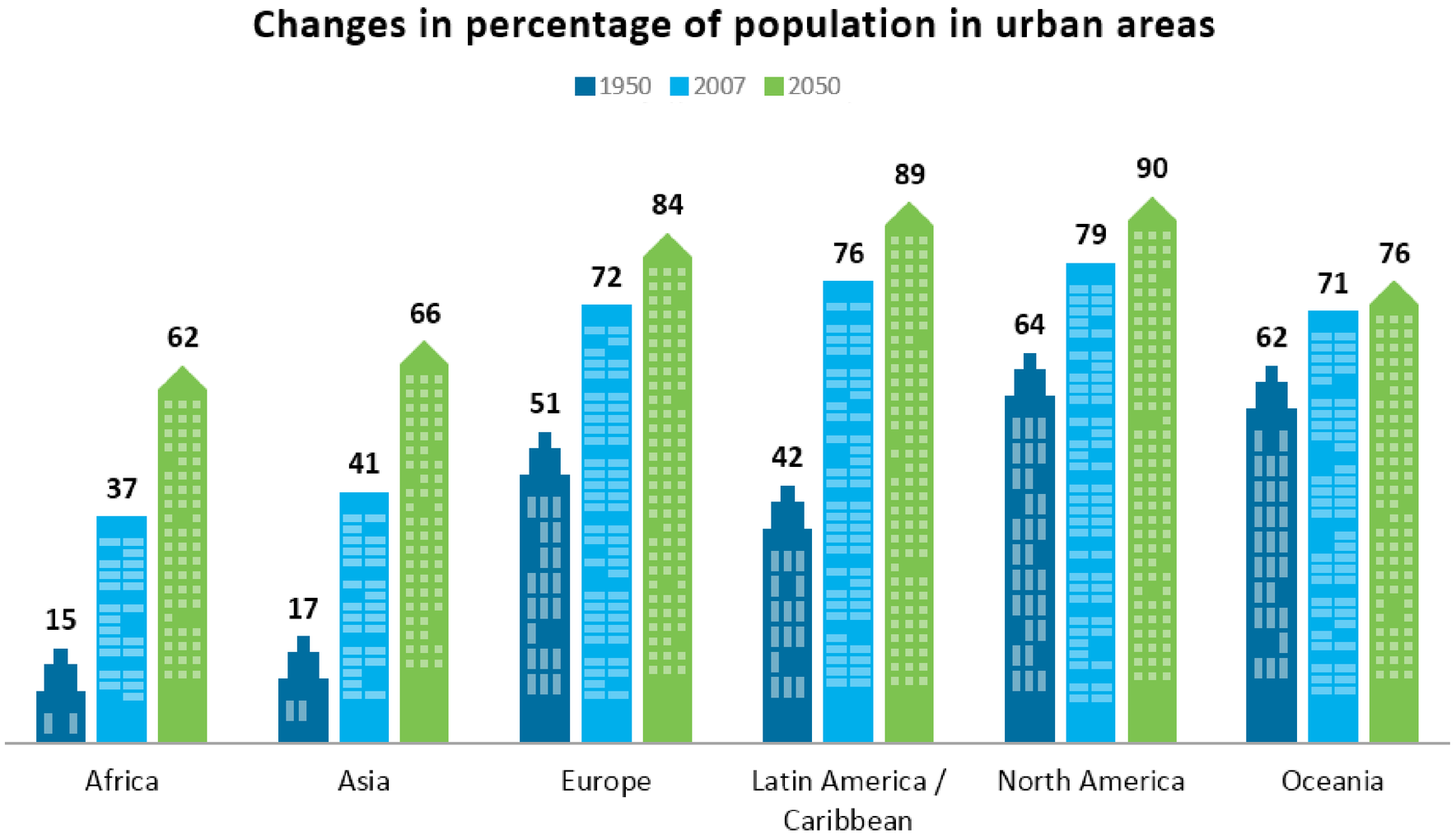
Background

- The building sector (comprising residential, non-residential, and construction) accounts for 54% of global energy consumption.
- This significant share highlights the sector's energy demands and its critical role in global energy use.
- Residential, commercial, and industrial buildings collectively contribute to over half of the total energy produced worldwide.

Will the demand for energy continue to grow in the coming years ?

Background



Source : United Nation

Background

- The rise of urbanization globally will further drive up energy consumption in the near future.
- As urban areas expand, the demand for energy in the building sector will increase.
- This trend makes it crucial to develop energy-efficient buildings to mitigate future energy consumption growth.
- Immediate focus on sustainable building practices is essential for a more energy-efficient future.
- More planned cities are needed to be constructed globally.
- Countries should unite and focus on these issues urgently

Potential Methods and Implementation

- **Natural Energy Gains:** Buildings can reduce energy use by maximizing natural heating, cooling, and daylight, leveraging building orientation and ventilation to limit reliance on AC and heating systems.
- **Phase Change Materials (PCMs):** These materials change properties with temperature and moisture, enhancing thermal mass benefits in lightweight buildings without compromising structure.
- **Internal Heat Gains:** Heat from occupants, lighting, and appliances can reduce heating needs in winter but increase cooling needs in summer.

Potential Methods and Implementation

- **Improved Insulation:** Insulating floors and windows minimizes unwanted heat transfer, adapting seasonally for efficient heating or cooling.
- **Cooling Demand Reduction:** Lower cooling needs by controlling solar gain, reducing lighting load, and installing efficient lighting controls.
- **Preheating/Precooling:** Use natural thermal resources to precondition incoming air, reducing HVAC loads.
- **Low-E Glass Layers:** Low-emissivity coatings on glass reflect thermal radiation, reducing solar heat gain in summer and heat loss in winter.

Passive House Principles

What is Passive Homes ?

A Passive House is a building designed to require minimal energy for heating, using only 15 KWh per square meter annually. This is achieved by trapping solar heat through south-facing windows with triple glazing, preventing heat loss. Thick insulation, often made from materials like polystyrene or mineral fibers, further reduces heat transfer.

Passive House Principles

Historical Context

Carpathians

They used to make partially burried house to make indoor temperature stable

Ancient Romans

They used to heat the houses from the heat of the the burning gases passed theough cavaties

In late 1960's in Europe, developments in insulation, thermal bridges, ventilation, and air tightness—important concepts in this subject—were also explored

Passive House Principles

How is Passive Buildings constucted?

- **Insulation & Airtightness**: Insulate all surfaces in contact with the outside, and add an airtight layer for optimal energy efficiency.
- **Window Design:** Use low-emissivity glazing and noble gas-filled spaces to reduce heat loss. South-facing, large windows capture winter sunlight to warm interiors.
- **Thermal Bridge Elimination:** Identify, avoid, and minimize areas (e.g., wall joints, balconies) where heat loss occurs through Thermal Triad Method steps.
- **Ventilation with Heat Recovery:** Install a system to manage air quality while preserving indoor temperature.

Passive House Principles

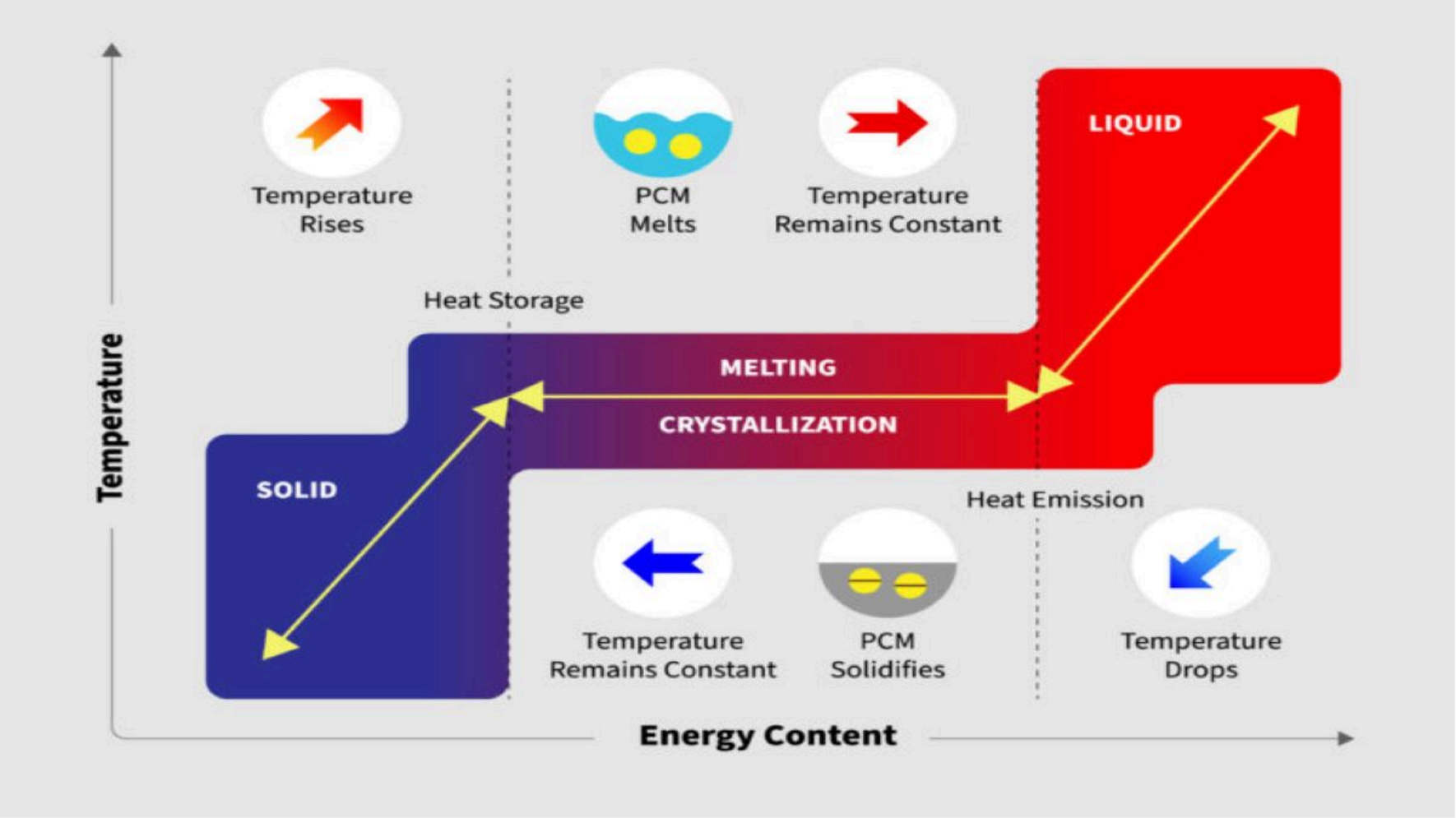
Phase Changing Materials

- **Phase Change Materials (PCMs) enhance building thermal efficiency by storing thermal energy in three forms: chemical, sensible, and latent heat. Latent heat storage is most effective, as it releases or absorbs a large amount of energy during phase changes with minimal temperature fluctuation, ensuring comfort.**

Source : Wikipedia

Passive House Principles

Phase Changing Materials

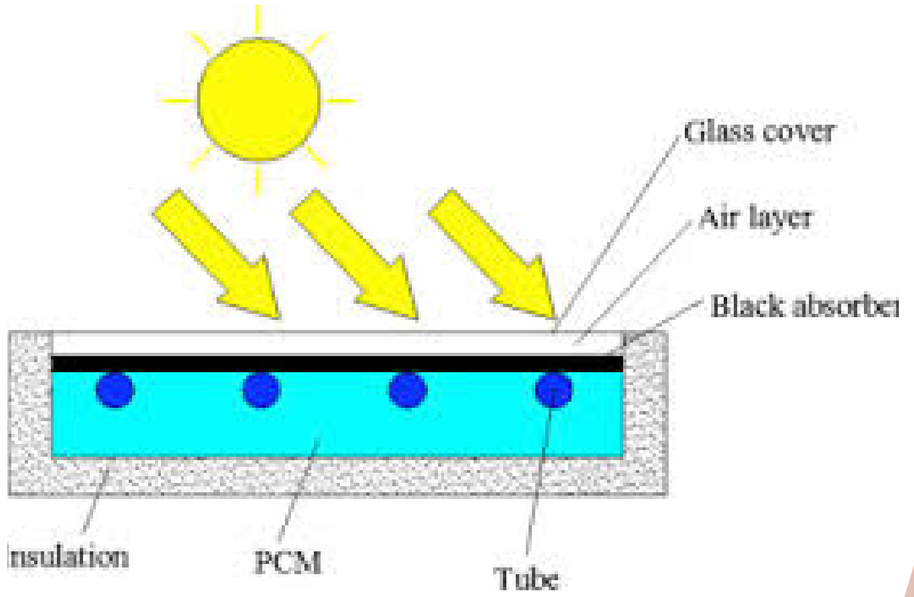


Source : Thermtest Handbook 2019 Journal Edition 2

Passive House Principles

How PCM is used for Energy Efficient buildings ?

- **Mixing PCMs into building materials (walls, floors, roofs) is cost-effective and simple.**
- **Roof Integration: Absorbs ambient and solar heat.**
- **Floor Integration: Reduces heat loss due to large surface area.**



Source : Handbook of Thermal Management Systems, 2023

Active Measures

Active measures that could be implimented in Energy Efficient buildings

Free cooling

Free cooling is an energy-saving process where cool ambient air is used to lower the temperature of chiller water directly, bypassing the refrigeration cycle when outdoor temperatures are low.

Waste superheat recovery

It is an energy-saving process where the excess heat from the compressed refrigerant in a refrigeration system is captured and used, typically to heat water, before it enters the condenser, reducing energy waste.

Active Measures

Free Cooling

- Chilled water (CHW) cools by transferring heat with condenser water (CW) and refrigerant (REFG).
- When ambient temperatures are low ($\leqslant$ +1°C), chiller water flows through a cooler, bypassing the evaporator.
- Compressor is not involved and thus saving significant energy.
- At moderate temperatures (up to 7°C), both evaporator and cooler work to cool the chiller water.
- Reduced electrical use due to partial compressor operation improves efficiency (COP) and lowers costs.

Active Measures

- **Free Cooling**

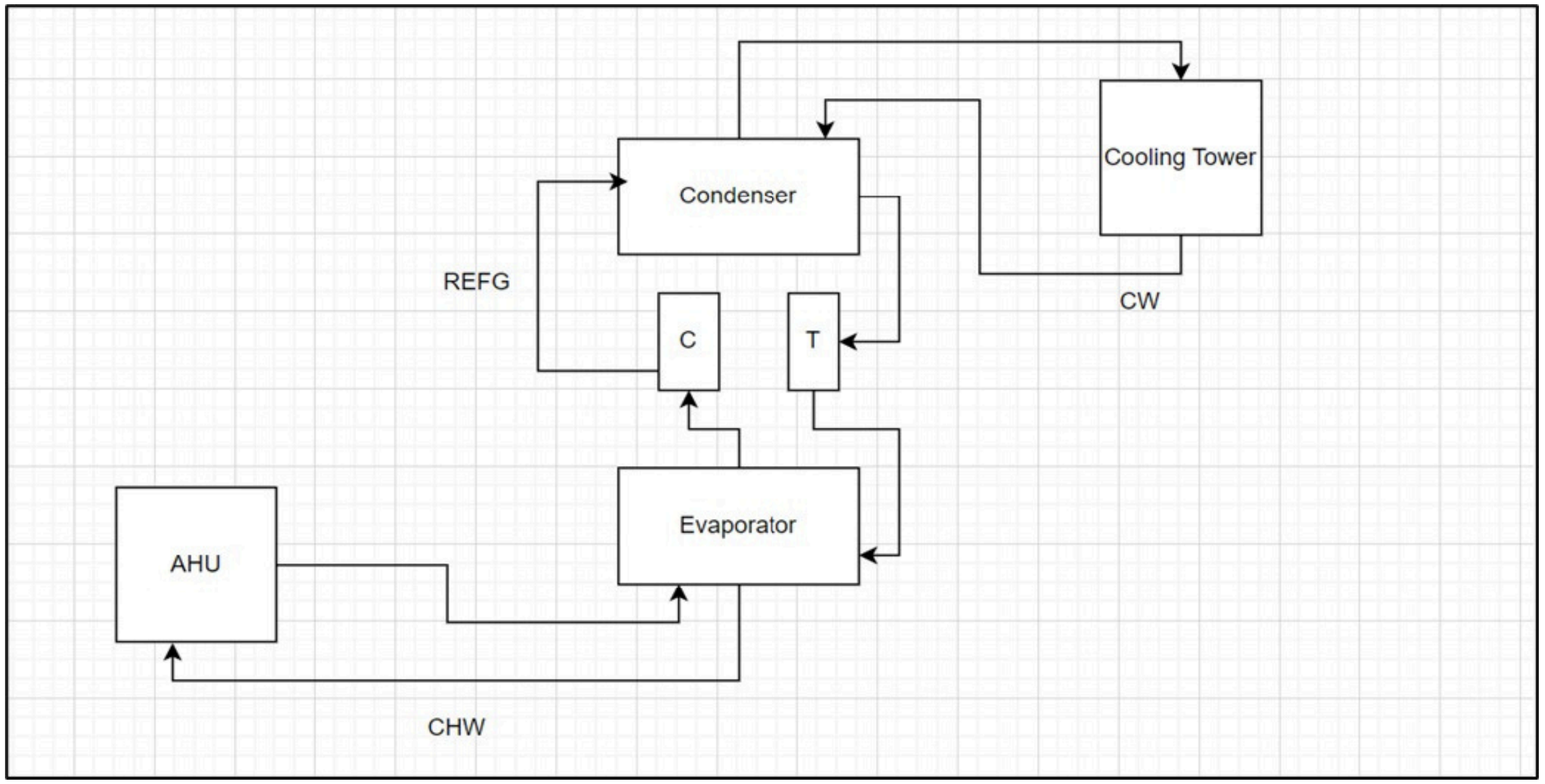


Figure 2: Traditional Chiller Working Plant

Active Measures

- **Free Cooling**

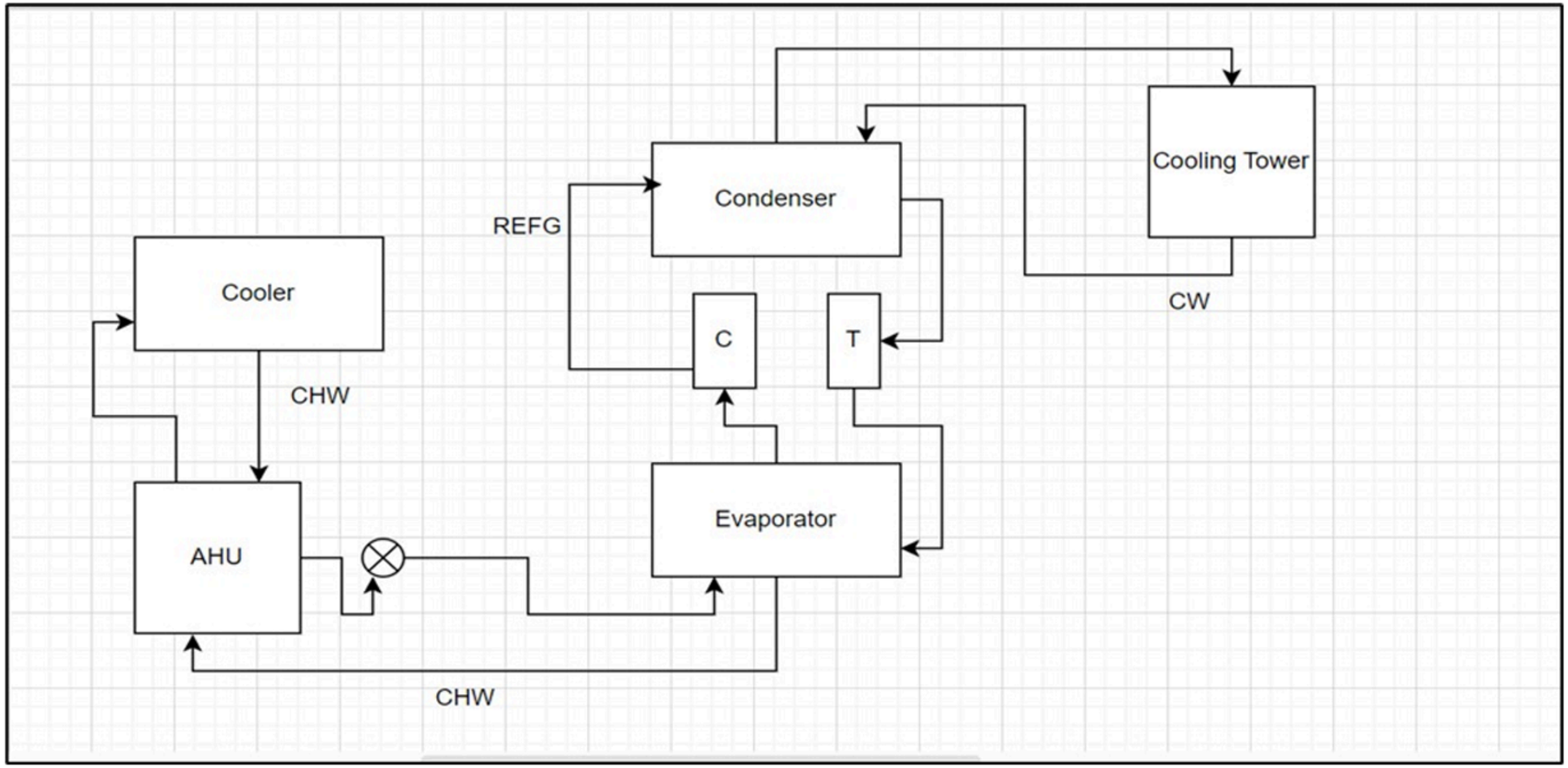


Figure 3: Free Cooling Process

Active Measures

- **Free Cooling Calculations**

Reduced Power Consumption = 647,816.40/358,300.02 × 100 = 35.2%

- Currently: 2,471,634kWh/year
- With Free Cooling: 1,704,088kWh/year

Reduction = [2,471,634.0 − 1,704,088.0]×[100/2,471,634.0] =31.05%

- Using free cooling results in a 31.05% annual reduction in power consumed by the refrigeration unit's compressor.

Estimated Savings = 767.55MWh×466.81PLN/MWh = 358,300.02PLN/year

Average electricity price of 466.81 PLN/MWh (gross).

SPBT = 647,816.40/358,300.02 ≈ 1.81years

SPBT stands for Simple payback time.

Active Measures

- **Waste superheat recovery**
  - The VCR cycle in homes generates low-grade heat energy.
  - Capturing this low-grade heat can save energy and improve efficiency.
  - In a typical refrigeration cycle, refrigerant is compressed to a high-temperature, superheated state (70°C–100°C).
  - This heat can warm water to around 60°C.
  - Heat recovery typically captures 10%–15% of the total heat rejected.
  - The desuperheater's circulating water absorbs heat from the hot refrigerant, reducing energy waste.
  - This heat energy can be used in boiler in Rankine cycle.

Active Measures

- **Waste superheat recovery**

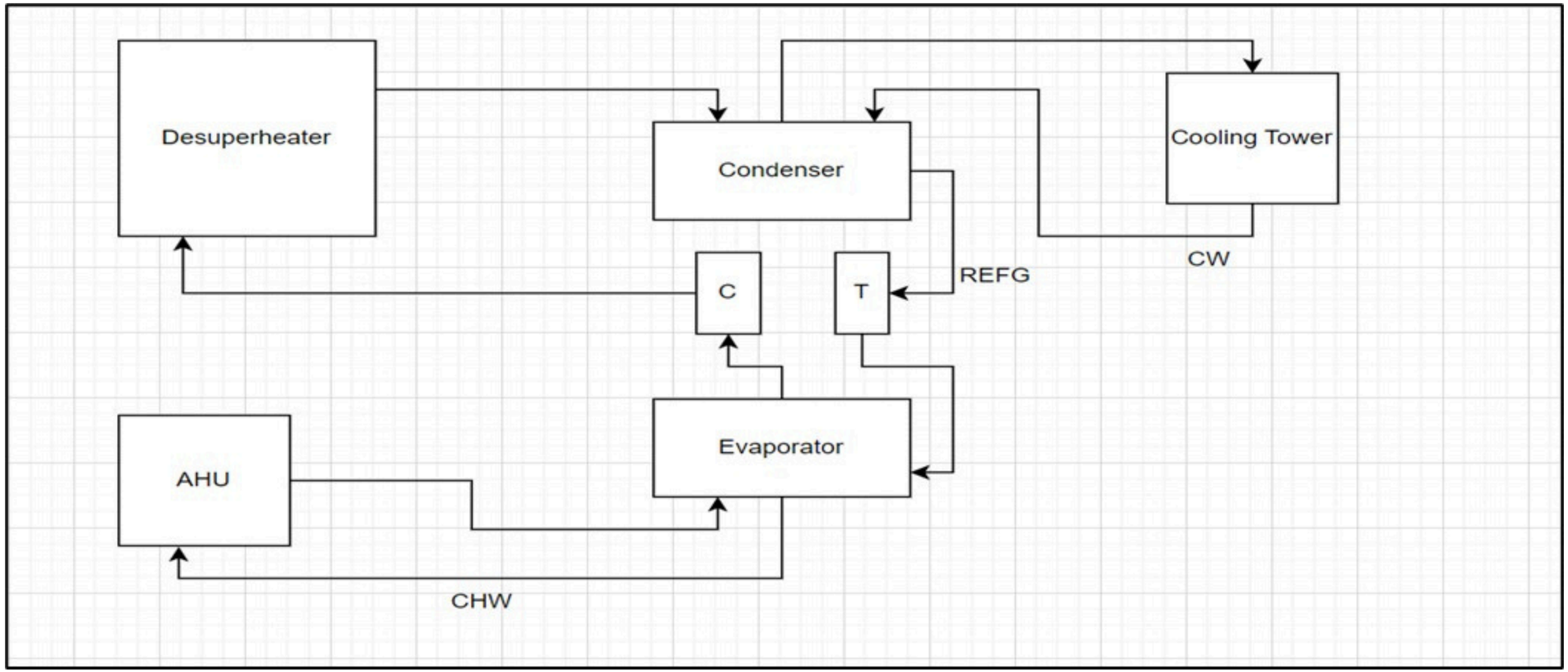


Figure 4: Heat Recovery System

Active Measures

- **Waste superheat recovery calculations**

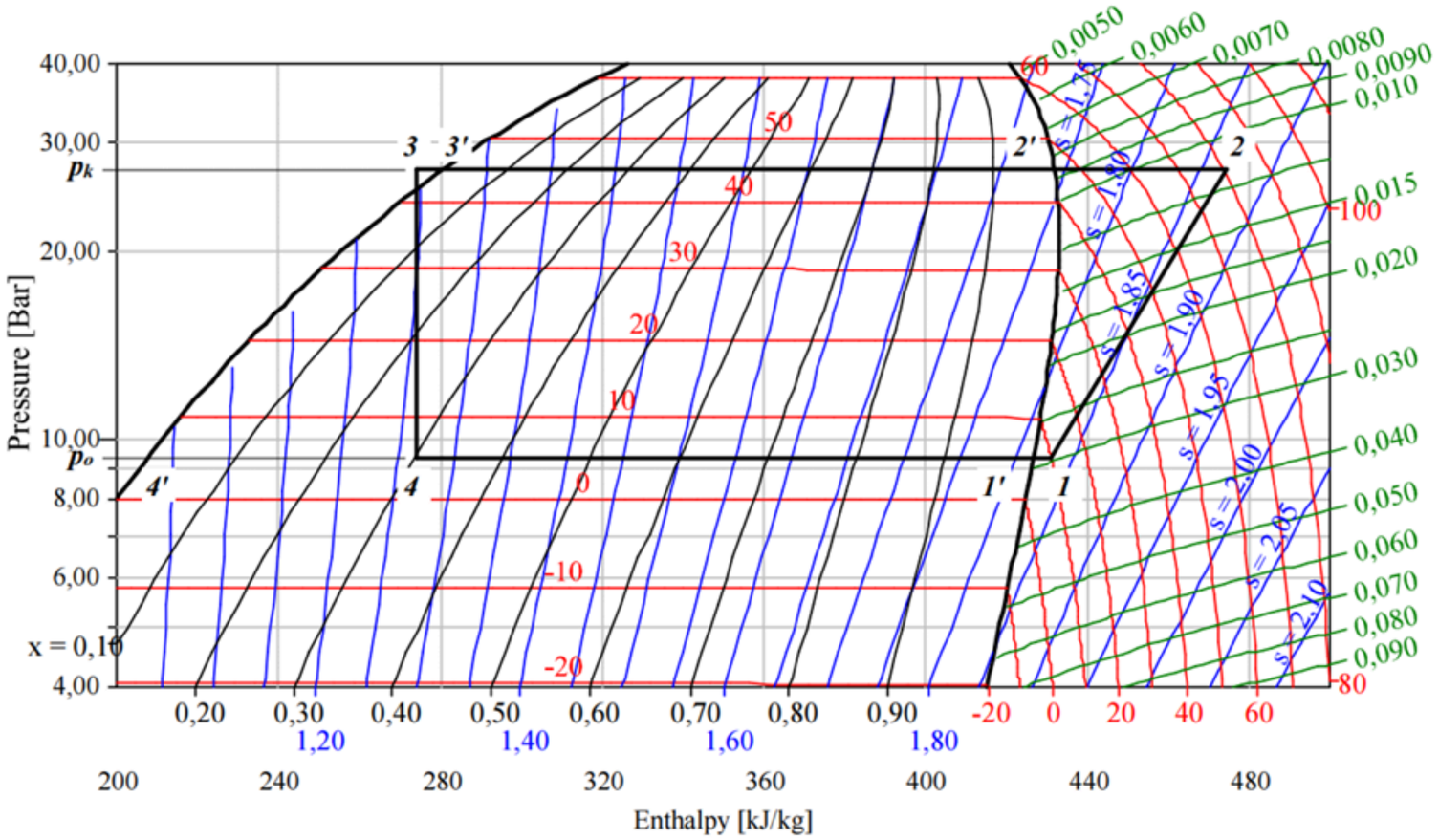


Figure 1: Typical single-stage refrigeration cycle

Active Measures

- **Waste superheat recovery calculations**

Superheat value :

$Q_P = \dot{m}*(h_2 - h_2')$ ← h_2 and h_2' are enthapies

Mass flow rate = 8.4 Kg/s

$Q_P = 8.4kg/s \times (435kJ/kg - 423kJ/kg) = 100.8kW$

Total Energy = 883,008kWh .... For 1 year

Annual average performance of approximately 85%
Energy loss 10%

Effective Energy = 883,008kWh ×0.85×0.90
= 675.50MWh/year = 2,431.80GJ/year

EnergySavings= 2,431.80GJ/year × 31.08PLN/GJ
= 75,580.30PLN/year

SPBT = 155,595.00PLN 75,580.30PLN/year
= 2.06years

Key Findings

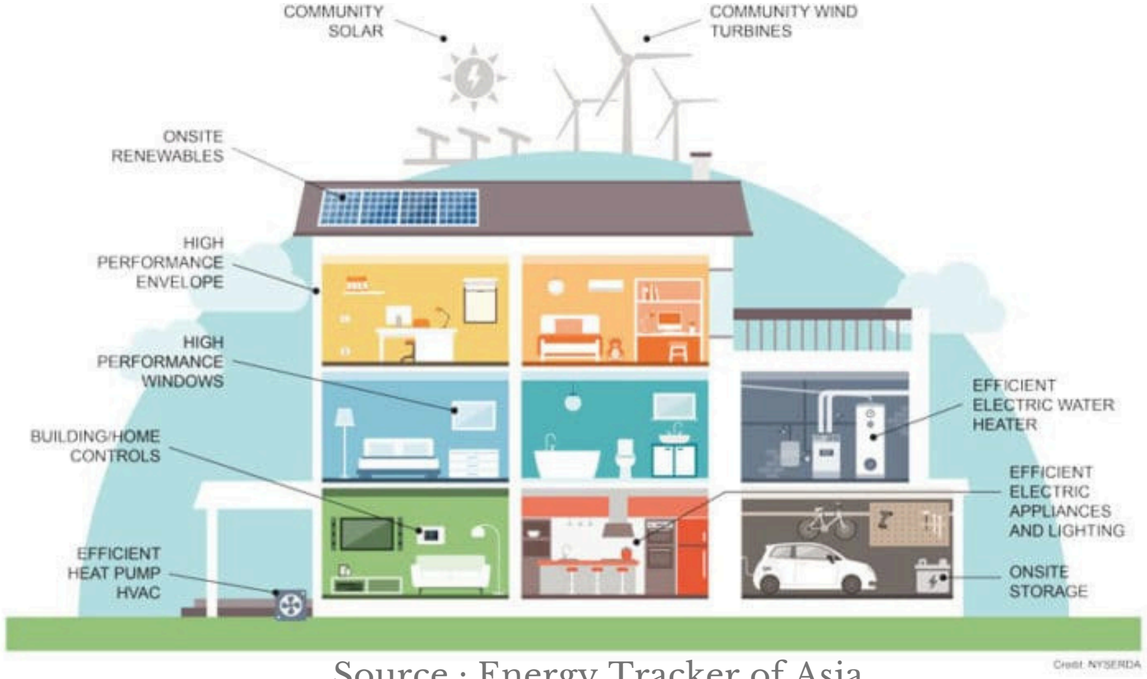
- **Passive buildings:** An approach to passive house design emphasizes minimal heating energy requirements through effective insulation, airtight enclosures, heat recovery ventilation, and smart use of solar gains.
- **Free cooling:** It provides an energy-efficient alternative for cooling in climates with sufficiently low ambient air temperatures.
- **Superheat Recovery:** reusing waste heat from refrigeration systems can signif icantly reduce energy consumption.

Future Directions

- **Net-Zero Energy Buildings**
- **Scalable Retrofitting Solutions**
- **Sustainability and Materials**
- **Policy and Incentives**

Core Components:

- Maximize energy efficiency
- Prioritize on-site renewables
- Utilize off-site renewables
- Measure and manage net zero operations



Additional Components:

- Electrification-ready and minimize/ eliminate on-site fossil fuels
- Optimize building-grid integration and on-site storage
- Specify low GWP refrigerants
- Consider low embodied carbon materials

Source : Energy Tracker of Asia

Some Key References

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Thank You

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