***Related to energy resources and building***

1. **What share do buildings have in the national energy budgets of industrialized countries?**

*35.3% (EIA, 1998). And currently around the world, 40% of the world’s energy is consumed in buildings (Melbourne World Sustainable Building Conference, 2008).*

1. ***What is the accepted definition of “Sustainable Development”?***

*Sustainable development is a pattern of resource use that aim to meet human needs while preserving the environment so that these needs can be met not only in the present, but in the indefinite future.*

1. **Explain the underlying tenets of global warming and peak oil.**

Global warming is the other side of the coin of Peak Oil. That is, in the process of rapidly depleting the Earth’s supply fuels, mankind is also a threat to the climate on Earth. Global warming is the result of burning up lots of fossil fuels. Both the energy source depletion as global warming can be considered as a general global problem.

***Global warming****: The energy coming from the sun in the form of lightwaves passes through the atmosphere and is then absorbed by the Earth, which gets warmed. However, some energy is radiated back into space in the form of infrared waves. Part of the outgoing irradiation is trapped by the Earth’s atmosphere and heats it up (which, in natural conditions, keeps the temperature of the planet within certain boundaries and relatively constant). The problem of global warming arises when the thickness of the atmosphere increases because of the pollutant gases emitted by human activity. In this case, more energy is trapped by the atmosphere and the heating of the Earth goes above normal.*

***Peak oil****: Peak oil is the point in time when the maximum rate of global petroleum extraction is reached, after which the rate of production enters terminal decline. M. King Hubbert created and first used the models behind peak oil in 1956 to accurately predict that United States oil production would peak between 1965 and 1970. According to the Hubbert model, the production rate of a limited resource will follow a roughly symmetrical bell-shaped curve based on the limits of exploitability and market pressures. Peak oil is often confused with oil depletion; peak oil is the point of maximum production while depletion refers to a period of falling reserves and supply.*

1. **What signifies the Trias Energetica and how does it relate to basic strategies of building design? Give of each strategy a concrete example**

Trias Energetica is a way of dealing with energy. Trias Energetica is a simple and logical concept that helps to achieve energy savings, reduce the dependence on fossil fuels, and save the environment.

The 3 elements of Trias Energetica are:

1. Reduce the demand for energy by avoiding waste and implementing energy-saving measures;

2. Use sustainable sources of energy instead of fossil fuels

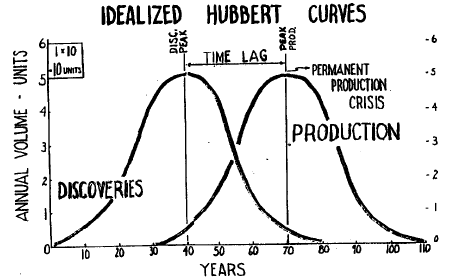
3. Produce- and use fossil energy as efficiently as possible

The main goal of Trias Energetica is using energy more efficient and introducing sustainable and cleaner energy sources. In the building design, energy used by a building is an important indicator that needs to be considered extensively.

*Incorporating passive and active systems to achieve each one of these elements is the way in which building design can be related to the Trias Energetica. For example, in the energy saving strategy, the shape and orientation of the building could be chosen to take advantage of the daylight for internal illumination and/or heating, which contributes in the reduction of electricity or gas consumption. In the renewable energy strategy, systems as solar cells, wind turbines geothermal heat pumps, etc. could be implemented directly in the building. And on the efficient use of fossil fuels strategy, heat recovery systems could be used, for example, to contribute in district heating.*

1. **Discuss the ‘peak’ problem as identified by Hubbert. What other peaks can be identified as well and what does this mean for sustainable solutions to the energy problem?**

The Hubbert peak theory posits that for any given geographical area, from an individual oil-producing region to the planet as a whole, the rate of petroleum production tends to follow a bell-shaped curve. Hubbert’s Peak indicated that the production curve has the same shape as the discoveries curve which it follows with a time lag peculiar to the region.



Although Hubbert peak theory receives most attention in relation to peak oil production, it has been applied to other natural resources as well. For natural gas, the peak is called peak gas and in case of coal it is called peak coal.

Peaking means supply begins to drop and growth is over, this peaking happens to all individual oil wells, oil fields, oil basins and global supply. The experts assume that the hydrocarbons will peak too. This means that the incentives for more sustainable solutions for the energy problem will be higher.

*Hubbert Peak means that when the maximum rate of oil extraction is reached, the supply begins to drop and its growth is over. The peak had happened in some regions, and now it is happening in the whole world. Other peaks that can be identified are for natural gas, coal, uranium and so on. If the world energy supply shift from oil to others, it will accelerate the peaks for other energy sources. An example is shifting to solar panels: it will also accelerate the peaks of some rare materials which are mainly used to produce solar cells, such as Indium.*

***Indoor environment***

1. ***Give some examples of ratings systems that currently are used to rate sustainability of buildings and describe which indoor environmental aspects are taken into account in these systems.***

Examples of building ratings systems:

* LEED (Leadership in Energy and Environmental Design)
* *Sustainable sites*
* *Water efficiency*
* *Energy & Atmosphere*
* *Materials & Resources*
* *Indoor environmental quality*
* *Innovation & Design process*
* BREEAM (BRE Environmental Assessment Method)
* *Indoor air quality*
* *Control of thermal environment*
* *Natural daylight levels and glare control*
* *Control of artificial lighting*
* *Degree of occupant control over ventilation, temperature and lighting*
* *General ambience and aesthetic environment*
* *Acoustic environment*
* *Scale of working spaces, which can effect degree of ownership*
* *Social meeting areas, rooms and other amenities*
* GreenStart (Australia)
* CASBEE (Japan)
* GreenCalc (Netherlands)
* GPR Gebouw (Netherlands)

1. ***Why should the indoor environment be taken into account when designing for low energy sustainable solutions***

*Energy costs represent >25% of life-cycle costs of a building, compared to people salaries this is a small amount. People spend around 90% of the time indoors. Energy efficiency measures may have a higher rate-of return when health, comfort and/or productivity (basic values) are improved as well. Indoor environment affects users of a building directly.*

1. **What indoor environmental problems may arise if the only focus is at low energy design solutions? Mention at least one clear example.**

Focusing on low energy design solution only, can lower the comfort of the building and people can get sick or perform worse than normal. For instance in Amersfoort people developed chronic illnesses as a result of energy-efficient ventilation system in their homes.

***Related to integrated design***

1. ***What is integrated design of buildings and what types of integration do you distinguish. Provide a concrete example of each type of integration.***

Integrated design is a collaborative design methodology emphasizing knowledge integration in the development of a design. The practices are in the “whole building design” approach. By viewing a building system interdependently as opposed to its separate elements (site, structure, systems and use), this approach facilitates sustainable design practices. The integrated design process requires multidisciplinary collaboration, including key stakeholders and design professionals, from conception to completion.

Types of integration:

* Goal Integration: stakeholders each have their values, they should agree on the goal for the building. So the building must be designed in its context. For the building owner, it is important to save costs, while for the ecologist it is important to protect the environment as much as possible. Some compromises and consensuses are needed.
* Functional Integration: integration of functions in building systems. For example installation, construction and façade should function for cooling. The goal with this is increasing building comfort.
* Physcial Integration: How to implement the concept. For example in some cases prefabrication is needed for the building.
* Utility Integration: combining all the types of integration together.

1. **How do you structure the overall integrated design process (in main phases) and what activities do take place?**

*Goal integration – Functional Integration – Physical Integration – Utility Integration . The activities that take place are design, build, maintain and learn.*

1. **What is the essential benefit of using value domains and functional levels of the building in the integrated design process? Explain what they are and how they are used.**

With the design of a building a lot of complexity and dynamics are involved. By using value domain and functional levels, some structure can be brought into the process, which should facilitate the process.

*Basic value* – Quality of life: building’s relationship with individual occupants and their sense of psychological and physical wellbeing.

*Functional value* – Multi-functionality: is concerned with how activities taking place inside the building are supported

*Strategic value* – Building strategy (future users): abstract human-building relationship as it considers performance requirements associated with time and the future. This includes the ease with which a building accommodates the needs of many different occupants and occupancies (universality) and/or how it can be adapted or modified over time to fit (changeability)

*Economic value* – long term (owner): is based on the relationship with people concerned with the ownership and marketing of the building.

*Ecological value* – building as climate transformer (Global community): considers the relationship of the building to the global environment. Considerations include how a building uses resources (Energy, materials & water), and/or creates waste and pollution.

*Local value* – Pluriform (Community): based on special conditions that are unique to a particular place; anything that may prevent a building from being constructed in the most straightforward way.

1. **What are the important value drivers for a building and describe for each shortly what building characteristics are related to it.**

* Basic value (spatial, acoustic, visual, thermal comfort and air quality)
* Utility value (support for production, manageability, operations & maintenance and cleanliness)
* Social or local value (need to response to earthquake zones, extreme climates, building regulations or historical context)
* Ecological value (resource usage (energy, materials & water)
* Strategical value (universality and changeability)
* Economical value (initial cost, life-cycles cost (operating &maintenance) and demolition cost.

1. **Which value drivers should be given highest weight when designing a sustainable building and discuss why.**
2. Utility value
3. Basic value
4. Strategical value
5. Economical value
6. Ecological value
7. Social value

**Utility:** The purpose to create a building is the use and need of a building, there is no other reason why a building should be built, and thus this comes on the first place.   
**Basic:** The employees must be satisfied with their working environment that will reflect in optimal results.   
**Strategical:** Versatility is important to gain as much profit.   
**Economical, ecological and social:** These are of less importance.

1. **Describe a sensible design process for designing a sustainable building.**
2. Pre-design/feasibility:
3. Conceptual design:
4. Detailed design:
5. Construction:

***Evaluation tools***

1. **Which categories of resolution levels for simulation (evaluation tools) can you distinguish and describe the feasibility of the use of these tools in the different parts of the design process.**

***Simple***: few inputs, limited information needed. It is generally useful for exploration of more detailed designs. This level is desired in the pre-design and conceptual design in the design process. The main concepts can be integrated this way.

***Detailed***: many inputs, with detailed information required. Generally for exploration of more detailed designs. This level is more preferred in the detailed design.

***Special purpose***: dedicated to a single task or purpose. Single purpose tools for investigating individual building parts/components (e.g. shading, *simple*, HVAC system, *complex*). The special purpose resolution level for simulation can be used in a stage during the design process. In every stage there are some decisions that you would like to evaluate with a simple/complex evaluation tool. When a concept is very important, it is a good choice to go more in depth for these concepts. This is used more in detailed design and construction.

1. **What is Performance Based Building and describe how evaluation tools are indispensable when applying this approach.**

The performance approach is thinking and working in terms of ends rather than means. Performance is concerned with what a building is required to do and not with prescribing how it is to be constructed. A design solution will always need a quantitative base for testing and evaluation of its performance, for which evaluation tools are indispensable. The evaluation tools help to design the building, what façade should be oriented in which direction, how much glass surface can be used, how much natural daylight can be used. Without these tools it is a mere guess if the requirements are met.

1. **Which performance indicators (at least five) could you mention that directly relate to the assessment of sustainable building designs. Give a short explanation for that for each indicator.**

Performance indicators:

* *Heating and cooling:* Using excess heat from exhausts or the coldness of the ground can lower the heating and cooling energy.
* *Load related*: (maximum heating and cooling load) The design of the building can lower these loads by providing enough ventilation, by lowering the maximum load means less energy is used.
* *Comfort related*: Comfort and sustainability is actually opposite of each other, when a comfortable situation is wanted, a certain refresh rate is needed. During colder times, this will mean that cold air will be brought inside, and extra heating is needed. While the sustainable concept is lowering energy usage, meaning the refresh rate suffers.
* *Daylight use*: The use of free light in the form of daylight is not only good for the environment, but also to save money on electricity and less wear on the lighting equipment.
* *Shading devices*: These lower the use of daylight, but prevent overheating during hotter periods.
* *Primary energy use:* which primary energy sources are used, are they sustainable and environment friendly is a question to be considered here.

1. **What is the main drawback of simplified evaluation tools for, e.g. energy performance assessment for innovative sustainable solutions?**

These are not very accurate , the data needed for these tools are limited and few. It is used more as an exploration of a concept. You can easily overestimate or underestimate certain situations which can eventually lead to catastrophically consequences.

***Related to passive solutions (building/façade)***

1. Provide a survey of design strategies for ecological value for the location level, the building level and the room level (each level at least 5 strategies with concrete examples);
2. **Give the five different functional systems in a façade and denote the basics of the physical processes that take place in these systems.**

* Window system: Transmission heat losses, insulation, ventilation heat loss, cold air drop, thermal buoyancy and air exchange due to wind
* Daylight systems: reflection, glass/wall ratio, light transmittance, daylight factor and light bending. Sunlight entering the building.
* Sun shading systems: Solar energy transmittance, solar heat gain coefficient. Controlling excess solar gain.
* Non-transparent systems: Temperature equivalent, inner surface temperature, sound level difference. Decreasing noise from the outside
* Productive systems: Heat gain from sun, electricity generation. Utilization of sun energy in PV or vacuum tubes to generate electricity.

**21. Describe the different façade systems that can be identified and give examples of sustainable**

**solutions for each façade system.**

* Perforated façade: Cheap, solid, natural ventilation can be difficult according to circumstances (cold, windy). Use in low wind speed location and low noise.
* Elemental façade: High solar contribution, high transparency, prefabrication, cold air for natural ventilation, no external sunshade. Use in low wind speed location and low noise.
* Baffle panel: Less overheating, less natural ventilation. Use in medium wind speed location and medium noise.
* Alternating façade: Overheating in casement, high sound reduction, high cost. Use in high wind speed location and food air quality.
* Box window façade: Overheating in cavity, high sound reduction, shading. Use in high wind speed location and high noise.
* Corridor façade: Overheating in corridor, high sound reduction, extra space. Use in high wind speed location and high noise.
* Unsegmented double skin façade: Overheating in cavity, high sound reduction, high transparency, low natural ventilation (mechanical needed), sound transmission. Use in high wind speed location and high noise.
* Controllable double skin façade: No overheating in cavity, sound reduction controllable, high transparency. Use in high wind speed location and medium noise.

**22. Give four different ventilation strategies of buildings with concrete examples and compare them in terms of basic value and ecological value**

* Pure natural ventilation **(**Atrium, Double skin Façade, Solar Chimney)
* Mechanical ventilation**:(**Air distribution equipment and refrigeration equipment)
* Mixed mode ventilation {Mechanical Ventilation (air distribution systems) together Natural Ventilation (operable windows)}

Concurrent (Same space, Same time)

Change-over (Same space, Different times)

Zoned (Different spaces, Same time)

* Hybrid ventilation

Natural & mechanical ventilation: Two Autonomous Systems

Fan assessed natural ventilation: Fan assisted to enhance the pressure difference.

Stack and wind assessed mechanical ventilation: mechanical systems are supported by natural driving forces.

**Basic value**: comfort, health, safety.

**Ecological value**: energy consumption, emissions

In terms of basic value, mechanical ventilation guarantees and gives the maximum comfort and control on air quality (Temp. and RH). So, mechanical ventilation is superior to other ventilation systems considering the basic value. However natural ventilation is the best alternative to reduce the energy required for ventilation so it is more advantageous to other ventilation systems in terms of ecological value.

**23. What is a climate facade and a double skin façade? How do they compare in terms of basic**

**and ecological value?**

A climate façade is built up out of 2 glass panels as a curtain wall, these panels are separated in a rather large distance (12” or more). Automatic sunshades can be installed in the space between the glass, this to avoid overheating, and can also be used to let sunlight in.

Double skin façade also has 2 glass panels, but in that space between the panels, there is no sunshades installed, the ventilation system of the building extracts the air in the space between the panels. This space with preheated air (heat from the sun) acts as a buffer during colder times.

They are almost exactly alike, only that the climate façade is used as a sunshading device and a buffer zone, while the double skin façade can contribute solar heat to the ventilation system.

They are both helping the building in a sustainable way, while it is an improvement for one aspect, it also decreases another aspect. As preheated air gets in the ventilation during the summer, more cooling energy is needed.

**24 What aspects of a climate do you need to take into account when building in a sustainable way and indicate for each aspect how this translates to the passive concepts that can be applied.**

According to the climate, temperature and humidity are important factors. Especially, temperature variation during the day and year are important. By considering these parameters one could determine whether low mass or heavy mass will be used. Also, orientation and size of the building will be affected according to the climate. Moreover, shading equipments, utilization of sunlight will be designed according to the climate. For example, fixed shading is never used for moderate climate.

**25. Describe at least three passive measures that can be taken at building level and indicate the importance of these measures for a building located in the Netherlands (moderate climate) and a building located in Singapore (hot, humid climate)**

**Three passive measures are taken:**

* Transmission Loss (Good Insulation in walls, floors and windows)(Also thermal bridges)

(Compact building shape)

* Ventilation Loss (reduce airleakage)

(Controlled ventilation)

* Solar Gain & Contribution (orientation of the building, overhang and use of green are important to control the solar gain)

Since during the winter, temperature in the Netherlands is decreasing below the 0 degree, transmission and ventilation losses are extremely important for the Netherlands. However transmission and ventilation losses are not that important for Singapore because the average temperature throughout the year is nearly constant and 26oC. Solar gain could be a problem for Singapore due to the excess heating in the summer. Also solar gain is important for the Netherlands climate to minimize the heating load.

**26 Which ventilation strategies at building level exist and indicate which strategies are best applied for a moderate climate when sustainability is of importance and why.**

1. Natural Ventilation
2. Mechanical Ventilation
3. Hybrid Ventilation

Natural ventilation is the best choice for the moderate climate. It will reduce the energy required for the ventilation most so it is suitable for the zero energy consumption goal in the passive systems.

**27 What is the advantage of using phase change materials in a building. How does it work and what limitations are related to its use.**

PCM can reduce the home heating and cooling loads. PCM (phase change material) is a substance with high heat of fusion which, melting and solidifying at certain temperature, is capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage (LHS) units.

**Detail not very necessary**--------------------

PCMs latent heat storage can be achieved through solid-solid, solid-liquid, solid-gas and liquid-gas phase change. However, the only phase change used for PCMs is the solid-liquid change. Liquid-gas phase changes are not practical for use as thermal storage due to the large volumes or high pressures required to store the materials when in their gas phase. Liquid-gas transitions do have a higher heat of transformation than solid-liquid transitions. Solid-solid phase changes are typically very slow and have a rather low heat of transformation.

-----------------------------------------------------  
One limitation is the range of temperature over which some of the materials change phase can be quite narrow or may be single temperature, limiting the material’s use in climates where both heating and cooling are important. Also, fire safety, perceived comfort factor and economic payback are other critical issues.

1. Related to Basic Values

**28.** In which main groups indoor environmental performance indicators can be SUBDIVIDED, and give at least TWO EXAMPLES of performance indicators for each group.

**DIRECT ANSWERS:**

Indoor Environmental Performance Indicators can be subdivided into four main groups: **Thermal comfort** (related to air temperature, Operative temperature, effective temperature, PMV/PPD, Asymmetric thermal comfort etc);   
**Hygienic comfort** (related to Ventilation; Indoor Air Quality, contaminant concentration level etc);   
**Visual Comfort** (related to illuminance, daylight usage etc); and   
**Acoustic Comfort** (related to sound pressure level, frequency level, reverberation time).

**SOME EXPLANATIONS☹(if someone is very interested or enthusiastic)**

**Ventilation:**

This is related mainly to the control of the indoor air quality through different ventilation systems; Natural, Mechanical or Hybrid. Ventilation mainly targets the control of different contaminants such as CO2 emissions from human’s activities; and emissions from different processes and from the building materials. As an additional purpose, Ventilation system is also used to control the temperature level of the indoor environment. The main indicators for a ventilation system include Ventilation air exchange rates and Ventilation energy loss. The air exchange rate depends on the type of building (office, hotel, living etc); level of activity, occupants etc and this requirements are usually stated in the building Decree of the specific country. Energy is lost by the ventilating air and this energy loss is mainly dependent on the type of ventilation system used (natural, Mechanical or Hybrid). Ventilation energy loss is also used as an indication of Energy performance of the building.

**Thermal Comfort:**

This is used to measure the level of satisfaction of the surrounding environment. Thermal comfort is used to keep the Indoor Environment healthy and to give High relative production performance for the occupants. The performance indicators used to measure the thermal comfort include air Temperature, Humidity, air motion and radiation. Air temperature measures the appropriate range of temperature for the indoor environment give the variable temperature of the external environment. This Air Temperature can be described by different parameters such as Directive temperature; Effective temperature; Operative temperature; adiabatic equivalent temperature, bulb (dry/wet) temperature. Air temperature depends on different factors such as Metabolic reactions/activities of the occupants, Heat losses/gains; Thermal insulation/material of the building.

**29.** What INDICATORS are available to assess THERMAL COMFORT in a building? (mention at least THREE). Why is the ADAPTIVE APPROACH interesting from a low‐energy use point‐of‐view for warm climates?

**DIRECT ANSWERS:**

The performance indicators used to measure the thermal comfort include air Temperature, Humidity, air motion and radiation. In Adaptive approach for thermal comfort, the standard temperate requirements are quite suitable to use pure Natural ventilation system in warm climate conditions. This helps to decrease energy requirement for the ventilation system and hence contributes to a low‐energy use options.

1. Related to Terminal Systems

**30.** Which three types of terminal systems can be distinguished? Provide for each type at least two representative examples of terminal systems.

**DIRECT ANSWERS:**

Energy flowing into or out of the distribution system may enter or leave through the terminal system. Three types of terminal systems can be distinguish namely: Water systems (such as concrete core activation, radiant panel heating, chilled ceilings, chilled beam, flat radiators etc); Air system (such as displacement Ventilations, induction devices, air coolers, air conditioning systems); and Air/Water systems (such as convertors, fan coils).

**SOME EXPLANATIONS:**

**Water Systems:**

Concrete core activation is used as heating or cooling system. In concrete core activation system; the concrete is used as heat storage mass. Flexible pipes will be incorporated in the floors of the building, and circulating water through these tubes will keep even temperature in all rooms of a building. The principle is high Heat in some areas of the building will heat the ceilings and is absorbed and slowly and evenly given off to the whole building by the circulating water. During cooling, cold water will be circulated through the pipe system, the concrete is cooled down and the heat is withdrawn and transported from the rooms.

Radiant Panel Heating is the using of radiant panels for heating the buildings. Radiant heating panels are installed in the floor (for flooring heating), wall (for wall heating) or ceiling (for ceiling heating), and a radiant energy is used to heat the room/building.

Chilled ceiling, Chilled beam: these systems have the same principle. In chilled ceiling panels, panels are installed in the ceiling, so these panels will interact with the surrounding room air to achieve convective effect, thus it will cool down the air in the room. In chilled beams, cold water will flow through the panels so it will collect the heat in the room and dump outside the room. During cold time, the reverse will happen; hot water will dump heat into the room. The water in these chilled beams will be heated/cooled by a separate system outside the room.

**Air Systems:**

Displacement ventilation: is buoyancy driven “displacement” process; fresh ventilation air is introduced at low velocity and at low level and displaces upward by buoyancy effect and thus heat gains and contaminants are ‘displaced’ towards the ceiling.

Induction devices: uses centrally preconditioned supply air and it is conducted through ducts to induction devices. The main purpose of these induction devices is to remove and cool the air from the room and increase cooling output.

Air coolers (Re-circulatory): in this system, air is extracted by fans, cooled in water-operated cooling register, and blown back into the room to re-circulate.

Air Conditioning Systems: in this system, centrally cooled and dehumidified air is supplied into the room.

**Air/Water Systems:**

Convectors: use convective devices to heat/cool the incoming air. A convector heater is a heater which operates by air convection currents circulating through the body of the appliance, and across its heating element. This heats up the air, causing it to rise and being replaced by colder air, and thereby creating natural ventilation, warming the surrounding area. A convection heater may have either an electrical heater element, hot water coil, or steam coil. Because of the natural ventilation, these systems are quieter in operation than fan heaters.

**31.** Which heat transfer mechanism is to be preferred when designing low energy buildings and why? Give an example of a terminal system that relate to this mechanism and adheres to the response of the first part of the question.

Convective heat transfer is preferred when designing low energy buildings. This is because, in low energy buildings, the terminal systems mostly work on water system, air system or a combination of air and water. In these mediums the main heat transfer mechanism is convection. Additionally, the heat sources used in the low energy buildings are usually low energy/temperature intensity, and thus the appropriate heat transfer mechanism for the above mentioned mediums will be convection. Due to this reason, most of the existing terminal systems in low energy building applications are basically working by convective heat transfer mechanisms. To mention as an example; Heating panels (under-floor, wall heating, ceiling heating) mainly by radiation and convective; Flat radiators – mainly by radiation and convection; Chilled ceiling panels –by convective heating/cooling; Chilled beams - by convective heating/cooling; Displacement ventilation – by convective; Induction devices – by convective; Air coolers – by convection; Convectors by convections; Indirect (combined) systems such as Heat pumps – support by convection; and Fan coils – mainly by convection.

1. Related to active systems [1]

**32.** Mention at least five low energy cooling techniques and describe how cooling is provided for.

Night Cooling / Natural Ventilation: in this technique, cooling is mainly achieved by a controlled opening of the different ventilation openings such as windows. It is mainly effective by cooling the building mass during night time, and letting to store the excess heat in the building during day time.

Night Cooling / Mechanical Ventilation: in this technique, the building will be provided with a selection of cooling options such as natural and mechanical night cooling. The building will be cooled depending on the type of features in the building such as wind towers, extracting air from the atrium etc.

Slab Cooling: this cooling technique utilizes the building structure as energy store to absorb the excess heat in the room and often removed by night cooling. Water or air loops can be used as a cooling medium inside the concrete slab. The cooling effect can be assisted by different systems such as mechanical ventilation to provide displacement ventilation through the loops of the cooling system.

Evaporative Cooling:Evaporative cooling can be used either as ‘direct’ in the supply air or "indirect". The principle in evaporative cooling is liquid will be evaporated by excess heat from the building, and thus the building will be cooled down. One application of evaporative cooling is supply air will be cooled by evaporating cold water in a cooling coils. Another application, as in the case of humidifiers, is the supply air can be cooled in air-air heat exchanger by humidifying the return air.

Chilled ceiling/Beams:With this system the temperature is controlled by chilled water supplied to convector coils at ceiling/floor level. This cools down the room temperature.

Ground cooling: ground heat exchangers with duct systems are used to cool down the supply air.

Other Examples:

Displacement ventilation:

Aquifer:

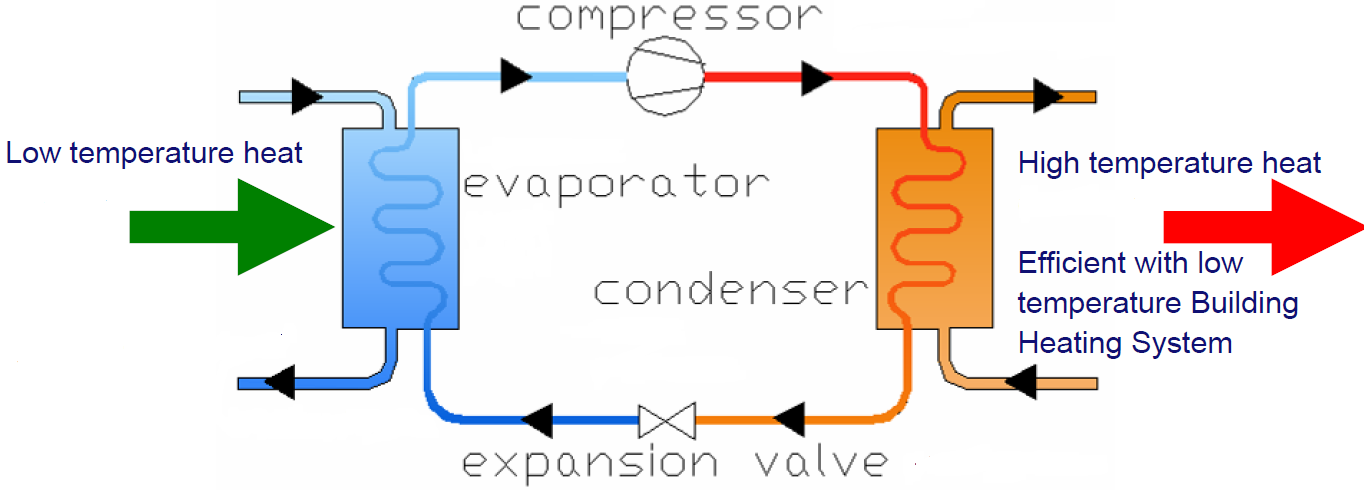
Sea/River/lake water cooling:

**33.** What additional information reveals the exergy concept compared to the energy concept. Where are the biggest gains to be found for the energy concept and for the exergy concept?

Energy is the ability to do some work, and exergy is the quality measure of energy; i.e. measures the usefulness of energy sources (amount of useful energy) relative to an environment. Laws of Thermodynamics are the biggest gains to be found for the energy and exergy concept. These thermodynamics laws are derived on the “observations” of Heat and Work properties of matter and systems.

**34.** Draw a simplified scheme of and describe the heat pump concept. Describe why it forms an important contribution to the use of sustainable active building systems

A heat pump is a device which applies external work to extract an amount of heat QC from a cold reservoir and delivers heat QH to a hot reservoir. Heat energy is absorbed from the low temperature source at the evaporator. Different low temperature/energy sources can be used. These include industrial waste-heat, ground water, outgoing ventilation air, process hot gases/air etc. these low energy sources are absorbed and supplied to interest of application through the condenser. This recovered useful heat can be used for different application such as floor heating, wall heating, air heating, convectors, hot tap water etc.



As shown above, Heat pump is used to recover usually waste heat and this recovered useful heat is used to different applications. Furthermore, the heat pump performance can be enhanced by coupling with different heat energy generation means such as solar collectors and aquifers. Because of this vast application, Heat pump greatly contributes to the use of sustainable active building systems.

**35.** How is the exergetic quality of heat defined? What is the Coefficient of Performance (COP)?

Exergy is the quality measure of energy; i.e. measures the usefulness of energy sources (amount of useful energy) relative to an environment. Heat Pumps are usually characterized by a coefficient of performance which is the number of units of energy delivered to the hot reservoir per unit work input. Mathematically the coefficient of performance is given by; COP = QH/W =Qcondensor/W = (Qcondensor/( Qcondensor Qevap). Interms of temperatures of the low and high temperature reservoirs, the cop is given by 1/[1-( Tevap/ Tcond)].

**36.** What are the main variables influencing the Coefficient of Performance (COP) of a heat pump.

Heat Pumps are usually characterized by a coefficient of performance which is the number of units of energy delivered to the hot reservoir per unit work input. The main variables influencing the cop of a heat pump (refer the above eqn of COP in Q35) are the temperature of the low heat source and high energy sink, i.e on Tevap and Tcond.

**37**. When applying an aquifer, an energy balance is required over a year. Which part (warm or cold source) is generally more difficult to obtain when applying an aquifer for an office building in the Dutch environment. Give an example of how this balance is corrected for.

**38.** An aquifer is one example of thermal energy storage (TES) system. Which three types of TES systems can you mention and give at least four examples of TES systems and indicate for these examples which storage period is normally related to it.

Thermal Energy Storage Systems can be classified into three; sensible storage, latent storage, and chemical storage. In sensible storages, the energy is stored in the form of sensible heat. The most common application of this principle includes aquifers, ground/soil, and reservoirs. In latent storages, the energy is stored in the form of latent energy in which energy is stored and extracted by phase change of the medium such as melting heat, crystallization heat. The most common application in this principle includes water, organic and inorganic PCMs, such as paraffines and polymers. In chemical storage, energy is stored in the form of chemical bond (reaction enthalpy).

Example of Thermal Energy Storage System: water tank (usually used as seasonal storages), Duct stores (usually used as seasonal storages), pit stores (usually used as seasonal storages) and aquifers (usually used as seasonal storages, but also applicable for daily storage).

**39.** What is a CSP system and give an explanation as to how it works?

CSP systems are used to produce heat or electricity. CSP systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The concentrated light is then used as heat or as a heat source for a conventional power plant. The most developed technologies in CSP are the solar trough, parabolic dish and solar power tower. Each concentration method is capable of producing steam at high temperatures and this steam is be used as a heat source or in steam turbines to produce electricity.