(Lecture #3)

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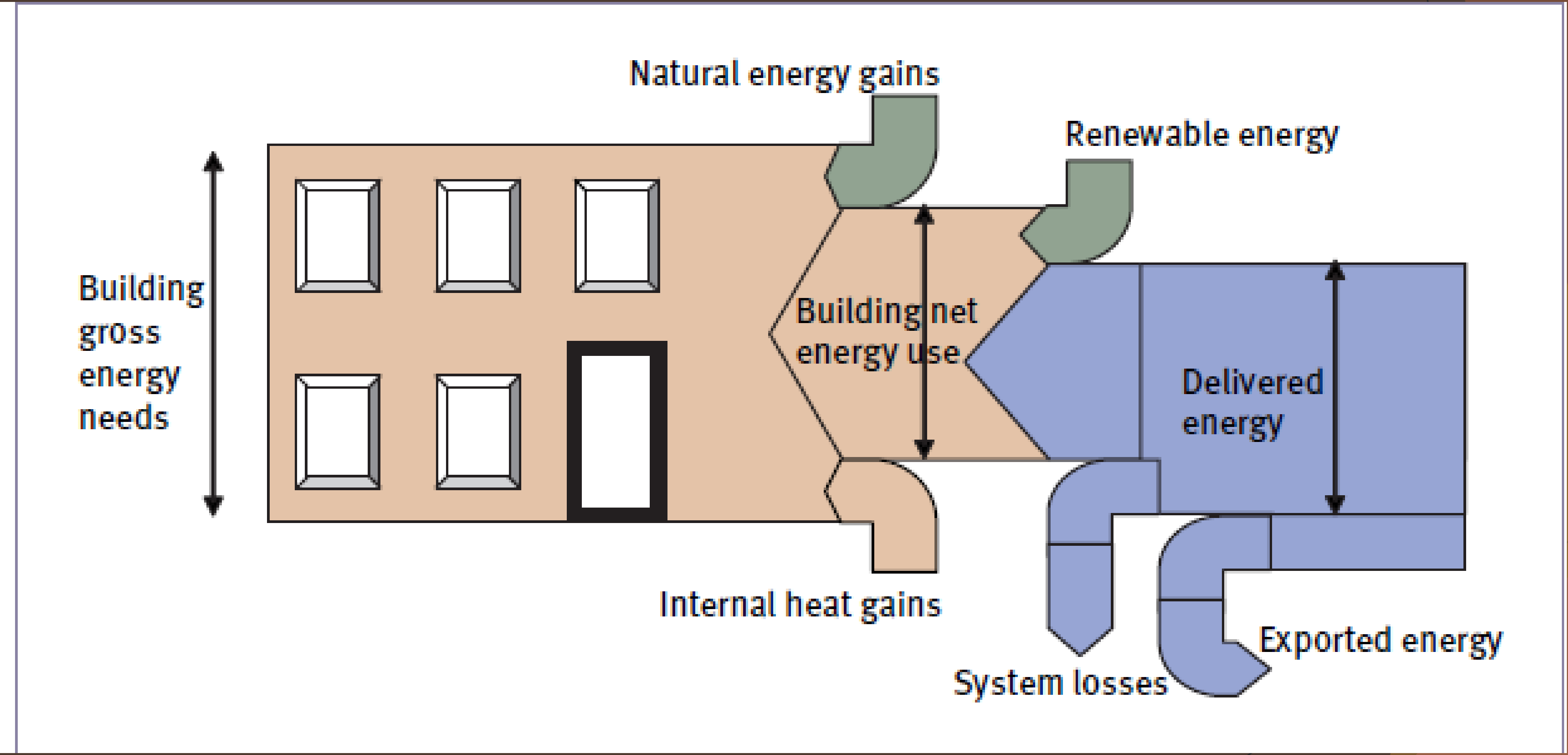
ENERGY EFFICIENCY IN BUILDINGS METHODOLOGY

1. Typical energy flow in buildings
2. Determining a building’s energy performance
3. Benchmarks
4. Certifying energy efficiency

1. Typical energy flow in buildings



- Figure above illustrates the typical energy flows in a building. The building gross energy needs represent the anticipated buildings requirements for heating, lighting, cooling, ventilation, air conditioning and humidification.
- The indoor climate requirements, outdoor climatic conditions and the building properties (surface/transmission heat transfer and heat transfer due to air leakage) are the parameters used for determining what the gross energy needs of the building will be.

- As illustrated in the diagram above, delivered energy, natural energy gains and internal heat gains all contribute to providing the energy needs of a building.

Natural energy gains

- These include passive solar heating, passive cooling, natural ventilation flow, and daylight. Intelligent maximization of natural energy gains can result in significant reduction of delivered energy required to meet a building’s energy needs.
- Environmentally smart buildings make intelligent use of energy resources, while minimizing waste.

- Natural energy gains can be maximized by exploiting the potential contribution to a building’s performance offered by the site and its surroundings through:
- A building plan which places functions in locations that minimize the need for applied energy;
- A shape which encourages the use of daylight and natural ventilation, and reduces heat losses;

- An orientation that takes account of the potential benefits from solar gains while reducing the risk of glare and overheating;
- Effective use of natural daylight combined with the avoidance of glare and unwanted solar gains;
- Natural ventilation wherever practical and appropriate, with mechanical ventilation and/or air conditioning used only to the extent they are actually required;

- Good levels of thermal insulation and prevention of unwanted air infiltration through the building envelope;
- Intrinsically efficient and well-controlled building services, well-matched to the building fabric and to the expected use.

Internal heat gain

- Internal heat is the thermal energy from people, lighting and appliances that give off heat to the indoor environment. Whereas this is desirable in cold weather as it reduces the energy requirements for heating, in hot weather it increases the energy required for cooling.
- In office buildings, commercial stores, shopping centres, entertainment halls etc., much of the overheating problem during the summer can be caused by heat produced by equipment or by a high level of artificial lighting.
- When there are a large number of occupants or clients their metabolic heat can also add to the problem.

Delivered energy

This is the amount of energy supplied to meet a building's net energy demand i.e. to provide energy for heating, cooling, ventilation, hot water and lighting. It is usually expressed in kilowatt hours (kWh) and the main energy carriers are electricity and fuel, i.e. gas, oil or biomass for boilers. As seen from figure III, the delivered energy could be supplemented by on-site renewable energy, this could be in the form of solar PV, solar water heaters or wind.

Exported energy

This is the fraction of delivered energy that, where applicable, is sold to external users.

System losses

System losses result from the inefficiencies in transporting and converting the delivered energy, i.e. of the 100 per cent delivered energy, only 90 per cent may be used to provide the actual services, e.g. lighting, cooling or ventilation, due to the inefficiency of the equipment used.

When addressing the energy efficiency issue in buildings the main focus is on the energy used to attain the required indoor climate standards.

The amount of energy a building will be required to purchase to attain this is dependent on the properties of the building:

- The level of heat transfer: the lower the heat transfer the lower the heat loss during cold weather and heat gain during warm weather. This will reduce the energy requirements for heating or cooling;

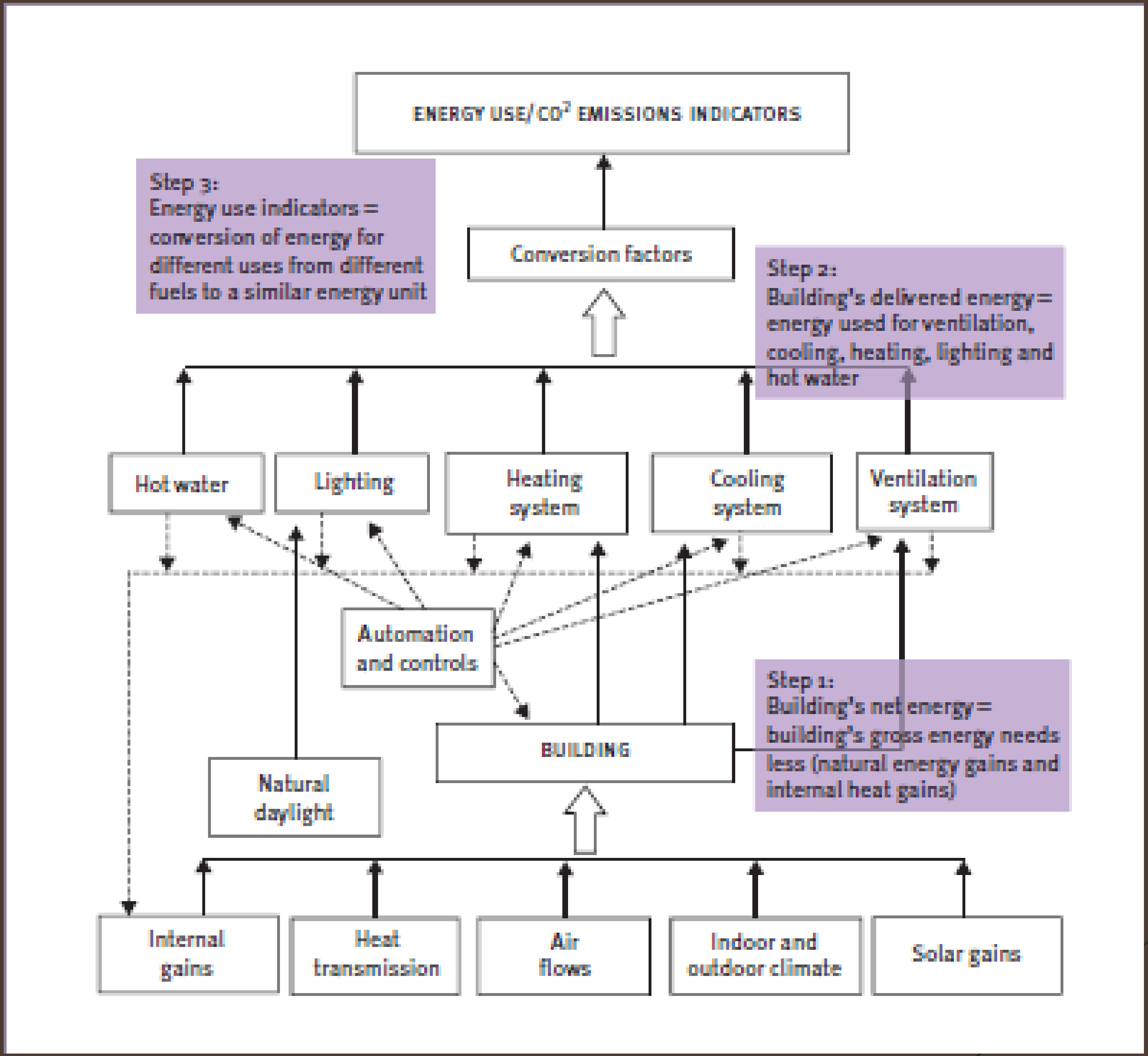
- Whether the building is designed to minimize the need for applied energy depending on the outdoor climatic conditions.

How efficiently the delivered energy is used to meet the building’s net energy demand i.e. the efficiency of the equipment and appliances used;

How efficiently energy is used by people in the building;

The percentage of the building’s energy requirement that is supplied by renewable energy.

2. Determining a building’s energy performance


ENERGY USE/ CO2 EMISSIONS INDICATORS
Step 3:
Energy use indicators = conversion of energy for different uses from different fuels to a similar energy unit
Conversion factors
Step 2:
Building's delivered energy = energy used for ventilation, cooling, heating, lighting and hot water
Hot water
Lighting
Heating system
Cooling system
Ventilation system
Automation and controls
Step 1:
Building's net energy = building's gross energy needs less (natural energy gains and internal heat gains)
BUILDING
Natural daylight
Internal gains
Heat transmission
Air flows
Indoor and outdoor climate
Solar gains

- The calculation of energy use in buildings is based on the characteristics of the building and its installed equipment. It is structured in three levels as illustrated below and the calculation is performed from the bottom up.
- Step One is the calculation of the building's net energy requirements, i.e. the amount of energy required to provide the indoor climate requirements9 as specified by the building code. The calculation is used to determine the net energy required based on the outdoor climate and indoor climate requirements while considering the contributions from internal gains, solar gains and natural lighting and losses due to building properties, i.e. heat transmission and airflows (air infiltration and exfiltration). This calculation is used to determine the intrinsic energy performance of the building.

Step Two is the determination of the building's delivered energy, i.e. the energy performance of the building in actual use. This is the amount of energy used for heating, cooling, hot water, lighting, ventilation systems, inclusive of controls and building automation, and includes the auxiliary energy needed for fans, pumps, etc. Energy used for different purposes and by different fuels is recorded.

Step Three is the determination of the overall energy performance indicators:
It combines the results from Step 2 above for different purposes and from different fuels to obtain the overall energy use and associated performance indicators. Since a building can use more than one fuel (e.g. gas and electricity), the different energy sources have to be converted and combined in terms of primary energy to provide the optional end result of the calculation of energy performance. Commonly used energy indicators for buildings are kWh/m2 (energy consumption in kilowatt hours per metre square of floor area) or CO2 emissions.

- For purposes of this calculation, buildings are classified into categories depending on whether they are residential or non-residential, the type of building design and the building size and use. In addition to calculating the performance of existing buildings, energy performance calculations are also undertaken at the design stage for new buildings and refurbished buildings to simulate their energy performance.
- It is the government’s responsibility to provide, at national or local level, calculation guidelines and methodologies for determining energy performance. In most instances, software is developed for these calculations.

3. Benchmarks

- Building energy consumption benchmarks are representative values for common building types against which a building’s actual performance can be compared.
- The two main purposes of benchmarks are:
- To identify if a building’s energy performance is good, average or poor with respect to other buildings of its type;
- To identify potential savings, shown by the variance between the actual data and the benchmarks: the worse the performance against a benchmark, the greater the opportunity for improving performance, and making cost savings.

- Benchmarks can be categorized into two types—modeled benchmarks and empirical benchmarks.
- Modeled benchmarks are obtained by using a simulation model to determine the performance of a building, usually at the design or refurbishment stage. The model calculates the delivered energy needed based on the use of the building, the indoor environment, the external climate and the properties of the building.

- Empirical benchmarks are obtained from statistical data from detailed studies of 20-100 buildings per sector. The minimum information required for benchmarking is how much energy has been used over the last year, which is best obtained from meter readings and energy bills and the floor area. Ideally the studies involve energy audits and in some cases sub-metering (metering the different energy end uses individually), but in most cases only bulk data on the building's energy use is collected. This data sets the good practice and typical standards for each energy use in the building.

4. Certifying energy efficiency

- An energy efficiency certificate is a summary of the building energy audit. It is meant to give information on the building's energy consumption and its energy efficiency rating.
- The purpose of energy efficiency certificates is to:

Inform tenants and prospective buyers of the expected running costs;

Create public awareness;

Act as a prerequisite of measures to improve its energy efficiency;

To effect incentives, penalties or legal proceedings.

- **Inform tenants and prospective buyers of the expected running costs** - With buyers and prospective tenants better informed, builders and landlords will have greater incentive to incorporate energy-efficient technologies and designs into their buildings, in return for lower running costs.
- **Create public awareness** - In large buildings, regularly visited by the public, display of energy performance certificates will raise awareness among citizens of the issue of energy efficiency in their local community.

- **Act as a prerequisite of measures to improve its energy efficiency** – In the final analysis, knowledge of a building’s energy efficiency is also the prerequisite of measures to improve its energy efficiency. The energy efficiency certificate is therefore essentially accompanied by modernization recommendations for lowcost.
- **To affect incentives, penalties or legal proceedings** – Any effects of these certificates in terms of incentives, penalties or any form of legal proceedings are subject to national legislation. Some countries, e.g. Bulgaria, offer 5-10 year exemptions on building tax to buildings that have high-energy efficiency ratings.t improvement of the building’s energy efficiency.

- What information should be displayed on energy performance certificates, and how that information should be interpreted is a key issue. In order to facilitate comparisons between buildings, the energy performance certificate should include reference values such as current legal standards and benchmarks and recommendations for cost effective investments which can be undertaken in the building to improve its energy performance.

- The empirical and modeled benchmarks mentioned above are used to indicate how a particular building compares to the rest of the stock. These benchmarks are used for two ratings normally displayed on the energy performance certificates-the asset rating and the operational rating.

- Modeled benchmarks are typically used to rate the intrinsic performance potential of the building and contribute to the building's **asset rating**. This is a rating of the standard of the building fabric and building services equipment and is based on theoretical values.

- Empirical benchmarks are typically used to rate the in-use performance of the building—the **operational rating**. This will be influenced by the quality of the building (as measured by the asset rating), but also by the way the building is maintained and operated. The operational rating is based on actual metered energy consumption, normalized in some way to account for the effects of building size, pattern of use, weather, etc.

- To supplement certification, in some European countries regular inspection of heating and air-conditioning systems to assess their efficiency and sizing compared to the heating and cooling requirements is carried out.

Figure V. **Illustration of a possible format for a non-domestic building energy certificate, proposed by the Europrosper project[a]**