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BIM digital competencies to evaluate and improve the energy efficiency of European buildings.

A digital way towards positive energy districts

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BIM digital competencies to evaluate and improve the energy efficiency of European buildings.
A digital way towards Positive Energy Districts

Current Heating, Ventilation and Air Conditioning (HVAC) systems and Energy Vectors

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Agenda

- 1. Why do we need HVAC systems?
- 2. Design solutions for energy efficiency HVAC systems
- 3. Current types of HVAC systems
- 4. HVAC variable refrigerant flow systems
- 5. HVAC system with ground-air heat exchanger

1. Why do we need HVAC systems?

How did we get here?

- Well, firstly, **our modern jobs are mostly indoor**, and computer related.
- Secondly, **we air-tightened our buildings for energy saving** but we neglected indoor air quality for many years.
- We **replaced all the natural building components** in our modern buildings with huge amounts of **synthetic materials**.
- Some of them even being classified as human carcinogens by IARC - International Agency for Research on Cancer.

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1. Why do we need HVAC systems?

The **purpose** of a HVAC system:

- ✓ to provide a **healthy and comfortable** indoor environment with **acceptable** Indoor Air Quality (**IAQ**);
- ✓ to be **energy efficient and cost effective**.

Acceptable indoor air quality:

Air in which there are **no known contaminants at harmful concentrations** as determined by cognizant authorities and with which a substantial majority (80% or more) of the **people exposed do not express dissatisfaction.**

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1. Why do we need HVAC systems?

In the context of IAQ, there are several types of **air contaminants** that affects our health.

- **Exposure** to indoor air contaminants can have a **wide range of potential health effects**, depending on the type of contaminant, the level of exposure, and the susceptibility of the individual.
- Some of the most common health effects associated with indoor air contaminants include **respiratory problems, allergies, and headaches**. However, the **most toxic indoor air contaminants** can also lead to more **serious health effects**, including cancer, neurological damage, and developmental disorders.

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1. Why do we need HVAC systems?

The air contaminants can be **classified** based on their **source and chemical composition**.

1. **Volatile organic compounds (VOCs)**
2. **Formaldehyde**
3. **Particulate matter**
4. **Particulate matter from cooking**
5. **Carbon monoxide**
6. **Nitrogen dioxide**
7. **Radon**
8. **Biological contaminants**
9. **Asbestos**
10. **Lead**

It is important to note that this is not an exhaustive list of all possible indoor air pollutants, but these are some of the most common ones.

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1. Why do we need HVAC systems?

Strategies to improve indoor air quality

1. Regular cleaning: remove dust, mold, and other allergens that can contribute to poor indoor air quality.

2. Minimizing the use of products that emit pollutants: choose products that are low in VOCs or are labeled as "eco-friendly".

3. Adding plants: Certain types of plants can help by **absorbing pollutants and releasing oxygen**.

4. Using air purifiers: Air purifiers can help to remove pollutants from the air, such as dust, allergens, and volatile organic compounds (VOCs).

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1. Why do we need HVAC systems?

Strategies to improve indoor air quality

5. Increasing ventilation: The **most effective ways** is by increasing the amount of outdoor air that enters into the building to dilute the concentrations of contaminants.

Air purifiers are good only if they are sized properly but keep in mind that **air purifiers recirculate** indoor air and have effect only on specific pollutants such as dust, allergens, VOCs, so it will not be useful for most of the contaminants presented.

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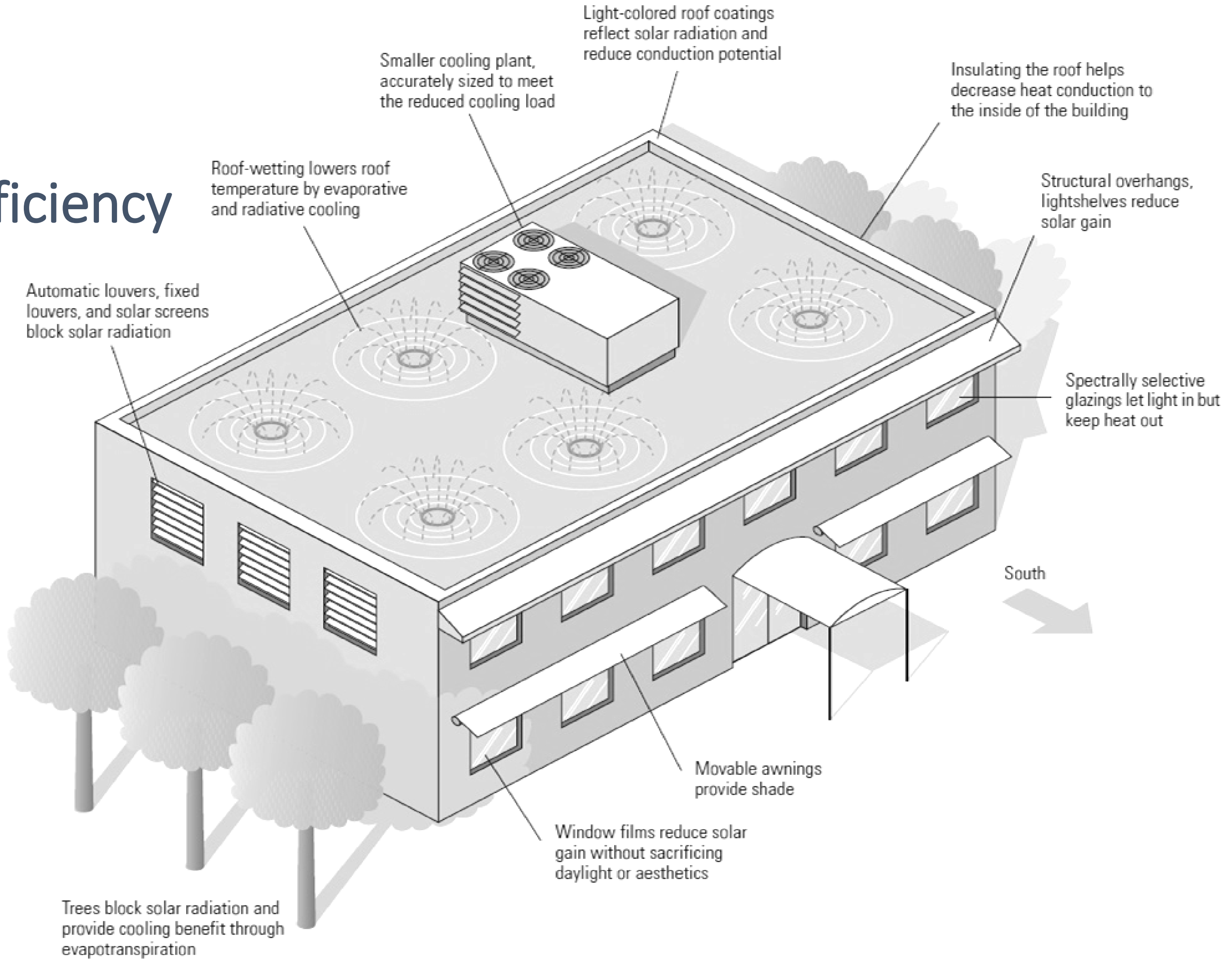
2. Design solutions for energy efficiency

HVAC systems

2.1. Design strategies

1. **Passive measures**
   - Reduce the cooling loads
2. **Active measures**
   - High-efficiency HVAC equipment
   - Demand-controlled ventilation
   - Ground source heat pumps



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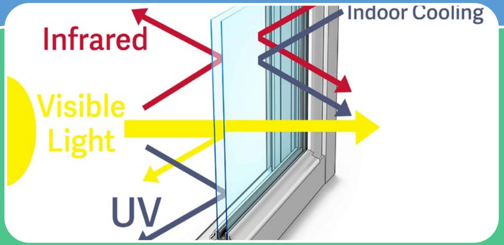
2. Design solutions for energy efficiency

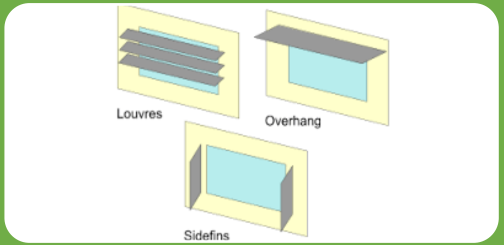
HVAC systems

Reduce Solar Gain

Site planning and orientation: Orient the building to **minimize east and west-facing windows**, favoring north and south for natural light without excessive heat gain. Utilize landscaping and **vegetation for shading purposes**.



Window design and selection: Install windows with **low-solar-transmittance glazing** (e.g., Low-E glass) **to reflect heat away**. Minimize window size on east and west sides, and potentially the south depending on climate.



Shading devices: Utilize **external blinds, shutters, or screens to block direct sunlight** before it hits the windows.

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2. Design solutions for energy efficiency

HVAC systems

Reduce conductive heat gain

Insulation: Ensure adequate **insulation in walls, roofs, and floors** to prevent heat transfer from the exterior. Pay particular attention to **roof insulation**, as it's most exposed to the sun.

Radiant barriers: Install **radiant barriers in attics** to **reflect heat** radiation back towards the roof deck, reducing heat transfer to the living space below.

Enhace heat disipation

Evaporative cooling: Utilize **natural evaporative processes**, such as misters or fountains, to cool incoming air. This works best in dry climates.

Cool roof materials: Choose roofing materials with **high reflectivity and emissivity** to reflect solar heat and radiate heat back to the sky.

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2. Design solutions for energy efficiency

HVAC systems

Additional strategies

Occupancy sensors and timers: Automatically control lighting, electronics, and ventilation based on occupancy **to minimize unnecessary heat generation**.

Energy-efficient appliances: Opt for energy-efficient appliances and equipment that **generate less heat during operation.**

Green roofs and walls: Install **vegetated roofs or walls** to provide insulation, shade, and evapotranspiration for cooling.

2. Design solutions for energy efficiency

HVAC systems

Active measures

- **Mechanical Cooling System Optimizations**:
  - ✓ **Variable speed drives** (VSDs) on fans and pumps. These allow the equipment to **adjust its speed** based **on actual cooling demand**, reducing energy consumption compared to fixed-speed systems.
  - ✓ **Demand-controlled ventilation** (DCV) system that **adjusts ventilation** rates **based on occupancy or CO2 levels**, reducing unnecessary air conditioning when spaces are unoccupied.
  - ✓ **Night cooling**: Utilize off-peak hours to **pre-cool the building using cool night air**. Store this coolness in a thermal mass like concrete floors or chilled water tanks for use during the day.
  - ✓ **High-efficiency HVAC equipment**: Invest in high-efficiency air conditioners, heat pumps, and other HVAC equipment with **higher SEER (Seasonal Energy Efficiency Ratio) ratings**.

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2. Design solutions for energy efficiency

HVAC systems

Active measures

- **Advanced Cooling Technologies**:
  - ✓ **Desiccant cooling**: In **humid climates**, consider desiccant dehumidification systems that **remove moisture from the air before cooling it**. This can be more energy-efficient than traditional vapor-compression systems.
  - ✓ **Radiant cooling**: Implement radiant cooling systems that use **chilled water pipes embedded in ceilings or walls** to cool occupants directly through radiation, rather than cooling the entire air mass.
  - ✓ **Ground source heat pumps** (GSHPs): Utilize GSHPs **to leverage the stable temperature** of the earth for both heating and cooling, offering high efficiency and low environmental impact.

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3. Current types of HVAC systems

Based on their **size, construction**, and **operating characteristics**, HVAC systems can be classified as:

- Individual Room or Individual Systems – Fig. 1
- Space-Conditioning Systems or Space Systems – Fig. 2
- Unitary Packaged Systems or Packaged Systems – Fig. 3
- Central Hydronic or Central Systems – Fig. 4

3. Current types of HVAC systems

An **individual system** normally employs either a single, self-contained, packaged room air conditioner (installed in a window or a wall) or separate indoor and outdoor units to serve an individual room.

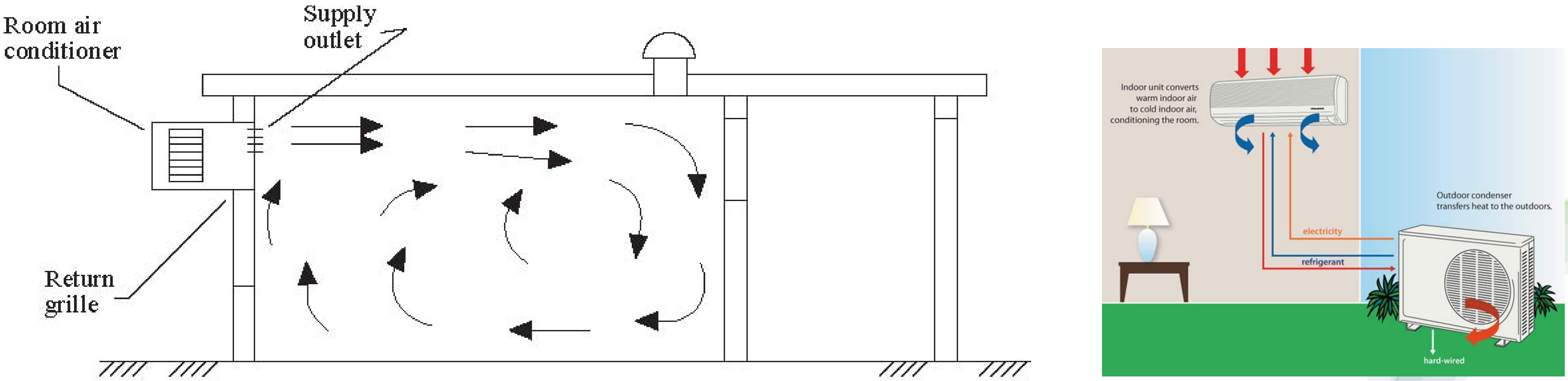


Figure 1: Individual room air conditioning system

3. Current types of HVAC systems

Space-conditioning systems have their cooling, heating, and filtration performed predominantly in or above the conditioned space.

Outdoor air is supplied by a separate outdoor ventilation system.

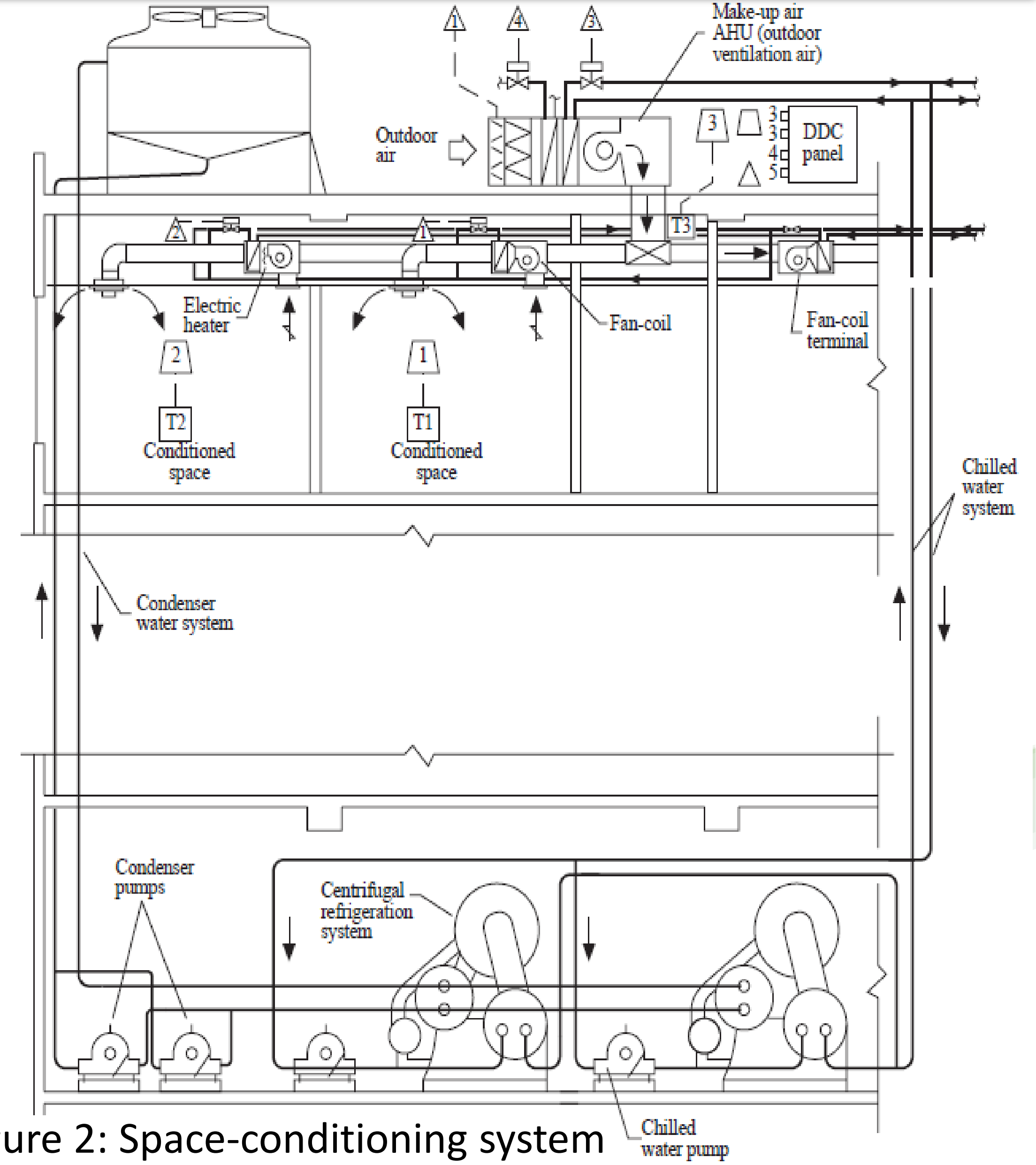
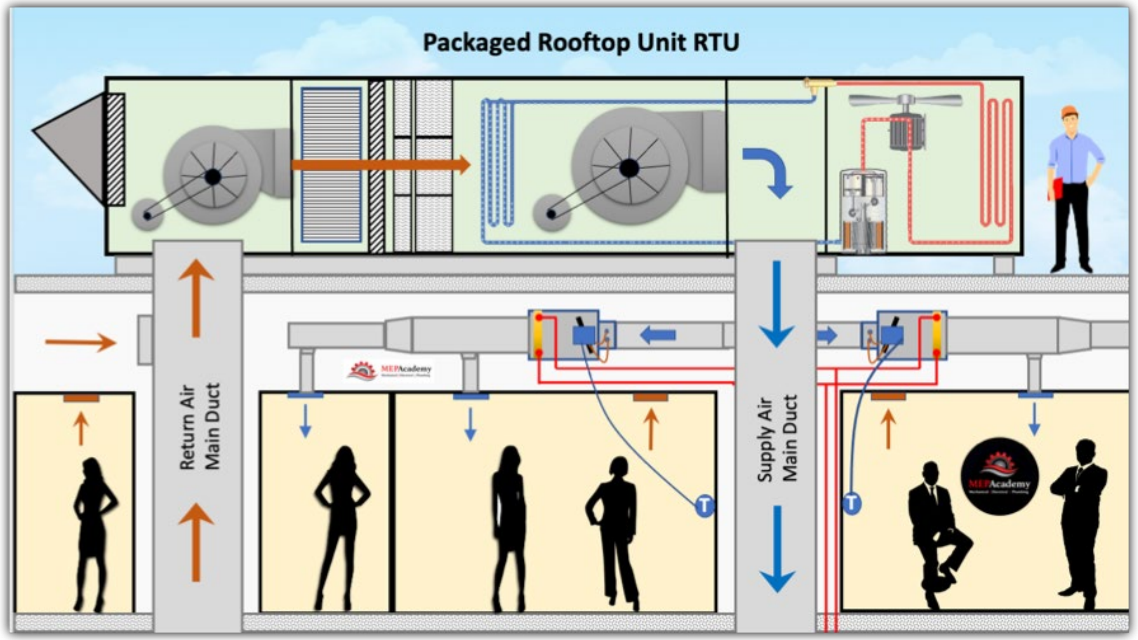


Figure 2: Space-conditioning system

3. Current types of HVAC systems

Unitary Packaged Systems are installed with:

- An outdoor single self-contained, factory-assembled packaged unit (PU), known as rooftop units, with all the heating and cooling equipments;
- an indoor air handler with ductwork.



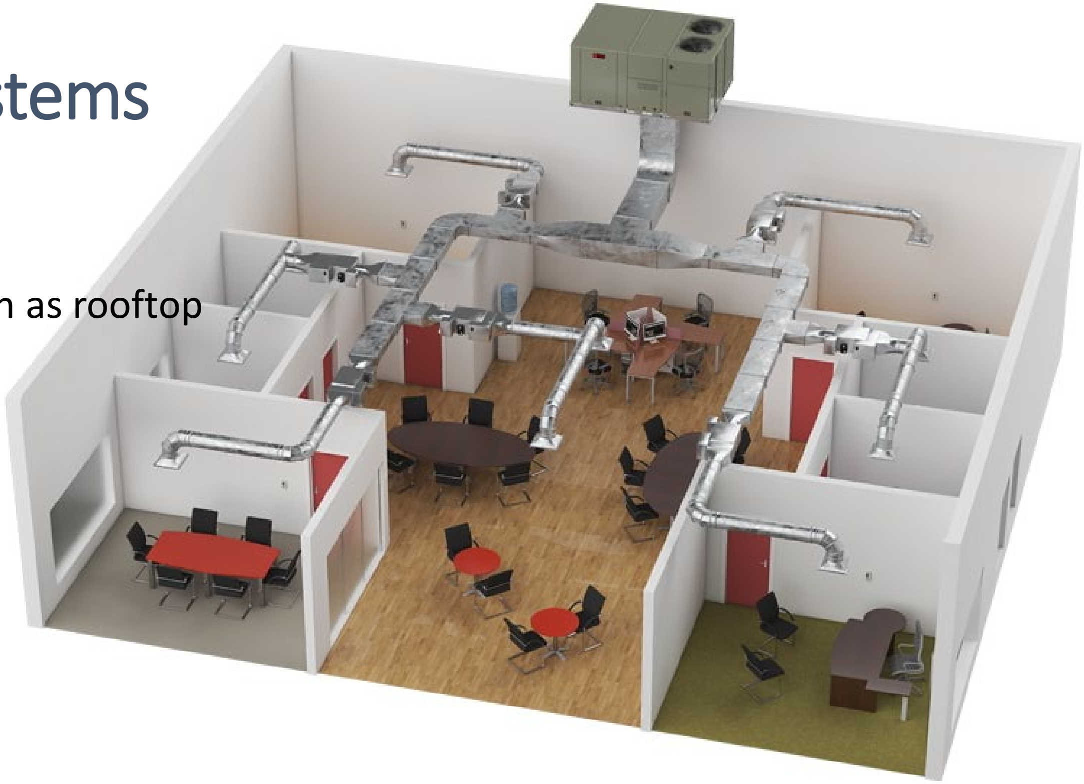
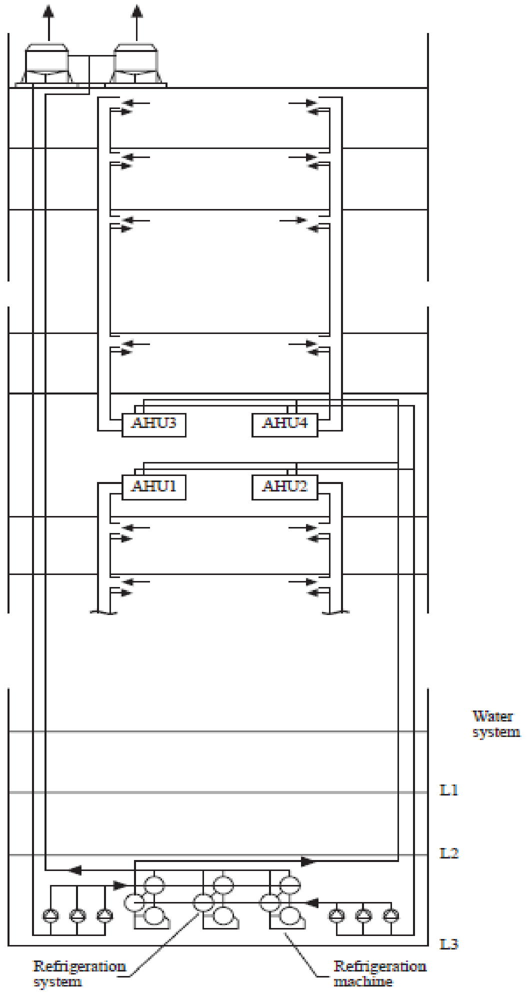


Figure 3: Packaged systems

3. Current types of HVAC systems



A **central system** uses **chilled water or hot water** from a chiller or a heating plant to cool or heat the air at the coils in an air handling unit (AHU).

For energy transport, the **heat capacity of water** is about 3400 times greater than that of air.

Central systems are built-up systems assembled and installed on the site.

Figure 4: Central system

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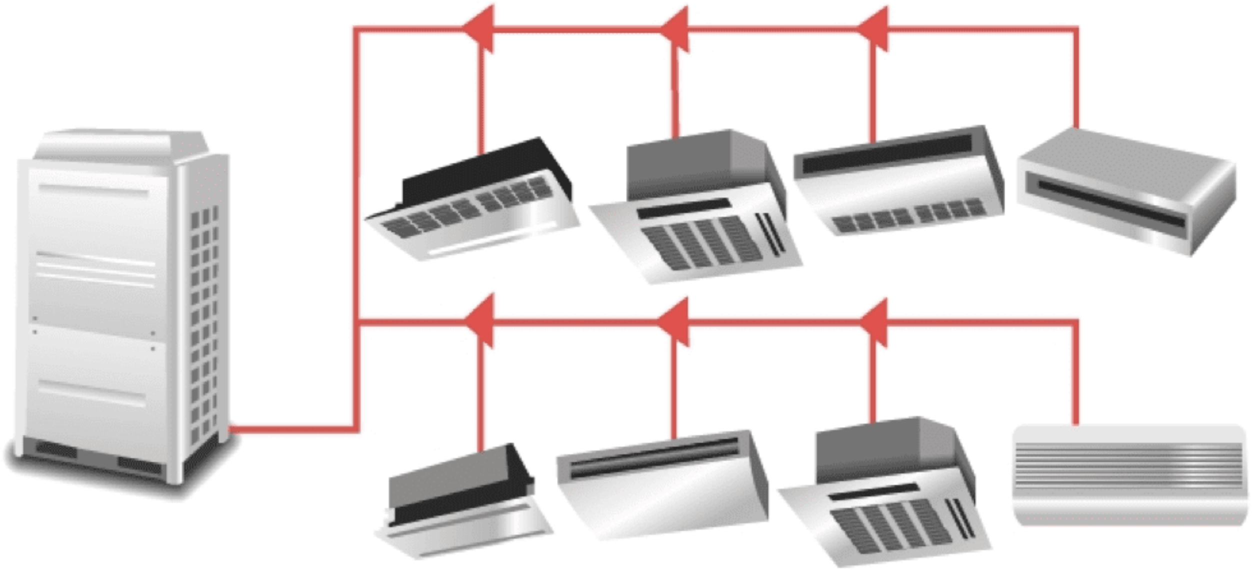
4. HVAC variable refrigerant flow systems

VRF refers to the **ability of the system** to:

- not require ductwork, so they are ideal for bringing older buildings up to date with new standards
- **control the amount of refrigerant** flowing to each of the evaporators;
- enable the **use of many evaporators of differing capacities** and configurations;
- **individualized comfort** control;
- **simultaneous heating and cooling** in different zones;
- **heat recovery** from one zone to another.

VRF systems can be used for:

- cooling only
- heat pumps (two-pipe systems)
- heat recovery (three-pipe systems)



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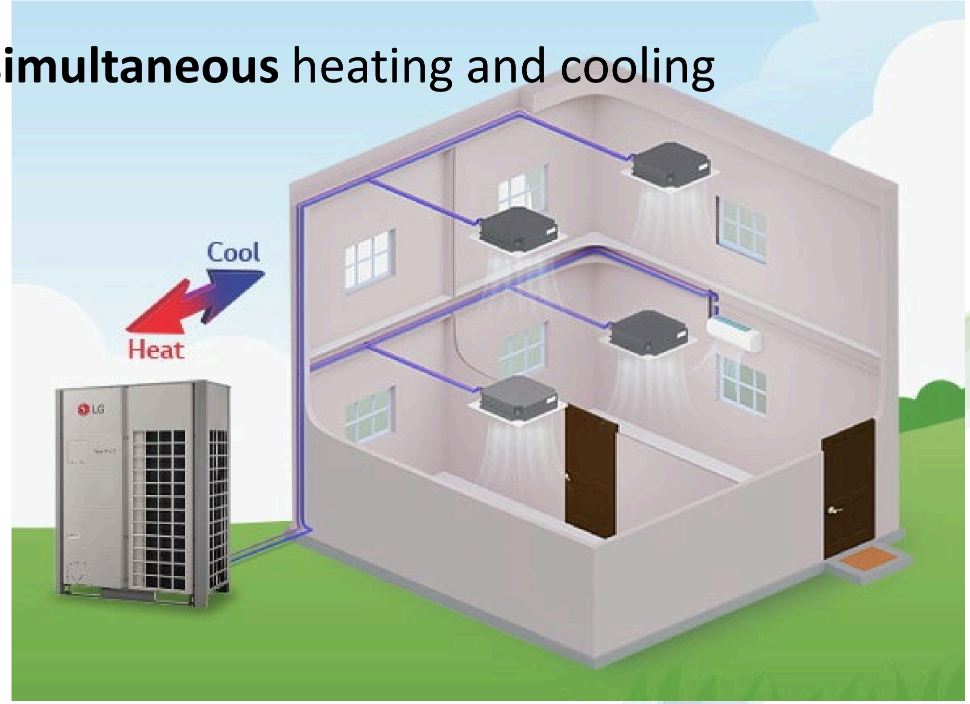
4. HVAC variable refrigerant flow systems

VRF heat pump systems (two-pipe systems)

- permit **heating or cooling** in all of the indoor units but **NOT simultaneous** heating and cooling
- indoor units in cooling mode – evaporators
- indoor units in heating mode – condensers

- applied in open plan areas, retail stores, cellular offices and any other area that require cooling or heating during the same operational periods.

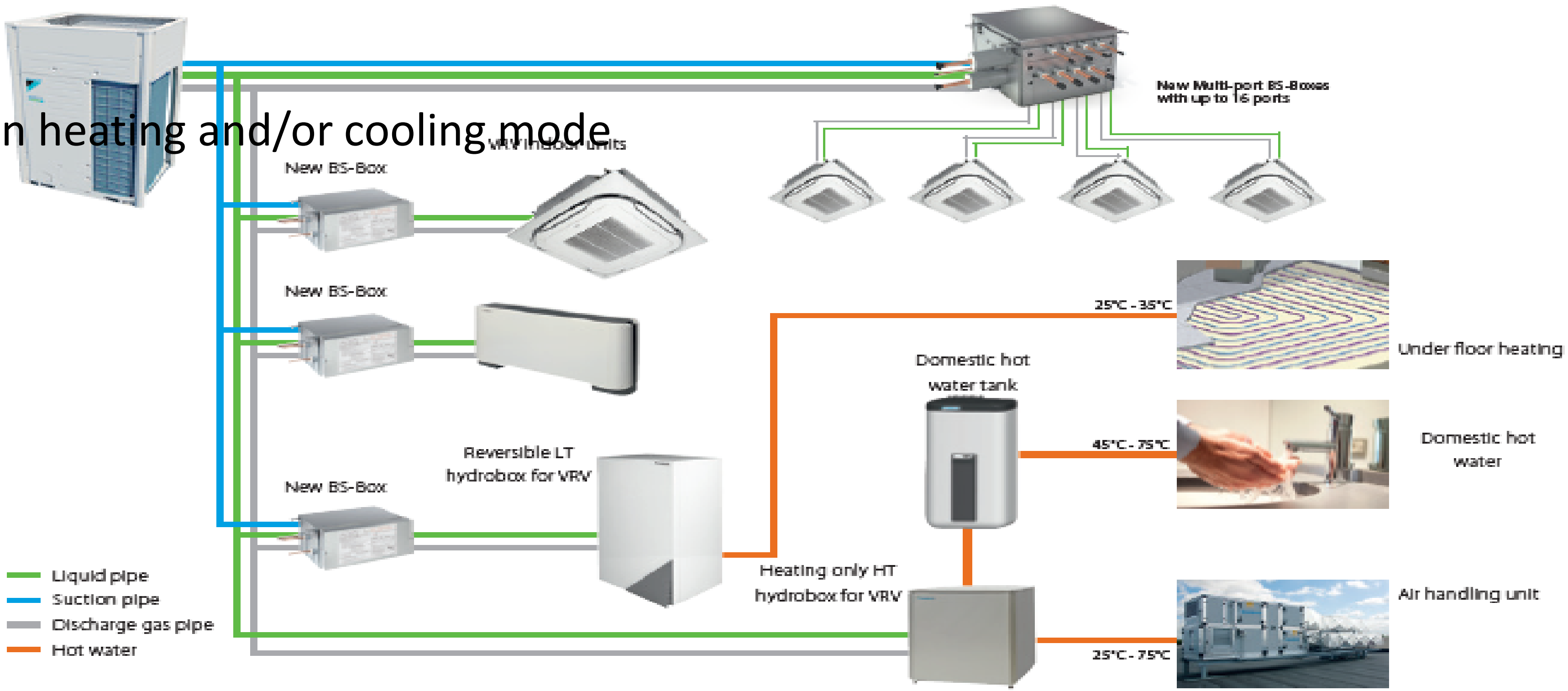


4. HVAC variable refrigerant flow systems

Heat Recovery VRF system (three-pipe systems)

- can **operate simultaneously** in heating and/or cooling mode

- an indoor unit requiring cooling will open its liquid line and act as an evaporator
- an indoor unit requiring heating will open its hot gas and act as a condenser



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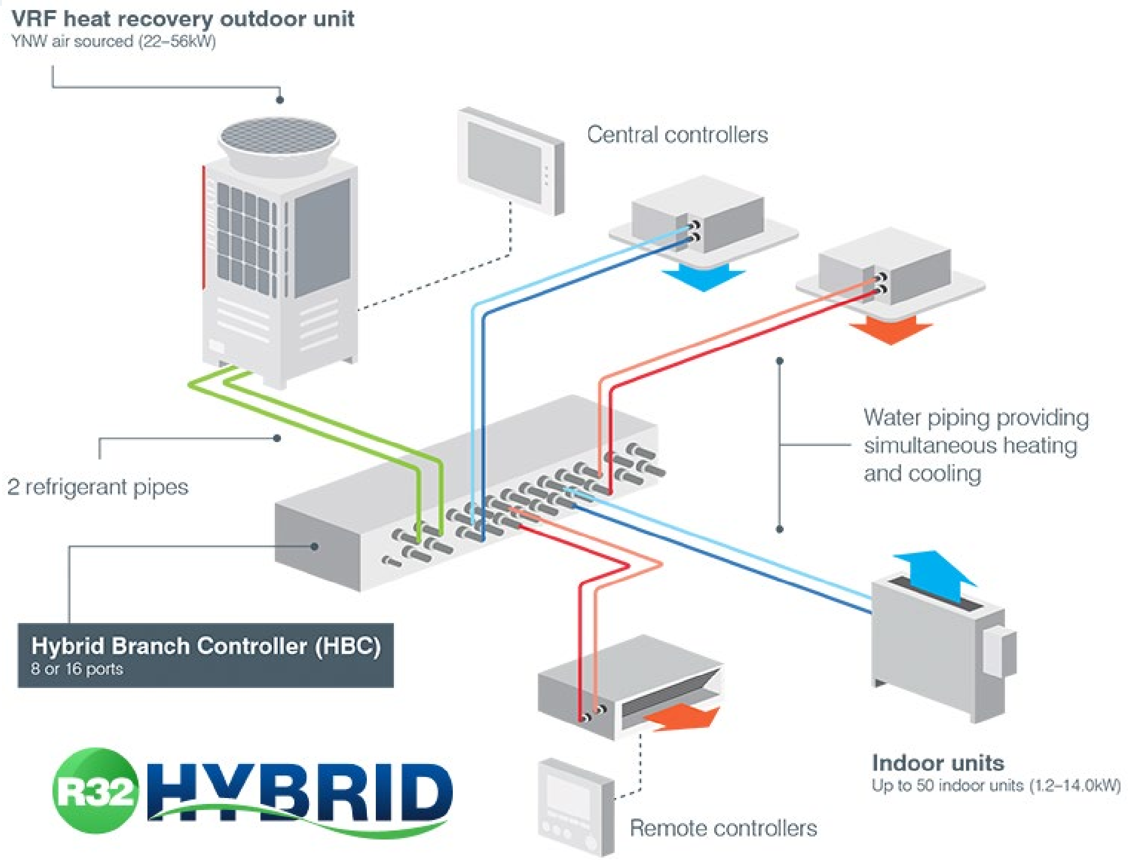
4. HVAC variable refrigerant flow systems



- Hybrid VRF system with a 2-Pipe Heat Recovery that **replaces refrigerant with water** between the Hybrid Branch Circuit Controller and the indoor units.
- This design **minimizes the need for leak detection** servicing.

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4. HVAC variable refrigerant flow systems

- When the indoor space requires also ventilation, an **energy recovery ventilator** (ERV) may be considered and/or a terminal **system for humidity control** with an energy recovery ventilator.

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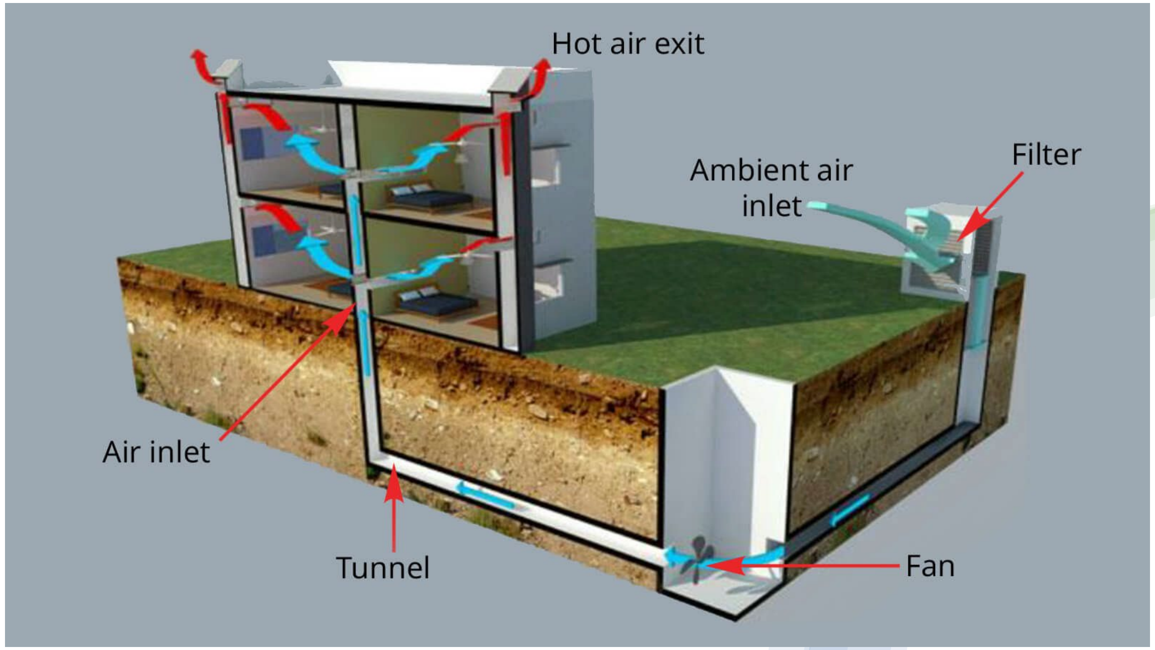
5. HVAC system with ground-air heat exchanger

- An underground heat exchanger **captures the heat/cool** from the ground;
- Provides **significant energy cost reductions** by using the **embodied ground energy** to pre-condition the incoming ventilation air
- The concept relies on the fact that at depths of **1,5 to 2,0 m** below the surface, the earth's temperature is a constant **(7-12ºC)** throughout the year.
- By drawing air through an underground network of pipes, this air is either **pre-heated in the winter or pre-cooled** in the summer by the ground.



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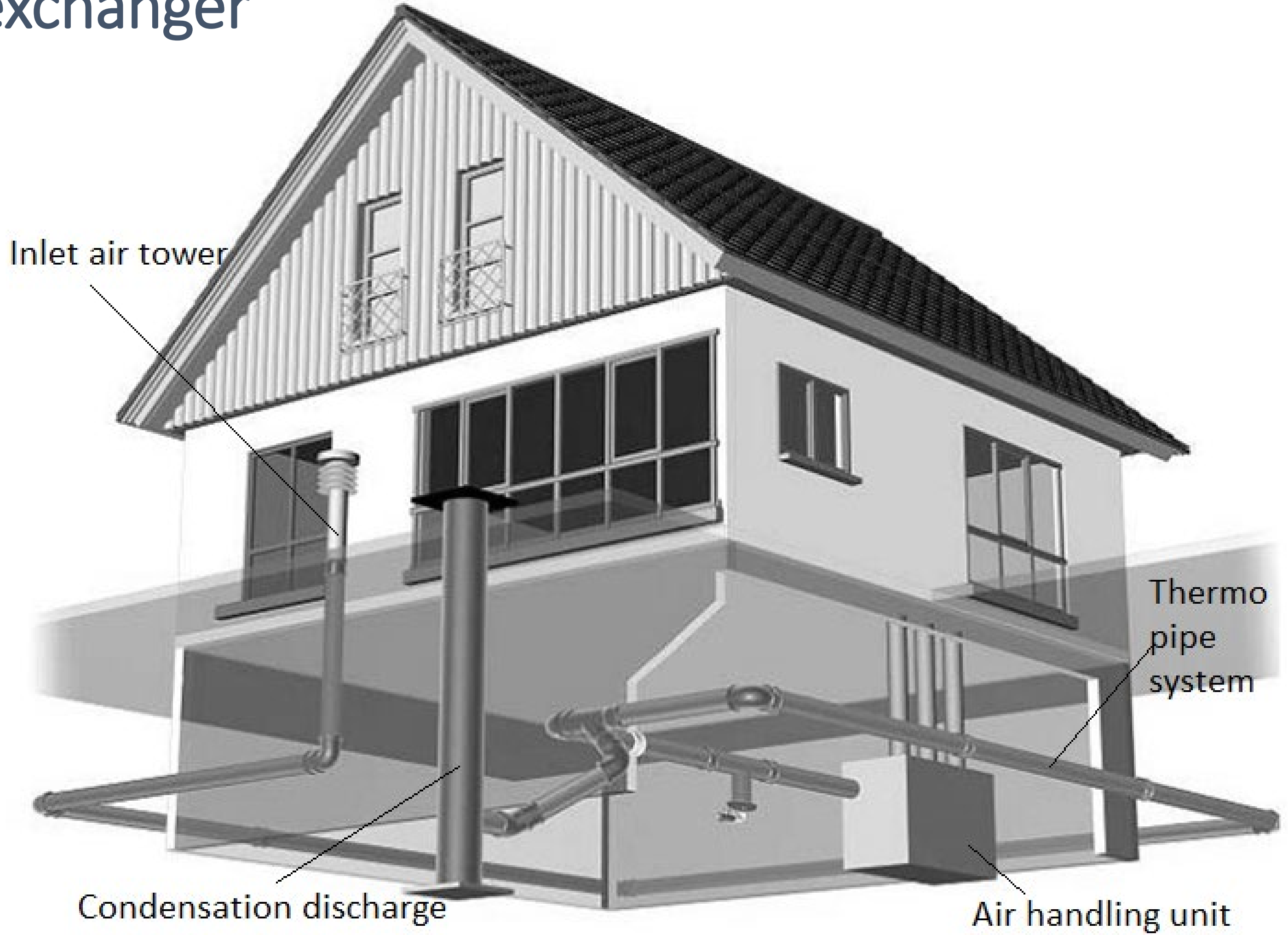
5. HVAC system with ground-air heat exchanger

- The optimal heat transfer between the ground and air results in the air being **warmed by up to 17ºC in winter**.
- The air can **be cooled by as much as 14ºC** during summer by the time it reaches the air handling unit.
- The **system significantly reduces the heating and cooling costs**.



Conclusions

When designing a HVAC system is important to consider the following factors

- ✓ building characteristics
- ✓ cooling and heating load requirements
- ✓ peak occurrence
- ✓ simultaneous heating and cooling requirements
- ✓ fresh air needs
- ✓ accessibility requirements
- ✓ minimum and maximum outdoor temperatures
- ✓ financial investment
- ✓ sustainability
- ✓ acoustic characteristics