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CO-EMEP – Improvement of cooperation for better energy management and reduction of energy poverty in HU-HR cross-border area

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Analysis of available technical solutions for enhancing energy efficiency in the cross-border area

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1. Introduction

European Union (EU) Member States are adopting and implementing policies aimed at reducing CO_2 emissions into the atmosphere. Some of these policies will deal with large system changes as Europe is switching from a dependence on fossil fuels to the use of other sources of energy. Other policies will encourage changes in everyday behaviour among Europe's citizens as they adjust to a more sustainable way of life.

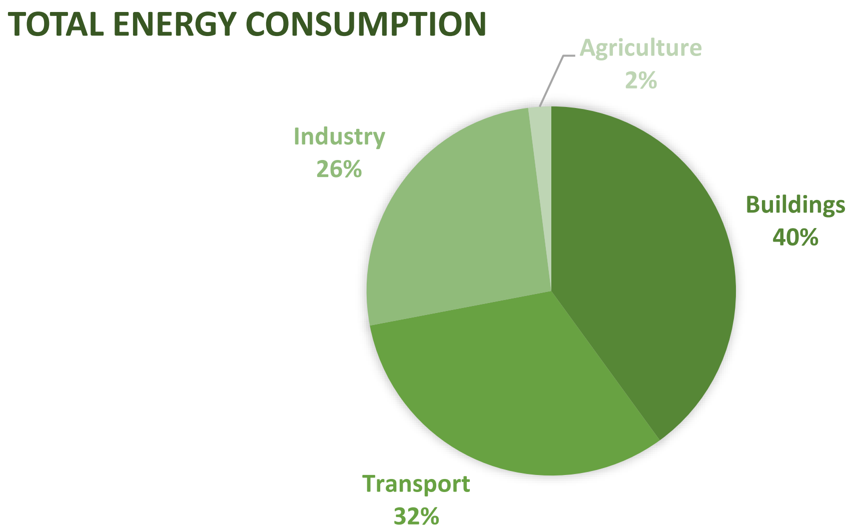


Figure 1.1 Total energy consumption by sectors

At EU level, around two thirds of the consumption of buildings is for residential buildings. Most countries started pursuing energy efficiency policies and measures after the second oil crisis in the seventies. The focus was mainly on heating of (existing) dwellings. In some countries more efficient supply was sought after by developing district heating. Only in the nineties, energy efficiency policies for buildings and energy using goods (e.g. minimum performance standards and energy labelling) were introduced at EU level. Step by step the coverage and strength of EU policy has increased, e.g., through car standards (transport), the Emission Trading System (industry and energy production) and energy performance requirements for buildings (households and tertiary). More recently, the EU has started to require that countries meet certain targets for energy efficiency, and set up comprehensive overall policy packages. This is requiring significant implementing effort from the Member States (MS) reflected by the fact that purely national new measures, not driven by EU policy, are emerging at somewhat slower pace.

Energy behaviour is either investment or habitual behaviour. The former typically involves the adoption of a new technologies, perhaps the purchase of a new appliances. Habitual behaviour is routine behaviour such as turning off the lights when leaving a room. Changes in this consumer behaviour can lead to important savings in energy use.

A reduction of energy consumption in buildings can therefore only be achieved by substantial energy savings in existing buildings. There is huge potential. If building owners make sensible and financially worthwhile energy improvements when they are carrying out renovations anyway, energy consumption can be substantially reduced. This strategy therefore focuses on reducing energy consumption in existing buildings by way of extensive energy renovations. The energy savings can be achieved best and most cost-effectively when the work is done at the same time as the general building renovation. It may for example be combined with replacing the roof or windows or renovating outside walls or floors. The energy savings therefore have to be viewed in conjunction with the ongoing need for renovation work to preserve the value of the buildings. Energy renovations also help to increase the utility value and quality of buildings, as they can improve the indoor climate and daylight conditions, making the buildings healthier and better to live and work in. Energy renovations also need to take account of the architectural value of the buildings. In many cases, energy renovations will actually mean an architectural improvement to the buildings. Energy renovation plans also need to take in account the environmental objectives for reuse and sustainability in the building industry.

Energy renovation of existing buildings has generally positive effects for the individual building owner and user, and also for society:

- **Energy renovation means a reduction in future energy bills** – there will be some initial costs associated with the renovation, but energy renovation can subsequently create a more robust financial position for the building owner and may increase the resale value of the building;
- **Improving the financial position of building owners** can also have positive benefits for society;
- A properly implemented energy renovation creates a **better indoor climate and greater comfort**, which can improve the wellbeing of users and the use of the buildings;
- Energy renovation can also give the buildings an **architectural lift**. It is important for energy renovation work to be organised in such a way that all these considerations are satisfied.

Major renovations of buildings are not normally carried out just to reduce energy consumption. The reason for a building owner's deciding to renovate may, for example, be that parts of the building are worn out or that the owner wants to adapt the building to meet future needs. These may include a change in the size of the family, or the desire for a more practical home or for a better indoor climate. But every time a modification or change is made to the building, there is an opportunity for cost-effective energy renovations to be carried out. For example, it may be possible to install new energy-efficient windows which reduce energy consumption in the building and provide greater comfort, when the existing windows are worn out and need to be replaced. Many building components have long lives, and a number of the components that have a major bearing on energy consumption will only be renovated once between now and 2050. If we do not take the opportunity for energy renovation, it will be many years before it comes around again, so it is important to start acting now.

Secondly, the strategy should ensure that ‘deep’ energy renovations are carried out with future-proof, energy-efficient and cost-effective solutions, so energy consumption is significantly reduced. If only ‘partial solutions’ are implemented, e.g., limited insulation of roofs or walls, it will be very expensive and perhaps technically impossible to realise the full energy-saving potential at a later date. The renovations must not only focus on reducing energy consumption. They should also be sustainable in the broad sense. Among other things, this means that they must also take into account of other environmental effects and other resource consumption. This may then affect the choice of building materials. It is also absolutely crucial to ensure that the renovations enhance the functionality of the buildings. The indoor climate is a key element here, but there are a number of other factors that have a major bearing on the quality of the buildings.

Thirdly, the strategy should help to ensure that when energy renovations are carried out, heating systems are converted to be based on renewable energy. The conversion of heating supplies to renewable energy is often best done alongside the general energy renovation of buildings, just as it is important that any conversion is accompanied by an energy renovation. This is especially important when converting to heat pumps and other forms of renewable energy systems, which work best with low flow temperatures and airtight buildings. Finally, the strategy should ensure that energy renovations are carried out cost-effectively, so the goal of independence from fossil fuels is achieved at the least possible expense. The investments should be viewed in relation to the long-term reduction in heating costs. At the same time, the other benefits in the form of better living quality and improved indoor climate should also be considered. In this connection it is absolutely crucial for the strategy to ensure that energy renovations are carried out in a way that provides for a good indoor climate.

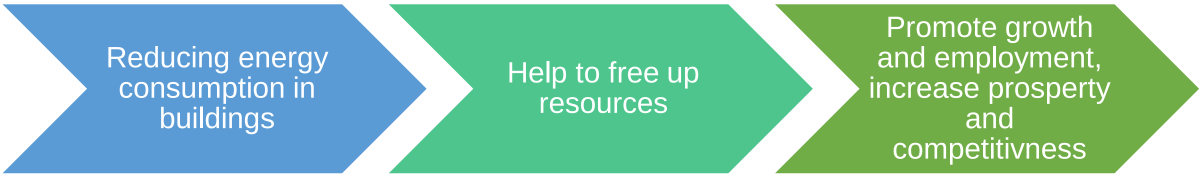


Figure 1.2 The benefits of energy renovation of buildings

2. Available technical solutions for enhancing energy efficiency in cross-border area

The objective from the thermal point of view is to keep the user in comfort conditions (around 21ºC in winter and 25ºC in summer, with relative humidity in both cases of 50%) with the lowest possible energy consumption. For this the building faces the external conditions of each locality by two means:

- **Passive systems –** understood as those that do not require the consumption of energy to act. They are based on a correct architectural design and the use of suitable materials for each function. We can divide them into:

  • **Thermal envelope of the building –** enclosures with the exterior, terrain or unheated spaces, such as facades, roofs, floors, etc.;

  • **Ventilation systems –** responsible for maintaining the sanitary conditions inside the building;

  • **Orientation and solar capture –** the way in which the building uses or protects itself from solar radiation according to the climate and time of year.

- **Active systems –** although the desirable thing would be that a building does not require the consumption of energy to maintain its comfort conditions, in most cases the reality forces the necessity to provide equipment, such as boilers or cooling systems, to complement the measures Passive insulation and control of ventilation with the generation of heat or cold when necessary.

2.1. Technical solutions for enhancing energy efficiency of thermal protection of building envelope

Thermal insulation of the outer wall, as a rule, should be performed by adding a new thermal insulation layer on the outside of the wall, and exceptionally on the inside wall. The design of thermal insulation on the inside of the wall is unfavourable on construction-physical standpoint and is often more expensive due to the need for additional solving the problem of water vapor diffusion, safety requirements against fire, loss of useful space, etc.

Installation of thermal insulation on the inside of the wall is physically worse, because although it results in achieved improvement insulation values of the wall, it significantly changes the heat flux in the wall so the base of the load-bearing wall becomes colder. Therefore, special attention should be paid to performance steam dams to avoid condensation and mold. Also, part of the partitions that connect to the outside should be thermally insulated. Rehabilitation of the existing outer wall by performing insulation on the inside is performed exceptionally in protected buildings, when the changes in the exterior of the building of historical value should be avoided. When making a thermal insulation layer on the outside of the wall, there are two possible finishing solutions that protect the thermal insulation layer and the rest of the wall from the outside atmospheric influences:

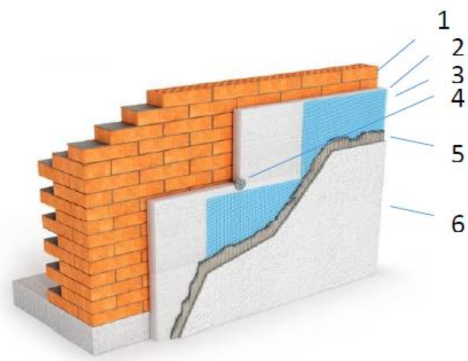
- first solution is characterized by the performance of the external protective layer by full surface gluing to the thermal insulation layer (so-called compact facade);
- in second solution the protective layer is in the form of individual elements fastened to the appropriate substructure so that between the protective lining and the layer of

thermal insulation remains a layer of air that is ventilated to the outside (so-called. ventilated facade).

The effective thermal insulation layer ends with a layer for ventilation through which air should circulate and dry the moisture. Depending on the type of plaster, compact facades can be thin-layer and thick-layer. Thermal insulation material is glued to the substrate (compact wall) with polymer cement glued or mounted with mechanical fasteners. Slabs or slats are placed with a horizontal offset from the previous row, and the corners and the openings need to be carefully treated as well as the entire outer surface so to apply polymer-cement adhesive and imprint textile-glass mesh (alkali resistant). It is smoothed again with polymer-cement glue. After drying, an impregnating coating is applied to even out the absorbency surfaces. As a final layer for a thin-layer system, silicate, silicone, silicone-silicate or an acrylic top coat with a minimum grain thickness of 1.5 mm in 2 coats should be placed. The thick-layer system uses 15 mm thick mineral plaster and final decorative layer up to 5 mm thick. It is necessary to apply a cement syringe as a bonding layer between thermal insulation material and light mineral plaster.

Figure 2.1 The value of heat transfer reduction after applaying 10 to 12 cm of thermal insulation

The building materials industry offers many variants of the complete systems of these two methods of thermal insulation of walls, where, for both solutions, the thickness of the thermal insulation layer should not be less than 10 to 12 cm, which would be the value the heat transfer coefficient of U decreased to from about 0.25 to 0.35 W / m^{2}K.



Key elements of the proposed technology

1. Existing concrete wall
2. Adhesive composition
3. Insulation plate
4. Fixing plug
5. Reinforcing fiberglass mesh is applied to the adhesive composition
6. Outer protective and decorative coating with preliminary primer layer

Figure 2.2 Principle for exterior wall insulation[1]

In the case of an uninsulated hollow brick wall 19 cm thick, U = 1.67 [W/m^{2}K], heat losses are approximately 134 kWh/m^2 of wall. In the case of insulation of a 19 cm brick wall with 10 cm of stone wool, U = 0.32 [W/m^{2}K], heat losses are approximately 26 kWh/m^2 of wall. In the case of an uninsulated hollow brick wall 19 cm thick, U = 1.67 [W/m^{2}K], heat losses are approximately 134 kWh/m^2 of wall. In the case of insulation of a 19 cm brick wall with 10 cm of stone wool, U = 0.32 [W/m^{2}K], heat losses are approximately 26 kWh/m^2 of wall.

[1] Source: https://unece.org/fileadmin/DAM/energy/se/pdfs/geee/study/Final_Master_file_-_March_11_final_submission.pdf

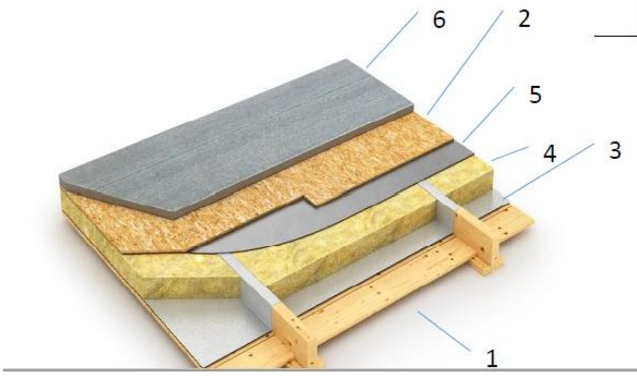
Some of insulation materials are fiberglass, rock wool, slag wool, expanded polystyrene (frothed non-pressed) and extruded polystyrene. The characteristics of each of the materials are described in table below.

Table 2.1 The characteristics of the thermal insulation materials

Material	Characteristic	Advantages	Disadvantages	Restrictions
Fiberglass	Initial raw materials for production of fiberglass are: sand, soda, limestone, drill (or etibor), cullet. Heat conductivity - 0.038-0.046 W/mK. Max operational temperature - 450 °C. Min. operational temperature -60 °C.	• Lightness • Elasticity • Good sound-proofing properties; • Non-flammable • High compression for easy transport	• High fragility of fibres • High water absorption	It is necessary to use the coveralls made of a dense material, gloves, respirator, and safety glasses during installation.
Rock wool	The main raw materials for production of stone (basalt) cotton wool are rocks. Heat conductivity – 0.035 — 0.042 W/mK. Max operational temperature – up to 1000 °C (only in case of lack of deformation).	• Non-flammable • High elasticity • Immunity to mould and fungus • Resistance to short-term influence of moisture – can be mounted during rain • Fibres are not caustic	• Low compression of material; inconvenient for transport • High cost	Requires careful transport and protection against mechanical influences.
Slag wool	Initial material for production of slag cotton wool are domain slags. Heat conductivity – 0.04 – 0.07 W/mK. Max operational temperature - 300 °C.	• Low water absorption – is ideal for work under the open sky in any weather	• High fragility of fibres • Low indicators of heat conductivity	Not recommended to use together with metallic facade elements.
Expanded polystyrene (Frothed non-pressed)	Expanded polystyrene (or polyfoam) stands for the foam plastic which consists for 98 percent air. Heat conductivity – 0.036 – 0.050 W/mK Max operational temperature - +70 °C. Min operational temperature - 50 °C.	• Low price • Excellent flexibility • High durability on compression at the low density • Simplicity of installation	• Flammability • High water absorption • Repeated transition of temperature through 0ºC leads to destruction	Prohibited to use without covering – requires cement and sand or plaster protection from the open environment.
Extruded polystyrene	Extruded expanded polystyrene consists of granules of polystyrene formed by an extrusion method. Heat conductivity - 0.028 -0.034W/mK Max operational temperature - +75 °C. Min operational temperature - 50 °C.	• High durability on compression at the low density • Low water absorption • Low vapor permeability • Low coefficient of heat conductivity	• Combustible material6 • High cost	Prohibited to use without covering – requires cement and sand or plaster protection from the open environment.

Although the share of the roof is represented only about 10-20% in the total thermal losses in the house, the roof plays a particularly important role in quality and standard housing. It protects the house from rain, snow, cold and heat. The most common form the roof on family and smaller residential buildings is a **sloping roof**. Very often the space under the sloping roof is intended for housing, although it is not adequate thermally insulated. In such situations, large heat losses occur in winter, but also an even bigger problem of overheating in summer. If the roof is not thermally insulated, approximately 30% of the heat can pass through it. Subsequent thermal insulation of the roof is simple and economically very profitable, because the return of investment period is from 1 to 5 years. Non-flammable should be used for thermal insulation of pitched roofs and vapor-permeable thermal insulation materials, such as rock wool. The detail of the connection of the thermal insulation of the outer wall and the roof should be solved without **thermal bridges**. If the space under the sloping roof is not heated, or not intended for housing, thermal insulation should be placed on the ceiling of the last floor to the unheated attic. The recommended thickness of thermal insulation on a pitched roof is at least 16 to 20 cm. The insulation should be laid in two layers; one layer between the horns, and one layer under the horns to prevent thermal bridges. Thermal insulation with the lower sides are usually closed with drywall boards or wood. Flat roofs are the most exposed to the weather than any exterior elements of the building. That is why it is important to insulate them well with both thermal insulation and waterproofing.

Ground floor constructions differ from unheated floor constructions space along the load-bearing concrete base and waterproofing. Heat losses according to terrain account for up to 10% of total heat losses. In new buildings, the floor in the field should be thermally insulated with as much thicker layer of thermal insulation as possible, while for existing buildings, such measure is generally economically unprofitable, due to major construction projects that accompany it. However, economically very profitable measures are thermal insulation of the ceiling structure towards the unheated attic, and floor constructions towards the unheated basement. Also, it needs heat protect floor constructions above open passages. For the thermal setup code insulation, it is important to thermally insulate the entire outer shell without breaking the insulation, to minimize the impact of thermal bridges. The floor on the ground must be insulated with a minimum of 10 cm of thermal insulation. Although the losses through the floor to ground are relatively small compared to losses of other parts structures, the floor surface temperature is similar to the interior temperature in the rooms where it is much more comfortable to stay. To avoid thermal bridges and avoid unnecessary heat losses, it is necessary to insulate the entire outer shell of the building, including parts of the structure according to unheated spaces or spaces with different usage regimes. It is recommended to insulate them thermally with a minimum of 10 cm of stone wool or polystyrene. Finishing can be plastering or coating with drywall if it is about the interior space.



Key elements of the proposed technology

1. Existing attic floor
2. Plywood smoothing sheet
3. Air barrier (vapor control layer in some assemblies)
4. Insulation plate
5. Hydroisolation
6. Final floor coating

Figure 2.3 Principle for insulation of the attic floor[2]

The window is the most dynamic part of the building's exterior, which operates at the same time as a receiver that lets solar energy into the space and as protection from external influences and heat losses. Losses through windows are divided into **transmission losses** and **losses by ventilation**. If add the transmission heat losses through the windows and the losses by ventilation, total heat losses through windows represent more than 50% of heat building losses. Losses through windows are usually ten or more times greater than those through the walls, so it is clear how important the energy efficiency of windows plays in the

[2] Source: https://unece.org/fileadmin/DAM/energy/se/pdfs/geee/study/Final_Master_file_-_March_11_final_submission.pdf

total energy needs of buildings. In accordance with the technical regulation, the heat transfer coefficient for windows and balcony doors can amount to a maximum of U = 1.80 W/m^2K. While on old buildings the window coefficient ranges around 3.00-3.50 W/m^2K and more (heat losses through such a window amount to an average of 240-280 kWh/m^2 per year), European legislation prescribes lower and lower values and today they are most often in the range from 1.40 to 1.80 W/m^2K. On modern low-energy and passive houses this coefficient ranges between 0.80-1.40 W/m^2K. Recommendation for building a modern energy efficient building is to use windows with a coefficient $U < 1.40$ W/m^2K. Glass and window profiles participate in the total heat loss of windows. Window profiles, regardless of the type of material from which they are made, must provide good sealing, broken thermal bridge in profile, easy opening and low heat transfer coefficient.

Today, window glass is made as insulating glass, two-layer or three-layer, with different gaseous fillings or coatings which improve thermal characteristics. Different window frame materials are used: wood, steel, aluminum, PVC and a combination of materials: wood and aluminum, and the cavities of the frame can be filled thermal insulation. The type of frame material depends on the thickness of the frame and the possibility installation of thermal and sound quality glass. Thickness of windows frames are from 68 to 93 mm for PVC and wood, while larger ones are possible with aluminium thickness. It is necessary to ensure the sealing of the glass and the window frame itself and the window frame frames and window sills - triple (or five times, depending on the number of windows) sealing as protection against wind and rain so that moisture does not enter from the outside. The connection between the window and the wall must be made airtight.

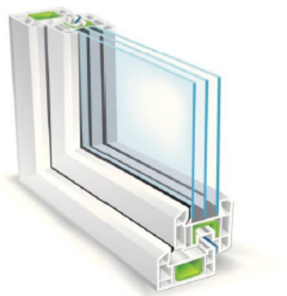
Wooden profile	Aluminium profile	PVC profile
		
Wooden windows made usually of oak, pine, ash tree or larch. Advantages: • Attractiveness • Good thermal insulation and frost resistance • Sound insulation • Possibility of changing colour either outside or inside Disadvantages: • Combustibility and hygroscopicity • Ongoing maintenance or finishing required	Aluminium windows are divided into two types: light and warm aluminium. Windows made of **light aluminium** are suitable for buildings which do not require significant sound and heat isolation. **Warm aluminium windows** consist of two parts: external – cold, and internal – warm, which are produced separately and later merged directly on the building. Advantages: • Lightness • Durability • Resistance to weather conditions • Possibility to customize the configuration and complexity of the window Disadvantages: • Susceptibility to electrochemical corrosion • High thermal conductivity of the aluminium – requires thermally broken frames to achieve high performance	These windows are made of polyvinylchloride (PVC). Advantages: • Good thermal insulation • Excellent sound insulation • Resistance to various atmospheric actions • Simple operation and maintenance Disadvantages: • Mechanical damages of a plastic window cannot be corrected

Figure 2.4 Energy efficient window profiles[3]

[3] Source: https://unece.org/fileadmin/DAM/energy/se/pdfs/geee/study/Final_Master_file_-_March_11_final_submission.pdf

2.2. Technical solutions for enhancing energy efficiency of heating and DHW preparation systems

Looking through history, local heating is known from time immemorial. The oldest local heating includes the usage of open fireplace which was burned with wood and at the same time served for heating and preparing food. Bad side in using fireplaces was the appearance of smoke. Usage of charcoal burned in metal furnaces has been known since Roman times. Charcoal burns without appearance of smoke. In the 10th century, the first closed fireplaces appeared in Europe which include fireboxes with smoke extraction through the chimney. These were originally clay stoves that were in the early 14th century replaced by tiled stoves which were constantly improved during the years. Hypocritic heating in Roman times is known as the first central room heating. The firebox was located under the house, and the fuel (wood or charcoal) was burned in a firebox without a grate. Flue gases are led through hollow bricks or a hollow space under the floor which also ensured heating of the floor. Only basic working principle of central heating steam, hot water and air used in the 19th century retained to this day.

Basic requirements for heating systems are **room air temperature** (sensory temperature) which must be uniform throughout the space and in the range of 20 °C to 22 °C (± 1 °C) establishing a permanent equilibrium between the body heat generated by metabolic processes and that devoted to the environment. The heating system is required to be able to regulate the temperature in certain limits and with a certain reaction rate and must be designed in a way that does not affect the air quality and comfort conditions in the premises (harmful gases, dust, noise, draft, etc.).

Accommodation of heat sources	By type of fuel	According to the heat carrier	According to the method of heat emission
• single • central • remote	• solid • liquid • gaseous • electricity • sun	• hot water • hot water • steam • air	• convection • radiation and • combination

Figure 2.5 Devison of heating systems

For individual space heating with solid fuel, it is possible to use fireplaces (open and closed), tiled stoves, steel furnaces. For other types of individual space heating, it is possible to use gas stoves, oil furnace and electric space heaters.

Central heating can be carried out by using hot water, hot water steam or air. In heating carried out by hot water, heat carrier is hot water with maximum temperatures up to 110 °C (according to today's standards the flow/return usually is 90/70°C in older system versions, i.e., 80/60 °C in newer versions and 55/40 in low temperature systems). The water is heated in boilers, heaters or/and heat exchangers and leaded through the piping system to radiators or convectors. After heat transfer, the water returns to heat source.

Remote code heating with hot water or steam is brought to the thermal substation in the building where in the heat exchanger the water for heating the object is heated. In heating carried out by air, the heat carrier is the warm air heated in heat exchanger, smoke gases/air or hot water/air and ducts divorces per facility. Efficiency of individual energy conversion devices (furnaces, boilers, heaters) are obtained by measuring according to the appropriate standards. Electric devices have an efficiency of 100%.

Individual room heating such as open fireplaces give off heat mainly by radiation. Their degree of action is about 40% depending on performance. They are fired with wood and have a connection to the chimney. They force range from 3 to 4 kW. Closed fireplaces with chimney connection are performed with air supply for combustion from the room or by taking air from the environment. Depending on the performance, they have efficiency up to 80% and their power ranges between 6 to 15 kW. Closed higher power fireplaces usually have a built-in heat exchanger for preparation domestic hot water or central heating. It is burned with wood or wood briquettes, i.e., brown coal. Burning time with one charge is about 1h at wood burning and about 2 hours for burning coal briquettes. Tiled stoves are characterized by rapid space heating and large accumulation of heat due to the relatively large mass of the furnace. Due to the large areas for rent, the heat creates a pleasant feeling of warm space. The possibility of regulation is poor which affects the occurrence of temperature differences in space. They take up a lot of space and their degree of action ranges between 70 to 85%. They are very favourable as auxiliary heat sources for the transition period. The mean value of heat release depends on the mass of the furnace and usually is expressed in kW/m^2. Electrical space heating devices are devices for direct and indirect heating. With direct heating the el. energy is directly used for heating (electric stoves, heaters, electric radiators and similar), while in indirect heating the heat is accumulated or cranes are used. Advantages of using el. energy lie in simple regulation and cheap installation. One of the newer ways is to use el. energy for underfloor heating. At the cable load is 10 to 25 W/m and the floor surface load is up to 60 W/m^2 for treads or up to 120 W/m^2 for edge zones.

Underfloor heating is one of the oldest methods of heating known since Roman times. It belongs to the group of surface space heating, which also includes ceiling and wall heating.

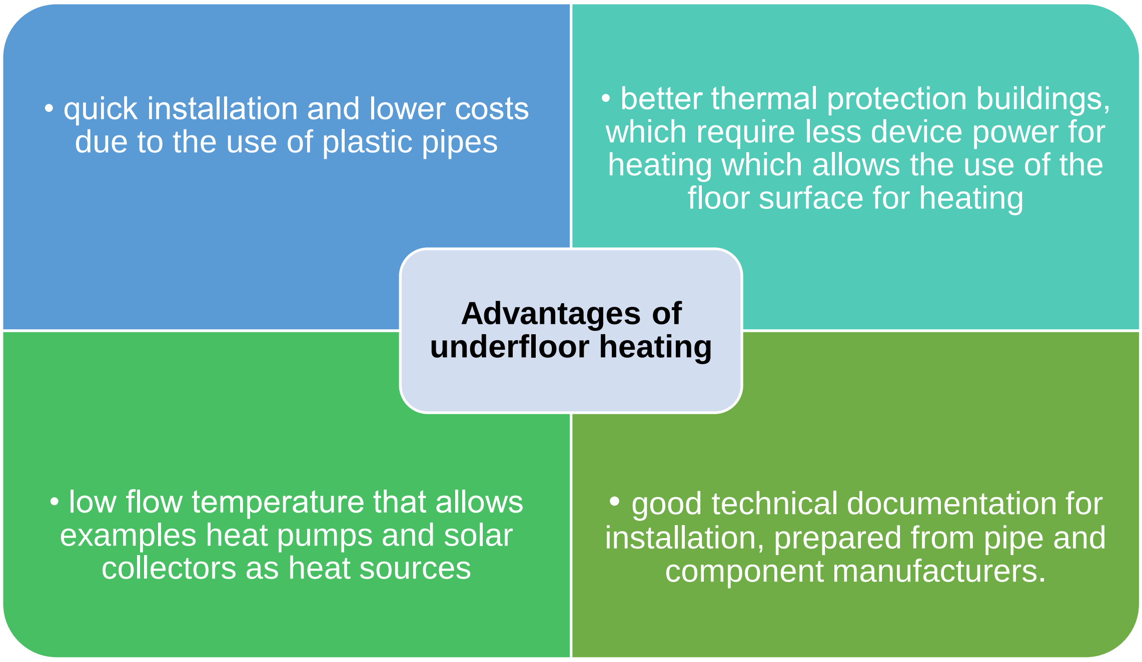


Figure 2.6 Advantages of underfloor heating

Due to the favourable temperature, the profile of the air temperature in the room can be lower by 1 to 2 °C thus saving 6 to 12% energy. The disadvantage is the inertia of the system, which makes it difficult to regulate. It is recommended to use combined underfloor heating with radiator heating where the system is not assembled from the classic radiator by 20 to 40%. Due to medical physiological conditions, the floor surface temperature is limited so the certain values of floor temperature are recommended.

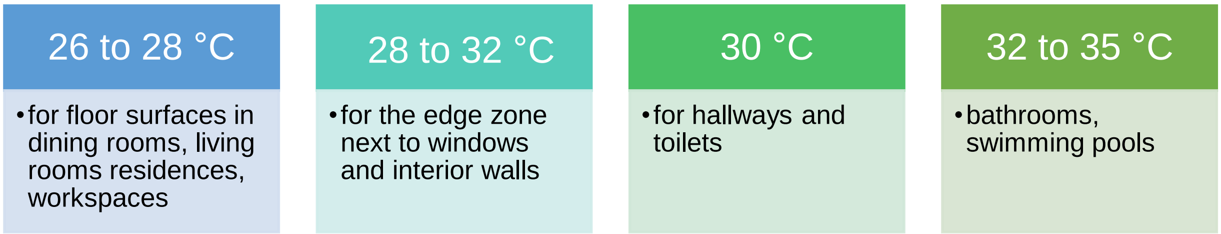


Figure 2.7 Recommended floor temperature values

When choosing the water temperature, it is necessary to take into account the value coefficient of thermal conductivity of the floor surface (parquet, ceramics, warm pods).

The preparation of domestic hot water (DHW) in the average household accounts for approximately 20% of total annual heat consumption energy, while the rest is spent on space heating (~ 73%) and cooking (~ 7%). The average citizen consumes about 200-300 l of water for living needs per day, of which in average 40-70 l accounts for waste water at a temperature of 45 °C which is mainly used for maintaining personal hygiene and washing dishes. In season with no heating, DHW represents individually the largest expenditure for the energy per household, regardless of used energy source. Effective preparation and use of DHW can therefore have a significant impact on reducing overall household energy costs. The choice of hot water preparation method mainly depends on the number of people in the household, consumption and energy selection. Depending on the needs of the household, the following types of devices can be used:

- Instantaneous gas or electric water heater (<2 persons);
- Accumulation gas or electric boiler (<4-5 persons);
- Combined gas boiler for DHW and space heating-flow or accumulative (<4-5 persons);
- Boiler with indirectly heated tank for central heating water preparation (> 4-5 persons);
- Solar collectors with tank (> 3 persons);
- Heat pump (> 3 people).

Water heaters can be divided into electric and gas. Electric water heaters are usually used in bathrooms to prepare water whit quantities up to 12 lit/min (at 45 °C). With newer devices there is a stepwise possibility of regulating power and water temperature. The advantage of such devices is low cost, high efficiency in operation, small heat losses in short pipelines and short heating time. The disadvantages are the relatively large connected power (12-27 kW), and depending on the tariff (1.7-3.2) higher costs of water preparation compared to gas boilers.

Gas boilers use natural or liquefied petroleum gas for heating domestic hot water passing through a tubular heat exchanger in which water takes part of the heat from the hot products of gas combustion (flue gases) on the burner, which are then discharged into the atmosphere. Burner is switched on when the water outlet (tap) is opened and switched off when it is closed. The largest flow capacity of the boiler is up to 11 l/min of water at a temperature of 45 °C with corresponding power of 26 kW. Gas instantaneous water heaters are characterized by high efficiency (~ 90%), low operating costs, the possibility of regulating the burner power, i.e., water flow and temperature. The disadvantages include the need for installation of chimney (or drain to the facade), more frequent burning of the burner compared to storage boilers and greater temperature variation in the immediate period after igniting the burner. Major problems in operation arise due to deposition limescale in the pipes which causes poorer heat dissipation, while the exchanger tube also burns due to limescale deposition. Precipitation limescale is especially pronounced when working with unnecessarily highly set water temperatures > 55 °C.

Electric storage water heaters are used in kitchens with power up to 5-10 l and in bathrooms (volume 50-120 l). The power of heater in the storage boilers is significantly lower than in instantaneous water heaters and amount to 1.5-2.6 kW, with a warm-up time between 10 min and 3 hours depending on tank size and heater power. Compared to instantaneous water heaters, hot water is more uniform in storage water heaters and is available in a shorter time intervals after opening faucets. The additional advantage over electric instantaneous water heaters lies in the ability to heat water in periods of lower tariffs using time regulators. The disadvantages of storage water heaters are manifested in lower work efficiency due to losses of accumulated heat through the insulation of the tank and a significantly longer time of heating the water on desired temperature in relation to instantaneous water heaters. As in the case of electric, the gas storage water heaters are used in cases when it is necessary to prepare larger quantities of consumables water at more discharge points. The volume of gas boilers ranges between 120 and 220 l, at which the power of the burner is lower than with instantaneous water heaters and ranges from 7-9 kW, with the required water heating time to a temperature of 45 °C in time frame between 10-20 min. Solid fuels (wood, pellets, coal) are mainly used in heating boilers for space heating and combined ovens for food preparation and space heating, while somewhat rarer in devices that use solid fuels only for the preparation of hot water (which can also be used for central heating). Such devices have a volume of 30 up to 150 l and in some cases smaller storage tanks up to 10 l are installed in classic wood stoves. The disadvantage of this preparation of hot water is the difficult regulation of water temperature. Advantage over gas and electric water heaters, lies in the fact that they used environmentally friendly biomass (in the case of wood and pellet devices). Lower costs are also an advantage in relation to electric heating (20-60% depending on the tariff) and heating oil (50%).

Combined gas boilers are used for space heating and hot water preparation. They can be divided into two types: flow and accumulation. Flow types are often used in district heating systems in multi-apartment residential buildings, allowing independent preparation and use of thermal energy in each individual apartment. Rated power of the device ranges between 11 and 32 kW with a capacity of 1.5-14 l/min for hot water at 45 °C. The burner power is automatically regulated depending on current water flow in order to maintain constant selected temperature of the water, which saves energy and reduces emissions of harmful gases into the environment. Such devices are characterized by high efficiency (90% or 110% for condensing versions) in relation to boilers with auxiliary tank for heating and DHW preparation when working in summer mode, because the boiler and his burner are dimensioned for both space heating and DHW preparation. Reduced heat consumption from the tank in summer causes frequent on and off switching of burners which reduces the overall efficiency of the burner and shortens the operation of the entire device. This results in unfavourable heat loss ratio through the insulation tank and energy usage because a much larger amount of water in tank is heated, given the needs for DHW. Combined gas boilers consist of a gas heater which is then used to heat the water in the storage tank most often via a spiral heat. The tank volume is moving from 100 to 150 l and power up to 20 kW. Automatic burner power control (30-100%) ensures efficient operation regardless of water consumption. Water in the tank is reheated during consumption which means that these boilers practically work with identical power as instantaneous water heaters, intended exclusively for DHW preparation.

2.3. Technical solutions for enhancing energy efficiency of ventilation and cooling systems

The task of ventilation in buildings is the continuous replacement of polluted air from premises, with fresh air from the free atmosphere to maintain the necessary hygienic conditions for a healthy and comfortable stay of people. The role of ventilation is also heating the air if necessary, removing excess moisture and harmful gases from space and cooling the air in the summer. For comfortable housing and preservation of health and full working capacity of persons, the following recommendations are important:

- the air temperature in winter in residential areas should be 21 ± 1 °C while in summer, pleasant temperatures are between 24 and 26 °C;
- deviations of the mean temperature of the circumferential surfaces from air temperature should not exceed 2 to 3 °C;
- in winter the relative humidity is between 40% and 50% and in summer 50 ± 5%. All values below 30% are medically undesirable because they result in dehydration of the airways;
- the speed of air flow in the living area of persons should be between 0.1 and 0.3 m/s.

Room ventilation can be **natural** and **mechanical**. Natural ventilation is realized through infiltration of air through the gaps of windows, doors and walls by opening windows and doors or air changes through ventilation ducts. Mechanical ventilation is divided into: **exhaust ventilation** (suction of polluted air through channels), **pressure ventilation** (supply of fresh air through ducts) and **exhaust-pressure ventilation**.

The term natural ventilation means the exchange of air in a room which is a consequence of different air temperatures inside and outside the room and currents due to wind. Natural ventilation is achieved through windows, controlled openings on the facades of buildings or ventilation ducts and to a lesser extent through walls. Natural ventilation through open windows and balcony doors refers to the most intense mode of natural ventilation. Approximate number of air changes that can be achieved with closed windows and balcony doors and with different positions of the window sash and window shutters depends on each room individual. Number of air exchanges depends on the wind speed, the difference between indoor and outside air, the type of windows and shutters and the layout of the windows in the building. The rule is that the rooms should be ventilated by opening or semi-opening windows and not just by infiltrating air through gaps and exterior walls. Thereby it should be borne in mind that short ventilation should be performed by fully opening the windows wings and balcony doors better than permanent ventilation through semi-open door or window wings.

Mechanical ventilation refers to the forced exchange of air in a room assisted by the action of the fan which provides additional mechanical energy. In residential premises, mechanical ventilation is carried out by suction air from sanitary rooms and kitchens, whereby due to pressure in ventilated spaces are entered by outside air or air from adjacent rooms. Bathroom fans are mostly made in diameters of 100, 120 and 150 mm. The fan is switched by a special switch or circuit breaker light with built-in timing mechanism. Some more modern systems have a humidity sensor that is installed in a ventilated room. Centrifugal fans used for extraction of moist, greasy air and steam from kitchen hood are powered by a single-phase 230V/50Hz motor with the possibility of control speed of rotation. They can be installed in or outside the kitchen hood. They are performed with a grease separator on the front of the fan and there is also a possibility of removing the working fan circuit for easier cleaning and maintenance. The air flow ranges from 200 up to 480 m^3/h. Fan power ranges from 50 to 150 W. As opposed to extracting air from the room, pressure ventilation devices insert outside air into the ventilated space. The room is kept in an overpressure in relation to the neighbouring rooms and the surroundings, thus preventing the inflow of polluted air into the ventilated area, excess air flows into adjacent rooms or towards environment through windows and doors. In winter, it needs air that is injected with heat in the room to approximately room temperature using an air heater. The basic parts of the ventilation chamber are the fan, heater, air filter and duct for air supply. The disadvantage of pressure ventilation is the inability to recover heat from room air.

Refrigeration units used in residential areas are the most common compression cooling systems for air cooling, wherein the condenser air cooled. The left-hand cooling process mediates heat transfer between heat source – the air that cools on the evaporator and the heat sink – the environment air receiving heat taken away from the space which is being cooled and increased by energy compression. The basic components of a compression refrigeration device are: compressor, condenser, throttle valve, evaporator and refrigerant as an energy carrier. The condenser and compressor are placed in an outdoor condensing unit, while the evaporator and the throttle valve are located in the indoor unit. Since the device consists of an outdoor and indoor unit in a separate design these systems are called SPLIT air-cooling systems. The term air conditioning is understood significantly wider as air preparation than that in a split air-cooling system: regulation temperature, humidity, air purity, air flow rate, noise level and name air conditioner is not the most appropriate, although it is often used in practice. Split systems can be divided according to several criteria (Figure 2.8).

By purpose	**According to the number of indoor units**	**According to the installation method of the indoor unit**
• air cooling devices • air cooling and heating devices	• monosplit systems - consist of one external and one indoor units • multisplit systems - consist of one external and several internal unit	• wall • floor • parapet • built-in attic and ceiling (cassette, duct, built-in)

Figure 2.8 Division of SPLIT systems

Each refrigeration unit is a heat pump because it allows heat to be transferred from lower to higher energy level, with performed external work. In practice, it has become commonplace the name for the heat pump for the refrigeration unit used for heating. Efficiency depends in a large extent on the location of the indoor and outdoor unit space cooling. The outdoor unit should preferably be installed on the north side of the building, to the coldest possible place that is preferably not exposed to direct sunlight with good circulation of ambient air. It must not disturb the external appearance of the building. The term heat pump is generally understood as any device that transfers heat from a lower temperature tank to the higher temperature tank in which the heat is usefully applied. Heat pump process is identical to the left-hand cooling process. It is contained in the ambient air, groundwater and surface water and soil thermal energy of the sun which due to the low temperature of its carriers cannot be used directly for heating but can serve as a heat source for heat pumps.

2.4. Renewable energy sources

Due to today's problems related to increased warming of the atmosphere, environmental pollution, the accelerated rise in fossil fuel prices and their predictions disappearing in the near future the world is increasingly turning to upliftment energy efficiency of energy production and consumption and in particular the use of renewable energy sources. The largest source of renewable energy is the sun whose radiation comes to Earth and is converted there into other forms of renewable energies such as wind energy, hydropower, biomass, wave energy. Solar radiation is by far the largest source of energy on Earth, which is why the irradiated energy is 15,000 times higher than the total world energy need. Today, the energy of the sun is directly used with the help of the sun collectors for DHW heating and space heating, with the help of photovoltaic cells for the production of electricity or passively in buildings using architectural measures for the purpose of heating and lighting the space.

Ways of using solar energy can be divided into passive, active and those for the production of electric energy. Active uses which aim to heat the space and domestic hot water and produce electric energy are described below. Solar energy is actively collected with the help of solar collectors and it is primarily used for the purpose of DHW heating and to a lesser extent space heating. Solar collectors are installed as part of a solar system whose are next to the collector and include the following basic parts: hot water storage tank, additional heater (boiler, electric heater) and control circuit. Solar collectors are the most common and they can be mounted on the roofs of houses, terraces or gardens and are installed whenever possible directs in a southerly direction with a deviation of up to ± 30°C without significant influence on the amount of radiated energy.

The solar tank must not be too far away from a collector that heats it to minimize heat losses in connecting pipelines. Plate solar collectors absorb solar radiation and transmits it to the liquid carrier heat (water or a mixture of water and propylene glycol) circulating between the collectors and a **hot water storage tank**. The collectors with a smaller amount of vacuum are the most presented in our market place.

Solar plate collectors consist of a thin (0.3-0.5 mm) metal absorber plate of average dimensions (0.8-1) × (1.9-2) m to which the pipes through which the heat carrier flows are attached. Solar radiation is absorbed in a thin coating of the absorber plate (absorption 90-95%). The absorbed heat is then conducted through the plate and tube material to the heat carrier. The absorber with pipes is located in an insulated (min. wool, styrofoam, sponge) housing (metal or plastic) and covered with special glass high permeability (90%) to reduce heat loss from heated absorber plates on the environment and protection against weathering.

Vacuum collectors consist of a number of glass collector’s vacuum tubes (6-10) in which metal (copper) tubes – flowing heat carrier (water, propylene glycol / water, alcohol, freon, etc.) are placed, taking heat from the absorber which may be in the form of a flat strip or strip wrapped around the inner tube itself. Air extracted from the glass tubes would reduce heat losses from the absorber to the ambient air, which has a beneficial effect on the efficiency curve of vacuum collectors which is less steep than the code plate. This means that compared to plate, vacuum collectors achieve better efficiency in the winter months and allow achievement of higher temperatures in summer months. Their main disadvantage compared to plate collectors is a significantly higher price that does not follow the increasement of efficiency and loss of vacuum over several years of use. The efficiency of the collector is defined by the ratio of useful heat, collected collector and the intensity of the incident solar radiation on the collector surface. The efficiency of the collector is mostly influenced by the properties of the absorber coating and the quality of attaching tube to the absorber plate.

Photovoltaic cells convert the energy of solar radiation into electricity. They are made of semiconductor material (most commonly silicon (Si)) in shape thin plates connected in modules. By adding small amounts of impurities (such as boron, phosphorus) to the base material the positively and negatively charged semiconductor wafers that are joined together when they are illuminate, generate direct current el. current in the external circuit are formed. Current strength is proportional to the intensity of solar radiation. Typical single crystal Si photocell produces a voltage of about 0.5 V and a current of less than 3 A, so it is necessary to connect several cells in series to obtain a voltage greater than 12 V because it is the nominal voltage of most batteries that are charged with the help of photovoltaic cell. Connected cells form photovoltaic modules that have a maximum power of about 73 W (at an insolation of 1000 W/m^2) and an area of about 0.5 m^2 (1 × 0.5 m). Therefore, the efficiency of such monocrystalline photovoltaic cells is about 14.5%. Electricity produced by photovoltaic cells is stored in batteries similar to those used in cars. Charging and discharging is regulated by a special regulator and is usually installed to a DC-to-AC converter suitable for operating the device in household.

In recent years, cognition has matured more and more both locally and on global plan on the benefits of obtaining thermal energy from biomass. Among the different types of biomass, wood has the widest application. Well designed forest complexes are a sustainable source of energy because they can be renewed, CO_2 is neutral and is a good replacement for existing fossil fuels. Biomass accumulates solar energy through photosynthesis. Water and carbon dioxide from biomass and solar energy form glucose while releasing oxygen. Approximately 0.8 kWh/mol (energy per unit) is required to produce glucose mass). When glucose is burned in a closed system, it releases approximately, without heat of condensation of water vapor, 0.78 kWh/mol (energy per unit glucose mass). In this way, the accumulated solar energy in biomass by combustion in the form of thermal energy is obtained. In the combustion process, carbon is bound from fuel with oxygen and in the case of complete combustion CO_2 is produced. If combustion it is not complete, other compounds are formed. Wood mass represents only one part of the substance of biological origin that is commonly called biomass and are potential renewable energy sources. It is distinguished from wood pulp intended exclusively for firewood and wood pulp which is a technological waste that can be used as fuel (waste, waste, sawdust, wood chips, etc.). It is indicative that 35 to 40% of the wood mass from the tree is intended for further processing remains as waste. For some specific products (parquets) this amount climbs up to 65%. All that waste material could be a great energy potential.

Cogeneration is the process where by using the primary energy of fuel for production two types of useful energy (thermal and electric energy) can be produced. An example of a cogeneration unit is an internal combustion engine which produces electricity with an efficiency of 30% using developed waste heat for DHW heating (and space heating). The overall efficiency of the device rises to 90%, thus achieving significant savings of fuel in relation to the case when the electric energy and heat for DHW products in separate devices (the ratio of the total useful energy obtained and total energy input from fuel was about 60%) are used. In addition to large cogeneration plants (thermal power plants) particularly interesting are individual plants that enable the supply of cheap electric and thermal energy of one or more family houses. It is also good to mention the existence of micro cogeneration devices with electric strength around 5 kW which consist of gas engines with water where the cooling circuit is connected to the DHW cylinder heat exchanger (still heating circuit). This allows the usage of another 18 kW of thermal energy to heat the DHW.

Great energy potential can be found in wind energy for electricity production which was used more significantly in European countries during the 90s of last century. Today we are witnessing the large increasement of usage this kind of energy (100% per year) where the leading countries are Germany and Denmark with more than 7 GW and 3 GW of installed capacity. To produce energy today, mostly are used wind turbines with horizontal axes with one, two or three blades, while those with a vertical axis are still mainly in the development phase. Horizontal axis turbines are used to pump water with a larger number of blades. At the top of the column a wind turbine with a horizontal axis a gearbox with an electric currents (usually alternating) is usually placed. Wind turbines run at wind speeds higher than 5 m/s (18 km/h) and achieve maximum power at 15 m/s which remains constant up to 30 m/s (108 km/h) when the blades stop to prevent damage.

Small wind turbins	Medium wind turbins	Large (offshore) wind turbins
• up to 30 kW • investment ranges from 1500 to 3000 EUR/kW	• 30 - 1500 kW • investment ranges from 700 to 1100 EUR/kW	• >1500 kW • amount of investment approx 1500 EUR/kW

Figure 2.9 Division of wind turbins

2.5. Technical solutions for energy efficiency domestic appliances and lightning

Today it is very difficult to find a household that does not have access to electricity. Most households are equipped with a stove, refrigerator, freezer, washing machine, water heater for hot water preparation, TV and radio. Also, increased number of households have dryers, dishwashers, microwaves, personal computers and watches. A significant part of electricity in Croatian and Hungarian households is used for electric lighting. Thanks to the development of technology today, households use the so-called energy saving bulbs which are cheaper than they were twenty years ago and available to everyone.

Standard bulbs are incandescent bulbs and generate the light by the principle of thermal radiation. Light is created by electricity where the current passes through the filament of tungsten and heats (radiates) to a temperature from 2,600 to 3,000 K. Most of the radiation is emitted in the infrared part spectrum. On the basic properties of a standard lamp – light efficiency and lifespan – the temperature of the filament is most affected. The higher it is, the efficiency of light is longer and the shelf life is shorter. Lifespan is reduced due to a sharp increase the number of tungsten atoms that separate from the filament as the temperature rises. This process not only produces a dark layer on the inside of the glass balloon (which leads to a decrease in luminous flux), but also leads to bursting incandescent filaments – bulb burns. Light efficiency of standard incandescent bulbs with a power of 25 – 500W is 9 – 17 lm / W. 5 – 10% of the invested electricity is converted into light while the rest is converted to heat. Lifespan of a standard incandescent bulb nor under normal operating conditions (rated voltage, room temperature and without vibration exposure) is 1,000 hours.

Halogen bulbs are also incandescent bulbs and they use the thermal principle radiation when generating light. In addition to halides (bromine, chlorine, fluorine and iodine) gas filling almost completely prevents blackening of the bulb bulbs, thus maintains an almost constant luminous flux throughout its lifetime. The main characteristic of halogen bulbs is the halogen circular process. Namely, tungsten that evaporates from the filament goes towards the wall of the balloon where temperatures <1400K combine with halides. Thermal current drains joint closer to the filament, where at a temperature >1400K it decomposes and the tungsten atom returns to the filament. In doing so, he does not come to the old place, so that the filament cracks at the end of its service life. In this process, the temperature of the filament reaches up to 3,000K and the glass up to 520K (250 °C).

Fluorescent lamps belong to the group of low-pressure sources on the discharge. Light is generated by a discharge in mercury vapor of high luminosity, whereby mostly invisible ultraviolet radiation, which is a phosphor layer on the inner wall of the tube turns into visible light is created. This principle of generating light is called photoluminescence. It distinguishes them by a long service life, on average over 15,000 hours. There are both round and fluorescent U-shaped tubes. The diameter of the pipe decreases, thus achieving greater utilization of the light system (the light source is closer dotted). Today, 26 mm diameter pipes (T8 – 8/8 ”) are most commonly used and the new generation pipes have a diameter of 16 mm (T5). There are also 38 mm (T12) and 7 mm (T2) pipe.

Household appliances occupy a central place in electricity consumption in every household. As with lighting by responsible behavior on occasion use of household appliances, significant savings can be achieved. By choosing the device with appropriate class, the initial larger investment returns during the life of the device is ensured. Of course, again, it is necessary to draw attention to the correct choice of size and power of the home appliances. Namely, there is no sense to buy a device three times bigger and more powerful than the actual need without considering a higher class of energy efficiency. By increasing the energy efficiency of the device, for the same or higher level of service less energy is consumed and in that way energy and money savings are realized. Of course, energy savings are directly related to reducing gases emissions because it also reduces the combustion of fossil fuels for production electricity. Energy labels inform the customer about energy consumption, price and impact on the environment of the device he intends to purchase. It is precisely the standardization of energy label and independent testing of the device introduced as an additional protection mechanism for buyers from false claims by manufacturers or retailers about energy consumption.

A **refrigerator/freezer** is a household appliance that retains inside lower temperature than ambient temperature. It achieves this by taking heat from its own the interior draws into the environment. When buying a new device certainly do not overdo the size because if the device is oversized, it certainly consumes more energy and therefore money. When placing the refrigerator/freezer in the space, care must be taken to the same, i.e., it should not be placed near to a heat source nor directly exposed to the sun because it will only increase the operating time of the compressor needed to achieve set temperature. It follows from the physical laws themselves that if the temperature of the space in which the refrigerator/freezer is located, the refrigeration unit will consume a greater amount of energy to cool the interior space. In very unfavorable situations an increase in ambient temperature by one degree also means an increase of electricity consumption by about 5% compared to the reference. It is also good to use the saving mode option but otherwise the thermostat should be set at approximately 4 – 5 °C in the refrigerator and -18 °C in freezer. For longer absences from the house, if possible, it is good to switch off a refrigerator and empty the icebox.

A **stove** is a basic household appliance that is intended for food preparation. It basically consists of a hot plate and an oven. Today it is a growing trend to buy heating plates and ovens separately, which are then installed separately in kitchen furniture. Especially popular is the glass-ceramic heating plate that has about 20 to 25% lower electricity consumption compared to conventional heaters plates. Of course, it must be emphasized that the utilization of input energy (up to 92%) is best with gas cookers. If production losses are added to this, transmission and distribution of electricity, then gas stoves are much more cost effective than electric.

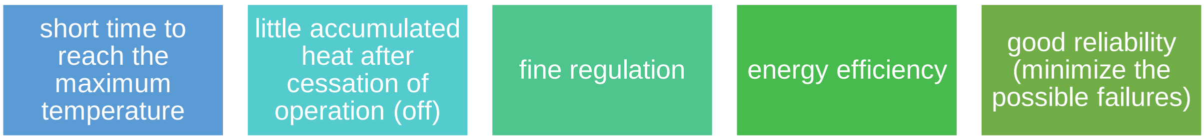


Figure 2.10 Basic requirements for modern heating plates and owens

Although induction heating plates are visually very similar to classic glass-ceramic plates, they should certainly be distinguished from them. Induction heating is the future of cooking from the point of view of electricity use and it already beginnings to attract many admirers because a special way of working allows extremely short warm-up time and enables quick reactions to any change in the power level.

The same rule applies to **washing machines** and **dryers** as to all other electric devices, i.e., proper choice (energy efficiency) and rational use are the basic prerequisites for achieving savings while using the device. Most of the energy and even up to 90% consumed by one washing machine goes to heating the water needed for washing. The average washing machine consumes about 100 l of water, while larger washing machines consume up to 160 l of water per wash cycle. From the above, it clearly can be seen how big these household expenditures are and how important they are in rational use of the device. Namely, most of the clothes used can be washed with cold or hot wash and cold rinse. This saving mode of operation the washing machine saves up to 65% of the energy consumed during hot rinsing.

It is important to keep the washing machine clean inside and out. Dirt on the washing machine and spilled detergent can contaminate freshly washed clothes which requires washing again.

Dishwashers are a very useful household appliances which are becoming almost unavoidable especially in younger households. With the correct and rational behaviour of the dishes washed in the dishwasher is hygienically cleaner than in hand washing and the washing process itself consumes less energy and water. As with a **washing machine**, it is very important that the dishwasher is adequately full and that the dishes in it are properly stacked. This way the dishwashing machine will be at its best possible way to do your job. Whenever possible economical dishwashing programs should be used.

The group of small household appliances includes all those small, auxiliary appliances which are found in almost every household. The most commonly used small household appliances are **vacuum cleaner**, **iron**, **hair dryer**, etc. These appliances on the market are marked with an energy efficiency label when they are purchased and additional care must be taken to ensure that the selected device satisfies exactly set goals. Rational behaviour and proper use (by regularly replacing full bags at the vacuum cleaner or by cleaning the bottom surface with irons) significant energy savings can be achieved and life of the devices extended.

3. Energy savings calculation

The decision to implement an energy efficiency measure will be made on the basis of an assessment of its cost-effectiveness. To ensure good profitability assessment several inputs are required (Figure 3.1).

Investment	Annual savings	Effect time	Inflation rate	Discount rate
• the investment includes all project costs, including design, procurement of equipment, installation of equipment, VAT, other taxes, etc.	• annual savings represent the total savings that are realized on an annual basis by the project	• the technical life of an equipment is the period of time in which the equipment is technically functioning properly, while the economic life is the time the period after which it is cost-effective to replace existing equipment	• inflation is defined as the average annual increase in the prices of goods and services	• the discount rate is a measure of the time value of money, ie the reduction of future monetary amounts or receipts to the present value

Figure 3.1 Profitability assessment inputs

In the following text brief descriptions of energy efficiency measures and an assessment of the value of the investment will be described.

According to the latest regulations, it is recommended to install thermal insulation 12 – 14 cm thick. Cost of the thermal insulation is around 40 EUR/m^2 and depending on the quality of the insulation, possible energy savings amount from 20 to 40%. Although heat losses through the roof have only 10 – 20% share in the total heat losses of the house, the roof plays a particularly important role in the quality and standard of housing. The recommended thickness of thermal insulation on a pitched roof is from 16 to 20 cm. The cost of thermal insulation of the roof is 65 EUR/m^2 based on market data. In addition to reducing heating costs, energy-efficient windows will also increase space comfort. New windows have 2-3 times less heat loss than old windows. According to the regulations, the total heat transfer coefficient should be U<1.8 W/m^{2}K. These windows are 20% more expensive than windows with ordinary IZO glass, but their heat losses are 50% lower. The price of PVC joinery ranges from 330 EUR/m^2, while the price for wood-aluminum windows is 400 EUR/m^2.

Heating systems are an indispensable part of installation in households. Which system to choose depends on the available energy sources. Renewable energy sources are used to achieve and maintain thermal comfort throughout the house and the recommendations include the installation of a central heating system. Replacing an old wood stove with a more efficient new stove or wood boiler can save up to 50% on firewood. Although the efficiency of a biomass boiler is not significantly higher than fuel oil boiler, it is an energy source whose price for 1 kWh of heat contained in the fuel is around 0.03 EUR, while for fuel oil the price is 0.06 EUR. Thus, the price of biomass is two times cheaper than the price of heating oil. Cost of new condensing boiler is 2.500 EUR when new wood stove cost 2.000 EUR. Cost of the new heat pump is 16.000 EUR. Replacing an old electric water heater with a new one, of identical volume and power (2 kW) which has a built-in "timer" which turns on the water heater in the period of low electricity tariffs, you can save up to 100 EUR per year. It is recommended to install a solar system with two collectors (effective area 3.6 m^2) and a tank of 200 l. With an investment in the entire system of around 4.000 EUR, it can be save around 430 EUR per year.

When choosing the right air conditioner, it is important to consult an expert and not buy a device with a larger capacity than need. The choice of air conditioning capacity is influenced by the size of the room, the area of the glass openings, the thermal insulation of the room, the number of people staying in the room and the number of heat sources.

The simplest way to save on lighting is to make the most of daylight that illuminates the room evenly wherever possible. The average durability of ordinary incandescent bulbs is up to 1.000 hours, and energy-saving and more than 10.000 hours. If you replace a classic 100 W light bulb with a suitable 20 W energy saving light bulb, assuming it burns in a home for 5 hours a day, you will save 15 EUR per year. The energy-saving light bulb will pay off in less than a year, and in its lifetime, this light bulb will save 100 EUR. The prices of energy-saving light bulbs range from 3 EUR (lower quality and lifespan) to 7 EUR (high quality and long lifespan).

The table below shows a brief summary of energy efficiency measures with estimated prices.

Table 3.1 Energy efficiency measures with estimated prices

Energy efficiency measures		
Measurements	**Description**	**Price**
Thermal insulation	Stone wool	40 EUR/m^2
	Glass wool	
	Polystyrene	
Thermal insulation of roof	Glass wool	60 EUR/m^2
	XPS	
	EPS	
Windows	PVC	330 EUR/m^2
	Wood-aluminum	400 EUR/m^2
Heating	Condensing boiler	2.500 EUR
	Wood stove	2.000 EUR
	Heat pump	16.000 EUR
Hot water consumptions	Electric boiler with solar system	4.000 EUR
Ventilation and cooling	Air conditioner	650 EUR
	Centralized ventilation systems	6.500 EUR
Lighting	Energy saving light bulb	3 – 7 EUR

4. Future challenges and recommendations on technical solutions for enhancing energy efficiency in the cross-border area

Traditional renovation techniques require extensive labour to carry out on site. On the one hand, with traditional renovation, the users are forced to leave their homes during the most invasive works, and have to bear the prolonged disturbances during construction site activities. On the other hand, the traditional approach presents high risks for the implementation, due to human error and damages from exposure to different conditions (outdoor forces, weather conditions). In order to significantly reduce energy consumption in building stock, Europe has to focus on scaling up the process of energy retrofitting of existing buildings. So far, business-as-usual practices include step-by-step, building-by-building energy retrofitting.

This building retrofitting process is indeed labour-intensive and lengthy, i.e., it usually takes several weeks or even months to replace old windows, install new thermal insulation layers on the external walls and roofs of buildings, and renew the heat distribution systems or attach renewable energy sources to the building's envelope. Most of Europe's residential building stock is due for deep energy renovation. The motivation is set by the EU's environmental goals, together with the users' demand for the energy and cost savings. However, the building sector is currently not able to offer an integrated solution for deep renovation toward nearly Zero Energy Building (nZEB) at a reasonable price. Deep retrofits are often associated to the concept of "cost-effectiveness", since higher energy performance is resulting in the lowest cost during the estimated economic lifecycle of the building, and quicker Return on Investment (ROI) for implemented solutions through energy savings.

Financial aspects are among the highest barriers for owners and co-owners when it comes to renovations. Payback and up-front costs are crucial in this context. Return of investment, the time taken for the initial outlay to be recouped is one of the major barriers. Users and owners are not likely to consider investments that do not pay for themselves within 3–7 years. Therefore, the profitability of renovation in terms of building life cycle costs and long-term maintenance costs that can be avoided, thanks to energy efficiency deep retrofitting, should be evident.

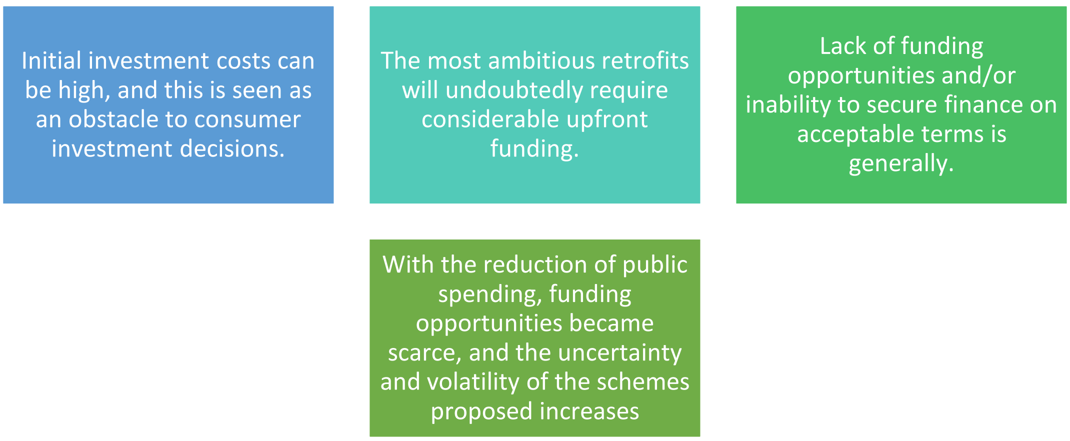


Figure 4.1 Obstacles in implementing energy effciency measures

In general, deep energy renovation needs a participative approach with early involvement of the user. This means a higher cost in terms of integrated design and analyses dealing with social aspects, which are time-consuming. These costs need to be foreseen taking into account the starting situation. Therefore, a community already mature in terms of environmental motivations and social cooperation will be easier to integrate into the process, thus less costly in terms of investment costs. Innovative technologies may cause reluctance from users.

Additional communication effort is needed to build trust within residents and communities. In terms of life-cycle cost, a higher investment in communication and social activities aimed at building trust and engaging the users may have a positive impact in both the designing and operation phase, because of fewer conflicts, blocking points and unexpected changes. The point of renovating while keeping the users inside their homes seems interesting, but it has appeared to be conflicting in many cases (noise, disturbances), even for short renovation periods. The business plan of the renovation needs to consider the cost of relocating people, since it can have a huge impact according to the site location and residence availability.

Socially-related costs in terms of initial investment in enhanced communication and similar are often taken in charge by research projects or by internal commercial/R&D budgets, because of promoting new markets or because of social interest. However, it may be considered a wider general need, instead of counting on specific punctual programs.

Taking into consideration the initial motivations of owners and tenants as regards environmental, energy and safety issues represents a positive driver.

It is good to include in the renovation business plan the costs needed to overcome social barriers such as lack of trust, lack of energy culture and lack of future vision. These costs may include training sessions, participative strategies, integrated design and many on-site visits to build a confident relationship between inhabitants and key stakeholders. These actions may need more or less effort depending on the initial situation and may need multi-disciplinary teams dealing with technical and social aspects at the same time.

A design approach in which the energy calculation is just one isolated step of the decision-making process, is no longer suitable in the concept of nZEB renovation. Energy and cost optimality calculations must be used in parallel with the definition of the technical solutions, already in the early stage of design.

5. Conclusion and final remarks

Buildings consume significant amounts of energy to maintain comfortable occupancy conditions, which requires space heating and domestic hot water preparation, ventilation and air conditioning/cooling, and power supply for lighting and other household appliances. There are advanced technical solutions for buildings to reduce energy consumption, CO_2 emissions, and energy wastage, while providing maximum thermal comfort and ensuring occupant safety. In general, such technologies either reduce the energy demand or increase the efficiency with which energy is used. Recently, effective building planning at the construction stage has become increasingly important; this includes effective planning of eco-design, building orientation, effective use of green plant systems for the roof and building facade, use of shading, planning of natural lighting and natural cross section ventilation, etc. Modern building regulations define the requirements of building engineering systems and set building envelope thermal performance limits, which also determine the most optimal energy consumption in terms of technical and economic conditions. Building codes provide guidelines for new construction and for retrofitting the existing building stock to create high-performance buildings by applying an integrated, holistic design process, which increases building life-span, reduces energy consumption, and contributes to a better, healthier, more comfortable environment for people to live and work. Several technological options exist which, along with providing energy efficient solutions, also:

- support sustainability measures
- reduce operating costs and environmental impacts
- increase building adaptability, durability, and resilience.

The building envelope has the greatest impact on building energy performance; it is a prime focus area to consider when energy efficiency measures are planned for both existing and new buildings. Considering the functions of the building envelope (i.e., security, comfort, shelter, privacy, aesthetics, ventilation, etc.) it is imperative to optimize the design of the building envelope to meet the occupants' requirements while reducing energy consumption and heat loss.

The importance of thermal insulation, airtightness, and reducing thermal bridging in buildings is equally relevant for countries in both hot and cold climates. Heat loss through leakage during cold months leads to increased use of heating energy, this is analogous to losing cool air from central air conditioning due to high heat gain in the premises during the summer months (both situations resulting in increased consumption and higher CO_2 emissions). Most building heat loss occurs through the walls, roofs, floors, and glazing, sealing joints, thermal bridges etc. Replacing outdated windows with the latest window technology insulation is much more efficient than repairing them. Building standards in several countries require the installation of energy efficient windows with high thermal characteristics. These windows are made using multi-chamber glazing profiles, which is a more complicated design than traditional wooden-panelled windows. Different approaches to the design of building heat supply systems depend largely on the availability of energy resources, fuel prices, infrastructure, technological development, and relevant energy policy. The principle of decentralized heat supply is based on independently-produced heat energy for internal needs. Decentralized heating systems can rely on both non-renewable fuel (e.g., installation of boiler equipment) and renewable energy (installation of roof-top solar collector systems and heat pumps).

Much progress has been made globally towards improving energy efficiency in buildings, helped along primarily by three types of public policy tools that are particularly successful at supporting energy efficiency improvements in buildings:

- **legal requirements** (such as building standards),
- **financial incentives** (rebates, reduced-rate debt, tax deductions),
- and **information awareness programmes** for various types of energy efficient technologies.

Countries with comprehensive and stringent building standards in place tend to have higher penetration rates of energy efficient technologies. Effective design and implementation of public policy is key to increasing energy efficiency. The substantial gaps between what is available in the market and what is being used makes it clear that effective governance and use of legal and financial instruments, rather than just technical advancement, are key.

6. References

[1] https://www.odyssee-mure.eu/publications/archives/energy-efficiency-trends-policies-buildings.pdf

[2] http://www.cres.gr/behave/pdf/Guidelines_Changing_Energy_Behaviour.pdf

[3] https://ec.europa.eu/energy/sites/ener/files/documents/2014_article4_en_denmark.pdf

[4] http://rehabilite.eu/uploads/downloads/mooc-1-english/en/mooc-1-english.pdf

[5] https://www.enu.hr/wp-content/uploads/2016/03/Priru%C4%8Dnik-za-energetske-savjetnike.pdf

[6] https://unece.org/fileadmin/DAM/energy/se/pdfs/geee/study/Final_Master_file_-_March_11_final_submission.pdf

[7] Technical, Financial, and Social Barriers and Challenges in Deep Building Renovation: Integration of Lessons Learned from the H2020 Cluster Projects; Simona D'Oca, Annarita Ferrante, Clara Ferrer, Roberta Pernetti, Anna Gralka, Rizal Sebastian and Peter op 't Veld