Qualification programme

Energy efficient refurbishment of multi-appartment buildings

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The CAMS Platform improves energy efficiency measures by aligning research, recommendations, audits and investments from 11 projects across the Baltic Sea region. In particular, the know-how comes from Interreg Baltic Sea Region's EFFECT4Buildings, LowTemp, AREA 21, Co2mmunity, Act Now, BEA-APP, RDI2CluB; but also HORIZON 2020's HERON, SIM4NEXUS, ENLARGE, and ARCEE funded by EuropeAid.

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Introduction

The refurbishment of residential buildings is one of the key challenges to reduce our dependency on fossil fuels. The building sector still releases significant amounts of greenhouses gases into the earth's atmosphere, contributing to global warming and subsequent climatic changes. The building sector has long been in the focus of climate change mitigation policies but with moderate success. The annual refurbishment rate lags behind the rate that would be necessary to comply with the Paris agreement and limit global warming to 1.5 °C or even 2°C and consequently a large number of buildings in the European union and beyond are still in an energy inefficient state. We expect that we will see an increased pace of refurbishment in the next years and decades – out of sheer necessity to combat climate change.

Refurbishing buildings poses a number of challenges. The fundamental structure of the buildings is determined and upgrading the building towards more energy efficiency and potentially more resilience against climate hazards will be highly on the type of building, its location, its ownership structure, and its energy supply. Consequently, it will not be possible to have a blueprint that serves as a template for the refurbishment of any building. However, there are general principles that are based on building physics and typical designs that can are useful to explain refurbishment concepts.

In this book, we follow this philosophy and explain overall approaches to refurbish a residential building with a focus on reducing the energy consumption of the building. In total, this book consists of 10 modules that address different aspects of the refurbishment process. We understand the process of refurbishment in a wider sense and do not only look at the "hard facts" such as heating systems or thermal bridges. We consider it important to also stress the role of flat owners or renters in energy consumption and in the decision-making process that precedes the actual refurbishment. Consequently, technical and less-technical chapters have been treated with equal importance and make up each approximately half of the book. Almost all of the chapters can be read independently from each other, but elementary aspects are covered in earlier chapters while specific issues can be found in the second half of the book.

This book is the 2nd edition of the qualification programme for energy efficient refurbishment, developed during the CAMS platform project, part-financed by the INTERREG Baltic Sea Region Programme. The first version of this book was released in 2015 and had a special focus on residential buildings in former socialist countries. The first edition was used to teach courses on that subject in higher education institutions in Belarus, Russia, Ukraine, Latvia and Estonia. It was also distributed among homeowner associations preparing for a potential refurbishment. For this updated version, all chapters were screened and updated in some parts. The introductory module was completely rewritten and shifts the focus to the Baltic Sea Region with a reference to relevant EU legislation. Finally, a completely new module on adaptation to climate change was developed and how it can be a part of the refurbishment process. This will become increasingly important in the coming years, as we will have to face the consequences of climate change that are inevitable, even it we would cut our greenhouse gas emissions to zero this very instant.

Who should read this book?

This book fills the gap between pamphlets intended for homeowners making up their mind about refurbishment and specialist books for architects or engineers. That is to say, reading this book will not enable you to refurbish your house all by yourself, but it goes beyond basic facts, and we do not shy away from physical or mathematical descriptions to explain the underlying principles. The intended readers of this book are semi-professionals that want to learn more details about the refurbishment process, working e.g. in housing associations, planning departments or energy agencies. It is also suitable for students of environmental or sustainability studies that want to learn more about energy efficiency in the building sector. Last but not least, this book is also valuable for architecture and engineering students that want to look a bit left and right and get a more holistic view on the matter of refurbishment.

Hamburg, Spring 2022

1

Introduction to energy efficiency

WHAT WILL YOU LEARN IN THIS MODULE?

This chapter serves as an introduction to the topic energy efficiency in the building sector. The section 'Energy' constitutes the basis for the technical know-how addressed in later chapters and introduces the topic of energy. In the section 'Climate Change', the importance of environmental-friendly behaviour is stressed and the consequences of climate change in the Baltic Sea Region are addressed. The section 'Energy Efficiency' introduces to climate friendly refurbishments and proves its realizability. 'Guidelines', as a subtopic, presents international requirements and rules of energy efficient buildings and addresses the technical aims of such a refurbishment. The 'Climate Change Adaption' section takes up the need for preventive renovations. Finally, we will cover basic aspects of renewable resources in relation to the construction sector.

1. Energy

1.1 Why do we need to talk about energy?

The world population is predicted to continue growing by around one percent per year, resulting in a total world population of more than 8.5 billion people by 2030 (OECD, n.d.). Amongst other things, this leads to an increasing energy demand, which according to the International Energy Agency (IEA) may increase by 25-50% depending on the extent energy efficiency guidelines are followed. As long as major parts of consumed energy are derived from fossil fuels, higher energy consumption implies increasing CO_2 emissions.

Up until now, renewable energies only account for rather small parts of the energy production worldwide. In 2018 less than 20% of energy consumed in the European Union was generated by renewable sources, with immense differences in the Baltic Sea Region: Whereas in Norway the share of energy derived from renewable sources is 72%, renewable energies only account for 16% in Germany, 11% in Poland (Eurostat, 2020) and only 6% in Belarus (IEA, 2020). This shows that there is potential for improvement. In contrast to energy generated by fossil fuels, renewable energy usage leads to reduced CO_2 emissions, which will decrease the impacts on the climate. Furthermore, unlike fossil fuels, renewable energy sources themselves are endless. Support for energy derived from renewable sources may further the local economy and end the dependence on oil and gas imports.

Buildings are responsible for 40% of the energy consumption in the European Union and account for 36% of the EU's CO_2 emissions. The European energy consumption could be reduced by 5-6% when buildings become more energy efficient. This would also decrease CO_2 emissions by 5% (EP, 2020). Therefore, energy efficiency as well as the use of renewable energy should be considered in refurbishment and construction processes. Another important issue is adaptation to climate change, as the consequences of the human made climate change are already observable: longer and warmer summer, mild and short winters, more extreme rain events, drought spells, changing patterns of tropical storms. In addition to preventing further climate change, buildings need to adapt to the current and future situation (Kornhuber, 2019).

This chapter aims at underlining the importance and realizability of energy efficient refurbishments in the light of man-made climate change.

1.2 The Concept of Energy

Energy needs to be understood as the ability of a system to do work. A system can be everything, from a plant, over a human being over a machine up to a light wave. The word work in this context has to be understand rather broad, too. A plant that is growing, a light wave travelling, a human being that talks or a plane bringing hundreds of passengers to another place are all systems that do work.

The most important thing to remember about energy is that it cannot be lost or destroyed, neither can it be produced. The primary law of thermodynamics implies that the amount of energy does not change in a closed system. The energy in such a closed system can only change its occurrence and can be transformed into another form of energy. Such energy transformation naturally happens all the time: A human being that eats transforms the chemical energy stored in the food into mechanical energy, which is used for things like breathing, thinking, or walking. Photosynthesis of plants is the process of transforming the radiant energy of sunlight into chemical energy which the plant needs to live, to grow and to grow its fruits. However, technologies were developed that transform the chemical energy stored in coal, natural gas, or the radiant energy of the sun and the kinetic energy of water into electric energy which is used for machines in factories, computers in offices or light in our houses.

Still, "energy production" and "energy losses" are terms which are frequently used. Energy production means the transformation of energy into another desired form to be used for an intended system to do its work. During this transformation process not all of the given energy can be transformed into the desired energy form. A coal fired power plant that for example aims at transforming the chemical energy of coal into electric energy to be used in households or the industry. However, only 30-45% of this potential energy is transformed into electric energy. This is called the efficiency factor. The rest of the energy is unintentionally transformed into thermal energy and is often called the energy loss (Aachen hat Energie, 2018). Power plants that are able to use the "lost" thermal energy for heating systems are called co-generation plants. These type of power plants have a much higher efficiency than conventional ones.

Scientists differentiate between different types of energy: Potential energy is the energy that an object, that is stored on a higher level, has, for example water masses in a water reservoir have potential energy which is transformed when the barrier is opened. Kinetic energy exists when a system is moving. It can be used as an energy source (wind and hydro power stations) yet it is most often the aim of energy transformations (e.g. moving a car). Thermal energy can, depending on the temperature, be used for the melting of e.g. iron, or for heating in buildings. It also is the most common waste-product in energy transformation. Electric energy is what is most commonly used in households, as it is easy to produce and transport, however, it is hard to store and can lead to large "energy losses". Nuclear energy is released in the process of nuclear fission which has the advantage that no greenhouse gas emission are released from nuclear power plants. However, history showed that accidents can have devastating consequences and the storage of nuclear waste is an unsolved problem to this day. Radiant energy describes the energy of the sunlight, which not only causes sunburns, but is used by solar panels and photovoltaics and by plants for photosynthesis. Chemical energy is included in all fossil fuels and freed when they are burnt. They are then used for heating and electricity in buildings. Food also contains chemical energy which is transformed by the human body and used for living (Aachen hat Energie, 2018).

1.3 Units of energy

In the International System of Units (SI), 1 joule (J) is taken as the unit of energy. 1 J is defined as 1 newton metre (Nm). As an example, 1 J is needed to lift up 1 kg by 10 cm. Another important unit is Watt (W), which is a unit of power, and not a unit of energy per se. As 1 J corresponds to the amount of energy required to provide the power of 1 watt for 1 second, it is also called 1 watt-second (Ws). Vice versa, this means that 1 W corresponds to the power of 1 J per second (1J/s). Electric energy is most commonly expressed in kilowatt-hours (kWh), which implies that per hour 1000 W are provided. If calculations are related to thermal or chemical energy, then calorie (cal) is sometimes used as the unit of energy. Derivatives of joules and calories are widely used: 1000 J= 1 kilojoule (kJ), 1000 kJ= 1 megajoule (MJ), 1000 MJ= 1 gigajoule (GJ); 1000 cal= 1 kilocalorie (kcal). Other units commonly used are ton of oil equivalent (toe), which relates to the energy released when a ton of crude oil is burnt, and ton of coal equivalent (tce), which relates to the energy released when one ton of coal is burnt. The former can also be indicated as barrels of oil equivalent (boe), which refers to the energy released when one barrel (159 liters) of crude oil is burnt. These units are used to compare the effectiveness of thermal power plants and for economical calculations and planning.

Name of Unit		Conversion in Joule	Description of Unit
Joule	J	1 J	International Unit of Energy, used for all types of energy
Newton metre	Nm	1 J	Commonly used for torsional moment, rather than for energy
Watt	W	1 J/s	Unit of Power
Watt-second	Ws	1 J	Used to express power of one Joule
Kilowatt-hour	kWh	3,6 million J (=3,6 MJ)	Unit most commonly used for electric energy
calorie	cal	4,19 J	Unit used to express thermal or chemical energy
Tonne of coal equivalent	tce	29,3 billion J (=29,3 GJ)	Used in economy, expresses amount of energy freed by burning coal
Tonne of oil equivalent	toe	41,9 billion J (=41,9 GJ)	Used in economy, expresses amount of energy freed by burning crude oil

Name of Unit		Conversion in Joule	Description of Unit
Barrel of oil equivalent	boe	6,1 billion J (=6,1 GJ)	Used in economy, expresses amount of energy freed by burning a barrel of crude oil

Table 1-1: The basic units of energy

1.4 Forms of energy

When talking about energy consumption, differentiations between primary, secondary, final and useful energy need to be made. Primary energy is the energy embodied in natural resources, such as sunlight, or fossil fuels like crude oil, gas, and coal at their geological origin. Often energy from primary energy sources is not directly usable and requires preparation. Primary energy is converted into secondary energy sources, such as briquettes, heating oil or diesel, which can be used by the consumer. Secondary energy represents the primary energy from which losses due to conversion and transportation are excluded. Secondary energy can for example be described as the energy content of fuel made from crude oil. We would like to point out that in many cases the term primary energy (and related terms such as primary energy demand) is used less strict in our sense and can refer to the energy before conversion in general, regardless of whether it refers to primary or secondary energy as we have defined it here.

After undergoing a series of human-made conversions or transformations, the final resultant energy to be directly used by the consumer is the final energy. The final energy is left when conversion, transportation and storage losses are excluded from the secondary energy. This represents the energy delivered to the consumer before the actual consumption. Finally, the useful energy represents the final energy minus the conversion losses at the place of consumption. The delivered final energy will be converted into heat, light, or power for electronic devices, for example.

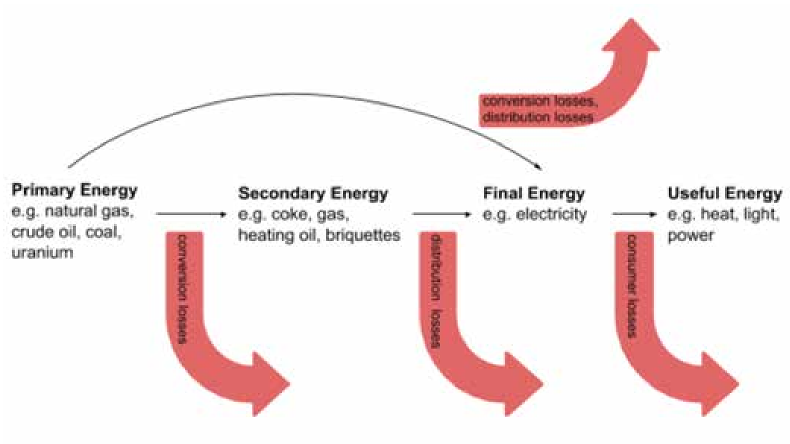

Figure 1-1: The basic units of energy

1.5 Types of energy resources

Energy resources can be classified in two main categories: energy from renewable sources and energy from conventional sources. The main difference between the two types of energy resources is the limit of their availability. Whereas the latter category comprises non-renewable energy sources like fossil fuels, hence crude oil, coal and natural gas, and nuclear fuels, whose availability will come to its limits, the energy sources comprised in the second category are renewable and unlimitedly available (EnBW, 2020c). Renewable energy sources are generally less harmful for the environment when converted to final energy, however, they often are less efficient than conventional sources (BBC, 2020).

Fossil fuels contain chemical energy which is transformed into thermal energy when burning them. However, heat is not the only result of this transformation: the stored carbon is converted and released into the atmosphere as CO_2. Apart from the environmental damage during extraction, the use of fossil fuels is the main driver of man-made climate change. Still, they are the most common energy source, as the energy production is rather efficient and "energy losses" are rather low (BBC, 2020).

Fossil fuels are quasi natural products made of organic matter which matured over millions of years until they became oil, gas, or coal. As they account for more than 80% of the energy consumed worldwide, the resources are much faster used than they develop, the moment where no physically available fossil fuel resources are available will come. Before that happens, it will probably already become economically unfeasible to extract fossil fuels by ever greater efforts from the earth. However, until now crude oil is said to be the only fossil fuel whose limitation lies in the foreseeable future (BGR, 2020).

Nuclear energy is generated by nuclear fission. This method is the most effective one: One kilogram of uranium one can produce a million times more energy than 1kg of coal (BBC, 2020). Still, this is a relatively complex process, which requires a certain composition of the uranium and specific knowledge. This may be one reason why nuclear energy only accounts for 5% of the energy consumed worldwide. As no greenhouse gases are emitted during the energy generation from nuclear energy sources, the immediate pollution of the atmosphere is very low. It is therefore, in some countries classified as an environmentally friendly energy source. However, even if there are no emissions, nuclear fission produces highly radioactive and hazardous waste, which needs to be safely stored for millions of years. In addition, a certain risk remains that during accidents or unforeseeable events radioactivity is released into the environment. In contrast to other accidents, a nuclear accident is a rather unlikely event, however, when it occurs, its consequences can be dramatic for the environment and mankind.

There are two ways to make use of solar energy: On the one hand it can be used for the generation of electricity via solar panels, also called photovoltaic panels, and on the other hand solar thermal systems transform the radiant energy of the sun into warm water (EnBW, 2020b). Both technologies have the same advantages and disadvantages: Advantages are that it is environmentally friendly, and that the source is unlimited. However, solar energy is less efficient than fossil fuels and, possibly the biggest struggle, that its generation is highly unreliable as it depends on the weather.

The latter problem also applies to wind energy. Wind turbines can only generate energy when the wind is strong enough, which might not always and everywhere be the case. One could furthermore argue that even though it is eco-friendly, as it does not lead to CO_2 emissions, it is too noisy to be built too close to residential areas. Still, its efficiency eco-friendliness and the renewability aspect should weight more.

There are several ways to make use of hydro energy. Firstly, it can be generated using dams in rivers which transform the potential energy of the "falling" water through turbines. Secondly, hydro energy is generated in pumped storage schemes. In this case, two water reservoirs on different height levels are connected. Energy is generated when the water runs from the upper to the lower reservoir, parts of the generated energy are then used to pump the water back to the upper reservoir. A third option are run-of-the-river stations, a system in which water wheels transform the kinetic energy of the river flow. Hydro energy can also be generated using the energy of the ocean: Tidal power stations use the regular rise and fall of the ocean water to generate energy. Another option, which is yet not very common, is the usage of the energy of the waves within the ocean (BBC, 2020). Globally seen, hydro energy is the renewable energy source most commonly used (EnBW, 2020b). This is mostly due to the high reliability and availability of water, as the energy of all water sources can be used for energy generation. Furthermore, humans have been using hydro energy for more than 2000 years, leading to the existence of sophisticated and highly efficient systems nowadays (EERE, n.d.).

30 to 50% of geothermal energy used is residual heat from the formation of the earth, and 50 to 70% is heat from radioactive decay. This heat can be found in the earth's mantle and its usage for energy generation would normally require digging deep. There are, however, many places where a rather high temperature is already found relatively close to the earth's surface. Geothermal energy is also used in ground-based heat pumps.

Energy can be generated using biomass. Plants, manure, and food waste are forms of biomass. Energy is generated by burning the organic material, which produces electric energy as well as heat. The usage of this energy source is highly controversial, as, even if it is renewable, it is not emission free, as the burning process releases CO_2. Especially the usage of plants like corn, beets and tree trunks is criticized, as they additionally take up arable land (EnBW, 2020b).

1.6 Energy Sources used - worldwide and in the Baltic Sea Region

The sustainable development goals (SDGs) agreed upon by the United Nations (UN) and promoted by the EU state general goals about how to achieve a more sustainable world. SDG 7 is formulated as "Ensure access to affordable, reliable, sustainable and modern energy for all", (United Nations, n.d.), and generally demands the usage of more sustainable energy sources. On this basis the EU formulated a more concrete goal of reaching 20% of its energy supply being produces by renewable energy sources by 2020 and 32% by 2030 (European Commission, 2020).

Still, renewable energy sources only account for 13,80% of the world's energy mix, of which 9,25% are biofuels. In Europe the situation is similar: in 2018 only 15,3% of the energy consumed was obtained from renewable sources, again the majority of this originated from biofuels (IEA, 2020). The global trend furthermore shows an increase in the energy demand. This trend is most pronounced in countries with fast growing economies. A spark of hope is, that the trend also shows a slow increase in the use of renewable energy sources, which might be a signal that the countries are moving into the right direction of more renewable energies.

This development can also be observed in large parts of the Baltic Sea Region. Oftentimes, certain energy sources dominate the energy mix when the country has certain raw material reserves. This, for example, is the case in Russia. The country possesses over 19% of the world's gas and over 15% of the world's coal reserves. Furthermore, 6% of the world's oil reserves can be found in Russia. Therefore, the country mainly relies on those non-renewable energy sources and only obtains 3% of its energy supply from renewable sources. Belarus itself has no reserves of gas, oil or coal, still its close relation to the Russian Federation might be an explanation for the dominance of gas in the Belarussian energy mix. Poland has coal reserves, which explains the dominance of coal in its energy mix. In Estonia, Lithuania, and Latvia as well as Denmark and Germany a mix of natural gas, crude oil and coal is dominating, even if those countries have no own noteworthy reserves. The reliance on renewable energy in those countries is rather low, varying from 15.3% in Germany to 43% in Latvia. However, it has to be taken into consideration that in these countries the majority of the renewable energy is obtained from burning biomass. In Finland and Sweden nuclear energy plays a considerable role in the energy mix, too. Their usage of renewable energies is similar as in countries like Germany and Latvia: Biomass accounts for large parts of it. Norway obtains 56% of its energy supply from renewable sources, of which biofuels only account for a small part. Oil and gas account for other parts in Norway's energy mix, as the country has small reserves of both.

This shows that the share of renewable energies can be increased in almost all countries in the BSR, but also worldwide

1.7 Energy in buildings

Energy needed in buildings is predominantly energy for heating in most houses. The energy type depends on the installed heating system. Furthermore, electric energy used for electrical equipment and light, and finally energy is used for warm water preparation. In average private households, energy used for heating accounts for around two thirds of the final energy consumed. Another 15% of final energy consumption in private households are used for warm water and 10% for process heat (e.g. cooking, washing) and process cooling (e.g. refrigerating, freezing). The remaining 8% include lightening, electricity for electronic devices and others (Umweltbundesamt, 2020).

1.8 The concepts of producer, consumer and prosumer

Classically there were two roles to be taken in the energy industry: producer and consumer. The producer produces a good and provides it to the consumer. The consumer buys and uses the good. In the last few years, a third role to be taken evolved: the prosumer. Yet, there is no official definition of this concept, however, some features are widely accepted. A prosumer is a household, a company, a citizens' collective, or anything else, that PROduces energy, mostly through solar panel and photovoltaic installations, and is the main conSUMER of this energy. Still, being a prosumer does not necessarily mean being fully self-contained. Most prosumers are still connected to the grid: When there is an energy surplus, meaning more energy is generated than needed at that moment, the prosumer feeds energy into the grid. When there is an energy shortage, meaning more energy is needed than it is produced at that moment, the prosumer receives energy from the grid. The regulations about compensation of energy fed into the grid and energy obtained from the grid depend on national or even regional legislation. Whereas in Denmark, for example, prosumers can sell their energy surplus to the national grid, thus receive financial compensation for surpluses, prosumers in Poland receive compensation for energy surpluses fed into the grid in form of energy received from the grid. Slovakia is the only European country in which prosumers do not get any kind of compensation for energy surpluses, even if they are fed back into the grid (European Commission, 2017).

Not only is being a prosumer financially profitable for the prosumers, they also do a big part in furthering the use of renewable energies and hence reducing CO_2 emissions. Surveys showed that within all European countries the main driver to become a prosumer is to save money on electricity bills. Another incentive was the environmental impact of becoming a prosumer. 90% of surveyed prosumers stated that they are still happy with their decision to become a prosumer and that they would recommend the change to others (European Commission, 2017). Due to the fact that there is no official definition of prosumers by the European

Union and most of its member states, little information about the number of prosumers is available. Still there is a positive trend: More than 100 000 entities only in Germany decided to become prosumers between February 2019 and January 2020 (BSW, 2020).

KEY POINTS TO REMEMBER FROM CHAPTER 1

- **Energy is the ability of a system to do work. It cannot be produced, lost, or destroyed; it transforms.**
- **The most common unit of energy is Joule. Energy statistics dealing with large amounts of energy most commonly refer to kilo tonne of oil equivalent (ktoe).**
- **Energy embodied in raw materials is known as primary energy. After transformation into secondary and final energy and after conversion and distribution "losses" the useful energy is what is consumed.**
- **Non-renewable energy is generated from nuclear fission and fossil fuels such as natural gas, crude oil and coal. Even though they are known to harm the environment, non-renewable energy sources dominate the world's energy mix.**
- **Hydro energy, solar energy, wind energy, geothermal energy and biofuels are renewable energy sources. They are still less common, but increasingly used due to their environmental friendliness.**
- **The majority of energy consumed in private household is used for heating.**
- **Prosumers do produce (parts of) the energy which they consume. They are still connected to the grid, as they, depending on their production, may need more energy than they consume or produce more than they consume.**

2. Energy Efficiency

Environmentally friendly living not only implies the use of renewable energy sources but also an efficient usage of the generated energy. In the European Union buildings are responsible for 40% of the energy consumption and 36% of the CO2 emissions. Yet 75% of the buildings within the European Union are energy inefficient and yearly only one percent of them are renovated to be energy efficient (EP, 2017). If buildings would become more energy efficient, the European energy consumption as well as the CO2 emissions could be reduced by 5% (EP, 2020). Apparently, the energy saving potential of the residential and building sector is rather high. In the following, different concepts and principles of energy efficient building and renovation will be presented and explained.

The first step towards an energy efficient building is the reduction of the energy demand. This can be achieved by improving the building envelope and improving the efficiency of the technical equipment.

2.1 Improving the Building Envelope

Insulation is key to energy efficient buildings: through proper insulation of walls, floor slabs, windows, doors and roofs, less energy is lost to the outside environment. Special attention needs to be drawn to dockings between the walls and where elements such as balconies or windows are attached to the wall. Through proper insulation transmission losses are reduced and potentially less energy is required to supply the building with heat. In winter proper insulation keeps the generated heat and in summer the generated ventilation and cold air within the building and protects the inside from the temperatures outside.

Adding windows on the right sides of the buildings can reduce the energy demand further. Especially in the northern climate it is important to face windows to the south and increase the area of glass in those directions to maximize solar gain. Having windows on at least two different sides of the room allows for cross ventilating and is a quick and effective method to avoid overheating of the inside in summer, suitable equipment to cover the windows from the solar irradiation should be installed.

2.2 Efficiency of Technical Equipment

In addition to an optimal building envelope the required energy needs to be used as efficiently as possible. This implies the adaption of the technical equipment: Technical equipment should be as energy efficient as possible and well dimensioned. The EU energy labels help identifying energy efficient devices within the European Union.

Especially for devices with a high energy demand, such as heating and air conditioning systems, refrigerators and washing machines and dryers, attention should be drawn to its efficiency and energy labels. Technology develops quite fast, therefore older devices are often less energy efficient than newer ones. Hence investing in new energy efficient technical equipment might be recommendable, depending on the current gadgets. It is furthermore necessary to equip the household with well dimensioned devices, taking the size of the household and living area into account when choosing new gadgetry.

More details on how exactly these measures can be implemented will follow in a later chapter.

2.3 Criteria for Energy Efficient Buildings

When humanity started building houses, they were trying to adapt the forms, structures and materials of their buildings to the landscape and weather conditions in their region in the best possible way. They realized that small windows were helpful to keep the warm light created by the sun out over the day and that they additionally hinder the cold air to get insight during the nights. Already the Romans thought about the orientation of windows within a building, and heated their homes using thermal energy. Yet it took until the 20th century until technologies were functional and could heat up a building in winter using solar energy. When in the 1970s the term sustainability appeared in the economic world, science made great progress and scientists presented their ideas for energy efficient housing. Using insulation and air tightness to reduce the energy amount consumed and solar panels to produce energy, the buildings were partly already energy neutral. Only in 1994 German scientists presented the first autarchic building, which is not connected to the grid and produces more energy than it needed (Ionescu et al., 2015).

Depending on the degree of energy efficiency, buildings are categorized differently and underlie different criteria. In the following the most popular terms and connected building standards are introduced and explained. These standards and legal regulations apply to new buildings, however, at least in theory, it is possible to achieve such ambitious energy standards even in a refurbishment process. The question is if it is economically reasonable. Furthermore, it needs to be noted that energy standards change over time, what may have been an outstanding energy performance years ago may be standard today.

2.3.1 Low Energy Buildings

The term low energy building is more generally used for buildings whose energy performance is higher than the standards demanded by current building codes. Low energy buildings do therefore not underlie any international criteria. Buildings which are called low energy buildings are usually characterized by a high level of building envelope improvement. They mostly have highly insulated walls and windows and a low level of air leakage, meaning they only require small amounts of energy even in winter. Some countries, such as Austria for example, however do use "low energy" as a classification for buildings, and developed building and energy standards which the buildings need to fulfill.

2.3.2 Passive houses

The passive house is the most popular and fastest growing standard for energy efficient buildings. The concept refers to the independence of the active heating systems using heat sources and energy of the house and its surrounding area, the house heats and cools itself, thus being passive. Passive houses are characterized by an excellent thermal envelope and ventilation systems with heat recovery. Furthermore, they typically have large windows towards the south and smaller windows to the north. The passive house approach is only possible with a highly adaptable heating device which, of course, can be regulated. The annual heat demand for a passive house is very low - in the mid-Europe it is about 15 kWh/m^2a. The need for total primary energy consumption should not exceed 120 kWh/m^2a, including heating and cooling, domestic hot water, and household electricity. The passive house standard is not bound to a particular type of construction but can be performed on any type of building. The first passive house was built in Darmstadt, Germany, in 1990. In comparison to the common buildings at that time, the passive house required 90% less energy. Ever since, tens of thousands of passive houses have been built in nearly all climate zones.

2.3.3 Zero Energy Buildings

The term zero energy building (ZEB) describes a building, which produces as much energy as it needs. According to the EU Directive on the Energy Performance of Buildings all the energy consumed needs to be produced on site by renewable energy sources. A ZEB can only be reached by combining active and passive measures of energetically optimising the building: Passive measures include the improvement of the building envelope, the ventilation system and the air tightness within the building to reduce the energy demand. Active measures imply the generation of energy, e.g. through solar panels, to cover the energy demand of the building. In most cases the building is still connected to the grid. The most common understanding of zero energy building is the net zero energy building. Buildings like that may use energy from the grid in times where they produce too little energy to cover the building's demand and feed energy into the grid when more energy than needed is produced. Over a year a balance between using from the grid and feeding the grid needs to be achieved. Other definitions furthermore imply that over the years the amount of energy used during the construction process and the emissions that occurred in the production and generation of the building materials needs to be generated on-site to compensate for that.

2.3.4 Energy Plus Buildings

Energy plus buildings are buildings which produce more energy than they consume. This standard is an advancement of the zero energy building standard. Again, a positive net energy balance can only be reached by combining passive measures to reduce the building's energy demand and active measures to produce energy and cover the remaining energy demand. Energy generated on site which is not needed to cover the building's energy demand, the plus energy, is supplied into the energy grid. The first ever building to produce more energy than actually needed was the Heliotrope in Freiburg, Germany, which was built in 1994. Between 2000 and 2005 the same architect turned his concept into a mass residential form and realized the so-called solar settlement in the city of Freiburg. The concept was a whole success for its buyers, each house produced more than 5.000€ of surplus energy per year.

Figure 2-1: Solar settlement in Freiburg, Germany

KEY POINTS TO REMEMBER FROM CHAPTER 2

- **Insulation is key to energy efficient housing, as it reduces the building's energy demand. Furthermore, windows should be placed thoughtfully.**
- **Energy labels help to find more energy efficient technical equipment.**
- **Many different official and unofficial standards for energy efficient housing exist.**
- **Active measures, such as energy production on site through solar panels, and passive measures, such as an improved building envelop, need to be combined to reach a zero net energy balance.**

3. Energy efficiency policy in the European Union

The European Commission recognises that improving the energy efficiency of buildings is central to achieving a green energy transition and achieving its climate objectives. The directives existing today have been built on the back of the energy policies developed over the last half a century, with ambition and technological sophistication increasing over the years. Combined, these pieces of legislation provide concrete targets and standards for the sector, as well as the planning and monitoring frameworks necessary to coordinate these efforts across the EU.

The two EU directives directly regulating energy efficiency in buildings are the Energy performance of buildings directive (EPBD) 2018/844/EU and the Energy Efficiency Directive (EED) 2018/2002/EU. These are supplemented by the Renewable Energy Directive (RED II) 2018/2001/EU and Ecodesign and Energy Labelling Directives (listed here), whose regulations have implications for the building sector. Underlining all of these is the Regulation on the Governance of the Energy Union and Climate Action (GOV) 2018/1999/EU which sets common rules for planning, reporting and monitoring.

Strategies of which these Directives are part

- The Energy Union Strategy (COM (2015) 080)
- The Clean Energy for All Europeans Package (COM (2016) 860)
- The European Green Deal (COM (2019) 640)
- The Renovation Wave (COM (2020) 662)
- The Fit for 55 Package (COM (2021) 550)

Energy performance of buildings directive (EPBD)

Background: The EPBD is intended to boost energy performance of buildings and improve existing builidng stock. Adopted in 2002, the EPBD was recast in 2010, and subsequently amended in 2018. A recast proposal (COM/2021/802) was made in December 2021.

Key points:

- Mandates the use of National Energy Performance Certificates and sets Minimum Energy Performance Standards (MEPS), requiring the renovation of the worst performing buildings.
- Sets targets for Nearly Zero-Energy Buildings (NZEBS) and Zero-Energy Buildings (ZEBS)
- Mandates the creation of National Building Renovation Plans (NBRPs)

- Encourages the use of smart technologies and Smart Readiness Indicators (SRIs)

Energy Efficiency Directive (EED).

Background: The EED sets the overarching legal framework for energy efficiency policy in the EU. It came into force in 2012 and was revised in 2018. A recast proposal (COM/2021/558) was made in July 2021 as part of the European Green Deal.

Key points:

- Sets targets for energy efficient renovations to central government buildings
- Requires use of energy efficiency obligation schemes and alternatives
- Requires energy efficiency certificates to accompany the sale and rental of buildings
- Mandates preparation of national energy efficiency action plans (NEEAPs) every three years
- Regulates metering and billing of thermal energy by giving consumers clearer rights to receive more frequent and more useful information on their energy consumption.

Renewable Energy Directive (RED II)

Background: RED II is a 2018 recast of the 2009 RED I and was part of the 'Clean energy for all Europeans package. As part of Fit for 55, an amendment proposal (COM/2021/557) was made in 2021. The aim is to increase the share of renewable energy sources (RES) with particular focus on sectors where progress has been slow (transport, buildings and industry.)

Key points:

- Sets targets for minimum share of RES in final energy consumption and energy use in buildings.

Regulation on Governance (GOV)

Background: GOV was a product of the The Energy Union strategy in 2015. It sets common rules for planning, reporting and monitoring and ensures this is aligned with the Paris Agreement goals.

Key Points:

- Requirement of National Energy and Climate Plans (NECPs) from MS which address energy efficiency, accompanied by biennial progress reports

- Requirement of National Long Term Strategies from MS every 10 years which address the heating and cooling and buildings sector (residential and tertiary).

Ecodesign and Energy Labelling Directives

The Energy Labelling Framework Regulation (EU) 2017/1369 and Ecodesign Framework Directive 2009/125/EC set the framework for the introduction of product specific regulations on the designing and labelling of energy related products. In the building sector, this includes guidelines on energy efficiency in heating, ventilation and water systems (Guidelines 2018)

4. Climate Change

Energy efficient housing, building and refurbishment is not only a question of saving money. By doing so, you do a part and commit yourself to counteracting climate change. Climate change has been one of the prevailing topics for years now: Especially young people and scientists urge politics and economy to take action as soon as possible to at least reduce the consequences of climate change to a minimum. Greta Thunberg mobilized great parts of today's youth into the global movement Fridays for Future (FFF). The third global climate strike organized by FFF was attended by four to seven million people worldwide, depending on the source. The question is, why are that many people all over the world so worried and demand fast political action?

Infobox: Climate ≠ weather

Weather is the short-term physical condition of the atmosphere at a certain place and time. It is described using different measurements such as temperature and humidity of the air, velocity and direction of the wind, precipitation, and cloudiness. Climate on the contrary is the average state physical condition of the atmosphere at a certain place over a longer period of time, minimum 30 years. Climate is then characterized by the mean, frequency, and extreme values of the meteorological measurements of the weather at a certain place over this specific period of time. Generally, from one especially warm summer, one cannot extrapolate to global warming, but one would need to compare the data of several decades to observe a climatic change (UBA).

That the climate is changing already is no question of belief, it is a scientific consensus. In the last 30 years the Artic Ocean lost more than half of its ice covers, same for glaciers worldwide. Due to melting ice and the fact that water expands under heat, the sea levels rose by 20 cm in average since 1880 (Welthungerhilfe). New temperature records have been broken almost every year since 2015. 2020 has been found to be the warmest year ever since record began, replacing 2019 from this position. Since 1881 the global average temperature went up by 1 degree Celsius, in some places, such as Germany it even went up by 1,4°. The warmer the air and oceans, the more water evaporates and is taken in by the clouds. This, on the one hand, leads to droughts in some parts of the planet and causes forest fires, water shortages and crop failures with severe consequences for the population. On the other hand, the global warming leads to heavy rainfalls and floods in other regions. Additionally, violent storms have become more frequent also in regions where there were less typical decades ago (Greenpeace). Still, the worst is yet to come if no action is taken any time soon.

4.1 Forecasts for the Baltic Sea Region

Climate forecasts for the next decades are done with so-called climate models. Climate models are calculated by huge data processors using the available data from the last decades and centuries based on the law of thermodynamics. Scientists mostly do not only calculate one model, but develop different models, depending on different criteria. The ensemble of different models is expected to give a better prediction than the individual models alone. Yet calculations are limited, and climate models are potential models rather than exact forecasts.

Latest climate models for the Baltic Sea Region (BSR) predict that temperatures will generally rise. Warmer winters with less or no snow, especially in the north-eastern part of the BSR, with less extreme colds will become normal. Additionally, it is expected that temperature extremes in summer will increase. In the northern part of the BSR precipitation in summer will increase and decrease in the southern parts, which might lead to droughts. Furthermore, most probably the wind speed will massively increase. The models also reveal that especially in the southern and south-eastern parts of the region the sea levels will increase and expose lowland areas and densely populated areas to a higher risk of floods. Generally extreme events, such as heavy rainfalls, violent storms and dry spells are expected to happen more often. Higher water temperatures as well as the average wave height and frequency of higher waves are expected to influence the occurrence and distribution of various species in the Baltic Sea (EUSBSR).

Still, there are people who deny that those changes in the climate are abnormal. Their argument is that climate has always changed and that colder and warmer phases alternated. This is correct, yet science proved that the extremes humanity faced in the last decades is not a normal variation. Previously in the transition from a glacial period to an interglacial period the planet warmed up by 4-5 degrees within 10 000 years. Without any tightening of the current climate change mitigation measures scientists predict the planet will warm up by 4-5 degrees between the end of the 20th and the end of the 21st century. This means that the warming is currently happening 100 times fast than under former conditions. This warming is related with human action on the planet.

4.2 Action now!

Behavioral change towards more environmentally and climate friendly living and political action are now more important than ever. The effects of climate change/global warming which are already visible/evident are irreversible. Depending on the moment action will be taken and the degree of those actions global warming will continue to a certain degree. Scientists developed models which predict the consequences for planet earth for different degrees of global warming. The worst-case scenario, in which no action is taken any time soon, the planet will heat up 4-5°, in the best-case scenario, sufficient action is taken now, so that the earth only heats up by 1,5° until 2100. This so-called 1,5° goal is what different action groups promote. However, different studies found that the probability to reach this goal is very low and would require instant and drastic change. National and international climate goals often refer to interim goals by 2030. Yet 2030 is coming closer and many countries are not on track with their goals, as their policies do not match those goals sufficiently. A study showed that the 2030 climate goals can only be met when climate politics change drastically (Prognos, Öko-Institut, Wuppertal-Institut, 2020), and the near future will show if politics are ready to do that. If those changes will not come in time, critical thresholds, so-called tipping points, may be passed which may lead to sudden drastic change of our planet. Unfortunately, scientists are unsure when such a threshold will be passed and what changes are to be expected. Fact is that once a threshold is crossed, the changes could be irreversible and a chain reaction could be caused, which could seriously harm human live on planet earth.

The warmer the planet is going to become the more its inhabitants are going to suffer. Even a 1,5° warming will have severe effects and cause a degradation of the habitats for humans, animals, and plants alike. Only 0,5° more warming and additional ten million people will be affected by rising sea levels. In all scenarios the consequences are devastating: Various species of flora and fauna will become extinct and humans. People will need to leave their homes and people will die in natural catastrophes, weather extremes and its consequences. The climate crisis is a health crisis and caused millions of deaths. In summer 2003 alone in the EU more than 70 000 people died due to the extreme temperatures. The World Health Organization (WHO) expects approximately 250 000 death per year worldwide between 2030 and 2050. Climate change reveals another problem: global social inequality. Those who will be most affected by the consequences of global warming will be those who are most vulnerable. Within the affected region the poorest people will not have the capacities to react and will not be sufficiently supported. Generally small island states and coastal regions as well as megacities, mountainous and polar regions will be especially affected. Yet countries with weak infrastructures, which is mostly developing countries, might be the least able to cope with those consequences and protect its inhabitants. This is especially tragic taking into account that the main contributors to climate change are mostly developed countries. Seven countries alone are responsible for more than 60% of global warming (Spiegel).

4.3 Causes of Climate Change

Greenhouse gases (GHG) are the main driver of the human made climate change and global warming. GHG such as methane and carbon dioxide are natural components of our atmosphere, however, through human interaction their concentration massively increased. GHG in the atmosphere absorb the heat radiation and heat up the atmosphere. Due to changing standards of living the emission of those gases increased massively since the beginning of the industrialization: Carbon dioxide (CO_2) is released when coal, natural gas and crude oil are burned either for energy production or production of plastics used in a diversity of products; animal husbandry and extensive agriculture are responsible for further methane and nitrogen oxide emissions; products containing fluorinated gases release those into the atmosphere, where their greenhouse effect is 20 000 times as bad as of CO_2 (UBA); deforestation for economic reasons releases the CO_2 stored in the trees into the atmosphere. The greenhouse gases heat up the atmosphere and cause the warming of the oceans, which has influences on the whole ecosystem (European Commission).

As mentioned previously few countries are responsible for main parts of that emissions and hence global warming. This is mainly due to their energy politics and regulations for companies. Major companies and crude oil and natural gas deliverers are responsible for big parts of the emission of climate damaging gases. However, it is the responsibility of the governments to restrict those companies, and further environmentally friendly activities and behavior. This is not to say that individual behavior change is less important, still, if politics do not act and force companies to change, the effect is rather small. However, individual behavior change is always a signal for politics. The more people decide to act more climate friendly, the more important climate issues become in the political arena and political change is enabled. The political change is required as soon as possible, so that the consequences of the human made climate change are minimal.

Unfortunately, the climate has already been massively influenced and changed and consequences of climate change are already observable. Even if drastic political change will follow in the nearest future, further consequences are unavoidable. Therefore, it is crucial that we adapt our lives to those consequences.

4.4 Climate Change Adaptation

Even if we manage to protect our future climate through climate change mitigation, it will continue to change for several years, as the greenhouse gases which accumulated in the atmosphere will last there for periods between decades (methane) and thousands of years (carbon dioxide and hexafluoro ethane) and will continue to influence our climate (Quelle: DKK).

As climate change already does and in the next decades will further influence our ecosystems, solutions need to be found on how to deal with the inevitable changes and make our system more resilient. To reduce and even prevent damages of actual and expected changes, timely and active climate change adaptation in all sectors is required (UBA). Processes, practices, and structures need to be adapted to counteract the potential dangers and to benefit from the opportunities the situation offers. Those climate change adaptation measures need to be adapted to the newly created or expected situations, which are going to vary in different regions. As climate change and its consequences know no borders, international, multilateral, and multilevel cooperation between governments and organizations is indispensable (UN). This is especially important because developing and economically weaker countries generally have less capacity to adapt to a changing environment and protect its citizens, flora and fauna, as such adaptation measures are expected to cost billions. Yet the economic and social costs of unmitigated climate change are even higher.

Climate change adaptation is not only an important topic in politics and for large organizations but also plays a role in the individual housing sector. Buildings are especially prone to extreme weather and thus to climate change. An increase in the quantity of extreme weather events, such as storms, rainfalls, and high temperatures can reduce the lifetime of a building when no measures are taken (Climate ADAPT). Yet some buildings are more prone to the effects of climate change then others, which can be determined by doing a vulnerability assessment, considering the size, height, color, age, and geographical setting of the building (NCCARF). Generally, poorly constructed and maintained buildings will suffer the most under climate change (Climate Just). Additionally, non-adapted buildings make their inhabitants even more vulnerable. Adaptation measures of residential buildings are therefore essential and will become more important in the future. In the following weather extremes, their risks for the housing sector and potential solutions will be elaborated.

4.5 Adaptation to More Extreme Heat

The general global warming will lead to more extreme temperatures in summer, almost everywhere in the world. Not only might this increase the probability of droughts and forest fires, but it also increases the likelihood of overheating inside buildings, especially in large cities. These tend to cool down much slower than buildings in less occupied areas. This is called the urban heat island phenomenon (Climate Just). Overheating inside buildings can be counteracted using active methods such as installing air conditioning. However, this method is rather energy costly and on the long term neither climate friendly nor economical. An alternative is to integrate passive cooling measures in the architecture by placing windows on several sites of the building and enabling cross airing the rooms. Proper insulation of the building is another important measure to protect the inside from the extreme outside temperatures (Kinnane et al). Additionally, roof greening may help to cool cities, especially in summer. Choosing the right painting for the building's façade may also help to keep it cooler in the summer's midday heat (Stagrum et al.). Yet climate change adaptation of buildings is not only a challenge but can also be an opportunity: More sunny days increase the potential energy that can be produced using solar panels. The energy costs saved through this in the long term can compensate the extra costs which may occur from the cooling of interior spaces (Kinnane et al). Adding green oases which cool the air, create shadows for the buildings as well as for the pedestrians is another option which creates added value for the residents (Climate just).

4.6 Adaptation to More Severe Rainfalls

Climate models expect an increase in the quantity and severity of rainfalls also in the BSR. Especially the combination of severe rainfalls and storms may damage the façade and fundament of buildings, which is expected to cause costly repairs and changes in the infrastructure (Stagrum et al). Older buildings will therefore require renovations and adaptations to be better prepared. In the construction of new buildings other materials should be used for the façade to make it less prone and more stable. Yet damages in the façade are not the only consequences of intense rainfalls: The heavier the precipitation and the more water comes down in shorter periods of time, the more likely are floods. This is especially problematic in urban regions as the concrete and paved paths hinder the water to seep away. Additionally, the sewage systems are solely prepared for large volumes of water. Therefore, next to adapting the building's façade to rainstroms, the neighborhood needs to adapt to the possibility of floods. An improved sewage system is a good basis, yet the individual buildings should be adapted, too: doors and windows need to be more stable and can be protected by door guards; temporary flood barriers can be installed; indoor drainage systems could be used (Climate just). British scientists developed the concept IDEAhaus. This modular house is flood-proof to a depth of 750 mm and uses passive cooling techniques (Stagrum et al).

The Interreg project iWater dealt with integrated stormwater management in four cities in the BSR to improve urban planning of these cities and others in the region. Within the frame of the project common guidelines and tools for integrated stormwater management were developed. It was concluded that using a combination of several stormwater management solutions is advisable. Further information and a toolbox on how to deal with stormwater and improve its management can be found on www.integratedstormwater.eu.

4.7 Conclusion

The existing and predicted consequences of climate change require adaptations in several sectors, including the housing sector. Existing and newly built ones need to be prepared to be able to withstand extreme weather events such as intense rain, severe storms and extreme heat and protects its residents. Therefore, a diversity of measures exists and will be developed to make buildings more resilient against more extreme climatic conditions. These measures are strongly dependent on the changes climate models predict for the specific region.

Yet the problem of uncertainty remains: Climate model are just calculation using existing data from the last centuries rather than exact predictions. It could be that the predicted consequences will appear heavier and/or earlier or that it will be less heavy. If the calculated scenarios appear to be wrong, it could be that the costly adaptation measures were exaggerated or not enough. Still, the probability that adaptation is needed is rather high and as already indicated the social and economic costs of no proper adaptation are too high to ignore the consequences calculated by the models.

In module 10 we will look at more concrete aspects of adaptation to climate changes and possible ways to consider adaptation aspects during the refurbishment of multi-appartment buildings.

KEY POINTS TO REMEMBER FROM CHAPTER 4

- Climate and weather are two different, yet interdependent, things.
- Consequences of the human made climate change are already observable: extreme weather and natural disasters.
- Climate models predict an increase of those extreme events, also in the BSR.
- Political action is required now, so that global warming and its consequences can stay minimal.
- Those who are most vulnerable due to weak infrastructure will suffer most from the consequences of climate change which is mainly caused by few other countries and companies.
- Even with successful climate change mitigation climate change adaptation in various sectors is required.
- Adaptation of residential buildings is essential to make its inhabitants less vulnerable to existing and upcoming consequences of climate change and reduce and prevent damages.
- Adaptation measures vary per region and need to be adapted to the climate projections.
- Several methods to adapt buildings to climatic changes as extreme heat and severe rainstorm do exist.

5. Renewable energy

Renewable energy is energy that is derived from sources that are inexhaustible and are regularly replenished by nature -- sunlight, wind, rain, tides and geothermal heat. The basic principle of renewable energy is that it is not dependent upon underground resources such as coal and oil that cannot be replenished within the foreseeable human timescale, and which require massive and often ecologically destructive technology to access.

It needs to be kept in mind that energy from renewable sources is usually not directly usable and requires conversion from primary energy to secondary or final energy or storage in order to actually be available in the building as heat or household electricity. In the technical devices required for production, conversion or storage, some components require resources that are themselves finite, e.g. so-called “rare earths” such as indium and gallium that are used in the production of solar panels. The mining and processing of these raw materials have a negative impact on the environment and require the use of energy as well (grey energy). Therefore, even when using renewable energies, efficiency should remain the highest priority. Appliances should be manufactured to be durable, repairable and recyclable.

Info box: Recycling solar cells

A solar cell consists of a composition of silicon and rare metals such as indium, gallium and others, protected by glass plates, foils and plastics. It is not easily possible to mechanically disassemble a solar cell into its individual parts. The recovery of the rare metals is possible with special incineration at high temperatures. The return and recycling of the devices is regulated by the waste electrical and electronic equipment directive.

5.1 Solar energy

There are two ways to make use of solar energy. On the one hand it can be used for the generation of electricity via solar panels, also called photovoltaic panels, and on the other hand solar thermal systems transform the radiant energy of the sun into warm water

5.1.1 Photovoltaic panels

Photovoltaics is the direct conversion of sunlight into electrical energy using special semiconductor components - solar panels. It is based on the physical phenomenon of the photovoltaic effect. Solar modules based on silicon crystals convert from 13 to 18% (max 25%) of solar energy into electricity.

A photovoltaic system usually consists of the following components:

- Photovoltaic modules
- Mounting system
- Wiring
- Inverter
- Storage (optional)

Photovoltaic modules

The elements described first are intended solely for electricity production and do not themselves perform any covering or sealing functions. They are mounted on completely sealed roofs or on finished façades. Their installation must not damage existing building elements, e.g. waterproofing on flat roofs. Typical solar panes are approx. 1.5 m x 1.0 x 40 mm in size, however they differ by manufacturer and application, e.g. whether they are foreseend for mounting on the roof, mounting on the facade, on the balcony etc.. Polycrystalline modules are the most common modules, with the bluish colouring and clear grid. Monocrystalline modules have a more discreet black appearance, achieve a slightly higher output and are somewhat more expensive to purchase.

Figure 5-1: Polycrystalline modules on an agricultural building

Mounting systems

The elements cannot usually be attached directly to the façade or roof, but require a substructure. Since the efficiency of overheated modules decreases, it is recommended to install the modules at a distance of about 10 cm from the roof cladding. An unobstructed air flow cools the modules. On flat roofs, the substructure allows to create the optimal inclination. Depending on the geographical location of the building, this is usually between 30° and 60°. Elements mounted on the façade make sense on west, east and south-facing façades.

Roof-integrated systems

As an alternative to the pure PV elements described above, there are so-called roof-integrated systems in which PV modules simultaneously take over the function of the roof covering. There are various manufacturers of so-called solar tiles or roofing stones.

This can be a cost-effective option if the roof has to be covered or renewed anyway. Solar tiles can usually be combined with conventional tiles if only a part of the roof surface will be covered with solar tiles. Specifications regarding the possible roof pitch will be provided by the individual manufacturers..

Figure 5-2: Roof-integrated system: the solar panels are almost indistinguishable from other roofing elements

Wiring

The electrical connection cables between the individual modules and to the generator junction box are usually located outdoors. They must therefore meet many requirements: e.g. earth- and short-circuit-proof installation, UV resistance, resistance to high temperatures, as well as resistance to moisture. Caution: When these cables age or when unsuitable cables are used, insulation faults and electric arcs can occur.

Inverters

Inverters are used to convert direct current into alternating current. When looking for a suitable place to install the inverter, it is essential to follow the manufacturer's instructions. In the case of inhabited buildings, noise protection must be taken into account.

Storage

To decide whether a storage system is worthwhile, the usage structure of the building must be considered.

Are the users of a system also the consumers of the electricity generated? This would mostly be the case in single-family homes. Is the system to be as self-sufficient as possible or is it planned to feed it into the general grid? This question should be answered depending on the national promotion strategies or feed-in tariffs.

In the case of apartment buildings, the question arises as to whether the electricity generated can be used for communal facilities, e.g. lighting the staircases? Consideration should be given to how generated electricity can also be used by residents, whether owners or tenants.

Control technology is indispensable for regulating when electricity is to be used in the home or fed into the grid.

5.1.2 Solar thermal systems

Heating water through solar power is a simple basic idea. Solar showers in summer cottages or campsites are easy to make: A water tank on the roof heats up in the sunlight and the heated water is used directly for showering. In order to use solar energy on a large scale to heat water or even to support heating, several coordinated components are needed.

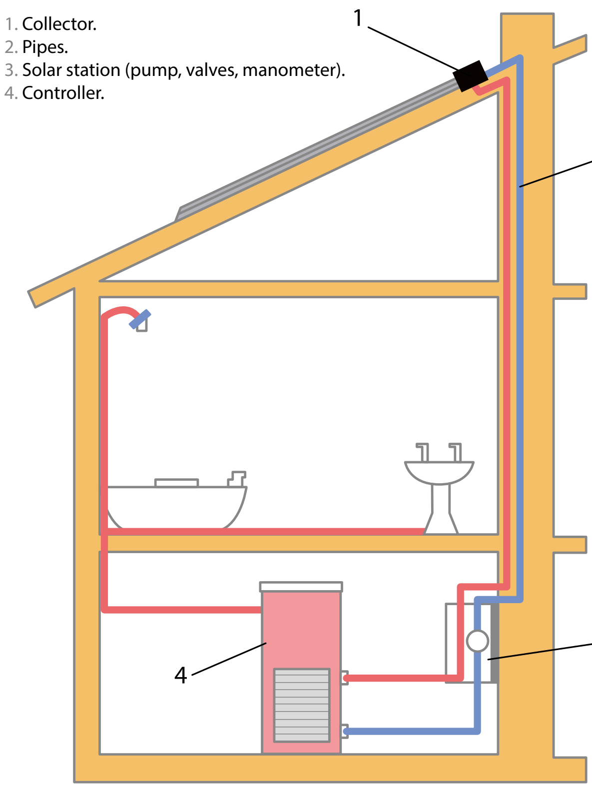

Figure 5-3: Basic components of a solar thermal system

Solar collector (absorber)

The solar collector corresponds to the black painted vessel on the roof in a solar shower. However, the water to be heated is not heated directly. A mixture of water and antifreeze flows through the collector.

There are different types of collectors. The most common are differentiated according to the type of insulation used to reduce heat loss from the absorber:

- Flat-plate collectors use conventional insulation such as mineral wool.
- Vacuum collectors achieve the insulating purpose by means of a vacuum. This more complicated process ensures higher efficiency, but is more expensive to purchase.

 he area of a collector (both types) is approx. 2 sqm (approx. 1m x 2m) each. Any number of collectors can be placed in a row. The larger the collector array, the greater the yield.

Figure 5-4: Vacuum or tube collector on the roof of a detached house

Substructure

Analogous to PV modules, solar collectors must be mounted on substructures on roofs or facades. Here, too, the most favourable orientation and installation angle must be determined. For flat roofs, mounting racks are available with the most common inclination angles of 30° and 45°. A minimum inclination should ensure the circulation of air in the collector. It is essential to follow the manufacturer's instructions.

Heat exchanger and solar storage tank

The mixture heated in the collector is fed to a heat exchanger. Here the heat is transferred to the domestic water. Ideally, the heat exchanger consists of a tubular shell immersed in a well-insulated storage tank. The size of the collector field and the storage capacity must be well matched.

Heat storage tanks with integrated boilers and heat exchangers are available in sizes from 600 to 700 litres, which can still be installed in the basements of single-family houses (height approx. 2 m, diameter approx. 90 cm). For larger systems, there is the option of connecting the storage tanks in a row as so-called cascade storage tanks or large storage tanks up to 350,000 litres, which then usually have to be buried in the ground. When used in large apartment buildings, however, it should also be carefully calculated how much hot water is consumed directly, as more people use hot water at different times.

Control system

Control technology optimises the utilisation of the solar tank. It regulates when cold fresh water must be added to the storage tank, when the solar energy is not sufficient to cover the heat demand and other energy sources are used or whether, on the contrary, enough heat is available to also supply the heating system.

5.1.3 Heat pumps

A heat pump heating system extracts heat or cold from the ground, groundwater or the air in order to heat or cool a building. In the following, the essential characteristics are described without going into the differences between the respective heat or cold sources.

A system roughly consists of the following parts. heat source system, heat pump and heat distribtion system.

Heat source system

In a first cycle, heat or cold (environmental energy) is extracted from the respective renewable, or infinite, source. Geothermal heat is extracted, for example, through pipes that are laid in long coils about 1.5 to 2 m deep in the ground. They are filled with water and antifreeze. The fluid absorbs the heat or cold and transports it to a heat exchanger.

Heat pump

Through heat exchange, the extracted heat or cold is fed to a second circuit. Here, the previously small temperature difference is made usable for heating or cooling through further conversion. The so-called heat pump works like an inverted refrigerator. Without going too much into detail, the basic principle is that a refrigerant is evaporated and compressed, whereby the heat transfer medium becomes warmer or colder. What is important in this context is that these conversion processes cannot be driven by renewable environmental energy alone. Electrical energy is used in the heat pump. Only if renewable electricity is available for the process, heating or cooling with the heat pump remains climate neutral. If not, the balance deteriorates considerably-

Heat distribution sysem

The cold or heat produced by the heat pump is fed into a third circuit, or the heat distribution syste,. Surface heating systems (wall or floor heating) with a large surface area are best suited for distribution. Here, even small temperature differences can achieve a heating or cooling effect. However, this is only successful if the building is well insulated. These properties are often not present in renovations of existing buildings. Therefore, heat pump systems are usually only used in new buildings.

Figure 5-5: Outside unit of a heat pump

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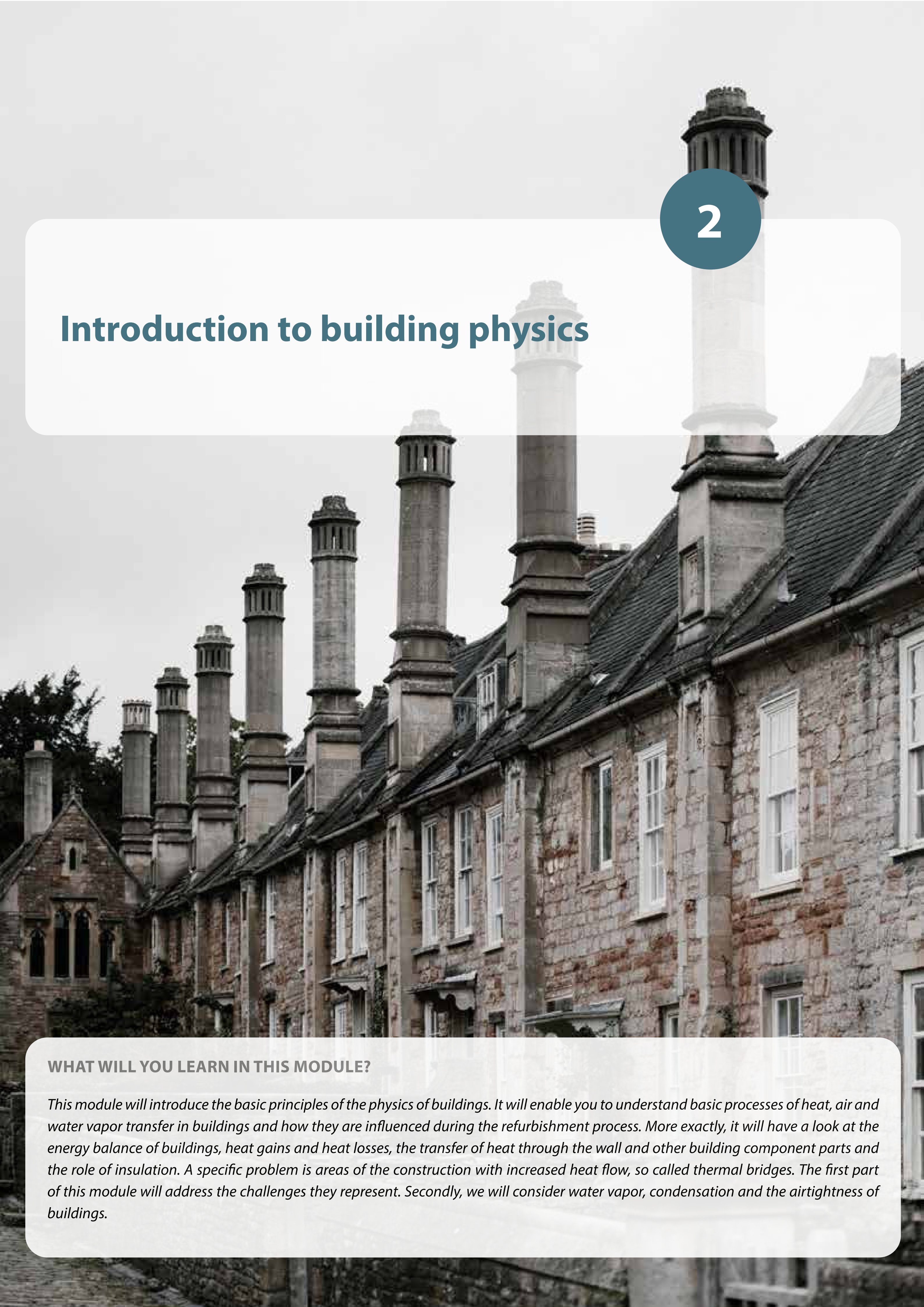


2

Introduction to building physics

WHAT WILL YOU LEARN IN THIS MODULE?

This module will introduce the basic principles of the physics of buildings. It will enable you to understand basic processes of heat, air and water vapor transfer in buildings and how they are influenced during the refurbishment process. More exactly, it will have a look at the energy balance of buildings, heat gains and heat losses, the transfer of heat through the wall and other building component parts and the role of insulation. A specific problem is areas of the construction with increased heat flow, so called thermal bridges. The first part of this module will address the challenges they represent. Secondly, we will consider water vapor, condensation and the airtightness of buildings.

6. Principles of heat gains and heat losses

Heat gains and heat losses have a significant impact on both the energy efficiency of buildings and comfort for the inhabitants. In order to minimize heat losses in winter and heat gains in summer the building envelope should be well insulated.

Heat losses

Heat losses during winter or heat gains during summer without solar radiation generally are calculated as follows for one building element:

Formula 6-1

$$Q = A \cdot U \cdot \Delta t \cdot \mu \quad [W]$$

where:

A – area of external element $[m^2]$

U – heat transfer coefficient $\left[\frac{W}{m^2 K}\right]$

Δt - difference between indoor and outdoor temperature $[°C]$ or $[K]$

μ – correction factor for wind impact, element orientation, etc.

The heat transfer coefficient expresses a heat flow in watts in 1 hour through 1 square meter of the building element with a temperature difference of 1°C. (Figure 6-1). Physics usually operates with Kelvin (symbol K) rather than with Celsius measurements. The difference of 1°C is exactly 1 K. We will use K as a unit from here on.

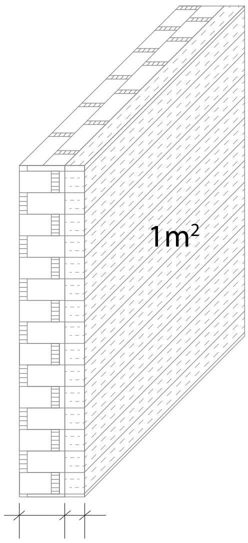


Figure 6-1: Principle of heat transfer coefficient (source: own)

The formula shows that heat losses depend on the temperature difference between inside and outside, the area of the external elements (windows, walls, roofs, floors) and heat transfer coefficient of the external elements. Thus, in order to reach maximal heat loss reduction the values of all abovementioned parameters should be as low as possible.

In practice it is almost impossible to reach a significant reduction of temperature difference, as the outdoor temperature depends on the location of the building but the indoor air temperature reduction is limited by human comfort levels.

Heat transfer coefficient

The heat transfer coefficient of building elements is limited by economical and technical factors. In practice the optimal heat transfer coefficient for new residential buildings usually varies between 0,15 W/(m^2·K) and 0,3 W/(m^2·K) for walls and 1,1 W/(m^2·K) - 2,1 W/(m^2·K) for windows. The heat transfer coefficients for energy efficient houses vary between 0,105 – 0,20 W/(m^2·K) for walls, roofs and 0,9 – 1,1 W/(m^2·K) for windows.

During the building design process, architects can reduce the energy consumption of the building by reducing the area of the external building envelope, or, in other words, by designing a more compact building. The area of the external building envelope can be reduced by choosing an optimal shape for the building. For example, the area of a cylinder surface is smaller than the surface of a cube with the same base area. The total area of the cylinder's surface is calculated using the following formula:

Formula 6-2

$$A = 2\pi \cdot r^2 + 2\pi \cdot r \cdot h \quad [m^2]$$

where:
r - radius of cylinder base $[m]$
h - height of cylinder $[m]$
π – mathematical constant - 3,141...

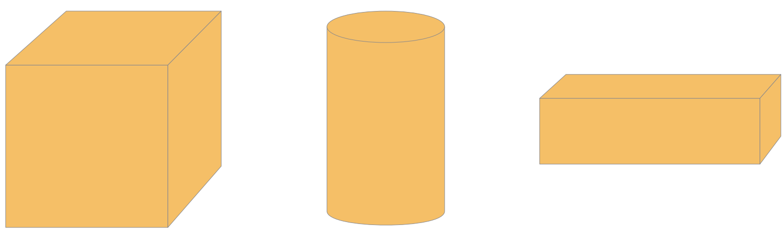
The total area of a cube and a rectangular prism can be calculated as follows:

Formula 6-3

$$A = 2(a \cdot b + a \cdot h + b \cdot h) \quad [m^2]$$

where:
h - height of the prism or cube $[m]$
a - length of base $[m]$
b – width of the base $[m]$

The difference between the area of cylinder, a square prism and rectangular prism with the same area of base equal to 100 m^2 is shown below.



Base size	10 x 10 x 3 m	r≈5,6 m; H = 3 m	6,6 x 15 x 3 m
Volume	300 m^2	300 m^2	300 m^2
Surface area	120 m^2	107 m^2	130 m^2
Ratio surface/volume	0,4	0,36	0,43

Table 6-1: The difference between the area of a cylinder, cube and rectangular prism with the same volume

If these geometric volumes were heated, the heat loses for the cube would be by 12% higher in comparison with the cylinder and by 22% for the rectangular prism. In terms of heat losses, the building shape should be very simple, without any complicated forms.

Surface area to volume ratio

In order to express the compactness of a real building, the *surface area to volume ratio* definition (S/V) is widely used. The building surface area to volume ratio expresses the ratio between the area of the external envelope and the volume of a building. Smaller surface area to volume ratio means smaller heat losses. Some examples are shown in Figure 6-2.

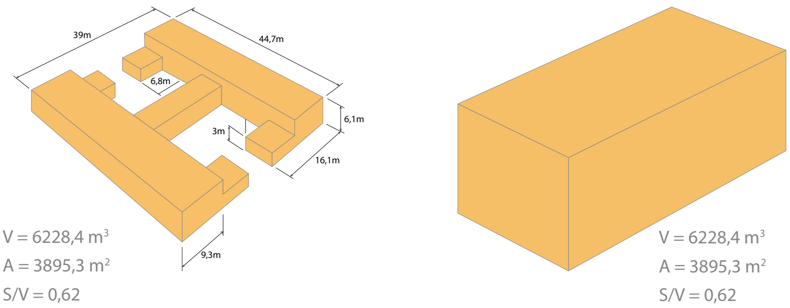


Figure 6-2: **Theoretical examples of surface area to volume ratio definition (source: own)**

KEY POINTS TO REMEMBER FROM CHAPTER 2

- **Heat losses through building components depend on temperature difference, material properties and the area through which heat is lost.**
- **More compact structures lose less energy. A measure for compactness is the surface-area-to-volume ratio.**

7. Energy balance of a whole building

Energy balance

Energy balance describes how much energy is needed to heat an entire building, showing not only the transmission heat losses through all building components (explained in Chapter One), but also includes the ventilation heat losses. Ventilation heat losses are caused by air movement, for example, warm air leaving through windows, air ducts or tiny cracks in the walls. These losses are balanced by heat gains such as passive solar gains, and internal gains (cooking, candlelight, technical devices, or inhabitants). The remaining difference must be covered by active heating to compensate for the heat losses. If the building envelope is insulated - if less energy escapes and if more passive solar and internal gains are used - less active heating is needed. Thus, the general formula for the energy balance is as follows:

Formula 7-1
Annual heat demand

$$Q_H = \eta_L(Q_{tr} + Q_{ve}) - \eta_G(Q_{sol} + Q_{int}) \quad [W]$$

where:
Q_{tr} – transmission heat losses through the total building envelope $[W]$
Q_{ve} – ventilation heat losses $[W]$
Q_{sol} – solar gains $[W]$
Q_{int} – internal heat gains $[W]$
η_G – utilization factor of heat gains (0,90 – 0,95)
η_L – correction factor due to night or weekends room temperature reduction (η_L=1 for heating systems without regulation possibilities and 0,90 – 0,95 for heating system with regulation possibilities)

Formula 7-1 shows the annual heat demand as the difference of heat losses through transmission and ventilation minus the useable solar and internal gains. The heat gains can be reduced by a utilization factor ηG, which results from the fact that not all gains can be stored in the construction parts.

As shown, thermal insulation of a building reduces the energy demand. Through better insulation and a tighter building envelope less energy is lost to the environment through transmission losses; the demand for heat is reduced.

Details follow for using the formula, illustrating basic physical principles of the energy balance of a building, including both heat losses and gains.

Transmission heat losses of whole buildings can be calculated as follows:

Formula 7-2
Transmission heat losses

$$Q_{tr} = \left(\sum_i U_i A_i \mu_i + \sum_j \Psi_j l_j\right) \Delta t \quad [W]$$

where:
$\sum_i U_i A_i \mu_i$ – envelope heat losses coefficient (sum of all walls, roofs, windows and floors of building envelope) $[\frac{W}{K}]$

$\sum_j \Psi_j l_j$ – thermal bridges heat losses coefficient (sum of all thermal bridges of building envelope) $[\frac{W}{K}]$
Δt – indoor temperature and outdoor temperature difference $[°C]$ or $[K]$

The total transmission heat losses of a building are calculated by summing up the losses through all building components and thermal bridges, multiplied by the temperature difference. The multiplication with the temperature difference is necessary because heat losses are calculated for 1 K difference between indoor and outdoor temperature.

The formula shows how thermal rehabilitation of a building can help to reduce heat loss. By adding insulation, the U-value of the entire construction decreases, thus less heat is lost. Furthermore, installation of a new heating system means the temperature can be regulated; in case of overheating in the cold season, the average indoor temperature can be decreased to more comfortable levels. This reduces the temperature difference between inside and outside, decreasing the heat transmission loss. Last but not least, proper design of the building can help minimize thermal bridges and reduces the heat losses they cause.

Ventilation heat losses

The second type of heat losses are those caused by ventilation. They can be calculated with the help of the average air change rate and an air exchange by additional infiltration. When ventilation heat losses are minimized, e.g. during the refurbishment of a building, it is important to provide enough fresh air for comfort and hygienic needs.

Ventilation heat losses can be calculated as follows:

Formula 7-3

$$Q_{ve} = V \cdot n \cdot c_p \cdot \rho \cdot \Delta t \quad [W]$$

where:
c_p – is specific heat of air - 0,279 $\frac{Wh}{kgK}$
ρ – is the density of air - 1,2 $\frac{kg}{m^3}$
V – volume of the apartment $[m^3]$
n – air exchange rate $[\frac{1}{h}]$
Δt – indoor temperature and outdoor temperature difference $[K]$

The thermal rehabilitation process influences two parameters - the air change rate n due to eliminating unwanted structural infiltration (e.g. cracks in the walls, space around windows) and the temperature difference between indoor air and the internal surface of the building envelope..

Heat gains

Heat gains must also be taken into account. The first type are solar gains - passive solar radiation coming through windows or opaque elements. Passive solar radiation raises the internal temperature of the building, helping to reduce the heat demand in winter. In summer, however, cooling energy might be required to prevent overheating. The calculation of the solar heat gains can help to detect the frequency of overheating in summertime.

Solar heat gains

To calculate the solar gains, the window areas and the material of the windows are required parameters, as well as climate data (radiation on horizontal surfaces as well as from different directions). The solar heat gains can be calculated as follows:

Formula 7-4

$$Q_{sol} = \left(\sum_i r_i A_i g_i \right) G \quad [W]$$

where:
G – solar radiation $[\frac{W}{m^2}]$
A_i – absorbing area $[m^2]$
g_i – solar transmissions
r_i – reduction factors due to shading

In most cases, the refurbishment process has little influence on solar gains. Usually the incoming radiation cannot be changed (although, theoretically, the building's orientation on the property could be altered): the size and properties of windows will remain unchanged, fundamentally, in terms of solar gains. Planting trees in front of the building will reduce the incoming solar radiation and can mitigate overheating in summer.

Internal heat gains

Internal heat increases can also be caused by activity of the building inhabitants and/or from technical devices such as computers or lamps that emit heat.

An exemplary calculation methodology is given here:

Formula 7-5

$$Q_{int} = q \cdot A \quad [W]$$

where:
q – internal heat gains $[\frac{W}{m^2}]$
A – apartments area $[m^2]$

Internal heat gains can be assumed to be 5 to 10 W/m^2 in residential buildings. During the refurbishment of a building this parameter is usually not changed.

KEY POINTS TO REMEMBER FROM CHAPTER 3

- **Heat losses occur through ventilation heat losses and through heat transmission. Heat gains result from incoming passive solar radiation and internal activity. The difference between losses and gains must be balanced by active heating to maintain a comfortable indoor temperature in cold seasons.**
- **Insulating an apartment decreases the heat losses through reduced transmission and air infiltration, thus decreasing the need for active heating in cold seasons.**

8. Indoor thermal comfort

Indoor comfort

Indoor thermal comfort, in brief: Generally, the indoor air temperature is assumed to be between +20 and +24°C; relative humidity is assumed to be between 40% and 60%. Along with temperature and relative humidity, the human comfort level is also significantly influenced by environmental and individual factors such as air velocity and mean radiant temperature (see below). Individual factors include, for example, the human activity level and type of clothing. The proper choice of indoor air parameters ensures not only human comfort but also allows for reduction of unnecessary overheating during winter and a reduced cooling load in summer. In that way, correctly designed indoor air parameters ensure the reduction of energy consumption without compromising the human comfort level.

Mean radiant temperature

One of the most crucial environmental factors having a strong impact on human comfort level is the mean radiant temperature. The *mean radiant temperature* describes a specific temperature of all surrounding surfaces, including the ratio of all surfaces with different temperatures. The mean radiant temperature can be calculated using data (1), (2) approach:

Formula 8-1

$$MRT = \frac{t_1 A_1 + t_2 A_2 + ... + t_i A_i}{A_1 + A_2 + ... + A_i} \quad [^\circ C]$$

where:
A – surface area $[m^2]$
t – temperature of the given area $[^\circ C]$

The principal scheme of mean radiant temperature is shown in Figure 8-1.

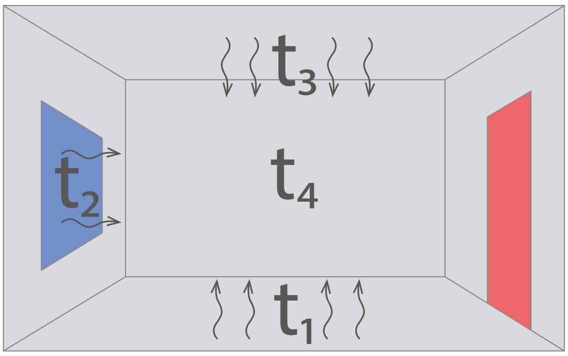
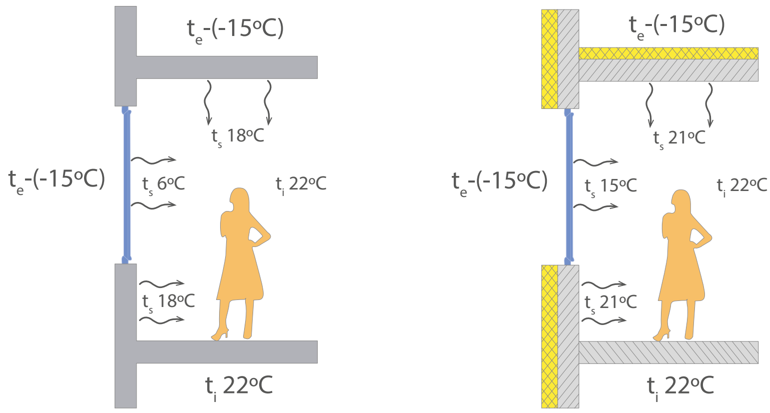


Figure 8-1: The principal scheme of mean radiant temperature

If two rooms have the same indoor air temperature but different mean radiant temperature, an individual will feel more comfortable in the room with the higher mean radiant temperature.

Existing buildings with a non-insulated envelope will have lower mean radiant temperature than buildings with well-insulated envelopes, as the outer walls will be colder. The figures below (Figure 8-2) illustrate two situations with the same internal temperature. On the left, a non-insulated building with lower thermal comfort; on the right, the same building – insulated – has higher surface temperatures, thus better thermal comfort.



Non-insulated building envelope

Well-insulated building envelope

Figure 8-2: Mean radiant temperature in non-insulated and well-insulated room (source: own)

Operative temperature

Currently, both European Standards and ASHRAE (American Society of Heating, Refrigeration, and Air-Conditioning Engineers) standards work with the *operative temperature* of indoor air instead rather than simply the indoor air temperature. According to data (3) (4) the operative temperature in apartment buildings can be calculated in a simplified way using the following formula:

Formula 8-2

$$t_0 = \frac{T_{MRT} + t_i}{2} \quad [°C]$$

where:

t_i – indoor air temperature $[°C]$

T_{MRT} – mean radiant temperature $[°C]$

The human metabolic activity and clothing type should be taken into consideration while choosing the optimal indoor air temperature. A sleeping person produces around 55 – 75 watts; moderate work such as writing will produce between 125 – 150 watts and hard work, up to 450 watts. A person doing hard work will feel more comfortable at lower surrounding temperatures; the warmer the clothing, the colder the air temperature can be. For example, someone dressed in pyjamas, under a blanket, feels comfortable at 16 °C, while someone lightly dressed doing moderate work can accept air temperatures up to 28 °C. These factors can be efficiently used in order to reduce the indoor air temperature in winter or to increase it in summer, thus reducing energy consumption.

More detailed information on thermal comfort, human heat production, impact of clothing level and comfortable parameters in rooms can be found in European and ASHRAE standards (5) (6) as well as in the handbook (4).

KEY POINTS TO REMEMBER FROM CHAPTER 4

- **Indoor thermal comfort is not only influenced by the air temperature but also by the surface temperature of the surrounding walls. Good insulation can increase the thermal indoor comfort.**
- **Activity level and clothing choices allow people to feel comfortable at different indoor temperatures.**

9. Heat transfer

Working through the details of heat transfer in this chapter should provide a better understanding of why insulation materials help to reduce the heating demand in cold seasons.

U-value

To describe heat transfer more exactly, we use the term and concept of the *heat transfer coefficient (U-value)*. Older books include calculations for thermal resistance, but there is a direct relation between both values. The heat transfer coefficient expresses heat flow in watts in 1 hour through 1 square meter of the building element with a temperature difference of 1 Kelvin. The heat transfer coefficient depends on thermal properties of the different building materials of analyzed building elements. The general formula to calculate the U-value is the following:

Formula 9-1

$$U = \frac{1}{R_{si} + R_1 + R_2 + ... + R_i + R_{se}} \quad \left[\frac{W}{m^2K}\right]$$

where:

R_{si} – internal surface thermal resistance $[\frac{m^2K}{W}]$

$R_1, R_2, ..., R_i$ – thermal resistance of the external building elements layers $[\frac{m^2K}{W}]$

R_{se} – external surface thermal resistance $[\frac{m^2K}{W}]$

The formula shows the direct relation between the heat transfer coefficient and the thermal resistance – they are inverses of each other and thus easily converted. In order to calculate the total U-value of an entire external construction component you will need to consider the different thermal resistance properties of all its layers, adding the thermal resistance of the innermost and outermost surface to the surrounding air. This internal surface thermal resistance can be assumed as 0,13 W/(m·K) for walls, and 0,10 W/(m·K) for ceilings. The external surface thermal resistance can be assumed as 0,04 W/(m·K) for all parts of the building envelope (7) (8). The thermal resistance of all other homogenous layers is calculated using the following formula for each layer:

Thermal resistance

Formula 9-2

$$R = \frac{d}{\lambda} \quad \left[\frac{m^2K}{W}\right]$$

where:

d – thickness of the layer $[m]$

λ – thermal conductivity of the layer $[\frac{W}{m^2K}]$

With a well-ventilated air layer in the construction, the total thermal resistance should be calculated taking into consideration only layers between the indoor air and well-ventilated air layer.

Thermal conductivity

The thermal conductivity (λ) is a material property and can be found in manufacturer’s datasheets. (Local normative databases or handbooks can be used when manufacturer’s data are not available.) In modern construction the heat insulation materials have a significant impact on total thermal resistance. Therefore manufacturer’s data, if available, must be used to get a more precise value of the heat transfer coefficient of insulation materials. For instance, when the heat transfer coefficient of an external wall with area 300m^2 is calculated by 0,01(W/(m^{2}K)) less, the approximate additional non-estimated heat losses through this wall will be 295 kW during the heating season with an average outdoor air temperature of 0°C. Consequently for a wall with an area of 3000 m^2 the additional heat losses could be up to 2950 kW.

The following examples illustrate the changes in thermal properties as different types of insulation are used in a building.

EXAMPLE 1. The first example is a basic brick wall without internal and external finishing; we will calculate the heat transfer coefficient. The thickness of the wall is 380 mm (Figure 9-1). The thermal conductivity of brick is assumed as 0,81 W/(m·K)

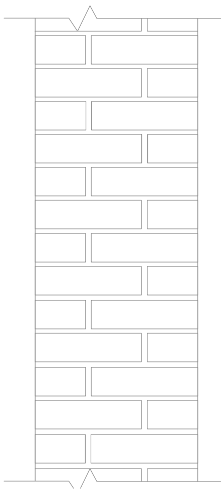


Figure 9-1: Simplified brick wall

First, we calculate the thermal resistance for the brick layer then add the obligatory thermal resistance for the internal and external surfaces:

$$R = R_{si} + \frac{d}{\lambda} + R_{se} = 0,13 + \frac{0,38}{0,81} + 0,04 = 0,639\frac{m^2K}{W}$$

The heat transfer coefficient of this wall is calculated by taking the inverse:

$$U = \frac{1}{R} = \frac{1}{0,639} = 1,56\frac{W}{m^2K}$$

This value is approximately 10 times higher than modern requirements for an energy-efficient building. In order to reach the current requirements thermal insulation should be used. The next examples explain the procedure.

EXAMPLE 2. The calculation of the heat transfer coefficient for the same brick wall but with internal and external finishing and a thermal insulation layer on the outside of the wall (Figure 9-2).

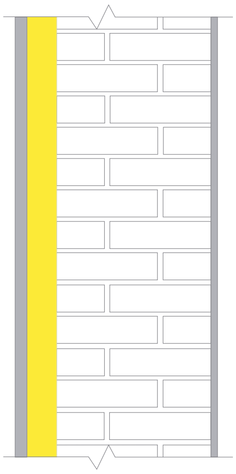


Figure 9-2: Brick wall with heat insulation

It is assumed that the insulation layer is fixed with an adhesive and special wall insulation anchors with nylon cover. In that case it is not necessary to make additional corrections for mechanical fixings (explained later). The properties of the analyzed wall are shown in Table 2. The values for the thermal conductivity used for calculation are average value of materials currently available on the market.

Material	Thickness, [m]	Thermal conductivity, [W/m·K]	Thermal resistance, [m^2K/W]
Internal surface	-	-	0,130
Internal finishing (drywall)	0,013	0,250	0,052
Brick wall	0,380	0,810	0,469
Heat insulation	0,150	0,036	4,167
External finishing (plasterboard)	0,020	0,900	0,022
External surface	-	-	0,040
		Total	4,880

Table 9-1: The properties of brick wall with extra insulation and finishing

$$R = 0,13 + \frac{0,013}{0,25} + \frac{0,38}{0,81} + \frac{0,15}{0,036} + \frac{0,02}{0,9} + 0,04 = 4,88\frac{m^2K}{W}$$

$$U = \frac{1}{R} = \frac{1}{4,88} = 0,20\frac{W}{m^2K}$$

The heat transfer coefficient is only a fraction of the un-insulated wall. Note that adding insulation and finishing is very effective, reducing heat losses by 87%.

Mechanical fixings

In some cases a correction for mechanical fixings penetrating the insulation is necessary. For example, such a correction is necessary with double façades or decorative external finishing (see Figure 9-3) when mechanical fixings cross the insulation layer. In these cases the following proposed methodology (7) can be used to calculate a correction for mechanical fixings:

Formula 9-3

$$U_f = \alpha \cdot \lambda_f \cdot h_f \cdot A_f \quad \left[\frac{W}{m^2K}\right]$$

where:
α – constant value which depends on construction type and materials. For brick walls $6m^{-1}$, for roofs $5m^{-1}$
λ_f – thermal conductivity of mechanical fixing $[\frac{W}{mK}]$
A_f – cross-sectional area of fixing $[m^2]$
h_f – the number per square meter of wall

The total heat transfer coefficient can be calculated as follows:

Formula 9-4

$$U_T = U + \Delta U_f \quad \left[\frac{W}{m^2K}\right]$$

EXAMPLE 3. Calculation specifics of the heat transfer coefficient for an insulated wall with mechanical fixings and a well-ventilated air layer. The analyzed construction is shown in Figure 9-3. The properties of the construction layer wall are similar to construction shown in Example 2.

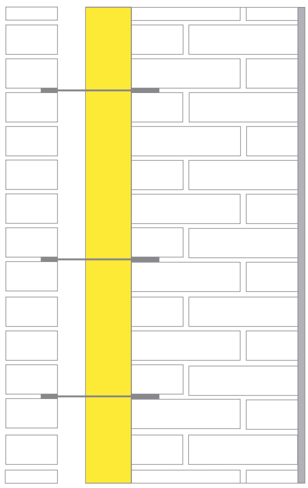


Figure 9-3: Brick wall with heat insulation and mechanical fixings

The external element is decorative brick wall which is connected to the main wall by steel fixings. The number of fixings is 4 pieces per square meter and the diameter of each fitting is 6 mm (cross-sectional area is 0.0000283 m^2). Steel thermal conductivity is assumed as 17 W/(m^{2}K).

The U-value of the main wall is calculated for the layer between the indoor air and the well-ventilated air layer:

$$U = \frac{1}{0,13 + \frac{0,013}{0,25} + \frac{0,38}{0,81} + \frac{0,15}{0,036} + 0,13} = 0,20 \frac{m^2K}{W}$$

U-value correction for mechanical fixings:

$$U_f = \alpha \cdot \lambda_f \cdot h_f \cdot A_f = 6 \cdot 17 \cdot 4 \cdot 0,0000283 = 0,00321 \frac{W}{m^2K}$$

The final U-value of construction presented in Figure 9-3 is 0,203 W/(m^2K). The impact of the mechanical fixing is not critical in this case, although the larger number and/or size of mechanical fixings can lead to greater heat losses. Each individual case should be evaluated separately, taking into account the construction's coefficient of thermal uniformity.

Heat transfer in frame constructions

The previous examples presented the calculations of the heat transfer coefficient for an external wall consisting of homogenous layers. In many cases it is necessary to use frame constructions for the construction of new buildings or the renovation of existing ones. Calculations of such constructions are more complicated and take into account the proportion of areas using different materials. The very precise methodology is described in national standards and handbooks. The data (9) provides a simplified method for estimating the heat transfer coefficient of frame constructions. According to this data the heat transfer coefficient of inhomogeneous constructions (Figure 9-4) can be calculated as follows:

Formula 9-5

$$U = \frac{U_1 \cdot b_1 + U_2 \cdot b_2}{b_1 + b_2} \quad \left[\frac{W}{m^2K}\right]$$

where:

U_1 – heat transfer coefficient of wooden beam $[\frac{W}{m^2K}]$

U_2 – heat transfer coefficient of insulation material between the carcass elements $[\frac{W}{m^2K}]$

b_1 – size of wooden beam $[m]$

b_2 size of insulation material $[m]$

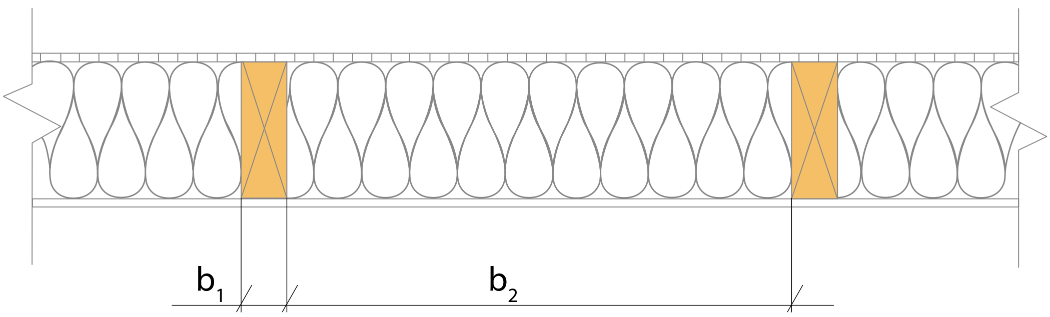


Figure 9-4: Vertical cross section of wooden carcass construction

KEY POINTS TO REMEMBER FROM CHAPTER 5:

- **The heat transfer coefficient (U-value) describes the thermal properties of construction elements, which depends on the different layers and materials of each part. Additional insulation layers on walls decrease the heat transfer coefficient of walls and reduce heat losses.**
- **Mechanical fixings and frame constructions have an influence on the heat transfer coefficient and should be considered in the calculation.**

10. Thermal bridges

A thermal bridge is a section of the building where the thermal resistance of homogeneous parts of the building envelope is changed by the following factors:

Reasons for thermal bridges

- material with higher heat conductivity crosses the building envelope or part of it (material thermal bridge);
- different thickness of the external elements or materials of the building, e.g. corners of buildings (geometric thermal bridges);
- differences in the dimensions of building elements, junctions between walls/floors/roof (structural thermal bridges).

Some common thermal bridges are shown in figure 10-1.

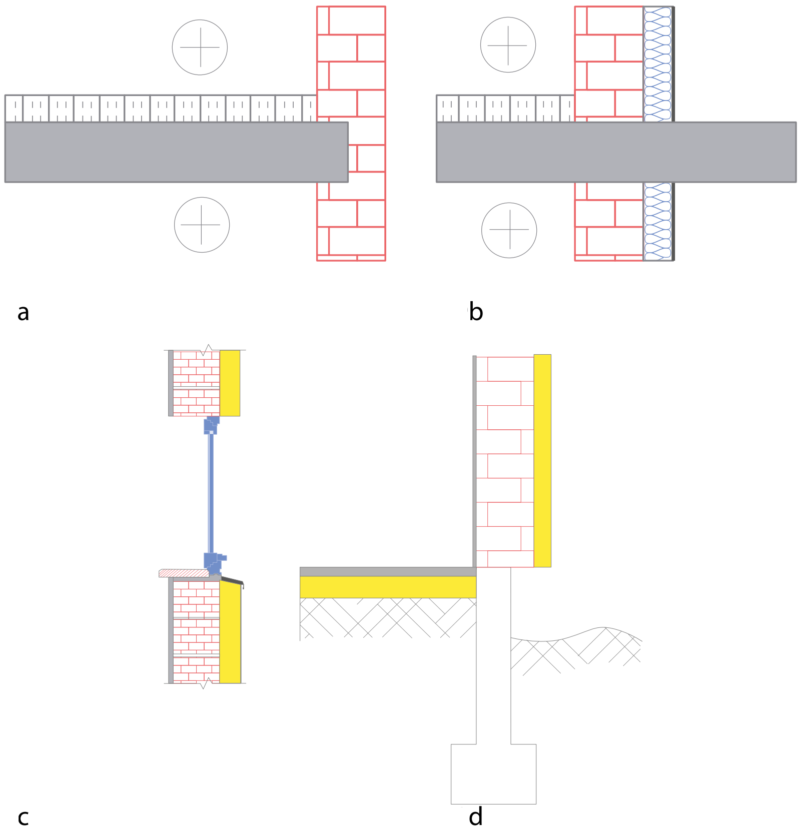


Figure 10-1: Common thermal bridges

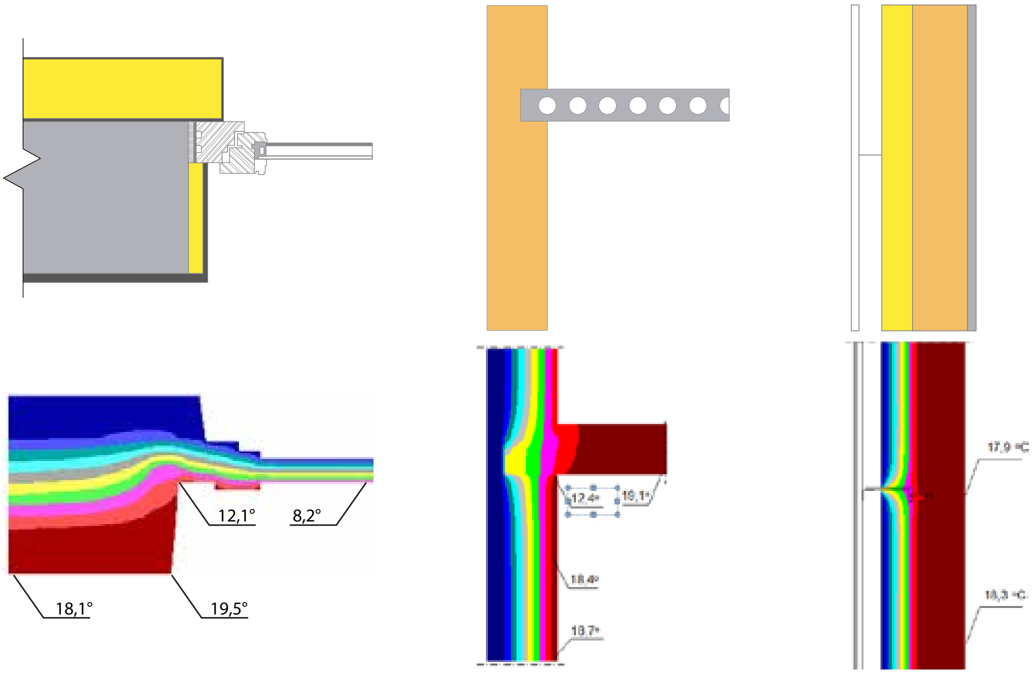
In Figure 10-1a and 10-1b, the floor concrete slab is crossing the thermal envelope. The thermal conductivity of concrete is two times higher than for bricks and approximately fifty times higher than for insulation materials. The heat flow is increased through this construction. The heat loss is higher in the second drawing (b), because the concrete slab completely penetrates the wall.

Figure 10-1c shows a thermal bridge at the window frame due to missing insulation. Figure 10-1d illustrates the missing insulation just above the ground (perimeter insulation). The insulation is finished a few centimeters above ground. This creates a thermal bridge under the brick wall.

Negative effects of thermal bridges

Thermal bridges have two negative effects: additional heat losses and a high risk of water vapor condensation on the internal surface. In addition, condensation on the internal surface for a longer period of time can cause mold growth. In order to minimize heat losses and to avoid condensation problems, the thermal bridge should be insulated as well as possible.

The temperature distribution in some common thermal bridges is shown in figure 10-2.



Horizontal cross section through window

Ceiling

Mechanical fixing

Figure 10-2: The temperature distribution in some common thermal bridges (figures with temperature distribution provided by Darja Nemova)

Ψ-value

The heat losses through the thermal bridges can be characterized by linear thermal transmittance coefficient (Ψ-value) which expresses heat flow in watts in 1 hour through 1 meter of the thermal bridge (W/(m·K)). The principles of additional heat losses due to the thermal bridge are shown in figure 10-3.

Figure 10-3 presents a particularly bad case, when the heat insulation layer is interrupted by a concrete panel. The heating season is assumed to be 200 days, with an average temperature of the heating season at 0°C.

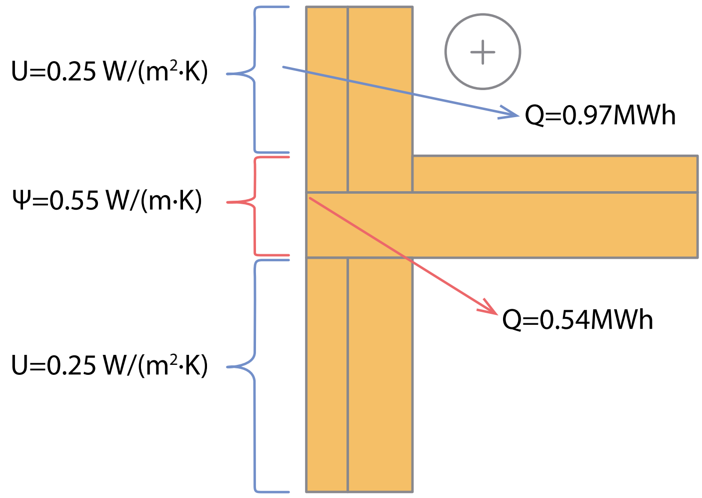
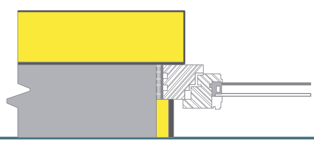
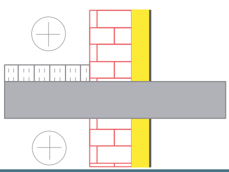


Figure 10-3: Additional heat loss due to the thermal bridge in heating season

Nowadays heat transfer coefficients of thermal bridges are calculated using special software. All computer programs are able to estimate not only the Ψ-value but also provide information on the temperature of internal surfaces, which is crucial for evaluating the risk of mold growth. As an alternative to computer programs, thermal bridge catalogues can be used. It should be noted that although the catalogues are more convenient, they are less precise: calculations found in bridge catalogues can be inaccurate, possibly even up to 50%, in comparison to exact calculations. In addition, the thermal bridge catalogues do not provide information on internal surface temperatures under specific indoor and outdoor air parameters.

Today's new buildings have a well-insulated building envelope without any significant thermal bridges. The Ψ-value for thermal bridges for well-insulated external and internal corners is close to zero. Window/wall junctions and balconies are the most critical places in terms of thermal bridges in both construction of new buildings and renovation of existing buildings.

Some average values of common thermal bridges are presented in Table 3.

Thermal bridge	Principal scheme	Linear thermal transmittance coefficient Ψ-value W/(m·K)
Window/wall (window frame is covered by heat insulation)		0,10 - 0,16
Floor/external wall (floor concrete slab is crossing the thermal envelope)		0,65 - 0,70

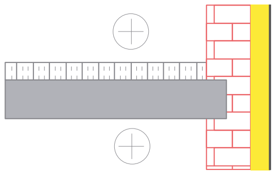
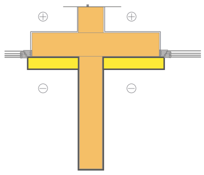
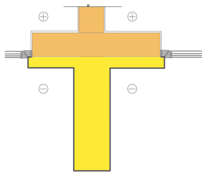
Floor/external wall (The heat insulation material isn't interrupted by concrete slab)		0
Internal/external wall (Internal wall fully crosses the external wall. Only external wall is insulated.)		0,55 - 0,65
Internal/external wall (Internal wall fully crosses the external wall. External wall is insulated.)		0

Table 10-1: Average values of common thermal bridges

Thermal bridge heat loss coefficient is calculated using the linear thermal transmittance coefficient and thermal bridge length:

Formula 10-1

Thermal bridge heat loss coefficient

$$H_{TB} = l \cdot \Psi \quad \left[\frac{W}{m}\right]$$

where:

l – length of the analysed thermal bridge $[m]$

Thermal bridge at balconies

Typical non-insulated balcony construction is shown in Figure 10-4. The floor slab which has high thermal conductivity interrupts the insulation layer and causes a structural thermal bridge. Such construction is still used in new buildings although it decreases total energy performance.

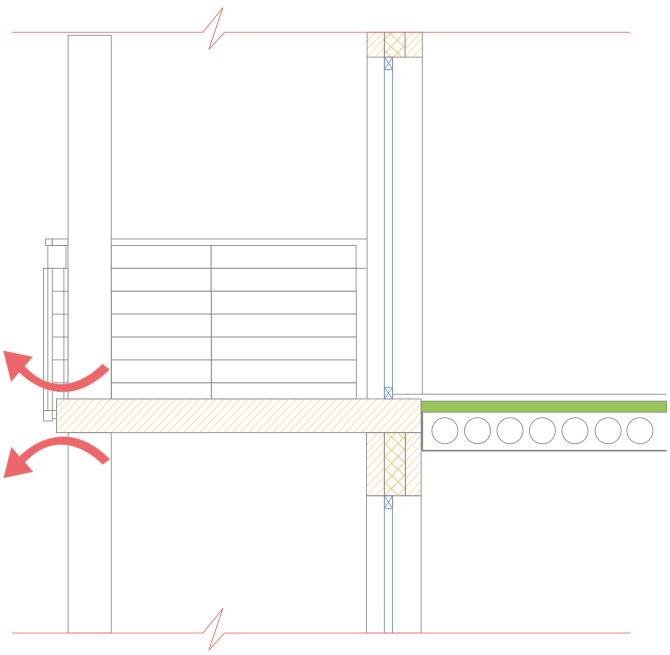


Figure 10-4: Typical non-insulated balcony construction

The linear thermal transmittance coefficient of the abovementioned junction could be up to 0,95 W/(m·K). Depending on technical solutions and applied materials, the implementation of special thermal breaks allows for significant reduction of linear thermal transmittance. More information on balcony thermal breaks can be found on producers' websites.

One possible solution to minimize balcony thermal bridges is to separate the balcony structure from the building envelope, as seen in Figure 10-5. The balconies have their own load-bearing structure. Steel anchors to the building envelope may still be needed to stabilize the balconies.

Figure 10-5: Balconies with own load-bearing structure, separate from building envelope

KEY POINTS TO REMEMBER FROM CHAPTER 6:

- **Thermal bridges are parts of the construction which have an increase in heat flow.**
- **There are three types of thermal bridges: material, geometric and structural.**
- **Typical thermal bridges are found in concrete floor slabs which cross the thermal envelope, e.g. for balconies. During the refurbishment process these thermal bridges can be eliminated by separating the balcony structure from the building envelope.**

11. Humid air

Indoor air has a direct impact on human health. According to the regulations (ASHRAE 2007) relative humidity should be kept between 30% and 60% for indoor environments. Long periods of relative humidity below 30% can cause drying of the mucous membranes and discomfort for many people while relative humidity above 60% for extended time periods promotes indoor microbial growth. The main moisture production source in buildings is the human body and household activities (e.g. bathing, dishwashing). New construction can produce up to 8 liters per day during the first year of use (8). Most excess moisture production can be removed by the ventilation system. Water leakage from water pipes, heating systems and the roof should be prevented wherever possible and, if it occurs, should be eliminated as soon as detected.

This chapter provides a brief overview of basic humid air properties and basic principles of water vapor transfer.

Water vapor concentration

Under natural conditions both indoor and outdoor air is constantly humid. The air humidity level usually is expressed by humidity ratio or water vapor content. The water vapor concentration expresses the total mass of water in grams or kilograms contained in 1m³ of humid air. The humidity ratio expresses the ratio between the mass of water vapor in grams or kilograms and mass of dry air in grams or kilograms with which it is mixed.

The ability of air to hold moisture depends on its temperature. Warm air can hold more moisture than cold air. The maximal possible water vapor concentration (saturated water vapor concentration) at the given temperature is shown in Figure 11-1.

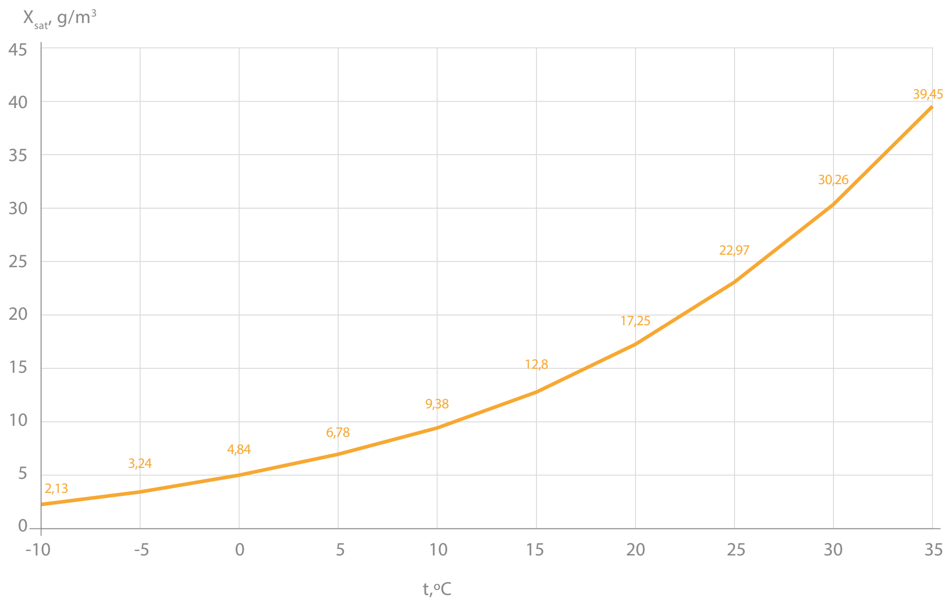


Figure 11-1: The maximal possible water vapor concentration, g/m³ (at relative humidity 100%)

One cubic meter of air at 20°C can absorb not more than 17,3 g/m^3 grams of water vapor. The extra amount of water vapor remains in liquid state. At -10 °C, the maximal water vapor concentration is 2,1 grams per one cubic meter.

Relative humidity

The widely used parameter which describes humid air is relative humidity. Relative humidity, stated as a percentage value, shows the ratio between actual water vapor concentration and maximal possible at the given air temperature. Relative humidity of 100% indicates that the air holds the maximal possible amount of water vapor at the given temperature. Any additional moisture at that temperature will result in condensation. The temperature at which the given moisture content creates 100% relative humidity is called the dew point. In other words, the dew point is the temperature to which the air must be cooled to reach 100% relative humidity.

Dew point

In practice, the relative humidity is calculated as follows:

Formula 11-1

$$\varphi = \frac{x}{X_{sat}} \cdot 100\%$$

where:

x – real water vapour concentration $[\frac{g}{m^3}]$

X_{sat} – saturated water vapor concentration (the maximal possible water vapor concentration $[\frac{g}{m^3}]$

A hydro-thermometer is used to measure the air temperature and relative humidity. By knowing the air temperature it is possible to evaluate the saturated water vapor concentration (Figure 11-1). The real water vapor is calculated by rewriting the formula:

Formula 11-2

$$x = \frac{\varphi \cdot X_{sat}}{100\%} \quad \left[\frac{g}{m^3}\right]$$

EXAMPLE 4. Indoor air temperature is +22°C, relative humidity is 60%. As an example, we can calculate the actual amount of moisture in the air x, g/m^3. The saturated water vapor pressure can be obtained using the Figure 11-1 data. At 22°C the saturated water vapor concentration is 19,7 g/m^3. Using Formula 17, the actual water vapor concentration can be calculated:

$$x = \frac{60\% \cdot 19,7\frac{g}{m^3}}{100\%} = 11,8\frac{g}{m^3}$$

Figure 11-2 shows a practical illustration of the evaluation result.

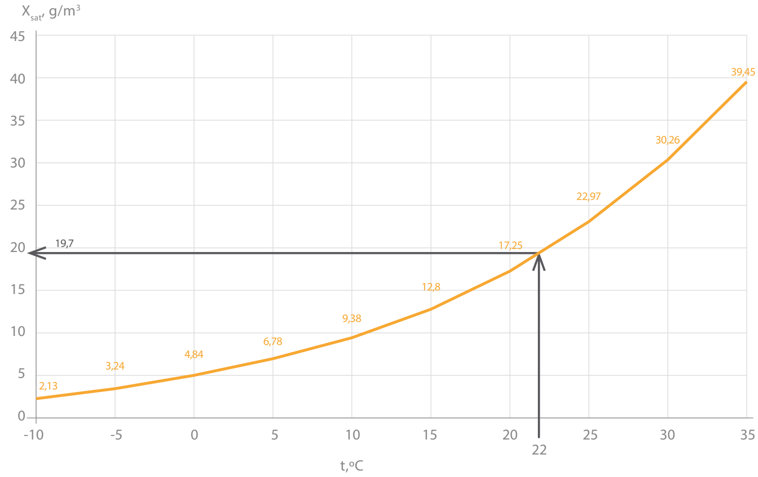
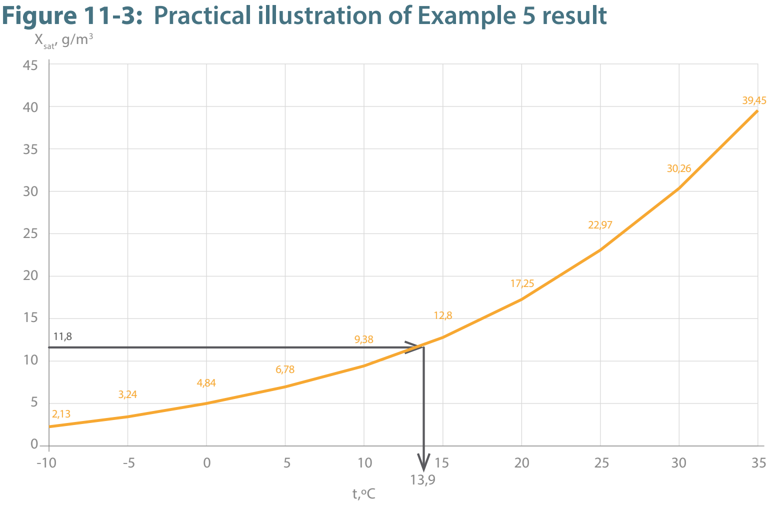


Figure 11-2: The practical illustration of the result of example 4

EXAMPLE 5. Air parameters are the same as in Example 4. At which temperature is water vapor condensation observed (dew point temperature)?

Example 5 shows that the actual water vapor is 11,8 g/m3 for air temperature +22 °C and relative humidity is 60%. According to Figure 11-3 data water vapor concentration 11,8 g/m^3 makes 100% relative humidity at the temperature 13,9°C.

Figure 11-3: Practical illustration of Example 5 result



One of the important parameters of moist air is the water vapor pressure. The water vapor pressure is usually expressed in Pascal and is used for evaluation of interstitial condensation. Interstitial condensation is formed when water vapor passing through construction meets the dew point temperature. Interstitial condensation can lead to structural damages, additional heat losses due to moistening of building materials and health problems caused by mold growth.

Water vapor pressure

Similar to water vapor concentration, the maximal water vapor pressure is limited by air temperature. The maximal possible water vapor pressure at the given temperature is called the saturation vapor pressure. The saturation vapor pressure is observed at relative humidity 100%. Figure 11-4 shows the water vapor saturation pressure at temperatures between -10°C and 35°C.

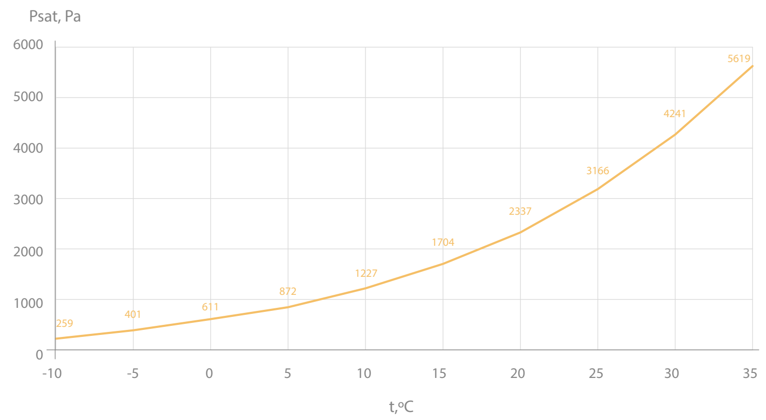


Figure 11-4: The water vapor saturation pressure, Pa (at relative humidity 100%)

The water vapor saturation pressure is only 259Pa under temperature -10°C and at +25°C, it requires 3166 Pa, 12 times higher.

Actual vapor pressure under given air temperature and relative humidity can be calculated as follows:

Formula 11-3

$$P_x = \frac{\varphi \cdot P_{sat}}{100\%} \quad [Pa]$$

where:

P – actual vapor pressure [Pa]

P_{sat} – water vapor saturation pressure [Pa]

EXAMPLE 6. The indoor air temperature is +20°C and relative humidity, 60%. The outdoor air temperature is +5°C and relative humidity, 90%. What is the difference between indoor and outdoor air actual vapor pressure?

Indoor air actual vapor pressure is:

$$P_x = \frac{60\% \cdot 2337Pa}{100\%} = 1402Pa$$

Outdoor air actual vapor pressure is:

$$P_x = \frac{90\% \cdot 872Pa}{100\%} = 785Pa$$

The difference of actual vapor pressure between indoor and outdoor air is 617 Pa. This vapor pressure difference causes the vapor movement from indoors to outdoors.

KEY POINTS TO REMEMBER FROM CHAPTER 7:

- **The water content of the air can be expressed in per cent, by amount and by the water vapor pressure;**
- **When the air is saturated with water (relative humidity 100%, dew point) the water condenses;**
- **Warmer air can store significantly more water vapor than colder air. As a result, water can cause condensate on cold surfaces when the dew point is reached. This poses a mold risk.**

12. Temperature and humidity distribution inside the wall. Condensation process

During the building design process it is important to choose correct properties for the building envelope with respect to building use conditions, taking into account indoor air temperature and relative humidity. Incorrect properties of the building envelope will result in interstitial condensation as well as in condensation on internal surfaces. The main building material properties which characterize water vapor transfer ability is the vapor transfer coefficient (vapor permeability of the material). The water vapor transfer coefficient is defined as the diffusion rate through one square meter of one meter-thick- material with the vapor pressure difference on opposite sides of 1 Pascal.

12.1 Condensation on internal surfaces

Condensation on internal surfaces occurs if the indoor temperature drops rapidly as well as on cold surfaces such as internal surface un-insulated walls, thermal bridges, windows, cold water pipes, etc.

Internal condensation

In the case of very moist air, internal condensation can also occur on relatively warm surfaces, usually due to a low ventilation rate. The principals of ventilation are shown in the module on heating, ventilation and air conditioning.

As we can see in Example 5, the dew point is 13,9°C for air with temperature +22°C and relative humidity is 60%. In this case, condensation will form on any surface with temperature below 14°C. But it should be noted that on surfaces with high water absorption properties such as lightweight concrete, cement finishing or wood, the condensate will be absorbed initially, and will be invisible. However, it can cause mold growth over time. Data (1) shows that surfaces with a monthly average relative humidity of more than 80% run a high risk of mold growth.

12.2 Interstitial condensation

As noted in Chapter 5, water vapor moves from indoors to outdoors in wintertime.

Interstitial condensation

The water vapor that would normally pass through the wall construction is decreased by the vapor resistance of the construction layers. Due to the temperature drop inside the construction, the saturation vapor pressure also drops across it; that means that less water content per cubic meter of air will lead to saturation and condensation. The construction is free from interstitial condensation when the actual water vapor pressure is lower than the saturation vapor pressure through the entire cross-section.

Figure 12-1 shows the temperature distribution in construction with equal U-values but different insulation methods. In one instance the water vapor that would normally pass through the wall construction is decreased by the vapor resistance of the construction layers. The illustrations show insulation placed in the building interior (right) and positioned on the outside/exterior (left).

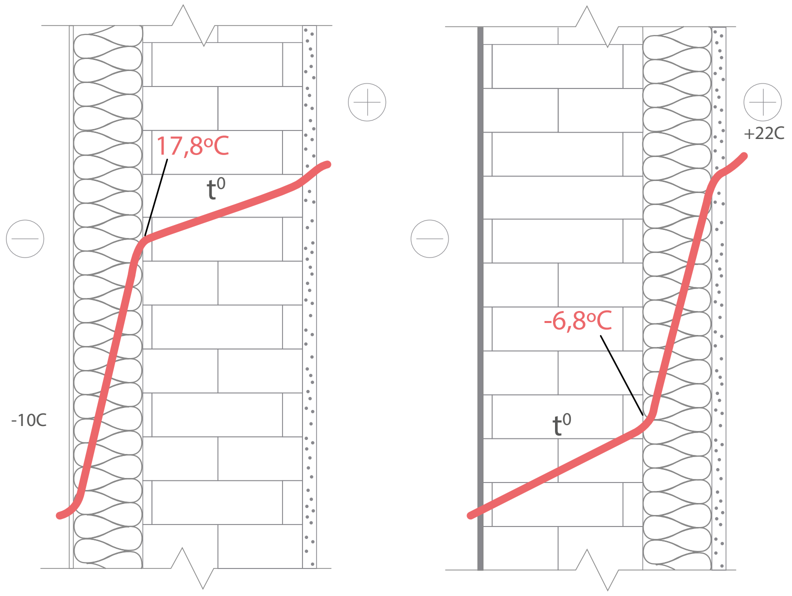


Figure 12-1: Temperature distribution in wall construction

The figures show that the temperature interfaces between a brick wall and the insulation are completely different. The properties of building material are the same as in those shown in Table 2. In the case of internal insulation, the interface temperature is -6,5°C, but with external insulation it is 17,8°C. The saturation water pressure will be much higher with external insulation, consequently the risk of interstitial condensation is lower.

The following steps are taken to determine if interstitial condensation is occurring:

1. Calculation of thermal resistance of each layer and total thermal resistance;
2. Calculation of temperature distribution inside the construction;
3. Determination of water vapor resistance of the construction layers and the total vapor resistance of the construction;
4. Calculation of the partial water vapor pressure distribution in the construction;
5. Comparison of the actual water vapor pressure and the saturation vapor pressure at each interface between the materials.

In general it can be concluded that construction is designed correctly if all moisture that comes into the construction can be released via the outside. In order words, water vapor resistance of layers on the warm side should be bigger than on the cold side. Some interstitial condensation is allowed in cases where all condensed water vapor which condenses in wintertime will evaporate in summertime.

The temperature at an interface between the materials can be calculated as follows:

Formula 12-1

$$t_x = t_i - \frac{\sum_{i=1}^{n} R_i}{R_T}(t_i - t_e) \quad [°C]$$

where:

t_x – temperature at the analyzed interface between the materials $[°C]$

t_i – indoor air temperature $[°C]$

t_e – outdoor air temperature $[°C]$

R_T – the construction total thermal resistance $[\frac{m^2K}{W}]$

$\sum_{i=1}^{n} R_i$ – total thermal resistance of all layers between indoor air and analyzed interface $[\frac{m^2K}{W}]$

EXAMPLE 7. The next example presents the calculation specifics of temperature distribution in a wall with external insulation. The analyzed construction is shown in Figure 18-1 The properties of the construction layers of the wall are the same as in Example 2. Indoor air temperature is assumed as 22°C and outdoor as -10°C.

The internal surface temperature is calculated taking into account the internal surface thermal resistance:

$$t = 22 - \frac{0,13}{4,88}(22-(-10)) = 22 - 0,027 \cdot 32 = 21,9°C$$

The temperature at interface between internal finishing and brick is calculates as follows:

$$t = 22 - \frac{0,13+0,052}{4,88}(22-(-10)) = 22 - 0,037 \cdot 32 = 20,8°C$$

The temperature at interface between brick and heat insulation layer is calculates as follows:

$$t = 22 - \frac{0,13+0,052+0,469}{4,88}(22-(-10)) = 22 - 0,13 \cdot 32 = 17,8°C$$

The temperature at interface between insulation layer and external finishing is calculates as follows:

$$t = 22 - \frac{0,13+0,052+0,469+4,167}{4,88}(22-(-10)) = 22 - 0,99 \cdot 32 = -9,7°C$$

The external surface temperature:

$$t = 22 - \frac{0,13+0,052+0,469+4,167+0,022}{4,88}(22-(-10)) = 22 - 0,99 \cdot 32 = -9,8°C$$

Before concluding discussion of the condensation process, we return briefly to water vapor. According to figure 11-4 data, using the temperature distribution, the water vapor saturation pressure distribution across the wall construction can be obtained.

The water vapor resistance of an individual layer (8) :

Formula 12-2

Water vapor resistance

$$R_{WR} = \frac{d}{\delta} \quad \left[\frac{m^2 \cdot h \cdot Pa}{mg}\right]$$

where:

d – thickness of the layer $[m]$

δ – vapor transfer coefficient (vapor permeability of the material) $[\frac{mg}{m \cdot h \cdot Pa}]$

This value shows the ability of the material to prevent water vapor flow through it. The higher water vapor resistance means less water vapor flow through the material.

Water vapor transfer coefficient

The vapor transfer coefficients of materials are usually provided by the producer or can be found in local normative data bases or handbooks. The water vapor transfer coefficients for some common building materials are shown in Table 3. Table 3 data presents average value on the basis of data (8) and market-available materials.

Materials		
Type of materials	Density ρ_0 [kg/m^3]	vapor transfer coefficients δ [mg/(m·h·Pa)]
Concrete	2200 - 2000	0,03 – 0,04
Plastering (limestone- sand-cement, limestone-sand)	1700	0,1
Brick work	1200 - 1600	0,17 – 0,14
Keramzite concrete	800	0,19
Wood	500 - 700	0,06 – 0,32
Plywood	600	0,02
Particle board	200 - 1000	0,024 - 0,12
Linoleum	1800	0,002
Metals	2700 - 11300	0
Expanded polystyrene foam	50 - 200	0,016 - 0,06
Stone wool, glass wool	17 - 40	0,49 - 0,73

Table 12-1: Water vapor transfer coefficients for some common building materials (the vapor transfer coefficient is valid for materials with the indicated densities)

It should be noted that all building materials have water vapor permeability and only metals and glass have a water vapor permeability coefficient equal to zero.

KEY POINTS TO REMEMBER FROM CHAPTER 8:

- **The temperature distribution inside the wall depends on the type and condition of materials. A good building should allow all water vapor to escape to the outside. Interstitial condensation occurs when the dew point is reached inside the wall construction.**
- **The water vapor transfer depends on the material used.**

13. Heat storage in walls

Thermal mass

The thermal mass is considered as the means for energy accumulation during wintertime in cold climatic zones and, in hot climatic zones, for the creation of indoor comfort parameters in combination with night cooling in summertime. In addition, the thermal mass ensures a stable indoor air temperature under a rapidly fluctuating outdoor air temperature.

In wintertime, the accumulated heat can be efficiently released back into the room in case of rapid outdoor air temperature reduction below the design level or in case of an emergency break in the heat supply. During sunny winter days the solar energy through windows can be also stored by floors and walls and released into the room during the night.

In summer, the internal heat gains during hot and sunny days can be absorbed by building elements such as internal and external walls, thus reducing an increase in indoor air temperature during the day. During the night, when the outdoor temperature is lower than the indoor temperature, the accumulated heat can be removed from buildings by extensive ventilation.

Specific heat capacity

The potential of materials for heat accumulation can be described by their specific heat capacity. The specific heat capacity is the amount of heat needed to change (increase or decrease) the temperature of 1 kg of a material by one degree. The specific heat capacity of different materials is shown below:

- Water – 4,19 kJ/(kg · K);
- Stone wool – 0,75 kJ/(kg·K);
- Timber – 2,3 kJ/(kg·K);
- Brick – 0,880 kJ/(kg·K);
- Concrete – 0,900 kJ/(kg·K).

In some cases, the volumetric heat capacity may be applied. The volumetric heat capacity is the amount of heat needed to change the temperature of 1 m^3 of material by one degree.

According to the abovementioned information, the heat capacity of 1m^2 brick wall with thickness 380mm will be 1m·1m·0,380m·1600 kg/m^3·0,88 kJ/(kg·K) = 535 kJ/K. The heat capacity of 1m^2 stone wool insulation with thickness 150 mm will be 1·1·0,150·40 kg/m^3·0,75 = 4,5 kJ/(kg·K). As shown, brick has a higher capacity for storing heat than stone wool. Thus, with internal heat insulation, the possibilities for night cooling strategies and passive heating are limited. In addition, the brick wall will be affected by outdoor air temperature fluctuation which can have a negative impact on the durability of the building.

The thermal mass is used for the proper calculation of the maximal heat capacity of a heating system. For such an evaluation, the average outdoor temperature of the coldest 5 days is used without respect to the heat storage potential of the building envelope. In practice it is recommended to use outdoor temperature depending on thermal mass. For example, for a wooden frame building with high glazing ratio, one would use the lowest recorded outdoor temperature over a ten year period for evaluating the maximal heat capacity of the heating system. In contrast, for a heavy structure (such as brick walls with external insulation and normative glazing area) the average outdoor air temperature of the coldest 5 days would be enough.

KEY POINTS TO REMEMBER FROM CHAPTER 9:

- **The choice of construction components can affect heat storage.**
- **The building's thermal mass has an influence on the design of the heating system.**

14. Airtightness

In addition to transmission heat losses, the infiltration of outdoor air can cause significant heat losses. The external building envelope should be airtight in order to prevent uncontrolled cold air infiltration. The rate of air infiltration through the building envelope can be expressed in air leakage rate or in air change rate. Air leakage rate expresses the amount of infiltrated air in cubic meters per square meter of external building envelope per hour at 50 Pascal air pressure difference. The air change rate expresses the number of air changes per hour at 50 Pascal air pressure difference.

Air leakage rate

Air leakage rate with pressure difference 50Pa calculated as follows (10):

Formula 14-1

$$q_{50} = \frac{V_{50}}{A_E} \quad \left[\frac{m^3}{m^2 \cdot h}\right]$$

where:
V_{50} – the measured air flow that flows through the construction with pressure difference 50Pa $[\frac{m^3}{h}]$
A_E – area of buildings envelope $[m^2]$

Air change rate

The air change rate coefficient n50 (h^{-1}) through the building envelope with pressure difference 50Pa calculated using the volume of analyzed building (10):

Formula 14-2

$$n_{50} = \frac{V_{50}}{V}$$

where:
V_{50} – the measured air flow that flows through the construction with pressure difference 50 Pa
V – building volume $[m^3]$

Blower Door test

An airtight building has both positive and negative properties. The positive impact is the possibility to create a controlled air supply scheme and to reduce energy consumption for supply air heating. Ventilation systems with heat recovery reinforce this positive effect. The negative property is lack of natural air supply and additional costs for equipment and use of mechanical ventilation. On the other hand, buildings which are not airtight have uncontrolled cold air infiltration which requires additional heat when rooms are not occupied. For the existing buildings the level of air leakage could be evaluated by using a fan pressurization method - the Blower Door test. In order to test the air leakage rate of a building envelope, all ventilation shafts should be sealed and all windows and external doors closed; the internal doors should be opened at the same time to prevent closed spaces. An example of Blower Door equipment installation is shown in Figure 14-1.

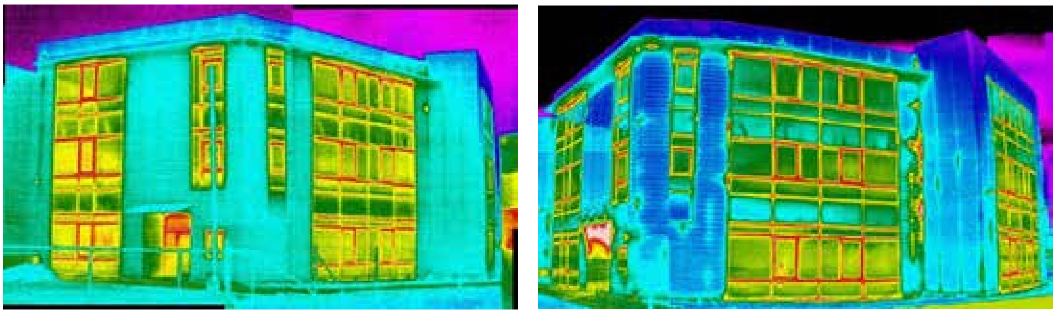
Blower door | Additional software and digital gauge

Figure 14-1: Heat flow without and with air pressure difference

For large buildings such as schools, kindergartens and multi-storey apartment buildings it is recommended to use two Blower Door systems. For low rise buildings (schools, kindergartens), Blower Door systems should be placed on opposite facades. For high rise buildings (multi-storey apartment buildings, dormitories) it is recommended to place one blower door system on the first floor and a second one on the top floor. Use of such measuring techniques can ensure uniform air pressure distribution and, as a result, more precise data.

In practice, there is no air infiltration through the massive building wall, so infiltration through walls does not have any impact on the building's total energy performance and the quality of indoor air. More attention should be paid to lightweight wooden carcass constructions. The use of special wind barriers is obligatory for such constructions in order to avoid air leakage through construction materials and air gaps between insulation material and carcass elements. The main source of air leakage is poor quality construction of wall/windows, roof/wall, ducts intersecting walls, and panel junctions. Such areas should be properly sealed to avoid air leakage.

Heat flow without and with air pressure difference is shown in Figure 14-2.



Heat flow without pressure | Heat flow with pressure difference 50Pa

Figure 14-2: Heat flow without and with air pressure difference (Photo by Andrejs Nitijevskijs LTD IRBEST)

As seen, the blower door test allows evaluation of constructional defects. The example above shows defects in window/wall and carcass/insulation junctions.

Under real use conditions in wintertime, the air pressure difference is up to 25 Pascal for first floor of multi–storey apartment buildings (up to 10 floors) and up to 7 Pascal for low rise buildings (up to 3 floors). With strong wind, the air pressure differences can reach 30 - 35 Pascal difference for both building types. Strong pressure differences cause significant air leakages and thus increased heat losses and a reduction of thermal comfort. Calculation methodology for evaluation of air leakages and energy consumption is well described in the handbook (11).

KEY POINTS TO REMEMBER FROM CHAPTER 10:

- **Airtight buildings prevent unwanted air leakage but require ventilation systems to ensure air exchange.**
- **The blower door test checks the airtightness of buildings and can help detect air leaks.**

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3

Architecture of multi-appartment houses

WHAT WILL YOU LEARN IN THIS MODULE?

This module explains the typical structure of multi-appartment buildings with a focus on prefabricated buildings that are omnipresent in dozens of countries from the East of Germany to Vladivostok. Especially in the former Soviet Union, we find a common building heritage. This module will introduce the structure of the typical concrete slab buildings built between the 1950s and 1990s, explain weaknesses of their individual components and of the building as a whole.

15. Structural schemes of buildings

Successful energy-efficient renovation of a building and its following energy-efficient maintenance requires knowledge of building construction, understanding of its structural features and influence of separate components to overall heat losses.

All buildings, in spite of their different purposes, consist of a limited number of structural components that are used for the same purposes in any building: basements, foundations, walls, roofs, slabs, and stairs. The structural scheme of a building shows the main bearing structure. It includes frameless structures with bearing walls, frame structures with bearing walls, composition of ready-made blocks.

The constructive scheme of a building is determined by its bearing frame. A construction with bearing walls forms a rigid structure in all three dimensions. It has a bearing and an enclosing function, withstanding all types of loads: wind load, live load and dead load.

The structural scheme of frameless buildings is presented in picture 15-1.

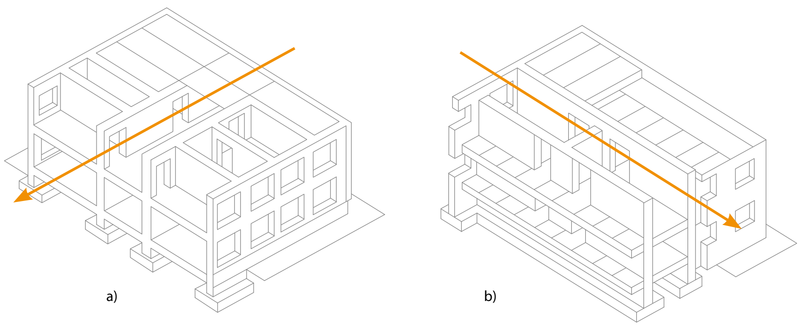

Figure 15-1: Structural scheme of frameless buildings with bearing walls: a - longitudinal, b - transversal (based on [28])

Longitudinal wall

In the structural scheme with longitudinal bearing walls all loads are transmitted by those longitudinal walls (figure 15-1a). They are the constructive components that provide stability of the building and are complemented by bracing floor slabs, staircases and internal walls which provide rigidity of the construction. The number of longitudinal walls can be from two to four or more, depending on the purpose and planning of the building. The walls can be made of bricks, blocks, large-panels, but the height of the building should not be more than nine floors. The construction of block houses with longitudinal bearing walls is presented in fig. 15-2.

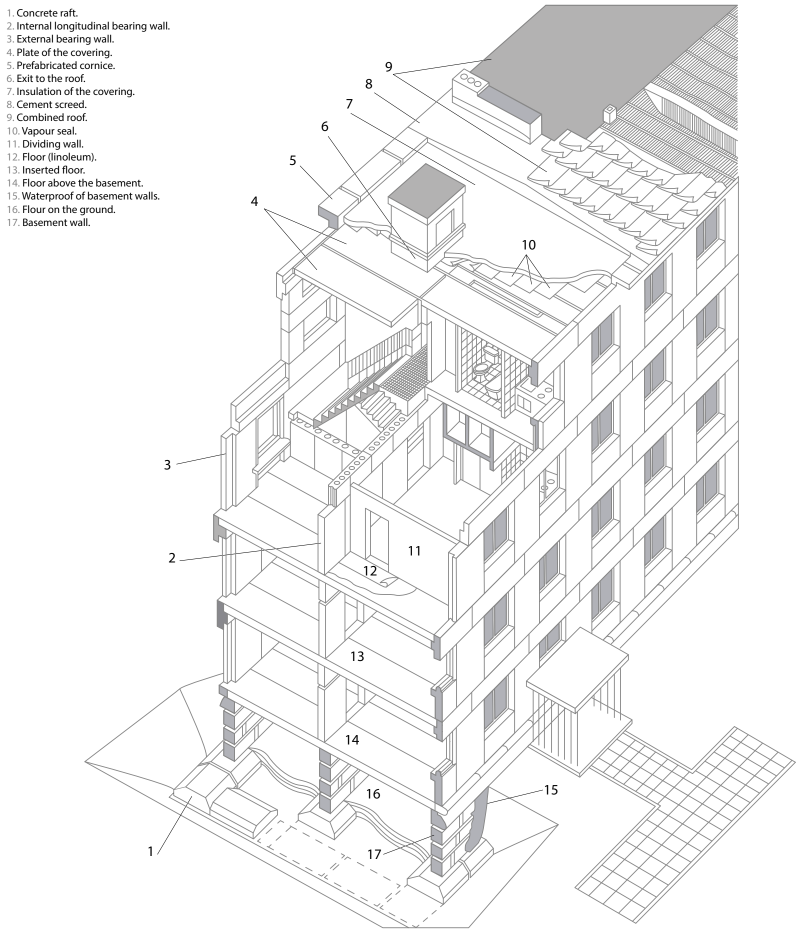

Figure 15-2: Residential house made of concrete blocks

Transversal walls

Frameless buildings with transversal load-bearing walls (fig. 15-1b) have a stiffer frame and allow the use of lightweight self-bearing or hinged exterior walls. Such exterior walls have no load bearing function; they only provide for thermal insulating. Exterior walls can therefore be made of low-strength thermal insulating material, such as expanded clay or gas silicate. Internal bearing walls do not have to fulfill thermal insulation requirements and therefore they can be made of high-strength material, e.g. reinforced concrete.

Mixed structural schemes (so-called cross-wall carrying systems), where bearing walls are both longitudinal and transversal, are often used in practice (fig. 15-3, 15-4)

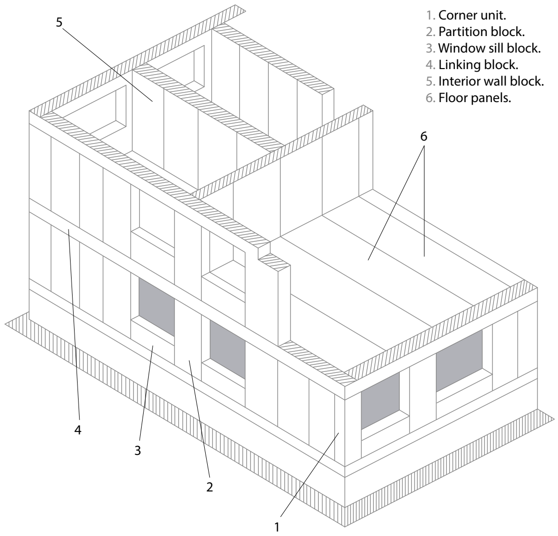

Figure 15-3: Sructural scheme of large-block building with the transverse and longitudinal load-bearing walls (based on [28])

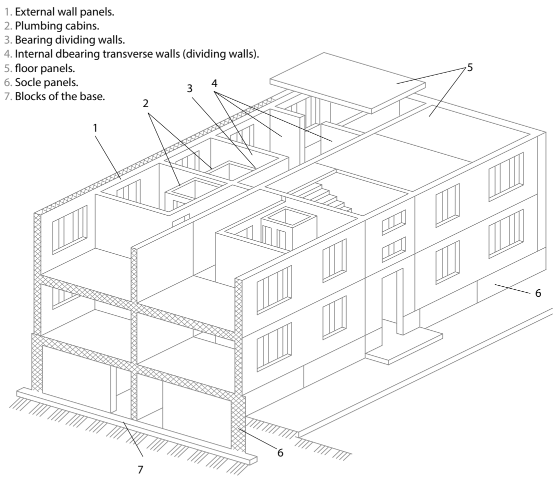

Figure 15-4: Figure 4: Structural scheme of a large-panel building with the transverse and longitudinal load-bearing walls

In the frame schemes loads are taken by a system of vertical and horizontal elements, linked together like a stack (fig. 15-5). Vertical elements are columns; horizontal elements are beams and girders. This scheme is used mainly for high-rise buildings, as they have a great rigidity and stability.

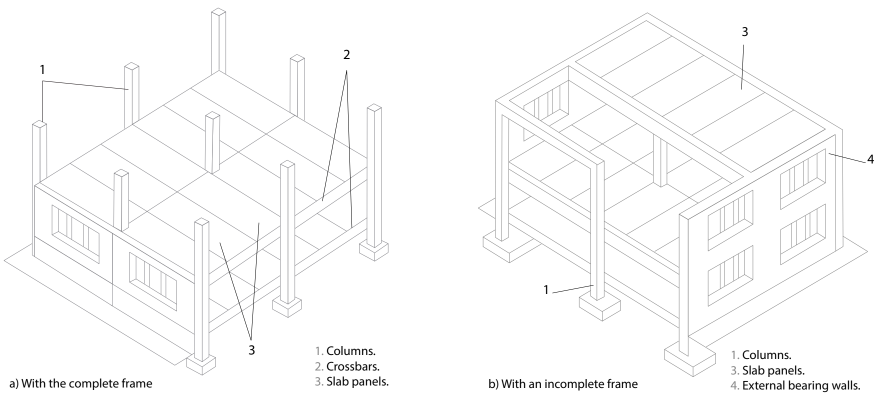

Figure 15-5: Structural scheme of framed buildings

In buildings with a complete frame columns are put inside the building and on its perimeter (fig. 15-5a); the walls are hung on the horizontal elements. In this case the walls are just protecting constructions. In the buildings with an incomplete frame columns are put only inside the building, and crossbars and girders are placed on one side of the exterior walls. Here the walls are bearing and protecting structures (fig. 15-5b).

Volumetric blocks

Buildings made of ready-made blocks are built of large-sized volumetric blocks, which are precast parts of the building, such as rooms (fig. 15-6,15-7). The vertical load-bearing structures of the building are the walls of volumetric blocks.

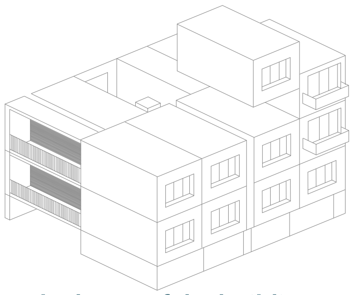

Figure 15-6: Structural scheme of the building made of three-dimensional elements (based on [28])

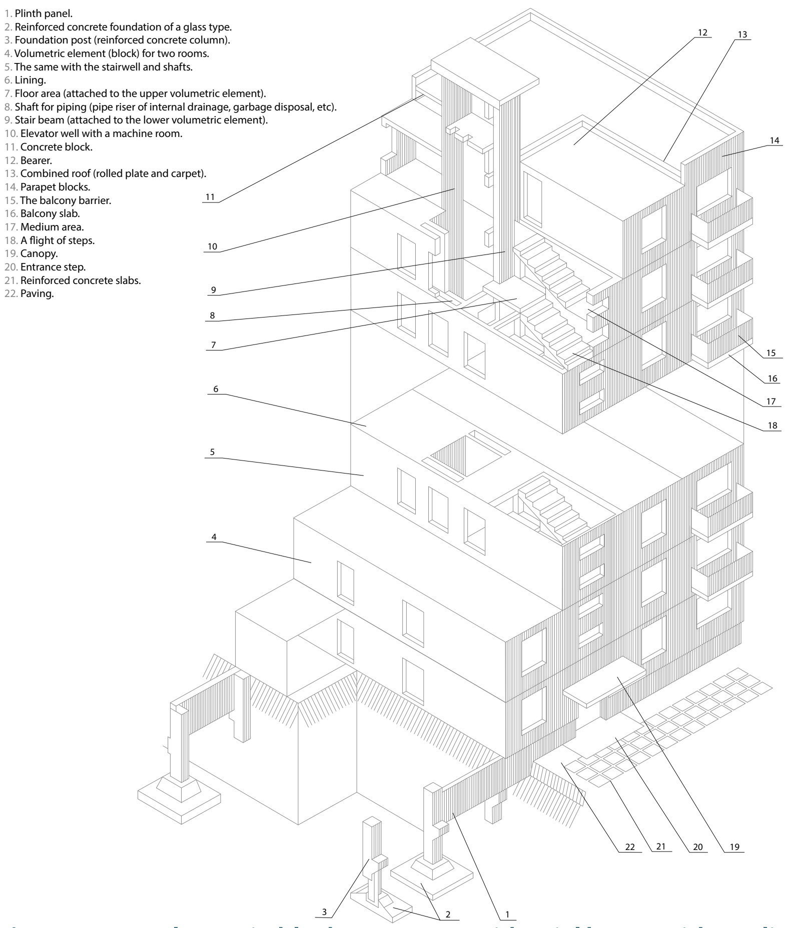

Figure 15-7: Volumetric-block 9 –storey residential house with a solid arrangement of blocks (based on [15])

16. Operational characteristics of typical prefabricated buildings

The running cost of the building is mainly determined by the level of its energy consumption. Energy efficiency of the building depends on the thermal properties of the building envelope, the state of engineering systems and networks.

Operational characteristics of the first mass series buildings are poor. The bad heat and sound insulation properties of these houses have a variety of causes: lack of energy-efficient design solutions and materials, poor quality of prefabricated construction details, poor quality assembling and poor technical maintenance of buildings and their engineering equipment. We shall consider the following factors influencing the heat demand of prefabricated buildings: materials of the building envelope and design disadvantages.

16.1 Materials

An important function of the building envelope is to support the temperature-humidity regime inside the building. This function is provided by specific parameters of materials that were used in the building envelope: heat conduction, heat capacity, water- and water vapour- and air-permeability.

Various materials were used in external wall constructions in residential buildings of the first mass series. In block buildings – brick and ceramic stone. In panel buildings – expanded clay lightweight concrete, cellular concrete (1 layer panels), or reinforced concrete, concrete with an inside layer of insulation in the form of expanded clay, cellular concrete, foamed polymers, mineral wool (3 layer panels).

The thermal conductivity of some materials which were used in construction of typical prefabricated buildings is presented in Table 16-1.

Material	Density ρ_0 [kg/m^3]	Thermal conductivity λ_0 [W/(mK)]	λ_p [W/(mK)] A (dry)	B (moist)
Reinforced concrete	2500	1,69	1,92	2,04
Concrete	2400	1,51	1,74	1,86
Expanded clay concrete	800	0,21	0,24	0,31
Slag concrete	1400	0,41	0,47	0,52
Gas silicate	600	0,13	0,16	0,18
	900	0,24	0,33	0,36
Loamy solid brick	1800	0,56	0,70	0,81
Silicate brick	1800	0,70	0,76	0,87
Gypsum plates	1200	0,35	0,41	0,47

Cement-sand mortar	1600	0,47	0,70	0,81
Lime-sand mortar	1800	0,58	0,76	0,93
Mineral wool	100	0,050	0,064	0,070
Products made of foamed urea-formaldehyde resin	25	0,043	0,063	0,074
Polystyrene foam slabs	25	0,038	0,043	0,053

Table 16-1: Heat conduction of various building materials (by DBN B.2.6-31: 2006-31:2006)

Thermal performance

The thermal performance of a building envelope of the 1960-70s is at least five times less than required by modern standards. In addition, thermal properties of a building envelope are not stable over time. Changes of the properties of building envelope materials with time lead not only to a deterioration of the heat and humidity regime, but also to a damage of structures, reducing their bearing capacity and durability.

Operating experience of large panel houses indicates that the combination of materials with different lifetimes (concrete 150 years, and mineral wool panel – 40 years) in one construction of exterior walling panels was unsuccessful. After 30 - 40 years, 3-layer panels began to lose their thermal insulation properties, which led to freezing and condensation on the inner surfaces of the external walls, leading to corrosion of metal reinforcement.

Freezing of wall constructions

The freezing of wall construction is influenced by both natural and operational factors. The freezing of a building envelope of large panel houses has occurred more often in the last 5 - 7 years because the heating capacity of the flats has diminished. This is caused by a temperature reduction of the heating system. Consequently, the accumulated moisture inside the exterior wall panels does not have time to evaporate in spring and summer [12].

16.2 Structural causes of heat losses

16.2.1 Combined roofs

The vast majority of roofs of typical multi-storey residential buildings are flat combined coatings: the roof is combined with the construction of the attic floor and the lower surface is the ceiling of the upper storey. Due to the large surface and poor thermal insulation properties, combined roofs cause significant heat losses in cold weather and excessive heat gains in the warm weather: they are a constant source of discomfort for the residents living on the upper floors.

More often, coatings are made from reinforced concrete elements. The slopes of the combined roofs have an inclination of 1,5%. They are formed by a variable thickness of insulation or panels with the necessary slope towards the exterior walls with an external drainage system, or to the middle of the building with an internal drainage system.

There are two main types of combined coatings: unventilated and ventilated. Unventilated roofs are allowed above the premises with normal humidity conditions. Unventilated combined coatings fulfill different functions - thermal insulation and bearing function.

Combined unventilated roofs

The design of the combined unventilated roof is shown in Pic. 16-1 (upper). A vapour seal of one or two layers of ruberoid on the bitumen mastic (may be a layer of bitumen) is installed by a reinforced concrete slab to protect the insulation layer against humidity from the inside. In coatings of residential and public buildings, a continuous water vapor barrier layer is not required. In this case, joints between panels were allowed [13, § 1.13] to paste with strips of ruberoid of minimum 250 mm in width.

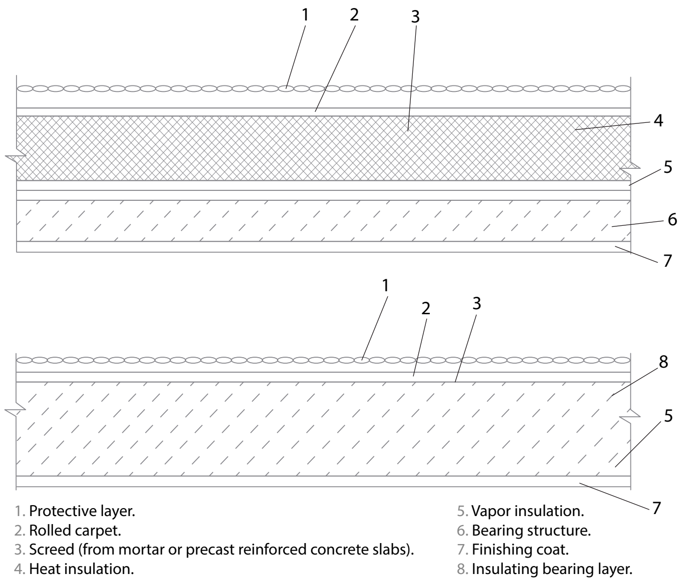

Figure 16-1: The principal constructive schemes of combined unventilated roofs

Cement screed is placed on top of the thermal insulation layer, the thickness and installation depending on the type of insulation layer below. The roof is constructed on the screed as a multi-layered roll carpet of ruberoid or other rolled materials on the roofing mastic and a protective 6-8 mm layer of small gravel or sieved slag condensed into a bitumen layer.

It may be a design decision of a non-ventilated combined roof (fig. 16 lower), where the insulation layer is made of reinforced aerated or lightweight concrete (aerated concrete, expanded clay, etc.) which is a supporting structure at the same time. [14]

The conjunction of a combined cover with the external wall is shown in figure 16-2 [15].

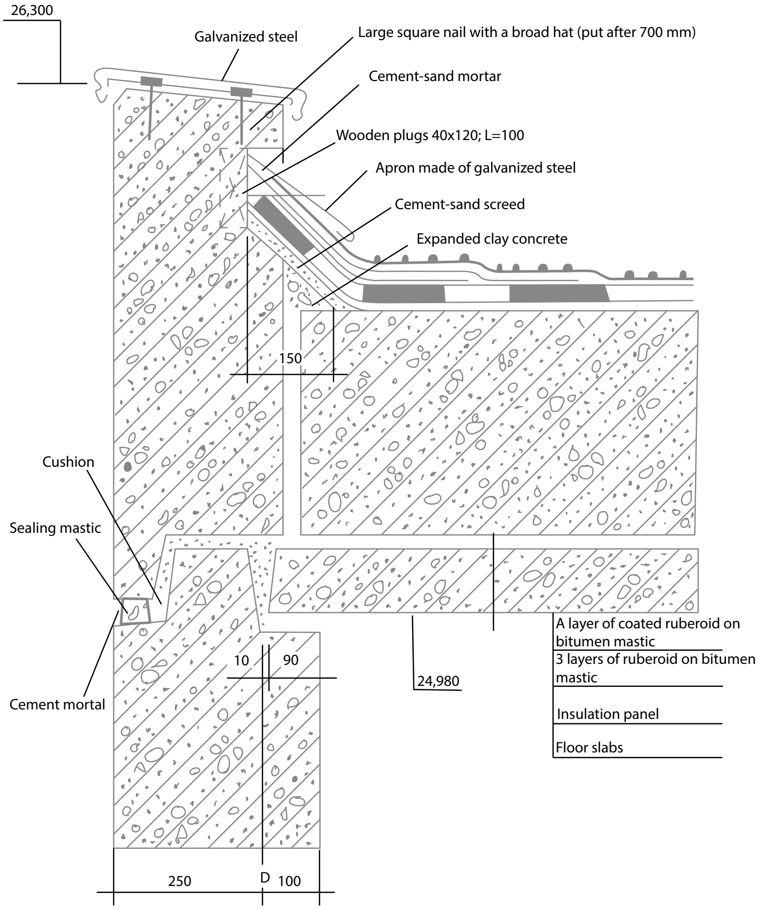

Figure 16-2: The construction of the combined covering of a large panel house (conjoined with the external wall).

16.2.2 Thermal bridges

Significant heat losses occur through the so-called "thermal bridges": depending on the level of thermal insulation and design features of connecting elements, up to half the heat can be lost through the thermal bridges.

Interruption of the building envelope, temperature and humidity deformations, mistakes during the construction cause the disruption of joint sealing between panels and blocks with the fallout of the mortar, followed by the flowing of heat and formation of thermal bridges.

Types of thermal brigdes

Very often, geometric, structural and material thermal bridges occur in building practice, significantly increasing the risk of building damage. Increased heat emission through thermal bridges leads to negative consequences:

- consumption of energy for heating increases;
- surface temperature becomes lower on the side of the building elements, which may lead to the formation of condensate and accumulation of moisture, followed by the inevitable appearance of mould.

The removal of thermal bridges is necessary to achieve sanitary and hygienic standards, contributing to human health and creating the preconditions for long-term conservation and functional safety of buildings.

It is almost impossible to visually detect thermal bridges caused by engineering defects on the facade of the building; thermography makes their detection possible. A thermographic image of the building in figure 16-3 reveals defects (green areas) in the non-insolated concrete frame structure of the building and the floor slabs. Areas of high heat losses - the joints of panels, pipe risers of the heating system and gaps around radiators under windows, are visible on the thermal image of the panel building (fig. 16-4).

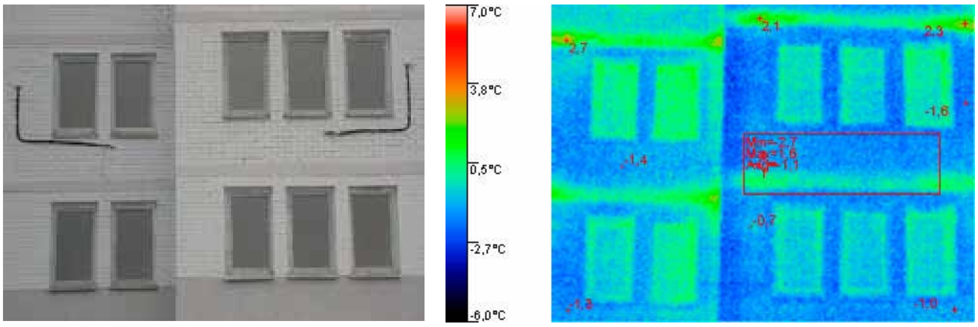

Figure 16-3: The façade of a framed building and its thermogram [35]

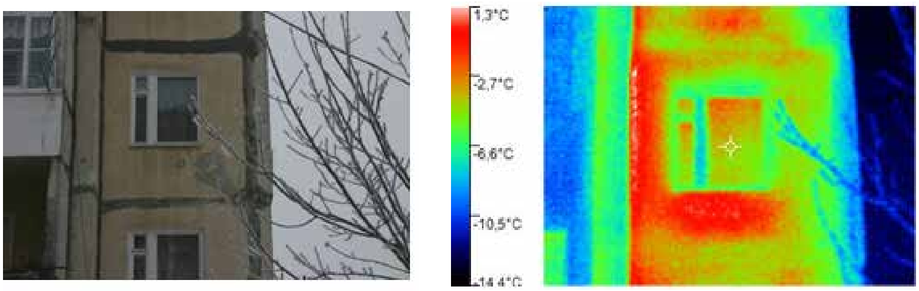

Figure 16-4: The façade of a panel building and its thermogram [36]

17. The deterioration of buildings

Before considering buildings as potential objects of thermal modernization, it is necessary to take into account the status of their obsolescence.

Physical (material, technical) deterioration characterizes the degree of deterioration of technical and operational indicators of the building at a particular time.

Physical deterioration

Physical deterioration of the building Dp is defined as a percentage, depending on deterioration of separate constructive elements. The minimum service life of constructive elements of buildings is given in the table 17-1 [17]. The condition of the building with physical deterioration Dp > 60% is considered as worn-out (more than 80% - unusable); it is not worthwhile to repair and modernize such a building.

In general, bearing and protecting structures of existing buildings of mass series which are in a satisfactory condition and have proper maintenance can last for a long time. The remaining bearing ability of existing buildings, and their high durability allow thermal modernization and reconstruction using lightweight, energy-efficient elements. [18]

Obsolescene of buildings

The poor thermal insulation properties contribute to the accelerated obsolescence of those standard prefabricated buildings. In summertime the rooms overheat, especially the upper floors, because of the combined roofs, and in winter, the joints, corner panels and walls may freeze. Damages in the joints of wall panels lead to problems in the heat and humidity regime of the houses. And, because of poor construction of the flat roofs, rooms of the top floors are humid which impairs the living conditions.

Living quarters on the first floor also suffer from unfavourable conditions: the microclimate is substantially affected by the poorly insulated basement, unheated lobbies and entrance doors.

In most five-storey buildings, the sound protection of interior walls, ceilings and partitions do not meet the standards. Large windows intended to maximize daylight cover 30% of the external wall area and cause increased heat loss.

The listed circumstances led to noticeable decrease in operational characteristics and obsolescence of residential buildings of this category.

In some cases, the obsolescence is the determining factor in deciding whether the repair and renovation of the building is financially justifiable. Thus, despite high constructive durability, it was decided to demolish the buildings of some series: apartment buildings in which the internal load-bearing walls are located on a narrow pitch, which does not allow them to improve their floor plan, and also buildings with exterior walls made of thin concrete panels with poor heat-shielding properties. Such building are in the process of being demolished in parts of the former socialist countries.

Construction element	Minimum service life (years)
Floors with coverings	
Of ceramic tile, terraced	60
Cement	30
Made of grooved boards :	
on the overlaps	30
on the ground	20
Parquet :	
oak on the strips of wood	40
the same, on mastic	20
Beech on the strips of wood	30
the same, on mastic	20
birch and aspen on the strips of wood	25
the same, on mastic	15
Of the floorboard	15
The solid fiberboard plate	15
Of linoleum	10-30
Of polyvinyl chloride tiles	10
Stairways	
Of precast reinforced concrete large-size	
Elements	100-150
Monolith reinforced concrete	100-150
Of stone, concrete, reinforced concrete steps	-
on steel and metal strings	100-150
Wooden	30
Balconies and porches	
Balconies:	
of reinforced concrete large-size plates	60
the same, on steel cantilever beam	50
Drainage system	
Drainpipes and small coverings on the façade made of:	
galvanized steel	12
black steel	6
Internal storm sewage pipes:	
cast iron	30
Steel	20
Polymer	30
Partitions	
Made of brick, concrete, or ceramic blocks and etc.	100-150
reinforced concrete , gypsum concrete «for a room»	100-150

Plate gypsum, light concrete	80
Wooden plastered between rooms	50
The same, in sanitary units	20
Paneled by a dry plaster on a wooden skeleton	30
Wooden doors and windows	
Window and balcony fillings	30
Door fillings	
inside apartments	60
entrance to apartments	30
entrance to a building	10

Table 17-1: Minimum service life of construction elements of buildings

KEY POINTS TO REMEMBER FROM CHAPTER 3:

- **Energy efficiency depends on the thermal properties of the building envelope and the state of engineering systems. The building envelope's performance is determined by its material and its design.**
- **Thermal properties of a building envelope deteriorate over time.**
- **A combined roof and thermal bridges are the main structural causes of heat losses.**
- **Substantial heat losses not only lead to higher energy consumption but also to lower surface temperatures of building elements. This fosters the accumulation of moisture followed by mould.**
- **Poor thermal insulation accelerates the physical deterioration of the building due to intrusion of humidity and frost.**

References module 3

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4

Behavioural approaches

WHAT WILL YOU LEARN IN THIS MODULE?

Daily decisions and actions are not random. Regardless of whether someone switches on the light or decides to refurbish his house, he made a decision beforehand to do that. Such a decision is usually quick - switching on the light does not require much thinking - but it will probably take weeks or months before deciding to go for a refurbishment. In most cases people will spend some time to weigh the pros and cons. Why are some decisions so quick and easy, and why are others so difficult? Many researchers try to answer those questions with sociological and psychological models. In this chapter, we want to introduce some of the key concepts and ideas that were developed in the last decades. While this is certainly theoretic, at times such models help to explain why people think or act the way they do. We will illustrate this with practical examples from refurbishment processes including energy-saving aspects.

Refurbishment processes are not only a technical matter. In large block panel buildings, many parties have to agree to undertake such a project. This includes sensitive discussions about finances, roles and responsibilities of residents, and aesthetic preferences. Understanding why people take certain stands will help you on your way to an energy-efficient multi-family apartment house.

18. Sociological and psychological concepts

18.1 Values and social value orientation

The first concept that we want to introduce is "values". Values can be described as guiding principles or standards of behaviour that serve as guiding principles to live by or strive for. Typical values are freedom, environmental protection, or honesty. Not all values have the same importance for us, but regardless of their importance they usually do not change in different situations. However, values do not need to be free of contradiction. In some situations people may have different values competing inside them, but they usually base their choice on those they consider most important. [8] Values that are shared by a group can become norms; we will talk about those in the next section.

Types of social value orientation

Why values play a part in energy efficiency will become a bit clearer after the introduction of the next concept - the social value orientation. Social value orientation describes how a person attributes resources between themselves and others. If the outcome or benefit for both the self and others is maximised, we talk about a cooperative social value orientation. People that only take advantage of their own benefit while disregarding the benefit of others are said to have an individualistic social value orientation. Last but not least, if personal benefits are advanced in order to disadvantage others and their interests, we talk about a competitive social value orientation.

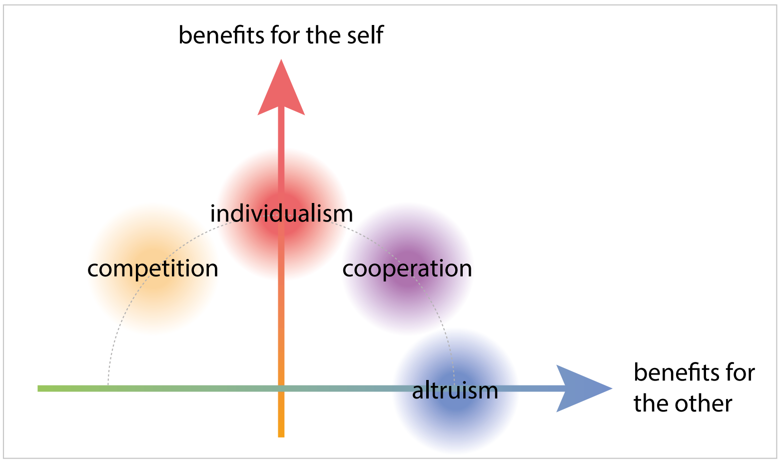

Figure 18-1: Social value orientations

Values and social value orientation play a role in refurbishment processes. The more cooperative partners in large block panel buildings might be persons who give importance to measures that will benefit others as well as themselves. When communicating with flat owners, it might be helpful to address values that those people generally endorse – remember that values are not situation-specific. It could be, for example, that many inhabitants share the value of "social justice" or "fairness". In this case it is important to address and to discuss the issue of how the burdens of refurbishment can be shared equally or at least balanced among residents. Similarly, if there are inhabitants that share the value of "respecting traditions" it might be helpful to find arguments which are consistent with these values.

18.2 Social norms

While values are, first of all, something personal, the concept of social norms arises out of a group. Social norms can be understood as rules and standards that a group of people share and which support or constrain individual behaviour. Social norms are not legal norms, e.g. a norm could be that lying is frowned upon, nevertheless it is not forbidden by law. Social norms are often not verbalized, but can prevail as beliefs about how other members of the group behave. For example, a social norm is, "Don't litter the street." We assume also that others also disapprove of littering, but we usually do not talk about that with each other.

Injunctive and descriptive norms

Norms can change over time and can be a powerful factor. People tend to compare their behaviour with the norms that they assume their peers have. If the difference between the peer norms and personal evaluated behaviour is large, people may change their actions as they do not like to deviate from the assumed or observed norm. [7] We call the assumed norms that we generally approve or disapprove of, the "injunctive norms" and those norms that we actually observe in other people's behaviour, "descriptive" norms. Descriptive norms have an influence on all of us. If someone observes that everybody else does something - e.g. picking up (or dropping) trash - they tend to adjust – towards this desired (or undesired) behaviour. If every house owner in an area suddenly started to refurbish their buildings, chances increase that observers might do the same, after some time. This individual response to descriptive norms is the reason why some awareness campaigns fail. If a campaign points out a certain undesirable behaviour, people who are guilty of such behaviour may not see it as intended to change their habits, rather, they conclude, "Everyone does it" and carry on as usual.

18.3 Behaviour and habits

Behaviour, in short, describes all the observable actions of a person. We notice that there is often a gap between the attitude of a person and their actions. This phenomenon is called the "attitude-behaviour-gap". This gap is explained by the difficulty to take an action because it involves additional costs. A rather trivial example from house management is the following: Saying that it would be good to have a more professional management company in charge is easier than actually hiring one and spending more money.

Behaviour can be differentiated into symbolic, affective and instrumental elements. Symbolic behaviour is an action that targets the quality of a person, his or her social standing, group affiliation or gender role. Affective behaviour is an action that targets personal emotions, e.g. actions that are perceived as fun or pleasant or satisfying the curiosity of the person. Finally, instrumental behaviour is an action that aims at a practical benefit, e.g. it is considered useful or saves money.

We know from psychological research, that behaviour is not only based on rational choices; other symbolic, affective and instrumental motives also come into play. Addressing these realities might increase achieving the desired behaviour, and might even play a role in the refurbishment of a building. For example, affective behaviour is purchasing a wood-burning chimney for a house, which gives pleasant warmth although the house already has an effective heating system. From a financial or energy consumption point of view, this chimney would not be necessary, but such decisions are not purely rational.

Habits

Before moving on to behavioural change, we will briefly introduce the concept of habits. We speak of habits when certain triggers or circumstances, also called cues, automatically lead to a certain behaviour. Habitual actions tend to be done unconsciously and are often part of our daily routines. A typical habit for many people is to switch off the light when leaving an empty room, or taking a shower after getting up.

18.4 Behaviour change

A change in behaviour is needed, for example, after a comprehensive refurbishment of a building has been finished. Residents must adjust their heating and ventilation habits because the air exchange through closed windows and walls is significantly reduced and radiators can be manually adjusted in all rooms.

Three-stage-theory of behavioural change

Psychologist Kurt Levin developed what he called the three-stage-theory which describes behavioural change as occurring in three stages, unfreezing, change and refreezing. In the first, unfreezing stage, it will be demonstrated to a group or an individual why the current behaviour is not desired and why a change is necessary. In our refurbishment example, this could mean demonstrating the consequences of insufficient or poor practices in ventilation and heating to the inhabitants of a newly refurbished apartment block. In the next stage, the change stage, the group or individuals need to develop and test a new behaviour. Interventions or supplementary information on what to do can be helpful in this stage. Incentives for changing behaviour or eliminating barriers to achieving it can support the change stage. In our example, the inhabitants of the refurbished house would now need to learn how to ventilate and heat correctly. Additional leaflets or energy advisors that explain or demonstrate procedures can help the residents to heat and ventilate correctly, e.g. “Windows should be opened widely for just a few minutes several times a day", or " the heating regulator should be set at a constant level and should not be turned up and down all the time."

The last stage of Lewin's model is the refreezing stage in which the behavioural changes are internalised and perhaps even fossilised as habits. If the inhabitants routinely heat and ventilate their flats correctly, the group in our example would have reached the refreezing stage, and would enjoy a better quality of living, as well.

It is important to point out that behaviour change is not always permanent. We sometimes tend to fall back into old behaviour patterns, especially if new behaviour takes more effort or has not yet become a habit. There are several methods to support behavioural change and prevent falling back or relapsing into old routines. Two main strategies are

Strategies to support behavioural change

- informational strategies and
- communication of consequences.

There are different types of informational strategies aimed at increasing the awareness or knowledge of the target group or at changing a norm or attitude. The implied assumption is that increased knowledge or awareness or a changed attitude will eventually lead to the more desired behaviour. The more direct and interactive the information is provided, the higher the chances of a behavioural change.

18.4.1 Informational strategies

Provision of information

The first type of informational strategy is the mere provision of information. This is usually done by announcements, leaflets, brochures, TV or radio broadcasts. In most cases, the information provided is general and not specific enough for the individual situation of the reader or listener. Often, such generic information does not lead to behaviour change as it does not directly address or motivate the reader or listener; further, it requires mental abstraction to translate the provided information into action. A more effective way to provide information is to address specific groups or even individuals, if possible, or to provide information about how other members of the group behave. This can have either a positive or a negative effect. An example: Some electricity providers print the figure of the average energy consumption of their private customers on their bills. While this will usually motivate many people with energy consumption above average to reduce their bills, the opposite effect might be that people with significantly less consumption start to be less frugal in their energy use.

Goal setting

Another strategy is goal setting. This requires a higher degree of interaction with the target group. The basic idea is rather simple. Individuals or a group of people are asked to set realistic goals for changing their behaviour. If the goal is set high enough, it will lead to an effective change, especially if feedback is provided in a timely manner, whether the goal has been met or not. If the goal has been met, it is a confirmation that a changed behavioural pattern was successful.

Commitments

A similar strategy is commitments. Commitments work much like goal setting, but instead of formulating goals (e.g. reduce energy consumption by 10%), they can include concrete actions (e.g. install new energy-saving light bulbs, use washing machine at lower temperature, go to work by public transport instead of by car). Commitments are not only useful on an individual or household level, but they are also a tool in energy saving for municipalities. A quite popular example of a commitment tool is the Covenant of Mayors, which has been signed by some cities and towns in Belarus and the Ukraine. By this declaration, the signatory towns agree to meet a 20% CO2 reduction target by 2020. The towns commit to develop sustainable energy action plans which lay out concrete actions to reduce the CO2 emissions in their towns or cities.

Prompting

Last but not least, prompting is another informational strategy. Prompting means that the user or consumer is asked to do or warned not to do something, or the user's behaviour is simply pointed out. A typical small example would be a sign at an office door, "Please switch off the light when leaving the room". Another example would be positive reinforcement, e.g. through a simple thank you note after residents pay their contribution to the homeowners' association fund.

It is equally true for all informational strategies that behavioural change will be more effective if the user receives timely feedback: i.e. was the strategy to change the behaviour successful or not. Feedback should be provided, if possible, not only directly after the behaviour has changed but also again after some time. People tend to fall back to old behaviour and a new stimulus, e.g. additional feedback on their behaviour (e.g. six weeks after completion of the project) can prevent this fall-back or correct an on-setting relapse.

18.4.2 Communication of consequences, rewards and penalties

Another strategy to induce a behavioural change is the communication of consequences. In general, consequences that occur soon and are certain are more powerful than consequences that are distant and unclear. This is an important issue when talking about the refurbishment of a multi-storey building. Although there is indeed the possible consequence that the building will deteriorate to the point that its structural stability is in danger, this is not an immediate threat for most buildings. The communication of consequences should therefore be focused on more immediate issues, such as cracks in walls, leaking roofs or mould invasion, etc.

Consequences can be communicated through rewards and penalties. Rewards can be used to reinforce positive behaviour or stop adverse behaviour. This can be monetary or non-tangible. An example including a non-tangible reward would be a competition for the most energy-efficient building. In Latvia, for example, in one project, the building's "energy efficiency class" (this is a way to categorize the energy consumption of the building) was painted on a board in big letters and fixed on the side of the building. This created a positive momentum in the district and people became motivated to reach as good an energy standard for their buildings as their neighbours' more efficient building.

Rewards

Sometimes, even adverse behaviour receives rewards. A typical example: electricity tariffs. Many energy providers offer special tariffs for customers who use large amounts of electricity when the unit price, the price per kWh, drops beyond a certain threshold of energy consumption. This leads to the paradoxical situation that it might be economically beneficial for some consumers just slightly below this threshold to expend more energy instead of less.

In contrast to rewards, penalties increase the costs of unwanted behaviour. If the penalty is high enough, the costs will soon outweigh the resistance to changing towards the wanted behaviour. If, on the other hand, the fines are too low, people might consider the penalty as a purchased right to be wrong/misbehaving. Again, penalties can be tangible or non-tangible. A tangible penalty would be classic fines; a non-tangible penalty would be, e.g. the exclusion from meetings or decision-making processes.

As a rule of thumb, rewards should be preferred over penalties whenever possible. Penalties tend to limit people's choices and increase the costs of their current behaviour. Rewards, in contrast, do not penalize the current behaviour but offer additional incentives to re-consider and change the behaviour. Thus, rewards facilitate the change towards behavioural alternatives.

Penalties

18.5 Rebound effect

The rebound effect is a well-known and researched effect which was prominently put forward by the economists Daniel Khazzoom and Leonard Brookes in the early 1980s. Although the "Khazzoom-Brookes-postulate" is found in 20th Century psychological literature, the idea of the rebound effect dates back to the English coal mining industry in the 1800s. In essence, this effect explains the paradox that efforts to reduce energy consumption, e.g. by efficiency increases, do not lead to the desired reduction and sometimes even to an increase. The causes for the rebound effect are human behaviour or principles of economy. There are several types of rebound effects that counteract possible energy savings. We will briefly outline 5 different types here, based on [6]:

- Direct rebound effect
- Indirect rebound effect

- Energy-price effect
- Comfort effect
- Eco-balance rebound effect

Direct rebound effect

The direct rebound effect states that the increased availability or effectiveness of a product or a service can increase the demand for more such goods and services, e.g. because costs have decreased. The decrease in demand counteracts the efficiency increase so that any possible energy saving is balanced. As an example, electric bicycles illustrate direct rebound effect: they consume much less energy than a conventional motor bike or car, and have become significantly cheaper in recent years.

Indirect rebound effect

The indirect rebound effect explains that efficiency increases for one type of goods lead to financial savings for others. These financial savings are used for other energy-intensive activities or goods which otherwise would not have been undertaken or purchased. A classic example is the refurbishment of a building. If the monthly heat bill becomes cheaper, more money could be spent, e.g., for cars or additional energy-consuming household-appliances. Thus, unfortunately, in the end, the previous energy saving is used up by these compensating activities.

Energy price effect

The energy-price effect, a third kind of rebound effect, is explained as follows: If the range of energy carriers is increased, e.g. by the increased use of renewable resources, the amount of available energy is increased on the market. This puts pressure on prices and the price of the energy, or of a certain kind of energy, drops. A price drop in certain energy carriers can also occur for other reasons, e.g. the crude oil price depends on a range of factors. Lower prices are an incentive to use more energy. That again counteracts all efforts to reduce the energy demand.

Comfort effect

The comfort effect is a specific type of rebound effect that is especially relevant in refurbishment projects. It explains that rising energy efficiency in buildings, e.g. after a complete heat insulation, can lead to increasing energy consumption. The reason is that in badly insulated buildings, inhabitants are a bit more inclined to accept lower temperatures and less comfort. After the insulation of the building, people expect an increase in indoor comfort and heat their flats to higher temperatures, especially if they had low temperatures before and are now able to regulate their heaters. This leads to an increased use of energy compared to baseline temperatures that the inhabitants were ready to accept or had to live with before the refurbishment.

Eco-balance rebound effect

Last but not least, there is an eco-balance rebound effect. This effect occurs if the energy consumption is shifted and occurs elsewhere. A classic example is certain types of insulation materials. Although they contribute to a significantly decreased energy demand of buildings, the production of certain types of insulation material, such as polystyrene or glass wool requires a lot of primary energy. Thus, the energy consumption is shifted from the using phase of the residential building to the production phase in the life cycle of the insulation material. However, the increase of energy consumption in the production stage is balanced in the long run when the energy savings from the insulation exceed the bonus from the production stage. The eco-balance rebound effect is important for general considerations of the energy demand in housing, however it will usually not play such a big role for the private customer, as the energy demand in production is not directly reflected in the price of the insulation material.

KEY POINTS TO REMEMBER FROM CHAPTER 18:

- **Social value orientation of inhabitants should be considered in order to be able to direct communication.**
- **Behaviour is influenced but not determined by rational choice. Affective and symbolic motives play a role as well.**
- **Behavioural changes need to be internalised as habits and routines in order to be permanent.**
- **Informational campaigns that interact with the recipient through feedback are more successful in achieving and maintaining behavioural change.**
- **A measure to reduce energy consumption can lead to the contrary outcome through so-called rebound effects caused by changes in behaviour and by economic principles.**

19. Considering refurbishment

19.1 The refurbishment dilemma

When refurbishing a panel block building with many different owners, they first have to agree to refurbish the house and secondly, decide which refurbishment measures will be realised. This situation can be perceived as a dilemma for some of the participants – if they do not agree to the refurbishment, the building might not be refurbished at all and the status quo, i.e. inefficiency and, often, impaired indoor comfort, is maintained. On the other hand, a refurbishment will imply larger investments and a period of discomfort (noise, dust, etc.). Not all parties will benefit equally from a refurbishment. Flats at the outside wall, under the roof, on the ground floor and those with potentially colder flats, which are last in the heating circulation, will have a higher benefit than others, despite the fact that probably everybody has to pay a similar share to a refurbishment fund (at least per square meter). This leads to a mix of different interests based on the location of the flat, the available financial means, and a number of other considerations (more details in the following sub-chapter). In such a situation, it is difficult to obtain a consensus about a refurbishment. At the same time, the positive impact of a refurbishment project is the largest if a complex refurbishment is carried out for the whole building. Sometimes, flat owners start to undertake refurbishment measures for their flat on their own. These measures must be handled with care. Installing new windows is common, but it would be more efficient and energy-saving if the outside wall is insulated at the same time. Insulating the outside wall just around a single flat is usually short-lived and might prove to be counter-productive. If the insulation is not professionally attached, as happens in many cases, it will fall off after some time, rendering the investment redundant. Additionally, the savings will be much lower compared to a complex refurbishment of the whole building.

19.2 Motives to refurbish

Key motivations for energy efficiency measures can be categorized into economic, social, and environmental motivations [5]. A simplified sustainability model (Figure 2) is used to highlight the motives of flat owners to energy efficient refurbishment.

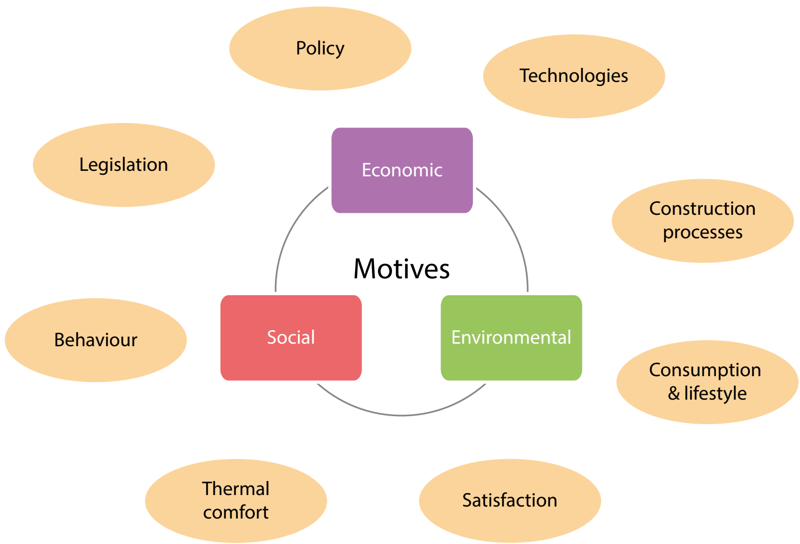

Figure 19-1: Motives for refurbishment

Economic considerations

Economic considerations are directed to achieve cost benefits savings by refurbishment activities. Refurbishments can be economically beneficial if a bank loan for the refurbishment pays off in the long run due to increasing energy expenses (rising tariffs for heating and electricity). Further economic aspects are the availability of subsidies and the increased market value of the building after refurbishment. However, economic considerations do not necessarily support the decision to refurbish. If no credit lines or not enough personal financial resources are available then there is hardly any enabling financial factor to trigger a refurbishment. In the worst case, a refurbishment does not even pay off during the owner's lifetime. When talking about the increased efficiency of a building, we divide measures into 4 main types:

Types of efficiency increase

- Type 1: Zero initial cost and small returns, e.g. changing the ventilation behaviour for smaller heat losses, switching off lights
- Type 2: Upgrade parts of the flat with low initial costs and a short payback period, e.g. seal window cracks, use foil behind radiators
- Type 3: Larger upgrades in individual flats with medium costs and medium returns. These are more complicated replacements and upgrades. Opportunities for energy-saving include substitution of the most energy-efficient products, e.g., installing new energy-efficient windows, larger household electric appliances of A+ or even higher energy performance class, up to very energy-efficient devices for energy production (boilers, etc.).
- Type 4: Complex refurbishment of the whole building with significant investment cost and significant savings, but long payback period, e.g., thermal insulation of the building, exchange or upgrade of the entire heating system

Most Type 3 and especially Type 4 measures do not always show the savings immediately. Thus it is important to make calculations as precise as possible to show the flat owners the benefits versus the costs in a time line.

Technical considerations

Technical considerations play a role when some construction components have reached the end of their lifetime or when the structural stability of the building is in danger. Unless it is cheaper to tear down the building and erect a new one on the same spot, the building will have to be refurbished at that point, despite the shortage of financial means. Technical considerations can also play a role when the building is only partly upgraded, e.g. when parts such as windows need to be repaired. Refurbishment out of purely technical considerations will not be undertaken if the house is considered to be in a good enough state. In case of doubt, a building survey can determine the need for technical upgrade and repair.

Other considerations

There are also a number of other considerations when it comes to refurbishing a building. Environmental aspects may be important for the individual`s approach to general values (environmental protection as value) and norms (expectation that others share these values) in one's lifestyle. It is furthermore important to consider such factors as a policy (legal requirement to upgrade houses), the availability of technologies on the market, construction practices in the particular region, consumption practices and lifestyle preferences of the people, factors for satisfaction, preferences for thermal comfort (remember symbolic, affective and instrumental behaviour). At the same time there are barriers to refurbishment that are not purely based on economic or technical considerations, such as scepticism towards new technologies, fear of noise/dirt/stress during the refurbishment and the lack of information about refurbishment of buildings in general. Research also suggests, that among the reasons for such scepticism towards technological upgrade is also the risk or fear of being an early adopter. (e.g. "The technology may improve, or may not work.") This insecurity causes many people to perceive the current situation as the safest option. [2]

Research from Germany shows that homeowners wait until building components reach the end of their lifetime and only then assess the of costs and benefits of an upgrade. Previous studies show that retrofits occur rather when they are needed (end of lifetime) or the opportunity arises, e.g. when the building is enlarged. Refurbishment measures were found to be less dependent on income, age, or education, etc. However, the threshold for refurbishment is, of course, lower when the owner can afford a refurbishment financially and when he is certain that the refurbishment is profitable for him [1]

19.3 Complex refurbishment

The associated costs increase, ranging from relatively simple Type 1 measures to a whole house "deep" retrofit (Type 4). In practice, some combinations of measures can give additional cost savings (e.g. improved insulation can reduce the capacity of the heating system required). It has been estimated that complex refurbishment of multi-apartment buildings can reach significant savings (up to 60-70%) of heating costs[9]. This is clearly a benefit of complex refurbishment. However, multiple measures tend to follow the law of diminishing returns, where energy saving from a combination of measures is not necessarily the sum of savings from individual measures. The calculation of several refurbishment variants can demonstrate at which point a complex refurbishment makes sense.

The refurbishment chain follows some logics of steps. It is important to notice that the succession of the energy-related steps in refurbishment is fundamentally different from erecting a new building. Although each building has its own characteristic features, there are some common steps to achieve the energy efficient refurbishment (own compilation, based on [4]):

Steps of refurbishment

- Step 1 - an evaluation of a building and energy audit. The determination of the energy consumption – measured either over a heating period or through the establishment of the co-heating curve during a shorter representative period – is a prerequisite for an initial validated energy balance.
- Step 2 - the optimization of the operation of the building before any immediate refurbishment (any investment in this stage is small with a short pay-back time)
- Step 3 – realization of partial improvements
- Step 4 – refurbishment reaching low energy consumption standards
- Step 5 – adapting of heating systems to low temperature function; this allows using a wider range of technologies (e.g. efficient heat pump)
- Step 6 – exploit application of RES for heat and electricity production
- Step 7 – use of energy efficient electrical household appliances, lighting, etc.

The general order of these steps follows an important logic: after evaluating the energy demand of a building, we need to reduce the demand, first, by using less energy, then reducing the consumption further by increasing the energy efficiency of the building and its components; last but not least, replacing the remaining demand with RES. If we reverse the order, we would need to install much larger facilities to utilize RES, as our energy demand is still the same as before. This is not a wise approach, neither from an economic nor an ecological point of view.

19.4 Benefits of refurbishment for the building and the city quarter

If planning and calculations are done appropriately, the right materials and products are selected, works are performed following manufacturer's instructions by trained and experienced specialists (craftsmen), any refurbishment will bring certain gains and benefits. These gains and benefits refer both to the living and urban context (surrounding environment). It should be kept in mind that only a complex refurbishment and not a single measure will bring the most desired effect.

Gains from refurbishment

Gains from the refurbishment (complex refurbishment in particular), increasing energy performance of the building for the level of the individual household include the following:.

- It brings reduction of energy consumption for heating, resulting in economic benefits – reduction of heating bills. If the energy demand for heating is substantially reduced, the remaining heating needs which can be fully or at least partly covered by renewable energy sources e.g., solar thermal collectors, heat pumps may be considered.
- Most often, the value of individual property, i.e. flat, increases after refurbishment.
- Refurbishment results in better indoor climate and more comfortable living conditions, e.g. improved thermal comfort during summer and winter - no droughts due to uncontrolled air flows, the possibility to adjust room temperature as needed in each room separately.
- Installation of heat meters or heat cost allocators allows flat owners to pay for individual consumption of space heating thus creating motivation to adjust the heating demand and to not waste heat.

Gains for the surrounding urban environment

In addition to gains resulting for households, the surrounding urban environment – the whole residential area – also benefits from the refurbishment.

- Most often multi-apartment buildings built in the 1960s-1970s not only have low energy performance, but also poor technical conditions. Construction elements are deteriorating. It is possible to eliminate the construction defects during the complex refurbishment thus increasing safety for tenants of the building, but also for passers-by. Moreover, such improvements in the construction increase the lifetime of the building and lower the maintenance costs.
- The insulated facades of the building at the final stage of the refurbishment usually are painted in nice colours thus improving the aesthetical appearance of the building and providing a pleasant feeling in the neighbourhood. The maintenance of good "eye appeal" of a building can play an important role in the urban context. The so-called "broken window theory", formulated by Wilson and Kelling in

1982, conjectures that the first appearance of small, harmless signs of deterioration, such as a broken window, can trigger a downwards spiral that leads to the deterioration of a whole area.

- Complex refurbishment increases the motivation of flat owners to take care of the building and implement further energy-saving measures. Positive achievements increase the sense of ownership and provide motivation to adjust everyday behaviour, e.g. taking care that windows and entrance doors are kept closed as much as possible.
- Good practice refurbishment examples also motivate other flat owners in the neighbourhood to follow the practice and possibly achieve even better results.

However, it is important to remember that all the above-mentioned gains and benefits can be reached only if the complex refurbishment is implemented following high quality standards, i.e. free of defects, so that the previously calculated savings are realized. The whole refurbishment process should be thoroughly monitored - from the initial planning stage until the finalization of works.

KEY POINTS TO REMEMBER FROM CHAPTER 19:

- **The refurbishment dilemma stems from the fact that not all inhabitants benefit equally from insulation of the building shell.**
- **There are different possible motives for refurbishment which can interact with each other.**
- **The most significant energy savings can be reached by complex refurbishment. In this case, synergies between different refurbishment measures give an added value.**
- **The refurbishment chain indicates a sensible order of actions and measures that build on each other.**
- **Refurbishment of buildings benefits the city quarter as a whole through aesthetic and economic upgrading.**

20. Energy saving in household

Efforts to save energy in the households can lower energy consumption further. A first step is correct ventilation and heating. Especially in refurbished flats with new heating systems, the inhabitants need to adjust their behaviour and habits to create a pleasant indoor climate, save energy and prevent damage such as mould which is caused by improper ventilation and heating. The next steps are small improvements in the household that, in sum, can help to reduce the energy consumption and thus the energy bill even further.

20.1 Heating and ventilating correctly

After a house is refurbished, the heating and ventilation procedures need to be adjusted to the new indoor climate. Generally, the room temperatures should be adjusted to individual comfort levels. It is advised to adjust the temperature in each room separately, if possible. Rooms which are not used most of the day do not need to be fully heated. Usually, a temperature of 20-21°C in the living room and in the kitchen is comfortable also in winter. In the sleeping room, 17-18°C is usually enough. The more the rooms are heated, the drier is the indoor air: that can make inhabitants more illness-prone. Recommended temperatures for different rooms are found in table 1 below.

Living rooms	20 - 21°C
Kitchen	19 - 21°C
Sleeping rooms	17 - 18°C
Bathrooms	20 - 22°C
WCs	18 - 19°C
Floors and hallways	15 - 17°C

Table 20-1: Recommended temperatures for different rooms

Advice for ventilation

It is advisable to keep the doors between differently heated rooms shut, to prevent humid air from warmer rooms from moving into colder rooms. Rooms should not be heated by leaving doors open. Use the radiator also in colder rooms, but put them on a lower temperature. If the flat is not used for some time – either during the day or for several days – the heating can be turned down, but not below 15 degrees, otherwise the indoor air gets too humid and the risk of mould increases.

Inhabitants should take care that the air can ventilate freely around the radiators and that no furniture is placed in front of them, nor should curtains should hang in front of the radiators. When the windows are opened to ventilate the room, the position on the valve should be remembered. Before opening the windows, the valves on the heating should be closed fully and opened after ventilation to the same position. The numbers on modern radiator valves correspond to the temperature inside the room, not to the speed with which the radiator is being heated up. That means that the radiator should be immediately set to the desired temperature, rather than putting it to the maximum when turning on the heating.

Ventilation in summer

Rooms should be ventilated by opening the windows widely, depending on the humidity sources and the outside temperature. Generally you should ventilate more than two times a day for two to five minutes in winter. In the warmer seasons, you can also keep your window open for longer periods. Do not leave your windows on tilt for longer periods, otherwise you waste energy and cool down the walls next to the open window.

Heat waves in summer can be a burden and can make it hard to sleep during the night. Indoor comfort can be increased with two simple rules:

- Ventilate your rooms mostly during the night and in the early morning hours. Reduce the ventilation during the heat of the day to the minimum.
- Install shading elements outside of the windows and balcony doors. Indoor shading does not help to reduce the heat. Keep in mind that installing an air conditioning system is a costly thing. Even the most efficient appliances still consume a lot of energy and air conditioning systems should be the last resort. Better to switch on ceiling or desk ventilators first.

20.2 Smart metering and customer displays

Metering of electricity consumption

Having a possibility to monitor, e.g. electricity, heat consumption in a household and paying according to the individual consumption is a strong prerequisite for encouraging flat owners to implement energy-saving measures. Various devices - frequently called “smart meters” are available to ensure accurate, real time measurements, and appropriate billing; this information can be communicated through a customer display.

There are devices called smart energy meters that allow measuring electricity consumption of single appliances (Figure 3). In such a way the customer obtains information on energy efficiency of household appliances, e.g. refrigerator, washing machine, and can consider replacing high consumption appliances with energy-efficient models. In addition, it is important to remember that several electric home appliances continue drawing a small amount of power (usually up to a few watts per hour) when being left on a stand-by mode or sometimes even when being switched off. These “phantom loads” are related to most of modern house appliances (e.g., TV, radio, video recorder, computer) that use electricity. These loads can be avoided only by unplugging the appliance. Application of an energy meter is quite simple. The electric appliance is plugged into the energy meter, then connected to electricity; the energy meter will tell how much electricity is consumed by the household appliance. It indicates how much electricity is used, as well as the related costs.

Figure 20-1: Measuring electricity consumption of electric appliances

Other devices allow metering of electricity consumption in a flat, not just accounting for the total consumption, but indicating the exact consumption of electricity over 24 hours per month or year. Such services are sometimes provided by electricity supply companies [10].

Smart meters can change consumers' energy use habits in two ways – reducing overall energy consumption, and shifting energy consumption (e.g. avoiding consumption in peak hours) [11].

Heat cost allocation

Heat cost allocation is an accurate way to distribute heating costs where conventional metering is not possible [12]. Devices called heat cost allocators (Figure 4) provide data for the billing of individual residents' usage of the heating system. This system is appropriate for buildings having no independent heat meter for each separate dwelling. Heat cost allocators measure and record both the radiator's surface temperature and overall room temperature by high precision sensors. They convert this information into percentages, providing the basis for calculating the cost of heating. A heat cost allocator needs to be installed on every radiator in all flats of the multi-apartment building. Thus dwellers have to make a common decision to install allocators and invite professionals who can install them correctly and explain how the system works. A heat cost allocator system works automatically and there is no need to control the operation of devices from dwellers' side.

Figure 20-2: Heat cost allocator

The cost for heating for dwellers in multi-family apartment buildings comprise the cost for heat consumption in flats and for heating of staircases and risers. Usually flat owners pay for heat according to the heated space of the flat. When thermostatic valves have been installed to regulate the temperature of each radiator, the additional installation of a heat cost allocator system allows residents to pay for actual heat consumption, rather than according to the floor space of the flat. In order to safeguard payment for heat losses as well as the heating costs for commonly used areas without heat costs allocators (e.g. stairwells), the charges for heat energy usage is divided into two parts – usually 60% based on exact consumption in flats and 40% based on calculation of heat consumption per square meter. Depending on individual cases, shares can be different e.g., 50%/50% or 70%/30%.

The application of the heat coat allocator system can result in average savings of 20-30% of the fuel consumed to heat a building with central heating [13].

Measuring of temperature and moisture level

A device called a thermo-hygrometer (Figure 5) indicates the amount of moisture in the air and the indoor temperature. Although preferences for heating comfort are different, usually, people feel comfortable if the temperature in the living room is 20-21oC, 17-18oC in the bedroom, and with a relative humidity of 40-60%.

Figure 20-3: Thermo-hygrometer measures the amount of moisture in the air and the indoor temperature

Detection of thermal bridges

With the help of a pocket size instrument – an infrared thermometer - it is possible to detect the thermal bridges, e.g. spots around windows or doors and other areas where the house is losing heat (Figure 6).

Figure 20-4: Detecting thermal bridges with an infrared thermometer

The infrared thermometer can do this by detecting the thermal radiation which is emitted by the object being measured and calculating its temperature. The accuracy of measurements is +/- 1 or 2°C. Infrared thermometers can also be used for other non-contact temperature measurements.

The abovementioned metering devices, among others, that give feedback on consumption, energy loss, and indoor comfort can create energy savings from consumers' behavioural changes [14]. However, it is important to keep in mind that the effectiveness of feedback can be influenced by several factors e.g., general context (social, educational and historical factors, energy infrastructure) [3].

KEY POINTS TO REMEMBER FROM CHAPTER 20:

- **Energy efficient refurbishment has to be complemented by behavioural changes of the refurbished building's inhabitants in order to further decrease energy consumption and prevent mould.**
- **Residents can greatly influence their energy consumption independently, by adjusting their indoor temperature, ventilating correctly and by replacing inefficient household appliances.**

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5

Management and transparency in homeowner associations

WHAT WILL YOU LEARN IN THIS MODULE?

This module explains how homeowners' associations represent a specific kind of community, focusing on those characteristics that have a direct impact on the process of decision-making. Being aware of the special features of this form of community may well contribute to more effective decision-making processes within homeowners' associations. A particular focus of this text is on the role of communication and the importance of transparency for both the cooperation and management of a homeowners' association in general, and the decision-making regarding a refurbishment in particular. Furthermore, the stages of decision-making will be described. The presentation of the main arguments against a refurbishment and ways to address them will help to overcome such difficulties in practice.

21. Homeowners' associations as a specific kind of community

The process of getting the agreement of each owner, searching for a compromise and making a decision about a capital refurbishment and energy efficiency modernization is an ambitious task. In particular when there is a heterogeneous social structure inside a homeowners' association with consequently different interests and varied financial circumstances among the owners, the process can be very difficult. However, keeping in mind some general facts about homeowners' associations and the communication with and among the owners, it is possible to manage this challenging task.

Homeowners' association as a form of self-organization

Before addressing the communication and decision-making inside a homeowners' association, it is first important to understand the particularities of homeowners' associations as a specific kind of community. Besides formal aspects of this form of self-organization of housing, there are numerous sociological features that characterize this kind of community. One of the most important ones is that membership is based on ownership of an apartment in a particular building. This means that members have no opportunity to choose the other members of this community and consequently cannot influence those with whom they share a common property and the related responsibilities. Another issue is the specific understanding of common property. Property rights comprise the rights of possession, use, and disposal (the latter is limited for homeowners' associations and cannot be divided among separate owners). However, owners do not only have rights, but also responsibilities regarding their common property and its condition. Formally, all owners are proportionally responsible for their common property. This aspect is often problematic as there may be a lack of understanding of the responsibilities and the related tasks are not carried out. In particular, this is the case when additional payments for the maintenance of the common property are required. This distorted perception of property rights is widely spread in post-Soviet societies and has negative impacts on the work of homeowners' associations.

When considering decision-making about refurbishment and modernization, what would an ideal homeowners' association look like? As research conducted in Saint-Petersburg has shown, the best association has an average size (50-100 apartments) and an equable social composition. Strong social inequality is often a ground for conflicts. The explanation for this phenomenon lies not only in some kind of social disaffection. Mostly, the problem is that diverse social groups have different possibilities regarding the payment of costs as well as differing preferences for how to spend their money. A fee of $100 per month can be insignificant for one owner, but an impossible sum for another. In some homeowners' associations, large projects could not be realized because some owners were unable to contribute to the costs. Therefore, it is important to estimate the average income of owners (a very rough calculation is sufficient), estimate the size of the group which considers additional payments as too high, evaluate the debts due to unpaid services during the last year and the average number of non-payers. These persons may not be able to contribute financially to a refurbishment.

KEY POINTS TO REMEMBER FROM CHAPTER 21

- **Formally, home owners have equal rights and responsibilities regarding their common property and its condition. However, not all owners are equally aware of their obligations.**
- **One of the main factors that hinder a decision-making process and creates conflict is social inequality. Diverse social groups have a range of possibilities regarding the payment of costs as well as individual ideas and preferences for spending their money.**

22. The role of communication in homeowners' associations

Communication and the dissemination of information among homeowners play a key role in homeowners' associations and housing communities. As it is usually impossible to inform each owner or tenant personally, the communication system plays a significant role not only for informing the tenants, but also for establishing a management system and providing and receiving feedback.

As regional research from different years shows, the quality of communication and information has a direct impact on the level of trust by homeowners in the management of homeowners' associations. If the communication system is evaluated positively by homeowners, the results of the chairpersons' work are usually appreciated and the level of participation tends to be higher.

Awareness

Research in three Russian cities has not shown a strong correlation between the information level and age of the homeowners. However, it was observed that the youngest and the eldest owners tend to have a lower level of awareness regarding the homeowners association and their activities (e.g. knowledge of the names of the chairperson and board members, familiarity with the association's activities and documents published). The most susceptible group for informative work within a homeowners' association is the group of homeowners who are between 40-70 years old.

So, should the communication be addressed mainly to the elderly people who presumably have the most time to spend time on provided information? Definitely not. When it comes to the decision-making process and later to the implementation of a refurbishment project, it is important that the majority – if not all – owners support the project. There are various methods for disseminating information among homeowners: it is useful to find the appropriate way to communicate with younger people who (might not be not at home during the day, and/or) have commitments (e.g. work/travel/young children/elderly parents) other than caring for their property. Additionally, if addressed directly in the initiation phase of refurbishment, elderly people may become important supporters of the project and convince others of its benefits.

Among the methods or channels of communication that can be used are phone calls, individual meetings, announcements in lobbies and courtyards, e-mails, announcements via individual postboxes, web-pages, an internal TV channel, an association's newspaper.

The communication methods can be classified according to different criteria:

Communication methods

- personal/ face-to-face vs. impersonal communication,

- formal vs. informal communication,
- regular vs. irregular communication.

The smaller the number of apartments in a block, the fewer information dissemination methods may be used. The methods themselves differ depending on the size of the apartment block: the bigger an apartment block, the fewer personal, face-to-face information dissemination methods are used successfully.

Asked about the most effective communication method, chairs of two homeowners' associations – both associations of large apartment blocks with more than 500 apartments – answered as follows:

Choosing communication methods

«Putting announcements in common areas is the most effective way to reach people. It is better not to submit information via the post-boxes of the owners, because these are already full of advertisements and people will not pay attention to announcements by the association.»

«We are planning to start using an e-subscribing system in future. Currently, phone calls are the most effective way of communication. Announcements are ineffective, and meetings as well, because usually just a few people come.»

These two citations show that for two homeowners' associations in buildings of a similar size, one single method – announcements in lobbies and courtyards – is assessed very differently. Is this contradictory? Actually not: The efficiency of communication methods depends not only on the size of the apartment block, but also on additional features of each building and the characteristics of the building's inhabitants. For example, is the courtyard or block accessible for non-residents? If so, distributed advertisements will make the delivery of house-related information to the owners' postboxes less efficient, because it will be just one paper among a lot of advertisement materials. Also, the number of active internet-users has an influence on the choice and effectiveness of communication methods. Obviously, if only a low number of owners/ tenants uses the internet regularly, information disseminated via internet, e.g. by email or websites will have little effect.

It is formal practice in many countries to distribute official letters to the postboxes and to post announcements in the common areas, such as lobbies and courtyards. However, these methods ways are not always sufficient. Observations in homeowners' associations have shown that the more alternate methods are used, the more owners and tenants are satisfied with the management system of their block. Also, the communication needs and preferences among owners are different; owners and tenants may prefer to be informed by communication channels other than those foreseen in the legislation (see also the following chapter).

Due to the diverse owner structure and needs, as well as differing characteristics of buildings, there is no universal information system that can be regarded as effective for all apartment blocks. However, two general rules for communication among the members can be kept in mind:

Rules for communication

- Larger apartment blocks require fast and impersonal communication – otherwise the large number of owners cannot be reached.
- The more methods of communication used, the higher is the information level of owners and tenants. A higher level of information, in turn, results in better evaluations of the transparency and democracy of the building's management system by the owners.

Importance of communication

Summarizing, it can be said that the system of information dissemination plays a significant role not only for informing owners and tenants, but also for preventing misunderstandings and solving internal conflicts. The dissemination of information is important for initiating a decision-making process on the refurbishment of a building, moderating such a process and reaching an agreement. Informing the homeowners is crucial not only legally, as it is obligatory to announce a joint meeting about a planned or completed refurbishment, but is also a highly effective tool for explaining the advantages of a refurbishment. It is therefore of vital importance to spend sufficient time and effort on planning how to disseminate information. However, it is crucial to take into consideration some general principles of disseminating and processing information. This issue will be addressed in the next section.

KEY POINTS TO REMEMBER FROM CHAPTER 22

- **The communication system plays a significant role in informing tenants, providing and receiving feedback, preventing misunderstandings and solving internal conflicts**
- **The quality of communication and information has a direct effect on the level of trust by homeowners in the management of homeowners' associations. A good quality of communication and information flow increases transparency and democratic decision- making**
- **The choice of the communication method should be based on the size of the house, the specific features of each building, and the characteristics of the building's inhabitants**

23. Cognitive processing of information and general principles of disseminating information

The importance of carefully thinking through how to communicate with the members of a homeowners' association depending on the special features of the building and the social structure of its inhabitants has become clear. What additional aspects must be taken into consideration when planning an information campaign?

Perception types

Humans can be divided into three different types according to their preferred or strongest way of perception:

- visualists, who process information best if it is provided visually;
- audialists, who process information best if it is provided by sound; and
- kinesthetic, who prefer "learning by doing".

The two first types are the most widespread; a mixture of these types can be observed very often. To reach different "perception types" – for example, in a homeowner association – it is important to use alternate ways of delivering information. Of course, it is impossible to address each homeowner individually in the best way for him or her. However, information can be communicated in different ways, both written and orally, to reach as many people as possible. This approach should also be taken when preparing a common meeting.

However, the kind and volume of information also play a role for processing information. Which are the issues owners pay particularly strong attention to? Not surprisingly, the strongest attention is paid to issues regarding payments and finances. Further, in general, elder owners are usually more interested and informed. When anticipating a decision about a capital refurbishment and energy efficiency modernization, financial aspects are extremely important; owners are usually keenly interested in getting the information about the planned project. This high interest, however, also means great responsibility for the head of the association. He must provide all the required information and is responsible for preparing and disseminating correct, truthful information.

An additional difficulty lies in the fact that information on financial as well as on technical aspects – the second most frequent topic related to a refurbishment - are difficult for an average owner to understand. Using complex concepts and providing too many details makes the process of perception even more difficult. Therefore, the information materials which are prepared for informing the homeowners should meet the following criteria for effective processing by owners:

Criteria for information materials

- the information must be concrete and should be provided in a clear language without metaphors;
- it should not be overloaded by excessive details and technical terms;
- the information must have a logic coherence.

Materials describing plans for a refurbishment project must also contain the main budget figures, a time schedule and a calculation of the possible profits for owners.

So if these criteria are fulfilled, the communication will take place smoothly without any problems? Probably not. It can be expected that in any homeowners' association, there is at least one meticulous owner. Such owners are usually interested in all details and pay great attention to any activity in their association, in particular if a large-scale project is planned. Communication with such owners can be challenging and can require a lot of time and effort. However, if these owners are convinced that the project will be effective, has been well prepared and intended for the common good within the association, such owners can be powerful allies.

Target group "number one"

There is a second group of owners to which particular attention should be paid. As research has shown, approximately 17% of owners in the studied homeowners' associations were well informed about the associations' work, but not active. This group of informed but inactive owners has two characteristics that make it "target group number one" during the decision-making process: they do have enough financial resources to contribute to a capital refurbishment or modernization, but might not have a strong opinion regarding such projects. With some additional efforts, this group could be successfully involved by active owners familiar with the details of the project - usually middle-class and middle age owners with children who pay attention to the information about the associations' activities.

To conclude, if a decision on a refurbishment project lies ahead, it is essential to invest time and effort in carefully planning the information campaign. Providing and promoting the main arguments and features of the project addressing different "perception types" is necessary to provide all owners with the relevant information and remove potential doubts and misunderstandings.

KEY POINTS TO REMEMBER FROM CHAPTER 23

- **People can be divided in three different types according to their preferred or strongest method of perception: visualists, audialists, and kinesthetic persons**
- **Information materials should be concrete, logical, in clear language, and without excessive details and technical terms**
- **Special attention should be paid to the group of home owners that are interested but not very active, i.e. middle-class and middle age owners with children.**

24. The importance of transparency of the management system

Very often, complaints about the passivity of homeowners in associations are heard. Also, it is often said that a lot of owners dislike participating in the meetings and initiatives of homeowners' associations. However, research has shown that in practice the level of participation in homeowner associations is not that bad. The studies came to another interesting result: the evaluation of the questionnaires showed a correlation between a transparent and democratic management one the one hand, and the active participation of owners on the other hand. In other words: A high level of transparency and democracy in the management system leads to a higher level of the participation of owners in the work of associations.

Transparency and participation

The following section will describe how a transparent information system and free access to documents and reports contributes to the activity level of owners within homeowners' associations.

Forms of participation

Three forms of participation can be distinguished:

- participation in the associations' work, attendance at joint meetings and participation in votes;
- participation by conducting voluntary works;
- participation in the financial obligations by regular payments and the willingness to accept additional financial contributions when necessary.

How do "high" and "low" levels of participation correlate with the homeowners' opinion of the management, as well as their assessment of the level of transparency and efficiency in their homeowners' association? The following trends emerged during research carried out in three Russian cities:

- Asked about their opinion regarding the common meetings organised by the association, respondents with a high level of participation answered that there are small difficulties during common meetings which can, however, be overcome. Respondents with a low level of participation answered that they regard common meetings as a waste of time.
- Respondents with a high level of participation said they are satisfied with the information provided about the associations' activities; respondents with a low level of participation expressed the opposite opinion.
- Respondents with a high level of participation judged the maintenance of their buildings as 'satisfactory' or 'good', while homeowners

with a low level of participation were unable to assess the maintenance work ('don't know', 'difficult to say').

- Homeowners with a high level of participation evaluated the qualification of the association's chairpersons as sufficient for his or her function; low-level participants gave the opposite view.
- Homeowners with a high level of participation expressed their willingness to entrust the maintenance of a multi-apartment building and the management of the association to the chairperson of the association. In contrast, homeowners with a low level of participation were more inclined to entrust these tasks to special housing management companies.
- As becomes obvious in the above mentioned correlations of homeowners' opinions and their level of participation, active participation mostly goes hand-in-hand with a good opinion on the quality of the maintenance and management of the house and the qualification of the association's chairperson. Not surprisingly, these active owners are also more willing to contribute to reaching an agreement about larger projects within homeowners associations by participating in discussion and convincing other owners. Such active owners do usually not appear by accident, but are the result of a transparent and democratic management system.

Importance of transparency

Transparency is thus important for the general effective functioning of a homeowners' association. It is also an extremely important tool and pre-condition for coming to a decision about a capital refurbishment and energy efficiency modernisation as it is in general easier to agree on such a decision if the owners trust the chairperson and board of the association.

Of course, the goal is not just to reach an agreement, but also to successfully implement the decision. Research has shown that, in some cases, difficulties regarding legal aspects hindered the realisation. Not all managers provided a detailed list or description of the plans before the vote, so that there was a decision about the general question but without complete information regarding a proposed capital repair. Another very serious violation of the legal requirements is the absence of a concrete or approximate sum for realising the whole project and the sum for each owner.

Not providing this important information is not only a violation of the formal regulations, but also negatively impacts the realisation of the agreed measures. If owners do not understand what concrete costs they are taking on with their vote, they are actually voting only for the idea, not for its realisation. This leads to numerous complaints afterwards and difficulties regarding the collection of payments.

For the abovementioned reasons, all activities during the preparation and realization of any project in a homeowners' association must be in accordance with the current formal regulations and should be transparent for all owners.

KEY POINTS TO REMEMBER FROM CHAPTER 24

- **A high level of transparency and democracy in the management system leads to a higher level of the participation of owners in the work of associations**
- **The homeowners with high level of participation tend to have a better opinion of the quality of the maintenance and management of the house and the qualifications of the association's chairpersons**
- **Provision of transparent information is a legal requirement of a homeowner association, since the members need to be fully aware of what they are voting for.**

25. Collective action and the free-rider's problem

Free-riders

The book "The Logic of Collective Action and the Theory of Groups" by Mancur Olson (1965) has become one of the fundamental publications for further studies in economy, political science and sociology. Why did this one book become so inspiring for numerous researchers? Because for the first time, it addressed the nature of freeloaders or 'free-riders', describing persons who benefit from resources, goods or services without paying for the costs. The book explains how collective action is organized and a common good is produced, how people become free-riders and how it is possible to neutralize this feature of human nature.

According to Olson, a collective good is a specific organizational good which can be produced and provided only by joint collective efforts, not by individual ones. Since some collective goods are understood to be indispensable, it is difficult to close the access to this good for a single community member.

Common good in homeowner associations

Put very generally, the main goal of homeowners' associations is to increase the level of efficiency of the housing management. Considering this, the most significant common goods which are produced by homeowners' associations, as one of the association leaders named it, are "cleanliness and beauty". The creation of public goods in homeowners' associations is an ongoing process of establishing and improving the conditions in the apartment house. For these maintainance and improvement conditions, regular payments are charged. The problem of a common good is that it is impossible or very difficult to limit or prevent the access to this good for single members of the commnity. Such is the case for homeowners' associations.

The division of common goods in the housing sector is a complicated process because the system of communal services in the post-Soviet countries was orginally designed for common consumption. In most cases, especially in old apartment houses, there are no systems of individualized access to communal services, and individual water and heating metres are rare. It is therefore impossible to limit the access to these services, allowing some people to enjoy the benefits of these services without paying for them, i.e. they become free-riders. Homeowners' associations thus need to find other techniques to solve the free-rider problem.

Free-riders in homeowner associations

Who are the free-riders in homeowners' associations? They are owners who tend to not participate in the assocations' work or do not pay their fees for maintenance regularly. Free-riders therefore contribute to the under-production or decreasing quality of a common good. Even though it is easy to identify free-riders in a given homeowners' association (they are not as anonymous as, for example free-riders in the public transport – usually it is obvious if a tenant does not participate in any activity to clean or improve the common areas), it is still difficult to solve the problem.

Who are they, these owners who dislike paying regularly for common needs? First, it was assumed that free-riders tend to be poor, like pensioners, families with many children, etc. But experts and association leaders debunked this assumption by pointing out that free-riders are in fact mostly from the middle class. Furthermore, free-riders in homeowners' associations are usually under thirty-five years old, well-educated, and in most cases they do not have children. This description does not include any particular characteristics and indicates that being a free-rider does not represent very specific demographic and/or social features. The problem of free-riders is therefore not merely a legacy of the Soviet era. Free-riding is a rather universal phenomenon which can appear in different economic and social systems, therefore the management system of homeowners' associations and the relations within them might be perpetuating the problem.

Free-riders have all sorts of excuses for not paying their bills – starting from having no time to go to the bank to claiming that they simply forget to pay– but in most cases they do not provide any explanation at all. As regards additional services, some free-riders explain their not paying with the argument that they do not need these services and therefore do not feel obligated to pay for them.

Dealing with free-riders

Which methods can be used to prevent and neutralize free-riding? According to the theory of collective action there are two ways to prevent people from behaving like free-riders:

- threatening with punishment,
- using ideological pressure.

The threat of punishment varies in different societies from fines to threat of violation. Ideological pressure means judging free-riders by creating conditions in which it is shameful to be a free-rider.

Which methods to solve the free-rider's problem are used in home-owners associations? Officially, homeowners' associations can take legal action against free-riders, but this, in most post-Soviet countries, is rather slow and ineffective. All experts and association leaders who were interviewed for the conducted research agreed that under the current conditions the legal process is not a viable solution for the free-rider problem. Many associations have therefore created informal methods of dealing with free-riders. Among such methods are attempts to limit the access to other common goods, such as parking places, plumbing services, etc. Another way is to post public lists with the names of the non-payers. The lists are usually displayed in common areas, like courtyards, entrances and announcement desks. Sometimes these lists do not merely contain the names of the non-payers, but also warn all tenants that the water and heating services might be cut off for the entire apartment house if the free-riders do not pay their bills. However, publicizing the names of the free-riders is only effective when used for the first time. After the third or fourth announcement, usually the attention paid to the lists is very low.

Free-riders, who do not contribute to the functioning of an association financially and avoid payments represent a serious problem in many homeowners' associations, in particular if legal prosecution is not efficient. Using ideological pressure has proven to be the most applicable method in this situation. A good homeowners' association manager should therefore establish the conditions in which it is shameful not to pay for common goods. As mentioned above, such conditions can only be established when there is a transparent management system.

KEY POINTS TO REMEMBER FROM CHAPTER 25

- **The system of communal services in the post-Soviet Union countries was orginally designed for common consumption, which caused the absence of systems of individualized access to communal services, like individual water and heating metres**
- **"Free-riders" in homeowners´ associations are owners who tend to not participate in the assocations' work or not contribute financially to the functioning of an association. Free-riders therefore contribute to the under-production or decreasing quality of a housing community. Using ideological pressure has proven to be the most applicable method to deal with "free-riders".**

26. The problem of deferred income

Deferred income

Before addressing more concretely the decision-making process in a homeowners' association, the concept of deferred income shall briefly be introduced as it is an important phenomenon when it comes to long-term decision-making. Deferred income is defined as money received for goods or services which have not yet been delivered. Typical examples are an annual maintenance contract where the entire invoice is invoiced up front, or a pension system, in which a person regularly pays a fee and gets the benefit later. It is clear that deferred income implies higher risks of not receiving exactly what was expected when making the payment. These risks are usually neutralized by a strong system of contracts, insurances and strict legal requirements.

How is this business term connected with the decision-making about a refurbishment project in homeowners' associations? Refurbishment can be considered as an investment intended to return a profit to all members of the association. This profit, however, will not be received at the moment of payment; the owners who paid for a good or service must wait for a certain period of time until they receive the benefits of their payment. Obviously, this situation and the related risks are not attractive for a homeowner. Consequently, the person, organization or company offering a good or service with deferred income is in a challenging situation.

This is exactly the case with refurbishment projects and the energy efficiency-modernization of buildings. The economic benefit, i.e. a decrease of tariffs and fees, will be received only at a future time, but the homeowner needs to agree now to make his or her financial contribution. This situation has a significant psychological effect on the homeowner: He is asked to invest "real" money which he holds in his hands for a benefit which seems rather hypothetical and not guaranteed.

How to deal with this psychological effect? The owners are sceptical about investing in refurbishment because they have doubts about the benefits and/or mistrust the agreement. The main rule for the argumentation in favor of the refurbishment project is providing as detailed, clear and transparent information as possible in order to disprove these doubts and allay the owners' mistrust.

KEY POINTS TO REMEMBER FROM CHAPTER 26

- **Deferred income implies higher risks of not receiving exactly what was expected when making the payment. These risks are usually neutralized by a strong system of contracts, insurances and strict legal requirements**
- **The best way to deal with owners´ scepticism is providing as detailed, clear and transparent information as possible**

27. The stages of decision-making

Coming to a decision about a refurbishment is a long process which involves various resources and requires serious preparation. There are differing opinions about the number of stages within a decision-making process. A related study regarding capital refurbishment and energy efficient modernization in homeowners' associations in Russia was conducted from 2011-2012, and included 2 400 owners. The 150 most active participants in the decision-making were interviewed in seven cities. Based on the interview results and decision-making theories, the main decision-making stages are as follows:

5 stages of decision making

1. identification of the problem,
2. search and articulation of alternative solutions,
3. lobbying,
4. decision-making procedure,
5. evaluation of decision's results.

How can these stages be identified and characterized in a homeowners' association?

27.1 Identification of the problem

The identification of the problem is the assertion of at least one person (or a group) about the necessity to conduct a refurbishment or modernization in the apartment block. The most wide- spread arguments in favor of such a project are the physical condition of the multi-apartment house and potentially lower fees for the communal services after the refurbishment.

It is important here who, exactly, states the necessity for conducting a refurbishment and energy efficient modernization and what particular arguments were proposed. Theoretically, such an initiative can be started not only from the chair or general manager of a home-owners' association, but also from the association's board, a single owner or a group of owners. Apart from these internal actors, the initiative could also be initiated by external agents - municipal authorities, non-governmental housing organizations, management companies and firms - hoping to become a subcontractor of the possible refurbishment.

Research indicates that in homeowners' associations, the chair of the homeowners' association and the board are the most frequent initiators. Other internal and external possible initiators are not common.

Informing homeowners

Once the necessity to conduct a refurbishment has been asserted, the idea needs to be communicated to the homeowners. There are different methods to disseminate information, such as organizing a joint meeting, informal meetings and talks, emails, etc (see also chapter 22). As for the initiation of the projected work, the chairpersons and boards of homeowner associations play an important role: in 65.6% of cases, owners learned about the idea from the chairperson or from the board; 34.4% of the owners were informed by other owners. The explanation: the chairpersons and members of the board are the most informed persons in a homeowners' association. Their position requires a higher level of involvement in such issues and they are among the most – if not THE most – known persons in an association.

At the initiation stage, it is important to formulate a concrete project with clear goals and possible solutions. However, even if a detailed plan of the project is prepared, the social potential of the homeowners' association, i.e. the financial possibilities of the home owners, the proportion of owners and tenants, and the social inequalities, also needs to be taken into account. Some these aspects will be addressed in the following section.

27.2 Searching and articulating alternative solutions

During the stage of *searching and articulating alternative solutions,* proposals for modifying the project can be made. The most common suggestions for modifications of the proposed project are the following:

Reactions to refurbishment proposals

- postponing the repair,
- implementing just a part of the suggested works,
- finding alternate funding of repair,
- extending the list of planned works or applying for a credit.

An additional and not uncommon "alternative solution" is to reject the entire project.

What kind of arguments can be used if such alternative solutions are being discussed? Postponing the work, especially making energy-related improvements, means losing benefits: instead of saving money immediately, the benefits of the proposed refurbishment will be received only in the future. Reducing the scope of improvements could mean a reduction of possible profits, and the larger purpose or sense of the refurbishment project could be lost, from both a technical and financial point of view. Rejecting the whole project would eliminate both financial benefits and an increase in living quality.

Regarding the funding scheme, there are not a lot of opportunities for modifications. Under the current law, homeowners' associations usually have to pay for the works with the owners' funds for capital refurbishment (either monthly or with one payment). An additional option is that owners/inhabitants with better financial means voluntarily contribute more. However, if any modification is made, it must be approved by the joint owners' decision and be carefully documented. Rejecting the project completely means negating the possibility of reduced fees and increased living standards.

Sometimes, external experts are invited to provide additional expertise. However, research shows that owners and tenants usually are not very active in searching for and proposing alternative solutions. Most owners form their opinion during joint meetings which are dedicated to discussing the project or making the decision.

27.3 Lobbying

Lobbying in general refers to two possible options: to conduct or not to conduct a capital refurbishment. The most important aspect for classifying lobbying attempts is whether the information is provided by an official source (from chairperson, manager or board) or an unofficial one (disseminated by other owners and, rarely, by technicians and specialists who serve the building). Lobbying methods can be classified according to two characteristics:

Formal and informal lobbying

- formal vs. informal,
- addressing all vs. addressing only some owners.

Lobbying attempts can also be classified according to the methods used for disseminating the information. In principle all the above described methods can be used also during lobbying.

Formal methods include the dissemination of official information among all owners and tenants. Informal lobbying includes, for example, spreading information in individual talks about possible consequences in case the refurbishment is rejected.

Formal lobbying often includes information on the list of planned alterations, the potential subcontractor and the necessary payments by the owners. The informal lobbying (as well as some of the formal information) covers the following issues: the increase of communal service fees, the probability of an increase in the prices of repair works, possible crashes of common property (elevators, engineering communications, internal facades and roofs) and the unreliability of information about the payments for co-funding the refurbishment (either overstating, or understating of payments). Another popular argument against refurbishment is possible corruption during the repair and modernization works. However, such arguments will not be found in a homeowners' association which has a transparent management and regularly reports on financial questions.

27.4 The decision-making procedure

The decision-making procedure is the direct act of either approving or rejecting the decision about refurbishment and/or modernization. According to law, such a decision must be approved by the owners in a joint meeting. Managers or chairpersons must pay high attention to the preparation and conduct of this procedure. Most complaints regarding this procedure refer to legal aspects, which underlines the importance of correctly fulfilling all formal requirements, such as taking minutes during the meeting (not afterwards). In addition, practice shows that possible letters from an attorney secured by some owners can provide the opportunity for various kinds of manipulation and falsification.

Conditions for voting

It is also very important to provide the conditions so that owners can vote confidentially, without observation and interventions from other owners. If experts or other external specialists are invited to this meeting it is very important that they do not have any possibility to influence the homeowners during voting. The organizers or persons responsible for such a meeting should be aware that, even if all formal requirements for preparing and conducting the procedure were taken into account, there could be dissatisfied owners. Due to the importance of a decision regarding a refurbishment or modernization, such meetings may be more formal than that of normal annual reporting meetings. If it is necessary to change the before-hand published agenda of the meeting, it is recommended to agree on the new agenda by a vote of all owners at the beginning of the meeting. Otherwise, unsatisfied owners might accuse the organizers of having manipulated the procedure.

It should be noted, that the deliberate or accidental exclusion of owners from the decision-making, e.g. by providing insufficient information, dismissal from participation, or distorting the information can be illegal and a reason for a court case. Transparency is thus crucial to prevent such escalation. Apart from these legal aspects, it should of course be the aim of each organizer to integrate all owners in the decision-making process and convince potential opponents with good arguments and clear information.

27.5 The evaluation of the decision

The evaluation of the decision's results is an obligatory stage in the decision-making process, though it is not always made publicly. The evaluation has two dimensions:

1. the formal dimension,
2. the informal dimension.

The formal dimension usually comprises action and budget reports. The informal dimension is more difficult to measure, but is rather a question of observation (this is possible if the number of members of the homeowners' associations is not too big). The informal evaluation includes owners 'opinions about the project in general, and the procedure and results of its' realization'.

The evaluation is important not only regarding that particular process and situation, but is also of value for the 'common history' of an association. A capital refurbishment or modernization is a cost-intensive, long-term event which requires not only resources but patience from the participants. The experience made during this process will have a strong impact on further decisions made in the association for several years. During the stage of evaluation, the chair and board of the association might be addressed with questions about the choice of subcontractor, the budget and the quality control of all planned works.

KEY POINTS TO REMEMBER FROM CHAPTER 27

- **At the stage of initiation, it is important to formulate a concrete project with clear goals and possible ways for a solution.**
- **The decision regarding the refurbishment project must be approved by all owners in a joint meeting.**
- **When it comes to a meeting in which homeowners make a decision on a refurbishment project, it is crucial to maintain a strong formal procedure and provide an opportunity for confidential voting.**

28. More about decision-making

There are different stages of a decision-making process. Additional detailed information will be found in the following sections.

28.1 Forms of voting

absentee ballot

The first task when preparing a decision-making procedure is to decide which form of voting will be used. The law foresees two forms: absentee ballot or voting during a homeowners' meeting. In an absentee ballot, homeowners are provided with special bulletins. This happens either by post-delivery with 'signature upon receiving, (zakaznoe pismo) or by making the bulletins available in the office of the homeowners' association in special opening hours. Formally, there are two ways for establishing the votes: either in separate bulletins or in a common list of owners in which each owner provides his opinion and signature. Each method has its advantages and disadvantages: while separate bulletins are difficult if there is a general lack of trust, a common list may be criticized for its lack of confidentiality. Both ways may also include so-called proxy voting, whereby some members of a decision-making body may delegate their voting power to other members of the same body to vote in their absence.

Having the choice between organizing an absentee ballot and the common form of voting in a owners' meeting, absentee voting is often preferred as it is not necessary to gather all (or at least the majority of) owners at one place and time. However, it has other difficulties: it requires the highest level of transparency and very accurate work when preparing, delivering, processing and evaluating the documents concerning the procedure and decision.

28.2 The list of refurbishment measures

When deciding for refurbishment measures, the members of a homeowners' association do not vote on the principal question of conducting a refurbishment, but on concrete measures to be implemented. Usually at the beginning of a decision–making process, i.e. during the initiation stage, a list of suggested measures to be implemented is published.

But what happens to this initial list? Sometimes during the process – from initiation until voting – this list tends to be shortened, i.e. the final list which is approved by the owners includes fewer measures than that initially suggested. The reasons can be found in the resistance of some owners, the higher costs when implementing additional measures and a re-evaluation of the association's funds and resources.

Why is this important to know? It is well known that in order to increase energy efficiency and the living quality in a building, it is crucial to conduct a comprehensive refurbishment, rather than undertaking single measures. The goal during a decision-making process should therefore be to adopt an extensive and not extremely limited list of measures.

In conducted studies, three measures received significantly higher approval rates at the end of the decision-making process than when initially suggested: the repair of the building's foundation, the installation of cold water meters and the installation of gas meters. It can be assumed that the repair of the foundation was lobbied by the chairpersons. The installation of meters might have been lobbied also by owners, as owners tend to support measures which bring a clear benefit to them. All other suggested measures had similar or lower approval rates than at the beginning of the process. This suggests that homeowners did not perceive such a personal benefit from these measures.

Another factor impacting the proposed changes under consideration is the specific characteristics of these works. Some measures may be more relevant to some owners than for others. Owners from top floors, for instance, are usually more interested in the repair of roofs, while owners from the bottom floors are more interested in basement repair. The same logic applies to elevators. Unfortunately, not all owners realize that even if their apartment is situated in the middle floor, a repair of the roof or basement is necessary also for them. Explaining this necessity is the task of the management of the homeowners' association. The main argument to be provided is the fact that these elements of the building are common property and therefore, the responsibility, especially financial, is proportional to all owners, not to just one or several specific floors.

KEY POINTS TO REMEMBER FROM CHAPTER 28

- **The law foresees two forms: absentee ballot or voting in a homeowners' meeting**
- **Special attention needs to be paid to explaining that certain parts of the building (foundation, roof, elevators) are common property for which everybody is responsible and all need to contribute to refurbishment costs**

29. Arguments against a refurbishment and how to address them

Persons initiating or supporting a refurbishment project will often encounter similar arguments brought forward by the opponents of such a project. Some of the main contra-arguments and possible ways to weaken or disprove their objections will be presented in this chapter. The contra-arguments presented below are based on the answers given by active homeowners, chairpersons and board members of associations in the framework of research on homeowners associations.

In previous research, 40% of the interviewed active owners, chairpersons and board members answered that some owners in their multi-apartment building were against making a capital repair and/or energy efficiency modernization. Based on the interview answers, four main contra-arguments against a refurbishment could be identified:

typical arguments against refurbishment

- the owners do not want to spend money for a refurbishment/energy-efficient modernization and do not believe that the invested money will lead to positive financial effects (i.e. saving of additional expenses);
- the owners do not believe that the works will be implemented with good quality;
- the owners do not believe that the collected funds will be distributed in a proper way or that the sub-contractor will be chosen in a transparent process;
- the owners believe that the execution of the works, such as providing access to their apartments, the related noises, etc., could be uncomfortable for them.

The first contra-argument can be neutralized by providing a clear and detailed project budget and a calculation of the possible future reductions of common expenses fees. The data provided should not only show the financial implications for the whole homeowners' association, but must also include a calculation for one single apartment as a concrete example. An additional argument regarding these doubts can be that fares and tariffs for communal services, especially regarding energy costs, have the tendency to increase, and the only way to reduce these payments is an energy-efficient modernization.

The second and the third contra-arguments are interconnected. Both these arguments refer to the management system in the association. As experience has shown, a very effective way to address these worries is to organize a special owners' commission which supervises and monitors all stages of the refurbishment, controls the distribution of funds and, as a group, chooses the sub-contractors.

The last argument is relevant in particular for non-pensioner owners. A transparent and detailed presentation of all planned work and discussion of possible compromises is important.

The interviewed active homeowners, chairpersons and board members were also asked whether they convinced other owners about the necessity of a capital repair and the need to participate in the joint meeting about the project. Slightly more than half of those interviewed answered that they had convinced other owners by actively participating in the lobbying stage.

external assessment of the building

They used different arguments for convincing others. The main argument used was the poor physical condition of the building and the possibility to get external funding for implementing a refurbishment (e.g. in Russia the program for capital refurbishment of the housing stock). The argument stating bad technical conditions can be strengthened if a specialized institution with expertise in this field is commissioned to assess the state of the building and confirms the low quality. As research has shown, such expertise was provided in approximately one third of the cases: 33.6% of the interviewed persons indicated that an external expert opinion was commissioned, conducted and presented to the owners before initializing the decision-making process.

principles of argumentation

Some general principles of argumentation should be followed when entering into communication with the homeowners with contra-arguments:

- the argumentation must be based on true statements;
- the provided arguments must not contradict each other;
- all arguments must be formulated in a clear manner;
- the arguments need to be strengthened by appropriate information and examples;
- no redundant arguments should be provided.

In summation, the initiators of a capital refurbishment and energy-efficient modernization – as with any high cost projects – may encounter very strong resistance from the homeowners. Various contra-arguments can appear during the discussion process, however, experience shows that it is possible to convince owners to carry out a refurbishment and energy efficiency modernization. Therefore, it is important to prepare argumentation for all stages of the decision-making process. A transparent management system, openness to share reports with owners and a well-established information system are the best pre-conditions to reach a positive decision. Implementing only single measures is not effective, either to improve buildings, physically and for energy efficiency, or for long-term financial benefits for owners. However, if the resistance of the owners is very strong, it may be more effective to start with only one or two measures; this has been shown to have a significant social result: If such "test cases" are successfully managed and implemented by the chair of the homeowners' association, homeowners may be more open to agree to further measures.

KEY POINTS TO REMEMBER FROM CHAPTER 29

- **The best way to convince the sceptics is to provide a clear and detailed project budget and a calculation of the possible future reductions of common expenses fees. The data must also include a calculation for a single apartment as a concrete example.**
- **Argumentation for a refurbishment project should be consistent. External experts can underline the necessity of a refurbishment by evaluating the condition of the building.**

6

Planning refurbishment projects

WHAT WILL YOU LEARN IN THIS MODULE?

A multi-family building should undergo capital refurbishment about every 30 to 50 years, depending on the building quality and individual elements which need to be renewed. At the same time existing large prefabricated buildings, especially those constructed between the 1950s and 1990s, today not only suffer from low structural quality but also from a severe maintenance and refurbishment backlog. Thus, the buildings show damages and deficiencies in their structure and fabric, technical installations and energy efficiency. It is obvious, that the implementation of complex refurbishment projects that aim to upgrade the current status of the buildings in these countries is an urgent task which should not be deferred any longer. The following module provides an overview of how to proceed in order to plan and organise such a refurbishment project successfully.

30. The need for complex refurbishment

A complex refurbishment project which tackles all structural building problems and leads to a higher energy efficiency needs to be very carefully planned. In the planning process, various steps are to be taken. The module explains the steps, tasks and instruments which have proved to be important and essential for the successful realisation of a complex refurbishment project. The first key step is to provide information and obtain the consent of all people affected by the refurbishment measures, especially when the building is owned by various single owners who have to reach agreement on the planned measures. Furthermore, in addition to the flat owners, there should be involvement from other actors involved in realising the project, i.e. institutions, contractors/subcontractors and authorities dealing professionally with building refurbishment and energy efficiency in buildings.

To enable a successful project realisation, several (planning) instruments are necessary and of course the project has to comply with the regulatory framework in the respective country or town. In addition, a financial concept needs to be developed that includes all immediately available as well as other funding possibilities that are offered, e.g. by support programmes. When it comes to a solid project implementation and construction supervision, various instruments and tools are available and have been proven successful in building refurbishment projects already completed. All of these topics are described in the following chapters, concluding with the final steps to be taken when completing the project, with special attention to the quality control and acceptance of the works.

31. Information and agreement on the refurbishment project

Energy efficient housing refurbishment projects are a long-term process which involve various components, stages, crafts and actors: therefore they require time and careful preparation. In this context, providing information that will allow homeowners to make an informed decision is the first crucial step.

Homeowner meetings

When the manager (board/administrator) of a building and/or the homeowners (association) consider that refurbishment measures are necessary, the board of the association must put this issue on the agenda of the homeowners' meeting. This first meeting should serve to present to the homeowners the obvious structural and thermal building deficiencies, and to explain and discuss possible refurbishment measures. In this context the advantage of combining the necessary maintenance and modernization measures can be explained, as well as the relationship of the energy efficiency potential to the modernization costs. At the early stage, it is also advisable to briefly point out why the implementation of single measures, which are not embedded in a comprehensive refurbishment concept, may impede the successful and most effective solution to energy efficiently upgrade the overall building and affect ultimate cost savings to tenants.

The aim of the above-described first owners' meeting should be to achieve general agreement on the necessity to refurbish the building. If this consent is achieved, several initial decisions must be taken: the board/administrator now functions as the project manager and in this position needs to be commissioned to collect further information and to involve an energy consultant as well as a construction expert. Furthermore, the foreseen budget for architects, engineers and energy consultant needs to be determined. It is also strongly recommended to establish an advisory board.

Advisory boards

The establishment of an advisory board in a homeowners' association is good practice. Especially within the framework of a large, detailed refurbishment project, it is advisable to have such an institution to accompany and support the activities and decisions of the building administrator acting as the sole project manager. An advisory board should consist of three flat owners, i.e. one chairman and two further homeowners as assessors. It is advantageous for the advisory board members to have different occupational backgrounds.

Following the first meeting and a general agreement of the homeowners, the project manager (whose concrete responsibilities are described in detail in this module) will begin to collect information, esp. with the responsible municipal offices re: legal and financial regulations and necessary application procedures. Furthermore, he should assign a qualified

Energy consultant

energy consultant to provide on-site advisory services on the energy efficiency status of the building and the possibilities to improve this status by implementing appropriate energy efficient refurbishment measures. Also, experts such as architects and engineers who will coordinate the project and are responsible for the technical implementation should be selected at this stage. This selection procedure is to be implemented in close cooperation with the advisory board (if in existence).

When all necessary information is available the project manager develops a first concept on the planned refurbishment measures which also includes the listing of the different financial support instruments, if available. This information must then be presented to the homeowners.

During a second homeowners' meeting the selected energy consultant as well as an engineer should take part, to discuss open questions with the homeowners and to explain planned measures. Based on this, further decisions need to be taken: the project manager should be authorised to involve expert planners, i.e. a project supervisor to develop a detailed refurbishment concept which includes a detailed cost-benefit calculation. These should be engineers or architects who are fully qualified to develop, coordinate and steer a complex refurbishment project.

After the second meeting, the building administrator together with the involved experts will begin to develop the refurbishment concept, calculate the costs and determine possible energy savings. Further, the project manager will evaluate offers from building contractors. It is good practise to involve the advisory board at this point. Subsequently, it is possible for the project supervisor to further specify and determine the concrete refurbishment measures as well as the time schedule/work plan. The financing concepts should be developed at this stage: on the basis of accrued reserves, support programmes and credit options, the project manager (building administrator) needs to generate one or two financing concepts. When all concepts are finalised, the project manager formulates the proposed resolutions for the next homeowners' meeting.

A third homeowners' meeting is mainly necessary to present the developed concepts to the flat owners. This meeting shall include the energy consultant as well as the architect or engineer, in order to answer all the flat owners' questions directly and quickly. When questions have been answered, decisions about the refurbishment project are to be taken. The following resolutions need to be taken:

Necessary agreements

- agreement on refurbishment measures;
- fixing of a time schedule;
- agreement on the budget;
- determination of project funding;
- authorisation of the building administration to conclude contracts with the executing companies.

It is advisable to approve each resolution separately, but also as a whole, so they may operate independently if necessary. This has the advantage that if one resolution is rejected, the whole refurbishment project will not be endangered. In general, the decision to start the housing refurbishment is taken by the homeowners in a voting procedure and the related adoption of a resolution. The legal principles of such voting procedures differ from country to country.

After the resolutions have been taken the refurbishment project can start.

32. Energy related building survey (energy audit) and energy performance certificate (EPC)

32.1 Energy audits

The completion of an energy audit should be the first step in the development of a refurbishment concept. This survey is primarily an analysis of the energy-related current state of the building, which is based on the evaluation of existing plans and papers documenting the energy consumption of the building as well as on a general description of the building's thermal and structural performance (state of the building technology, heating system, quality of the building envelope, etc.). It is to be developed by a (certified) energy consultant or auditor, a qualification that exists in most countries including most non-EU countries in Europe. The energy consultant has the task to evaluate the current energetic state of the building. Based on this, measures to improve the energy efficiency state of the building will be described and calculations about what is practically feasible and energetically as well as financially reasonable should be presented.

Certified energy auditors

An energy-related building survey is necessary for the following reasons:

First of all, measures which help to save energy in a residential building are manifold, starting from the insulation to a new heating system, new windows, up to the use of renewable energies. The energy consultant and the building survey will provide insight into the building deficiencies and will make clear what measures are possible, necessary, and how to coordinate and align them. Also, if only single measures are planned to be implemented, the energy consultant can help the homeowners to select the appropriate technical solutions and provide a holistic/integrated view on the impact of the measures on the thermal building physics, the expected (reduced) energy consumption and the economic efficiency.

ATTENTION! A building is a rather complex structural-physical arrangement and when single measures are implemented they have an effect on the whole building. This also means that when implementing measures in one building field, damages may occur in other places. For example, when exchanging the windows it is necessary to ensure that their thermal conductivity is properly aligned with the building envelope. Otherwise, problems with moisture and mould may occur.

Secondly, the main target of housing refurbishment is to reduce the heating cost. This will be reached much more efficiently with the support of an energy consultation as it provides a (neutral) analysis of the status quo of the building and the respective deduction of necessary measures, i.e. either single or comprehensive improvements.

Thirdly, energy consultancy is also important within the framework of a cost-benefit analysis. Most homeowner associations cannot pay all measures of a refurbishment project at once. Therefore it is worthwhile to examine the costs and benefits of the planned project during the energy-related building survey.

Building survey

Summarised, the main characteristics of an energy-related building survey (energy audit) follow:

- It is a feasibility study,
- it serves to identify energy use/waste in a building and strives to identify opportunities for energy saving;
- it reveals to flat owners, building administrators or housing associations/cooperatives the options available for reducing energy waste, the possible variants of alterations, the costs involved and the benefits achievable from implementing the refurbishment measures.

Types of energy consultancy

Types of energy consultancy - As regards the scope of energy consultancy, different levels are common in most countries. They are categorised as follows:

a) Basic check-up of the building as regards energy efficiency (rather inexpensive or even free of charge in some countries);

b) Initial on-site consultancy to provide an initial orientation on measures for the improvement of energy efficiency in the building;

c.)Comprehensive energy consultancy on-site.

As a basis for a complex refurbishment project a comprehensive and detailed energy consultancy is recommended.

32.2 Energy Performance Certificates (EPCs)

Energy performance certificates (EPCs) provide information on the energy performance of a building and also recommendation for cost improvements. These instruments are in existence in EU countries but also in other European countries such as Russia, Belarus and Ukraine. The objectives of an EPC can be formulated as follows:

a) to increase the rate and scope of building refurbishment by illustrating the status quo regarding energy efficiency to building owners and tenants and by proposing options for thermal renovation;

b) to raise the capitalisation of energy efficient investments by the provision of reliable information on the energy performance of buildings to potential buyers/tenants.

An EPC shows the energy efficiency rating of a dwelling or building. In the EU, the rating is shown on an A-G rating scale similar to those used for refrigerators or other electrical appliances. This scheme has been proved very useful.

Calculation methods of EPCs

There are several ways to issue EPCs, but in general two calculation methods can be differentiated:

a. A "consumption certificate", which identifies the energy performance of the building based on the past energy consumption of the residents.

b. A "demand certificate", which determines the energy performance using a calculation of the energy efficiency of a building based upon various building characteristics.

Consumption certificate

The "consumption certificate" provides information on the energy, i.e. heating and hot water which have been consumed in a building. Both are indicated in kWh/(m^2*year). Normally, for this, the heat cost billings from the past three years are needed. The "consumption certificate" is much cheaper but also less comprehensive and conclusive as it is based on the individual heating use of one household. Therefore, only limited conclusions can be drawn as regards the future energy consumption of the building.

Demand certificate

The "demand certificate" calculates the energy demand of a building on the basis of its size, structure and building materials as well as the heating and hot water installations (according to standard conditions). The method of calculation is rather complex and in order to answer all questions regarding the building, an energy consultant implements a systematic and thorough examination of the building. The recorded data are independent from the residents' heating behaviour and enable an objective comparison with other buildings. The deficiencies as regards energy efficiency and the derived recommendations for modernisation directly refer to the condition of the respective building.

It is recommended to implement and issue "demand certificates" in all countries as the "consumption certificate" does not reflect the real energy demand of a building or flat, but is determined only by how much energy has been used by the residents in the past year(s).

Who issues Energy Performance Certificates?

In those European countries were EPCs are issued, the qualification and eligibility of persons entitled to do so is mostly regulated by law. In Russia, certified energy auditors conduct energy performance audits for all public entities and commercial entities. The certification of the auditors is the responsibility of professional associations. In Belarus, energy audits and certifications are conducted by organisations that have a special certification by the "National System of Conformity Confirmation" which have expert auditors on their staff.

Layout / design of Energy performance certificates in Europe

There are different formats and rules for advice on energy efficiency improvements in all countries that offer energy auditing and certification. Accordingly, the EPCs look slightly different among EU and non-EU member states:

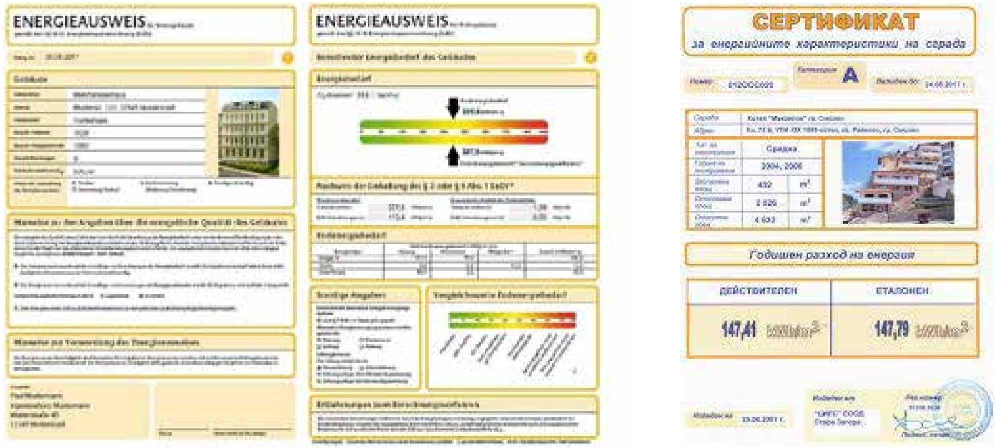

Figure 32-1: Energy passports (Germany and Bulgaria)

33. Actors involved in the refurbishment process

After the energy-related building survey has been completed, the actual planning and implementation of renovation measures starts. Depending on the size of the project, various experts are necessary. To guarantee successful project implementation, it is recommended that the following actors be involved in the construction process:

Project manager

The Project manager/lead represents the owner(s) of the building. He has managerial responsibility and in this context also is the financial manager, who has the mandate for decisions and instructions. These mandates may not be delegated to third parties. The tasks of a project manager include defining the project aim, organizing financing and refinancing of all measures, consulting building residents, assigning and controlling of all planning and construction works as well as the final accounting of the project. The project manager for a refurbishment project in a homeowner(s) association should be a member of the building administration and should enjoy the confidence of the homeowners.

It is ideal if the project manager is a building engineer, in which case he can also serve as the project supervisor. But in most cases, he is not an engineer and will therefore need the support of a project supervisor.

Project supervisor

The Project supervisor provides advice and support to the project managers and the homeowner(s). He is responsible for the costs, the meeting of deadlines and the quality of workmanship. The project supervisor fulfils operational tasks, some of which he can delegate to third parties. He has no authority to decide, to give directives or enforce actions. His task is the steering of all planning and construction works [5].

Architects

The first task of the involved architect(s) is to discuss the possibilities for renovation, step by step, with the owner(s)/administrators of the building and based on this to develop a comprehensive concept. The architects design the project implementation from outline to detailed planning, and compile, if necessary, the planning documents for the building application to the building authorities. Furthermore, architects calculate the costs for the planned application for credit with a financing institution. Architects also administer the design aspect of the building refurbishment, as the improvement comprises aesthetics as well as energy efficiency

Expert planners & specialist engineers

Expert planners and specialist engineers examine the building construction and assess the building technology. There are different types of specialist engineers to be involved in energy efficient building refurbishment, e.g. structural engineers, physicists, surveyors, building services engineers.

The actual implementation of works needs to be done by specialized craftsmen within the companies contracted. The relevant crafts in construction and building refurbishment include preliminary building works as well as finishing crafts, as e.g. windows, façade, sanitation, heating and plumbing, electricity, etc. The selection of the implementing companies should be made carefully; reliable references are essential.

Craftsmen

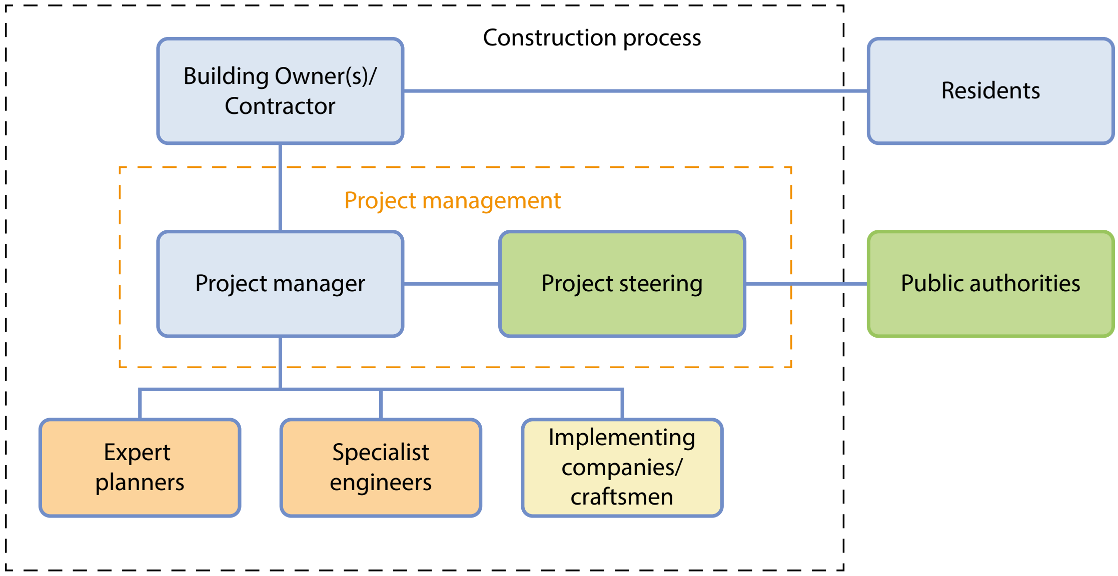

Figure 33-1: Actors in the refurbishment process

Public authorities

Public authorities will also be involved in a building refurbishment project, as provisions regulated by public law need to be observed. Depending on the size and type, a building permit may be required. For complex refurbishment projects a building permit is obligatory in most countries and can be applied for at the local building authority. If the building is a historical monument, the historic monuments protection authority must be contacted in an early phase.

Residents

The residents, especially when they are owners of their flats, need to be involved in activities to prepare the energy efficient refurbishment project at a very early stage. As described earlier, the information and decision-making by the homeowners is the first step in the planning of a refurbishment project. In this first phase, the homeowners will have to be informed on the building deficiencies and about the potentials and benefits of a complex refurbishment approach. Costs and financial instruments are to be discussed and respective decisions made. Constant information and communication with the residents is important before, during and after completion of the project. This may be executed via increased opening hours for consultations in the housing administration, regular homeowners' meetings with project steering, architects and engineers, information material, etc.

34. Complex and sustainable refurbishment concept

A complex refurbishment concept is a document and instrument that depicts both the necessary and possible additional measures to be implemented in the project. It provides a first cost estimate for the whole building and for each flat as well as information on the energy savings that can be achieved by the different measures to be implemented. Therefore, the refurbishment concept is based on the energy-related building survey. It needs to be "tailor made" and starts with the examination of the current state of the building. A necessary structural survey will attempt to identify all possible structural-physical problems or damages such as moisture, problems with mould, rust damages, cracks, etc. At the same time, the following aspects of the building physics should be covered in the survey:

Energy survey and building physics

- Thermal insulation: roof abutment/jamb wall, façade, connections windows and doors, staircases, basement ceiling;
- Noise prevention: windows, façade, intermediate floors;
- Moisture proofing: rainwater drainage of the roof and balconies, moisture in the cellar and flats;
- Fire prevention: fire zoning, firewalls, fire-protection doors.

In the survey, the residents will be involved in order to collect information on the possible problems they have experienced while inhabiting the building as well as on their needs, e.g. during the upcoming refurbishment phase. The results of the survey are to be recorded and monitored.

Based on this survey (and the energy-related building survey), the design (concept planning) for the refurbishment project is to be developed. Necessary measures and "additional" measures always need to be distinguished. Generally, in a complex refurbishment project of a multi-tenant building the necessary measures should include the following:

Necessary refurbishment measures

Measures reducing the heat conductivity

- Thermal insulation - roof
- Thermal insulation - façade
- Refurbishment of balconies
- Exchange of the windows
- Insulation of basement ceiling

Measures to renew and improve the technical installations

- Exchange heating system(s)
- Sanitary engineering
- Ventilation
- Exchange or modernization of the elevators

The additional measures may include the following works/crafts to modernize the building

Optional refurbishment measures

- Electrical installation
- New doors
- Tiling works
- Staircase(s)
- Painting works
- Floor covering
- Letterboxes
- Outdoor installations

Based on the above-listed necessary and additional measures as well as on the different levels of energy efficiency measures, different refurbishment variants should be considered and illustrated in detail: a basic variant = measures according to the setting of tasks, i.e. measures preserving the building structure and improving the dwelling value, as well as the maximized variant(s) including measures in addition to the basic variant.

The presentation of the refurbishment variants must be accompanied by a detailed calculation of the construction costs. This calculation also should include the possible energy saving potentials and the related reduction of costs for energy to be achieved via the refurbishment measures.

The refurbishment concept concludes with a summarized description of the chosen measures and the sequence of implementation. This information is presented to the flat owners at a homeowners' meeting, at which time they will decide on the measures to be implemented, the time schedule, budget and funding.

35. Regulatory and financial framework

35.1 Regulatory framework

A complex refurbishment project – as with the construction of a new building - needs to fulfil certain standards and regulations. In this context, various permits need to be prepared or applied for by the project management. The preparation of permit applications is an important step in the planning and development of a refurbishment project.

Permits

It is the task of the project supervisor and the involved specialist engineers or architects to develop templates and documents for the necessary permits according to the respective regulations under public law in the fields of design, structural engineering, thermal insulation and noise protection. The type of planning and building permission necessary depends on the measures to be implemented. E.g., if the exterior design of the building is changed significantly or annexes to the existing building are to be constructed, a permit may be required. To find out what specific permits are necessary, the project management must contact the local building authority. Note that regulations regarding building permissions not only differ from country to country but often, regionally or locally as well.

After the documents for the necessary permits and applications for exceptions have been submitted, it is quite common that negotiations with the building authorities must be conducted. When these negotiations have been concluded successfully and the necessary permits are issued by the authorities, the planning documents of the refurbishment project can be adapted and completed by the project supervisor.

35.2 Financial framework

The financing of a complex refurbishment project is a major challenge, often creating an obstacle for the homeowners' association. Therefore, at the outset, information on the (building and) currently available financial means of the homeowners' association must be collected by the project manager. The potential to reduce current costs via energy efficiency measures should be presented and explained to the homeowners with support of the project supervisor and the involved expert planners. Afterwards, a solid and detailed financing concept that clearly depicts the costs of the refurbishment measures and the available financial sources must be developed.

It is good practice that, following the initial building survey and the completion of a preliminary design concept, the first estimate of cost is developed by the project supervisor. At the same time the project manager

Financing concept

needs to elaborate on the financial possibilities of the flat owners. Based on these first financial estimations the preliminary calculation of overall refurbishment costs is to be presented to the homeowners' association together with an initial presentation, discussion and calculation of the available funds. Both should happen during the second homeowners meeting, as during this meeting the building deficiencies and the possible variations of refurbishment measures will be on the agenda. What needs to be taken into account and clearly depicted when calculating and presenting the costs for the refurbishment project per homeowner is the relation between the refurbishment costs and the costs that are currently a burden for the homeowners' association: i.e. the (rising) costs for energy, the regularly occurring maintenance costs and the monthly operating costs; the latter can be reduced after an energy efficient refurbishment. After this meeting the calculation of costs may be adapted and revised and turned into a final calculation for the cost of refurbishment measures that were decided on.

The aim of a refurbishment project and therefore also of the utilization of the available budget should be a maximum result achieved by highly cost-effective measures. Partial refurbishments may be the only option if the available financial means are very small. But in general, it is advisable that more complex refurbishment approaches are pursued, as a technically higher and more energy efficient level of refurbishment will be achieved. On first consideration, comprehensive refurbishment projects may discourage owners due to their high investment cost, but in the long-term, they also entail greater higher cost-efficiency. For example,

Comprehensive refurbishment projects

- measures can complement each other, leading to a higher degree of efficiency,
- construction works, including the planning procedure and provision of infrastructure (e.g. scaffolding) only need to be implemented and financed once,
- a complex approach increases the value of the building and the flats to a much higher level; as a result, the market value/potential selling price will be higher compared to a building where only partial measures have been implemented.

Usually, the homeowners' association is not able to finance a technically and economically reasonable complex refurbishment project from reserves and its own resources. Therefore, the financing concept needs to include external sources, for example, bank loans or regional support programmes. Refurbishment financing concepts have multiple stakeholders to satisfy and various market challenges to navigate. In many countries obstacles such as high (energy) subsidies, uncertainty over savings, low-income level of homeowners, etc. characterise the situation. In addition, there are various financial barriers such as the initial cost, difficulties in accessing regional or national support programmes, high transaction costs or lack of creditworthiness. Independent of the specific problems within a country, the following elements have prov-

External funding sources

en to be successful in a financing concept and therefore can be recommended to the project manager to be taken into consideration:

- include the personal, available financial funds of the homeowners in the funding concept of the refurbishment project;
- find out what national and/or local support programs are in existence – first contact point may be the municipality;
- collect and analyse information on the availability of favourable credits for energy efficient refurbishment at local banks and integrate that into the financing concept.

36. Detailed planning and work schedule

36.1 Time scheduling

A crucial task of the project supervisor is the planning, calculation and scheduling of the execution of various components of the refurbishment project. First of all, a start and finish date for the overall project should be defined. That should include determining the earliest and latest start and finish dates - this constitutes the basis for the overall project progress. All planned construction works should be indicated simultaneously in a clear chronological relation to each other. The time scheduling can be depicted in three different forms:

Illustrating time schedules

- as a deadline list, with a written depiction of activities and time frame,
- as a bar time table, where the activities are depicted in a bar chart on a time line,
- as a network diagram, where the activities are illustrated as connected knots or arrows and thus chronological as well as content-related connections of the construction activities can be easily pointed out.

The most popular display format of time scheduling in construction projects is the bar time table.

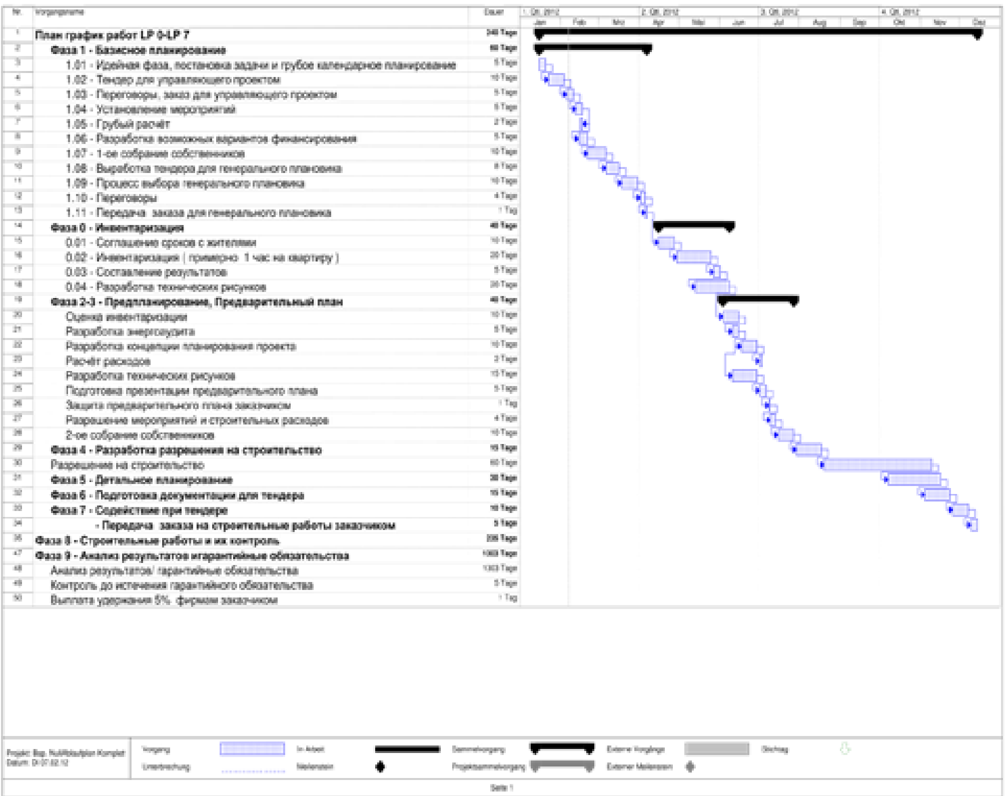

Figure 36-1: Bar time table of a refurbishment process

Generally, it can be stated that in a complex refurbishment project the planning and implementation phase (incl. control) of a complex refurbishment project each require around 240 days.

Different levels of schedules

In large building projects there are up to 1000 building components. They must be coordinated and, as not all of them can be depicted in one plan without being unclear and confusing, it is good practice to subdivide time schedules into different levels. Normally these are the following three:

Level 1 - Overall realisation plan

The overall realisation plan refers to the overall project and comprises all project phases, i.e. from preparation to implementation and utilization. It should be developed during the project preparation phase and provides frame dates for the main planning and implementation phases of the project.

Level 2 - Framework time schedules

Framework time schedules refer to the individual structure works and construction stages. Normally, they are separately set up for the planning and implementation phase. Along with the operation charts or plans of procedure, the schedule will show the estimated contract dates of all object and sectoral planning services. It will be used to determine the deduction of arrears notes. The dates for the tender phase are deducted from the operation charts or plans of procedure.

Level 3 - Detailed time schedules

Detailed time schedules refer to the individual structure works or construction stages and also to the individual phases of planning or implementation. They include intermediate deadlines for the single outputs of all parties involved in the project and serve as the basis for the organizational coordination, constant control and steering of the project.

36.2 Progress control

Time management

After the development of framework time schedules (level 2), the methods for following the timescale targets by the homeowners (association) and the project manager within the framework of the project steering need to be stipulated by contract. In this context, several important items regarding time management must be determined at the beginning of the project. These include:

- control and update of the framework time schedules,
- development of plans of procedures and steering plans for the planning and construction phase,
- constant control and update of the time schedules in the planning phase with the goal of process optimization,

- constant control and update of the time schedules in the implementation phase.

It is important that fixed dates are determined and controlled for each individual component, in order to actively steer and adjust them in every project phase.

The project supervisor must regularly monitor and present the actual status of the project and all construction works. By this, and via comparison with the planned target state of the construction works, deviations can be identified and estimations about consequences can be made in order to achieve appropriate and early corrections.

36.3 Conjunction of time and cost planning

Correlating time and cost planning of a refurbishment project allows management of the outflow of funds, i.e. it indicates the time and amount that specific financing is required. In other words, financing schemes in refurbishment and construction projects are not independent planning instruments; instead they are derived automatically from the time and cost planning of a project.

37. Technical specification, tender, offers, building contract

37.1 Preparation of the building contracts

When all refurbishment measures are defined within the framework of the detailed planning and the building materials have been agreed on, the offers from construction companies can be requested. The basis for this is the development of the technical specification. The technical specification must be highly detailed in order to receive comprehensive offers which can be compared easily.

37.2 Technical specification

The technical specification is the main part of the tender documents. Within the technical specification all decisions as regards type and quality of chosen material as well as execution of works are quantified and described. The building companies also receive relevant information about the planned time of execution and also about the construction site, e.g. if and where water, electricity, storage areas and scaffolding are available. This information helps the companies to calculate their costs.

Service specifications

The technical specification is based on the service specifications, which are to be structured into clearly arranged sections according to work components or crafts. The service specifications for the refurbishment of a residential building could cover the following fields/crafts:

1. renewal of windows,
2. scaffolding and renewal of concrete, including balconies,
3. insulation (exterior walls, basement ceiling and jamp wall),
4. roof covering,
5. heating, sanitation, ventilation,
6. works within the stairwells (painting and floor covering) incl. electricity,
7. tiles
8. new entrance doors.

Breakdown of specifications

Each of the service specifications provides a description of the specific tasks. An illustration of a service specification using "renewal of windows" as an example would cover the following issues:

1.1 Description of the construction site:

- accommodation for craftsmen
- costs for electricity, water and waste management

- protective foil for the building
- etc.

1.2 Description of the services/works:

- appointments with residents,
- complete dismantling and installation of the windows of all flats incl. plaster and painting,
- etc.

1.3 Description of the materials and works:

- 1 PVC window 1,0 m x 1,5 m, dismantling and disposal,
- 1 wooden window 1,5 m x 2,5 m, dismantling and disposal,
- 1 PVC window 1,0 m x 1,5 m, U-value=1,3, double glazing, delivery and installation,
- 1 PVC window, balcony element, U-value=1,3, 2,7 m x 2,5 m, dismantling and installation, incl. all back-works, as described above.

The technical specification is especially useful when large and complex refurbishment projects are implemented, as the construction companies may calculate with much more accuracy and, therefore, offer more favourable prices. For the project manager and the supervisor, the technical specification provides the security that only works that have been requested are offered. This allows exact comparison of the received offers.

37.3 Tender and award of contract

The technical specification in the tender documents can be developed based on standardized texts or freely phrased. In addition, further documents will be added to the proposals, e.g. general or specific conditions of the contract. This may differ according to the building legislation in each country. When all documents are prepared, the tender can be implemented by the project supervisor and the project manager.

Forms of tender

Generally, there are three forms of tender:

- public invitation to tender
- restricted call for tenders
- discretionary award of contract

These three forms of tender and awarding of contract are executed depending on the type and size of the construction. Homeowners' associations and private companies may refer to all three of these forms of tender but usually the restricted call for tenders is chosen. In this case the procedure is as follows:

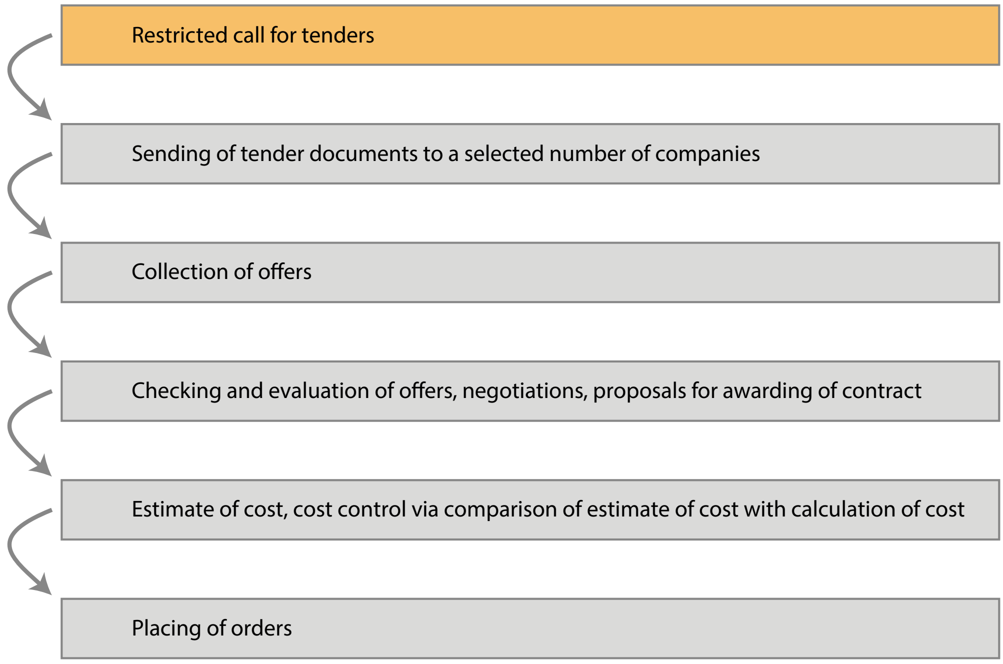

Figure 37-1: Tender procedure

37.4 Examination of offers

When the project supervisor examines the offers received, it is worthwhile to give close attention to the following points:

a. Make sure that the offers are complete. Some companies do not offer the full service required.

b. Most project supervisors offer a price comparison list which includes all items, including products and brands.

c. The tender sum should stay within the framework of the predetermined cost calculations.

d. The most favourable offer is not always the best and may lead to unanticipated costs. Therefore, companies which are not well known should be asked to present some references.

e. Before deciding in favour of a company, the following should be checked in the reference: how did the company perform its works, did it comply with deadlines and were there complaints afterwards. If so, were problems sufficiently resolved and in a timely manner?

Tender documentation

It is good practise with most construction projects to have a tender documentation and sometimes even a tender report. The tender documentation includes all documents and information in the tender, e.g. letter of invitation, form of contract, pricing documents, plans, design drawings, etc. Furthermore, a tender report is a useful instrument to ensure transparency and compliance in the selection process of contractors. The tender report is comprised of a description of the tendering process and an evaluation of each tender submission and the related negotiations. The tender report covers e.g. the following issues:

Tender report

- Background of the tender notice
- Evaluation of offers
- Scope of the contract
- Tender evaluation criteria (technical and financial)
- Reasons for rejection of unsuccessful tenders
- Reasons for the selection
- Conclusion

As the tender report is a good tool to ensure higher transparency in the selection process, it is recommended for use in countries that are struggling with the issue of corruption.

37.5 Conclusion of building contract

After the formal, calculative and technical examination of the offers and the assessment of tender responses by the project supervisor, a suggestion for the award of the contract should be handed over to the project manager, i.e. the homeowners' association. Based on the confirmation of cost recovery the project management may take the final decision(s) and the building contracts can be concluded.

Site supervision, quality control and acceptance of work

After all contracts with all building contractors/subcontractors have been concluded, the project is initiated. It is important that the implementation of all works is coordinated and controlled, i.e. a site supervision process should be incorporated into the process. Site supervision is mostly executed by the involved architect or specialist planner. The primary purpose of site supervision is to ensure that all regulations under public law are observed. Furthermore, monitoring the performance of the involved companies is a key task: all works must be inspected to be sure that they are implemented free from defects according to the description in the execution planning and the technical specification. The site supervision/supervisor also must coordinate the sequence of work of the subcontractors to ensure adherence to recognized standards of good practice in the execution of their works.

Site supervision

Experience has shown, that site supervision is essential to ensure the successful implementation of a construction or refurbishment project, not only regarding all technical aspects of the project but also playing a key role in maintaining cooperation and teamwork of the involved actors. A successful realisation of a construction or refurbishment project depends on the coordinated performance of every contractor and employee – this can be steered by site supervision.

The person to control the trouble-free course of works for the project manager is the so called building site manager, usually employed by the company steering the refurbishment project, i.e. the project supervisor. In general, a building site manager has the task to make regular inspections to ensure that the execution of all works is free of defects.

Time schedule as quality control instrument

The basic instrument for quality control throughout the project is the time schedule (see chapter 7) which defines which subcontractor is required to perform which service at what time. For each component, delivery time of materials, assembly time and if necessary, times for drying are determined. The time schedule needs to be constantly checked and, in case of time displacement, adapted. Within steering meetings critical procedures and time lags will be discussed between project supervisor, building site manager and other involved parties; the steering team will discuss, devise and implement measures to keep the project on schedule.

Construction workflow report

Within the framework of site supervision, experience has shown that maintaining a construction workflow report is a key management tool with particular importance. Unfortunately, it is often underestimated. For the building site manager, it serves as a memory aid, confirming which companies have been on-site during site supervision, what kind of extraordinary incidents occurred and what arrangements, if any, were made. The construction workflow report should be complemented by photographic documentation to record progress of construction works, delays, execution quality and other relevant aspects.

Quality control is the responsibility of the site supervisor and the building site manager. It is important, for example, that components of the construction which will be covered over are inspected immediately upon completion, and where necessary, improved or repaired. For example, insulation panels must be installed without gaps. Such gaps or un-insulated spots which are difficult to access later often turn out to be problematic and critical points in the building envelope.

Blower door test

The quality control to be implemented during the finalization phase of the refurbishment project relies on two main methods and instruments: first, the so-called "Blower door testing" method serves to identify weak points regarding energy efficiency, more specifically airtightness. With a blower door, the airflow can be measured and leaks as well as the resulting heat loss can be determined. Blower door testing is to be implemented after the finalization of all construction details but before the final acceptance of works.

Figure 37-2: Blower door test (Source: Wikipedia Commons)

Thermographic examination

In winter, i.e. during the first heating period following the refurbishment project, a thermographic examination, which would help to identify possible thermal bridges, may be scheduled. If a new heating system, solar or photovoltaic systems are installed, they should be tested shortly before the final acceptance of works by taking them into full operation for a short period.

Very important within the framework of the final acceptance of the refurbishment works is the issuing of the energy performance certificate. This document serves to prove the formal determination of the refurbishment results. In many countries, in the case of complex refurbishment projects, the issuing of an energy performance certificate is binding.

Pre-inspection

Before the final acceptances of works, so-called pre-inspections need to be implemented by the building site manager and the homeowners' association/project manager to identify and correct any defects in the construction. If necessary, a deadline for the elimination of defects should be determined, with a date sufficiently fixed before the date of the final acceptance.

Final acceptance

The final acceptance of all works should follow a joint survey of the works performed. Besides the building administrator, the building site manager as well as selected building companies and their craftsmen should take part. The results of the survey and possible defects need to be recorded in the acceptance protocol. The final acceptance of works has the following implications:

- The construction companies and/or the involved engineering companies can now present a claim for payment.
- The defects liability period starts.
- Reversal of the burden of proof i.e. now the contracting body = homeowners' association takes over the burden of proof in case of defects.

38. Conclusion

In the above chapters, the complexity of a building refurbishment project has been described, addressing the importance of a structured planning process, the impact of all actors involved as well as their various challenging tasks and responsibilities. From the beginning and throughout the process, it is essential to provide information, transparency, cooperation and a clear timetable. But the fundamental pre-condition is the definite will of the homeowners to undertake the upgrading of the building in order to eliminate structural deficiencies, to achieve an improvement of the living conditions and to save energy and money. Hereby, the residents and flat owners are the key actors and need to support the project in every stage. For the successful completion of the project, the inevitable stress and strains must be explained to the building residents in advance and in detail. Later on, they will need to be supported constantly, especially when construction in the flats create a (temporary) disturbance. At the same time the residents need to be reminded of the immense building improvements, gains in living quality and the increase of dwelling value from a very early stage till the finalisation of the project.

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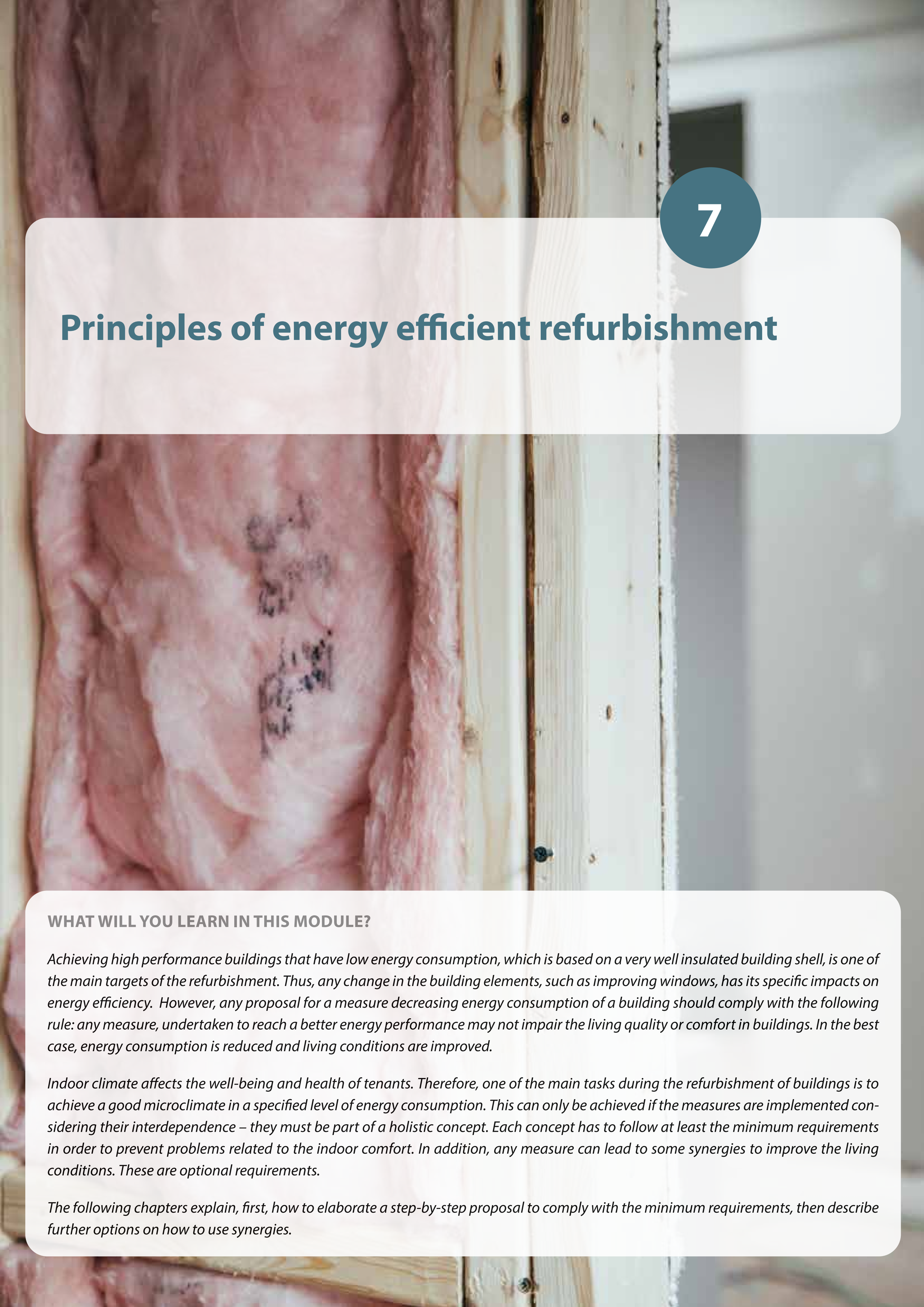


7

Principles of energy efficient refurbishment

WHAT WILL YOU LEARN IN THIS MODULE?

Achieving high performance buildings that have low energy consumption, which is based on a very well insulated building shell, is one of the main targets of the refurbishment. Thus, any change in the building elements, such as improving windows, has its specific impacts on energy efficiency. However, any proposal for a measure decreasing energy consumption of a building should comply with the following rule: any measure, undertaken to reach a better energy performance may not impair the living quality or comfort in buildings. In the best case, energy consumption is reduced and living conditions are improved.

Indoor climate affects the well-being and health of tenants. Therefore, one of the main tasks during the refurbishment of buildings is to achieve a good microclimate in a specified level of energy consumption. This can only be achieved if the measures are implemented considering their interdependence – they must be part of a holistic concept. Each concept has to follow at least the minimum requirements in order to prevent problems related to the indoor comfort. In addition, any measure can lead to some synergies to improve the living conditions. These are optional requirements.

The following chapters explain, first, how to elaborate a step-by-step proposal to comply with the minimum requirements, then describe further options on how to use synergies.

39. Structural design

39.1 Defining the heated volume

Heated volume

The information and data collection on the current building's state starts with the acquiring of information on the heated and unheated building areas. This has a high impact on the energy balance and influences the choice of the technical solutions. Since the heating demand of a building is correlated with the building volume, the space that needs to be heated (the heated volume) plays an important role in the energy balance. The heated volume is not always identical with the total volume of the building's living area. Different parts of the building could be heated unintendedly due to the fact that there is no insulation provided between heated living space and unheated space in the basement. During a refurbishment process the heated volume can be redefined. By reducing the heated volume the energy demand is reduced.

The heated volume is graphically marked on the construction drawings with a red line which delimits the heated spaces (Figure 39-1). In the same way the heated (ventilated or cooled) and not heated areas as well as the border of interior and exterior space are defined. In addition, the red line indicates where insulation material should be placed. The red line plays an important role when it comes to balconies, recessed balconies or staircases. The general guideline is that a more compact insulated volume is better. Therefore, the need to heat or not heat the staircases and basement rooms is always decided in an extended discussion.

Red line

As a basic rule, each interruption of the "red line" has negative consequences to the energy balance. Thus, each interruption of the insulation layer can cause thermal bridges which lead to energy losses or, in the worst case, to damages.

Descriptions of four examples of heated volume and placement of insulation follow.

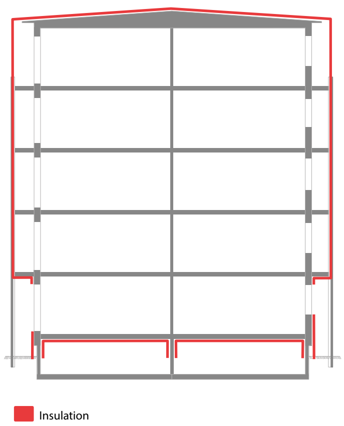


Figure 39-1: Graphical illustration of heated volume and indication for placement of an insulation layer. Balconies are excluded from the heated volume.

Example 1: In this example, the basement and the balconies are not included in the "theoretical" heated volume (Figure 39-1). Usually the space in the basement, which has a low quality for use, is not heated. Therefore, the basement was defined outside of the heated volume and the ceiling between the cellar and the first floor was taken as a separate building element. The theoretical line leads to the following insulation layers: insulation has to be fixed to the wall, under the ceiling of the basement and on top of the ceiling of the top storey or on the roof.

A crucial step in the preparation phase is the dismantling of the balconies to restore a plain façade, thus an uninterrupted insulation layer. After the insulation has been installed, new balconies can be mounted with minimized thermal bridges, for example, on their own new fundament.

Although the design of the insulation layer has just a few interruptions, there is still one crucial point at the connection of the floor and the wall. The interruption caused by the outer wall of the basement is still a thermal bridge. The effect can be minimized by insulating this wall as well. The most suitable solution for the roof depends on the condition of the building. If damages are identified in the roof structure, these have to be repaired before any insulation works are executed. When no damage is found, insulation can be applied directly onto the roof.

Example 2: The basement is not included in the "theoretical" heated volume (Figure 39-2). Balconies are kept as enclosed annexes to the corresponding rooms within the "red line". In this case it is assumed that the balconies are closed and heated and have the same internal temperature as the room to which they are directly connected.

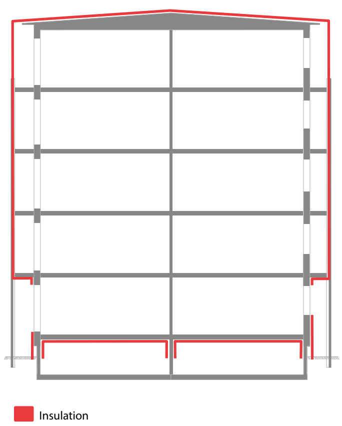


Figure 39-2: Graphical illustration of heated volume and indication of placement of the insulation layer. Balconies are included in the heated volume.

The insulation layer derived from this theoretical line encloses all balconies. A precondition is that the shape of balconies allows fixing a suitable insulation material properly. The corpus should have a plain surface. If these preconditions are given and no damages have been detected on the panels and the corpus, the insulation layer will be fixed at the corpus of the enclosed balcony and at these parts of the outer walls without balconies. The connection point between wall and balcony has to be planned carefully to avoid damages caused by different materials and surfaces. The treatment of the floor and roof is similar to the first example.

For the first two examples, the best solution is to include the staircase inside the heated volume, as in this way the heated volume is as compact as possible and the insulation layer can be placed without interruptions at the façade. For high rise buildings the situation is different as the staircase has an important function for the evacuation of the building.

Stair cases

Example 3: In high rise buildings there should be a lock between the storey and the evacuation tower (Figure 39-3). The stairs should be accessible from evacuation balconies. Inside the lock-area and the staircase, all materials and doors must be fireproof. The requirements for fire protection and energy saving are more or less contradictory. It is nearly impossible to find a solution without interruption of the insulation layer.

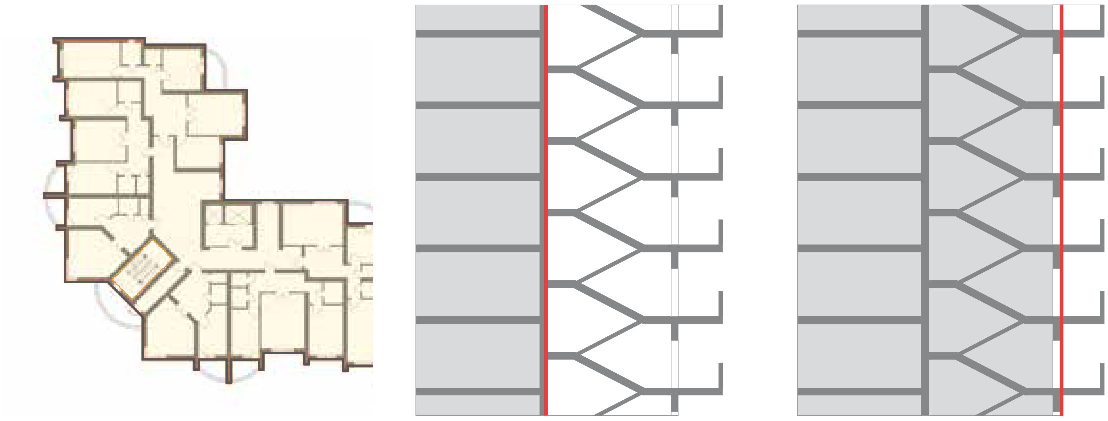


Figure 39-3: Graphical illustration of heated volume and indication where insulation layer ("red line") should be placed in an evacuation staircase. The sections show that it is nearly impossible to find a solution without interruption of the insulation layer.

Garbage shaft

Example 4: A special case of an interruption of the heated volume is the garbage shaft, as found in many panel houses of the 80s, intended to collect the waste as simply as possible. In some cases these shafts are located inside the heated volume, but they are conducting heat to non-heated areas, from the garbage room on the first floor to the shafts on the roof. The shafts operate like cold chimneys inside the heated zones. The best solution from the energy efficiency perspective would be to completely remove the shafts in order to achieve a really compact and non-interrupted heated volume.

39.2 Calculation of the energy balance

The saving potential of a building can be estimated by calculating the energy balance.

Heat energy demand in total and the fraction of losses through the individual building elements can be analysed and in this way, the weakest building elements can be identified. Moreover, the method can be used to simulate different theoretical refurbishment scenarios. In practice, this is done by using specialized software programs that allow exact parameterization of the building and its parts.

As a next step, the practical application of an energy balance is shown with an example of a five storey building in Odessa, built in 1967 and containing 96 flats. It is assumed that every room is heated up to the interior temperature of 20°C. In case of overheating in summer, a maximum interior temperature of 25°C was defined. The calculations for the baseline and for the different refurbishment scenarios were made using software package "PHPP 2007". The baseline calculation yields that the building has an annual heat demand of 230 kWh/m²a.

As a next step, four different refurbishment alternatives were selected:

- Alternative 1:5 cm insulation for the whole building envelope ,
- Alternative 2:20 cm insulation for the floor slab and the roof,
- Alternative 3:15 cm for the whole building envelope and exchange of all windows,
- Alternative 4:15 cm for the whole building envelope and exchange of all windows, installation of a ventilation system with heat recovery,

A new insulation material has been chosen with a thermal conductivity λ = 0,035 W/mK.

The calculation results of annual heat demand for the above mentioned refurbishment alternatives are graphically shown in Figure 39-4.

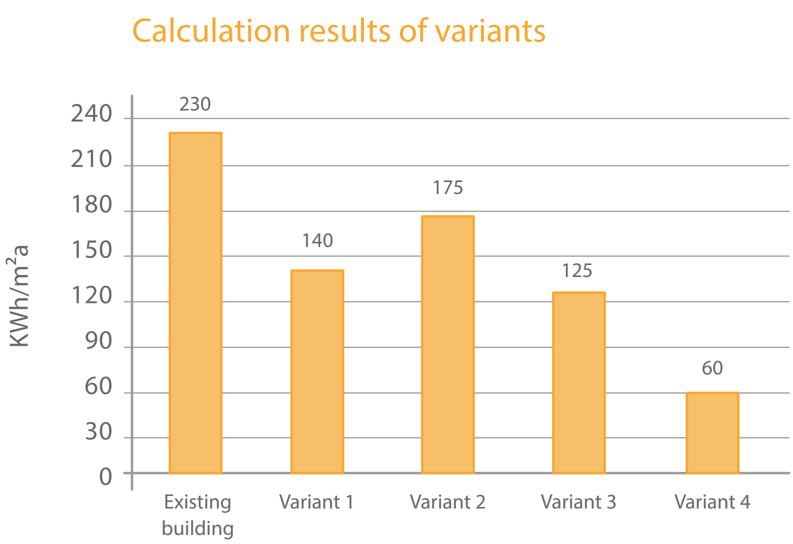


Figure 39-4: Annual heat demand (kWh/m²a) for refurbishment alternatives.

39.3 Planning of the insulation

Building survey

After the evaluation of the building envelope, the thermal characteristics and the share of heat losses through the different building elements need to be identified. The best measures to optimally minimize the heat losses are also identified in this initial step. A list of different alternatives can be calculated as shown in the Odessa example described in the previous chapter. All the above-mentioned procedures are included in the modelling phase, in theory, to help make decisions about the scope of the project. For modelling purposes it is only important to know about a specific thermal characteristic of an insulation layer. Neither the type of material nor its application to the building elements is specified at this stage. Technical specifications of the systems used to protect against sun, rain and temperature differences are not specified. And, in this phase there is no detailed planning elaborated to show the connection points between different elements, such as the connection between the wall and the window.

The next step is to choose the most suitable alternative. This leads to the main question: Which insulation system is best suited to for the project? In order to answer this question the following should be considered:

Selection of insulation materials

- Are the chosen materials allowed for use according to national legislation?
- Is this material available at reasonable prices?
- Are there skilled workers available who can fix the material?
- Is it possible to use the insulation system properly within a whole system of components, for example, gluing a panel to the façade with a suitable attachment and covering it for protection against sun and rain?
- What are the risks for health and environment?

Larger manufacturers of construction materials provide not only the insulation material itself, but the whole range of components, e.g. attachments and accessories for different connection points. The manufacturer has interest in selling the complete package and, at the same time, reliable providers are not interested in claims against their products. Therefore, they often provide comprehensive information on how to combine these components properly without causing damage. Often this information is available on the manufacturer's website or can be requested directly or through the local distributor.

The market usually offers a wide range of materials, thus the decision for selecting the optimal insulation system has to be considered carefully. The market is developing very rapidly. New product lines are improving the thermal characteristics, some lowering environmental risks. Therefore, recommendations for best solutions must be updated constantly; it is important to check for the most current recommendation. The following hints may help to get a basic understanding about the materials themselves and to find the most suitable solution for every new project.

As a general concept, insulation materials should be light-weight and should have minimal heat conductivity λ. Generally, materials enclosing cavities or caved air have good properties. The thermal conductivity is an important material property to be considered. Insulation materials have conductivity values significantly below 0,1 W/mK.

Properties of insulation materials

Heat conductivity

Typical heat conductivity values of common insulation materials are λ = 0,045 W/mK for natural materials, λ = 0,035 W/mK for mineral fibre and λ=0,030 W/mK for artificial foams. A vacuum isolation panel is a relatively new material and has values as low as λ = 0,005 W/mK. This means it is five to ten times better than conventional insulation materials.

U-value

The resulting thermal quality of a building element is characterized by its heat transfer coefficient U (U-value). The smaller the U-value, the better the insulation. In most European countries minimum requirements are defined for U-values of building elements. The U-values can be calculated from the material properties as follows (see the study guide 2 on building physics for details):

Formula 39-1

$$U = \frac{1}{R}; \qquad R = \frac{d}{\lambda}; \qquad U = \frac{1}{R_{si} + \sum_i \frac{d_i}{\lambda_i} + R_{se}}$$

To calculate the U-value the following components - thermal resistance (R), thickness (d) and thermal conductivity (λ) have to be known (Table 39-1).

	λ = 0,040 w/(mK)	λ = 0,035 w/(mK)	λ = 0,030 w/(mK)	λ = 0,020 w/(mK)	λ = 0,005 w/(mK)
d = 2 cm					U = 0,050 W/(m²K)
d = 10 cm	U = 0,400 W/(m²K)	U = 0,350 W/(m²K)	U = 0,300 W/(m²K)	U = 0,200 W/(m²K)	
d = 20 cm	U = 0,200 W/(m²K)	U = 0,175 W/(m²K)	U = 0,150 W/(m²K)	U = 0,100 W/(m²K)	
d = 30 cm	U = 0,133 W/(m²K)	U = 0,117 W/(m²K)	U = 0,100 W/(m²K)	U = 0,067 W/(m²K)	
d = 40 cm	U = 0,100 W/(m²K)	U = 0,088 W/(m²K)	U = 0,075 W/(m²K)	U = 0,050 W/(m²K)	

Table 39-1: Relations of thermal resistance, thickness and thermal conductivity.

Besides the thermal quality, several additional, important characteristics should be considered while comparing different insulation materials:

Is the material available in form of a board, panel, matting or loose fill insulation?

How will the specific insulation product be used in construction? E.g. as cavity wall insulation, between rafters or as interior insulation or external façade-boards. Not all materials can be used in every part of the construction. For example, some materials can be used for outer wall insulation; other types are required to insulate the outer walls of the basement.

Of great importance: How inflammable is the material? The national building codes classify materials and combinations of materials according to requirements for fire protection; these must be complied with.

How safe or harmful is the product for health? Some materials have disputed ingredients and not all have been proved to be harmless for residential use.

Primary energy content

One further criterion is the primary energy content. This figure indicates the energy used in the production chain, for example, for manufacturing or transporting. It is measured as kWh/m³. Cellulose flakes e.g. have comparably very low primary energy content of 50-80 kWh/m³. Expanded polystyrene foam boards have high primary energy content of 400-1050 kWh/m³ [1]. The energy balance of a refurbishment measure should be positive: the insulation system should save more energy over its lifetime than what is used in the production chain.

Some characteristics of exemplary materials are listed in the annex of this module, although the market for insulation materials is developing very fast. It is recommended to check the current situation on the market before undertaking a thermal insulation project.

Further insulation of different construction elements will be described.

Thermal insulation of the external walls

Insulation of the walls

Transmission losses through external walls account for the biggest share of losses in many buildings (about 20-30% in a multi-storey building). The following table roughly indicates the range of energy standards and the typical thickness of insulation applied on the outer walls (Table 39-2). Currently, typical refurbishment measures are using 12-15 cm of insulation.

≥ 100 kWh/m²	< 100 kWh/m²	low energy house	passive house	zero - energy building
≤ 10 cm	≤ 20 cm	≤ 30 cm	≤ 40 cm	> 40 cm

Table 39-2: Energy standards and the typical thickness of insulation applied on the outer walls.

The two most common ways to insulate exterior walls are described below.

ETICS

The most commonly used exterior insulation finishing system is ETICS. Such an insulated wall consists of the main layers: wall, insulation layer, plaster. The insulation layer is covered with a special cement-based render to provide weather resistance. A reinforcing steel or fiberglass mesh fabric is embedded in this render to provide strength and impact resistance.

Vemtilated curtain system

The second most used insulation method is the ventilated curtain system. The layers consist of wall, insulation layer, substructure, ventilation layer and outer shell. The insulation is protected against mechanical force and weather conditions by an outer shell of hard materials (wood, metal, ceramic materials).

The chapter on avoiding thermal bridges describes in detail how to handle problems and risks associated with both insulation methods. As previously mentioned, the market is developing rapidly. Problems described here have to be solved promptly or new risks can occur in future. An important criterion for analysing the economic weaknesses and strengths of a system is to know the expected average life-time expectancy of a building element.

Thermal insulation of the roof

Insulation of the roof

As a rough estimate, roof areas of detached buildings contribute approximately 20% to the total heat losses; in multi-storey buildings, the loss is about 10-15%. During the refurbishment process, roofs should also be insulated. Depending on the target for the energy consumption of the building, the thickness of the insulation layer needs to be selected. Table 39-3 shows the range of thicknesses for roof insulation (material with λ = 0,035 W/mK), depending on the energy consumption of the building after refurbishment.

≥ 100 kWh/m²	< 100 kWh/m²	low energy house (e.g. 40 kWh/m²)	passive house (≥15 kWh/m²)	zero - energy building (≥15 kWh/m²)
≤ 10 cm	≤ 15 cm	≤ 20 cm	≤ 40 cm	> 40 cm

Table 39-3: Range of thicknesses for roof insulation (material with λ = 0,035W/mK), depending on the energy consumption of the building after refurbishment.

The type of insulation technique depends on the roof construction. Many panel buildings have flat concrete roofs, which must allow for getting rid of rainwater and must also be waterproof. Therefore the typical flat roof consists of several important layers: the structural layer, the thermal insulation and the protection against humidity from rainwater (outside) as a waterproofing layer or from vapour condensation as vapour barrier (inside). All these layers have to be constructed or reconstructed as part of a refurbishment.

Thermal insulation of the basement

Insulation of the basement

Proper floor insulation plays an important role in preventing heat losses. According to rough estimations, the floor contributes to about 10% of the total heat losses in single detached houses and to 5-10% in a multi-storey building. A floor can be insulated without major effort. If the basement ceiling is high enough, insulation panels can be glued under the basement's ceiling. Outer walls of the basement can be insulated with special materials (Annex 1).

The thickness of the floor insulation (material with λ = 0,035W/mK) should be selected depending on the desired energy consumption of the building after the refurbishment.

≥ 100 kWh/m²	< 100 kWh/m²	low energy house	passive house	zero - energy building
≤ 4 cm	≤ 6 cm	≤ 8 cm	≤ 12 cm	> 12 cm

Table 39-4: Range of the floor insulation thicknesses (material with λ = 0,035W/mK) depending on the desired energy consumption of the building after refurbishment.

39.4 Energy efficient windows

U-value of windows

According to rough estimations, windows account for 15-25% of the total heat losses. Information about the glazing U-values, frame properties and spacers need to be compared carefully as there are many window options available on the market.

Single-glazed windows have an U-value of 5,8 W/m²K which causes huge heat losses. This is not much better than a single layer of paper, thus they are no longer used for residential buildings.

Double- or triple-glazed window panes have been on the market for many years. Each layer of glass will reduce the U-value by about 2,0 W/m²K, but even such a reduction is not enough for energy efficient buildings.

The wider the space between the panes, the better is the result (typical distances between the panes: 12 mm, 16 mm). Windows with airtight sealing between panes have better insulation properties.

Coatings

Additionally, windows can have a coated glazing which increases their insulation properties. Coatings help to minimize inside/outside heat transmission, preventing heat from entering the room in summer and from escaping in winter. A simple test with a lighter can show if the glass is coated: with glazing, the reflection on the glass will be dark and reddish (see illustration).

Figure 39-5: **The picture shows the reflection of the light, which is darker and more reddish: this means that the window is coated.**

Approved passive house windows have very good properties. Such windows can be sealed airtight, have a space between the panes, filled with noble gases (e.g. argon, krypton) and can have insulated frames and spacers. With highly efficient windows, the transmission heat losses can be lowered so that the difference between windows and well-insulated walls is minimized.

Regarding energy efficiency, a perfect window would minimize transmission heat losses and maximize solar heat gains. However, it is not possible to completely eliminate heat loss and maximize solar energy gains at the same time. Some layers or coatings that help contain heat within the room also partially block incoming sunlight. The solar factor or g-value, which describes the solar energy transmittance of glass, is a measure for this problem. The higher the g-value (dimensionless figure from 0 to 1), the more sunlight can pass through the glass.

The most important energy relevant characteristics are shown in Figure 39-6. On the left side you will find some typical g-values, with relevance for solar heat gains; on the right, some typical U-values for glass and frames. Depending on the window's geometry, the glazing area and the frame dimensions, the U-value for the window can be calculated. If the manufacturer offers only one U-value in their fact sheets, it's important to know which one it is.

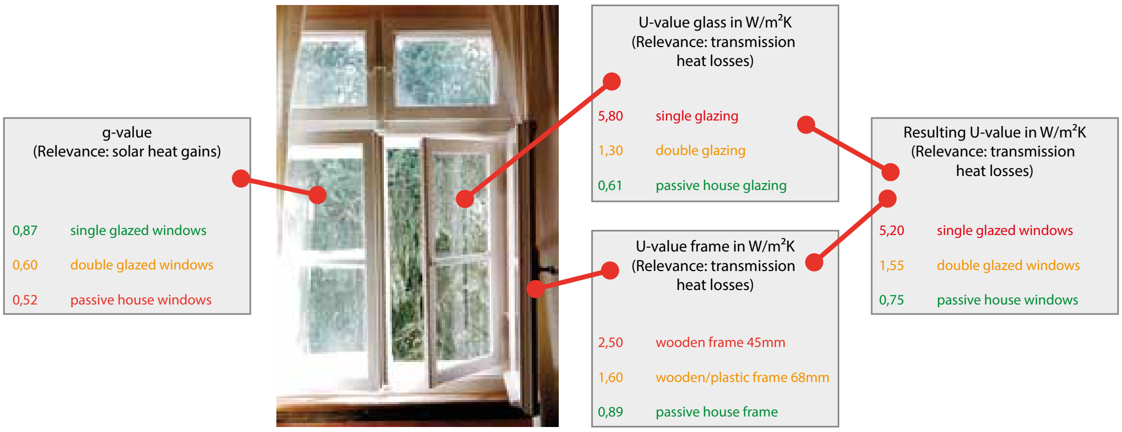


Figure 39-6: The most important energy-relevant characteristics of windows.

39.5 Avoiding thermal bridges as a minimum requirement

Insulation systems of all building elements have to be designed with minimized interruptions of the insulation layer to avoid thermal bridges which can lead to high humidity and energy losses.

Improving the energy performance of a building requires a careful and detailed planning. That means that the connections of building elements have to be checked for thermal bridges especially between wall/window, roof/wall, basement/wall and wall/balcony. This is usually done by architects or engineers.

In practice, insulation manufacturers offer many solutions for insulation. The big manufacturers provide not only the insulation material, but the whole package of components as well as accessories for different connection points.

Figure 39-7: Info material of manufacturers.

It is recommended to follow the advice on how to install the insulation and how to combine the additional components. Big manufacturers are, of course, interested in selling the whole package of components, but they are also interested in assuring that these components are combined properly without damages so that there are no customer claims against the products. Therefore, if instructions are not provided with the materials, it is worthwhile to search for information and fact sheets. (Many are available on line.)

The next sections describe two examples of detailed planning.

Connection wall-window

Connection wall – window

The illustration below shows principles of window installations (Figure 39-8). The left column describes the situation in existing buildings, without any insulation; on the right you will find various solutions for installing insulation. In some building series, the windows are installed like those shown in the first three examples. In this case, insulation can be installed as shown next to each example. If the window is installed as in example 4, there are two options to avoid the thermal bridge:

- by installing a thin piece of insulation (Example 4)
- by changing the position of the window (Examples 2 and 3)

Types of window-installation:

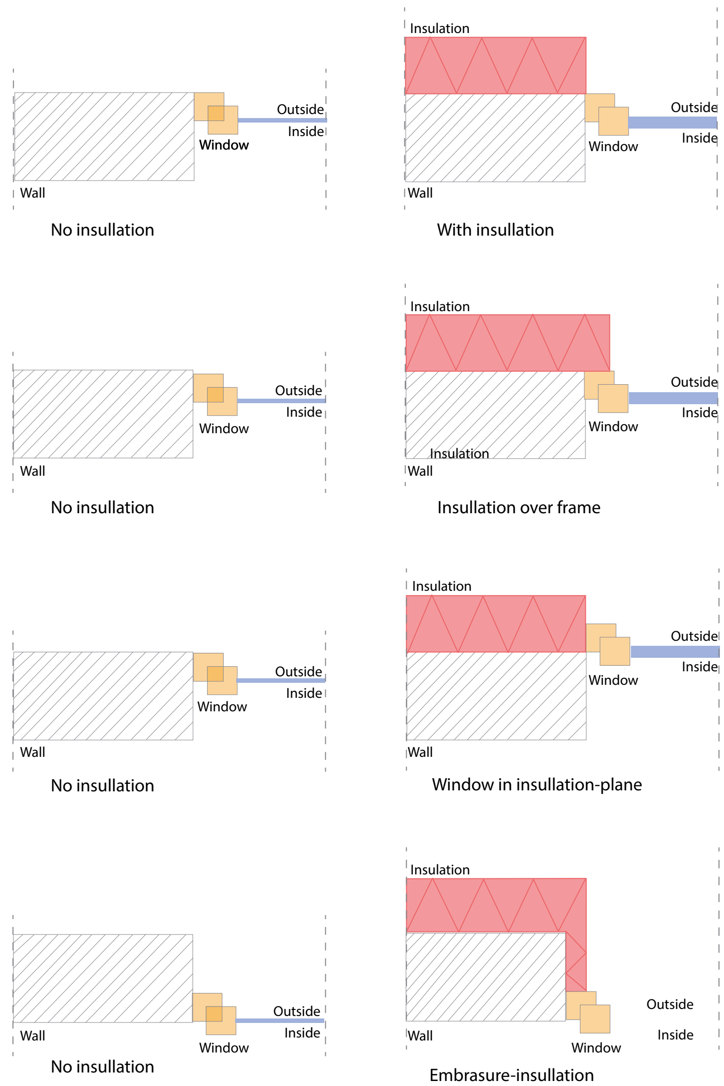


Figure 39-8: Types of window installation.

Figure 39-9: The yellow ellipse shows a potential thermal bridge. Further insulation is required to eliminate it.

Connection wall – balcony

Connection wall-balcony

The next diagram illustrates a typical situation: the balcony plate is connected to the building (Figure 39-10). On the left, a construction without a thermal interruption or a barrier between the warm ceiling slab and the cold balcony slab. That means that the heat can be easily conducted from the warmer building elements to the balcony slab and then to the outside. Even if the wall is insulated, this connecting point creates a thermal bridge. This thermal bridge can lead to colder spots in the connecting points on the inside. If the balcony remains in place, there is no way to correct the problem. Therefore, during the renovation process it is advisable to remove the old balcony, leaving a plain façade for the insulation. There are many technical possibilities to build up new balconies without thermal bridges. In the example below, the new balcony tower is built on its own fundament.

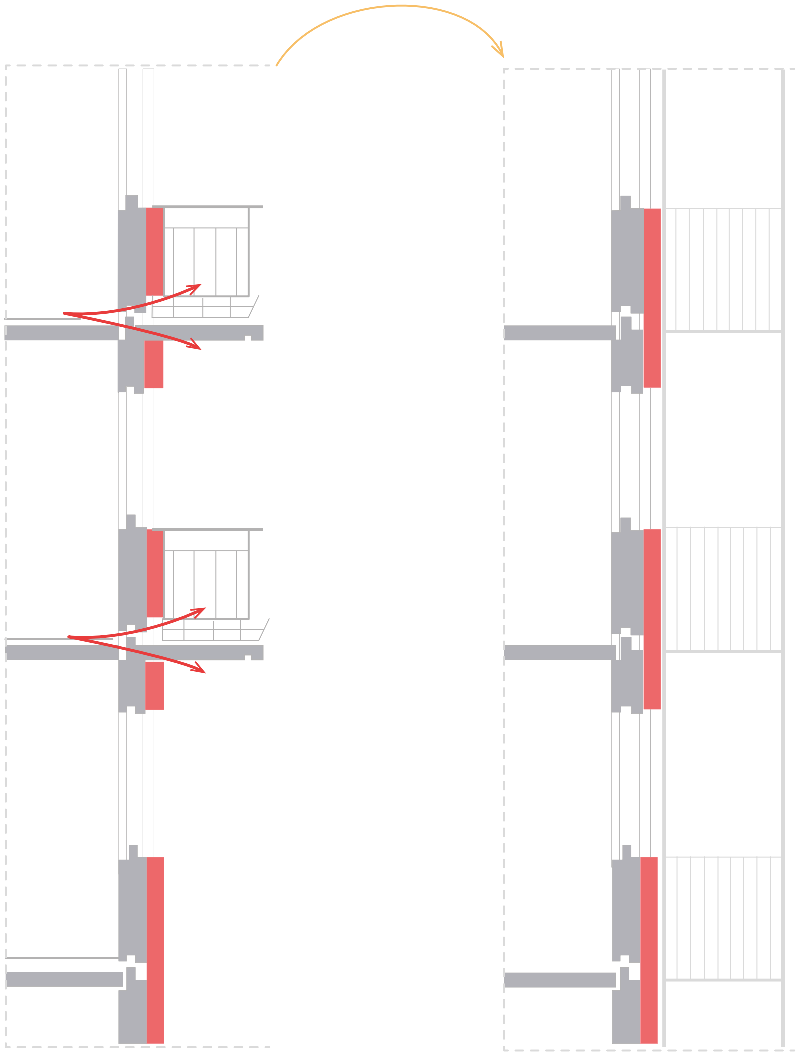


Figure 39-10: Old cantilevered balconies with thermal bridges; a new balcony tower.

Figure 39-11: Deconstruction of balconies

39.6 Ventilation as a minimum requirement

Ventilation (air exchange) is necessary to replace the exhausted indoor air by fresh air from the outside. The supply air per person can be assumed to be 25 – 30 m^3. For maintaining good indoor quality the average air change rate must be at minimum 0,3/h, which means that 30% of the air in a given space is exchanged per hour.

In old buildings with many leaks in construction elements, it may not be necessary to open windows for air exchange. However, once new windows are installed, air exchange becomes an important topic. If the former natural ventilation is now interrupted by the new airtight windows, moisture and mould may occur.

The easiest way to let fresh air in is to leave the window open over a long period. But this method causes relatively high heat losses, especially in colder seasons. The wall near a tilted window can get cold, so that moisture damages can occur. It is more advisable to open a window wide several times a day for 10 minutes. A refurbishment project should include an air exchange concept that guarantees a certain amount of fresh air independent of the tenants' ventilation practices. Controlled ventilation systems are technical solutions to provide fresh air, to minimize the risk of moisture and mould and, last but not least, to minimize ventilation heat losses. Possible concepts are:

Ventilation concepts

- natural ventilation (window/shaft – and cross ventilation)
- controlled mechanical ventilation
    - single fan ventilation
    - ventilation with exhaust system
    - ventilation with heat recovery
    - ventilation with high efficiency heat recovery (>80%)

An example is the window/shaft ventilation. Fresh air comes in through very small artificial openings between the frame and the window. These openings are optimized in a way that the air can circulate without getting too cold. The exhaust air will vent to existing shafts in the bathrooms. This solution is very easy to implement.

39.7 Airtight layer as a minimum requirement

A careful definition of the airtight layer and its execution is highly recommended for low-energy buildings. In the worst case, damages to structural elements may occur due to condensation. If the moisture condenses on the cold side or parts of the insulation, this can damage the material or form mould. Therefore it is important to hinder vapour from diffusing into the construction.

Normally, the airtight layer corresponds to the interior plastering of the outer walls. It is important to avoid leakages when joining building elements, e.g. walls to roofs and floors, all windows and doors, and all wires and pipes which go from the inside to the outside of a building shell. There are products on the market to cover building element joints. The heat losses through leakages in the building envelope can be up to 10% of energy losses.

39.8 Options to maximize solar heat gains

The grouping and orientation of buildings can result in energy savings by maximizing solar heat gains. Figure 39-12 shows the effect of different distances between buildings and arrangements of vegetation: In the first diagram, in wintertime, the flats on the ground level will have no sun or the flats in the second level will have shade caused by conifers.

Trees and sunlight

In the second illustration, the distance between houses is larger so that even the ground level flats will have sun in wintertime. Deciduous trees are a good combination for summer and winter months. In this example the distances are calculated for central Europe (recommendations of City of Münster, Germany).

These differences regarding the availability of solar gains have an influence on the energy balance of a building. Experiments have shown that up to 15% savings can be gained by an optimized orientation of houses [2].

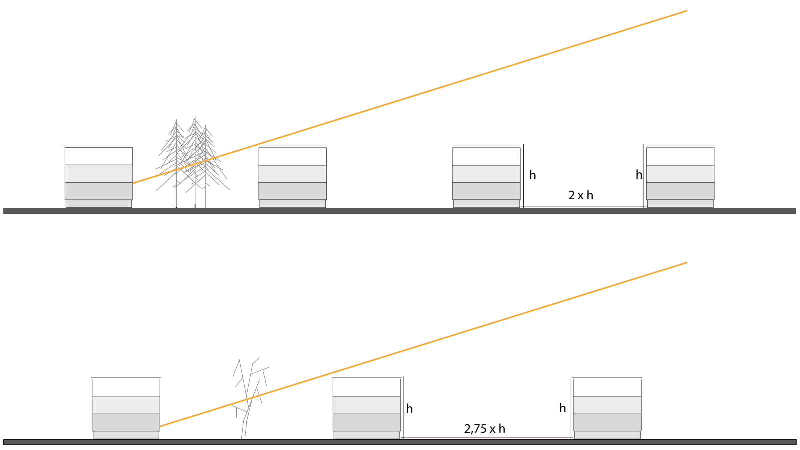


Figure 39-12: Examples of grouping and orientation of buildings.

In a refurbishment process, the grouping and orientation of buildings can certainly not be changed and there are few opportunities to optimize solar gains. Nevertheless, in some cases it is possible to reposition the window openings to let more sun and daylight in.

39.9 Options to avoid overheating in summer

During the calculation of a refurbishment project, the positive or negative effect of a new insulation layer on the indoor energy performance in summer can be estimated. If overheating in summer is likely to occur,

Shading

passive or active measures are necessary to prevent overheating such as adequate window covering and shading elements from the outside (e.g. shades, blinds, marquises, etc.) and the application of special glazing or materials which store night coolness. Eaves or balconies along the southern facades are another possibility to avoid overheating in summer and to optimize solar gains in winter.

Figure 39-13: Boxes of air conditioners on facades of residential buildings can be a first indicator that overheating in summertime is an issue.

39.10 Options to improve indoor comfort

Indoor climate is characterized by thermal and air comfort. Thermal comfort is determined by certain parameters of temperature and humidity of indoor air. Air comfort is characterized by the degree of contamination with pollutants like CO_2. Thermal and air comfort in residential buildings are influenced by the building envelope and engineering systems such as heating and ventilation. The building envelope should be "warm" enough and have sufficient thermal protection. The heating system has to heat rooms uniformly; the ventilation system must ensure the purity of indoor air.

40. Options for using the synergies of refurbishment

Complex refurbishment measures can lead to synergies for further improvements of living conditions in buildings and their surroundings. The following examples can help to identify opportunities to improve living conditions.

Additional measures inside the flats

Options for measures taken inside the flats:

- If pipes are to be changed, and shafts have to be opened, synergies can be used to renew water or electricity pipes as well. These installations have an average lifetime of 30 – 40 years before starting to cause problems.
- Flat owners can consider using these synergies to renovate bathrooms and kitchens.
- Flat owners might also take the opportunity to alter floor plans or the size of flats, e.g. two small flats could be combined into one bigger flat, or walls can be removed to increase heat and air flow between rooms.

Additional measures in the common areas

Options for measures for common areas:

- Daylight orientation and proper placement of windows results in good lighting conditions. The effect of reducing artificial light and increasing energy efficiency is high: in residential buildings, the energy spent for light consumes the highest share of electricity.
- A reorganization of the entire waste management collection system should be considered. For example, chutes can be removed and locked, and a new design created to collect, store and, ideally, separate types of trash. Depending on the specific conditions, such a reorganization can potentially reduce the maintenance costs.
- A concept for improving the existing building's energy performance in the future should be considered during the planning stages of the refurbishment. For example, the possibility of integrating renewable energy sources, e.g. solar energy to supply heat or electricity as part of the refurbishment, or at a later point in time, should be addressed. The preparation can include, e.g., empty pipes for future needs or space for storage in the basement.

Additional measures in the surroundings

Options for measures applied on the surroundings:

- When construction material has been removed following a refurbishment, it is a good moment to redesign and rearrange the surroundings of the house and to improve the layout of courtyards or entrances, Although these measures are not primarily meant to reduce the energy use, the improved appearance of the building provides a greater living comfort and increases the readiness of people to care for the public areas and facilities.

- If a garbage shaft is removed to increase energy efficiency, a new waste management system has to be designed.
- A complex renovation is an opportunity to improve the "parking space" for all kinds of vehicles: bicycles, baby strollers, motorcycles and cars. Their numbers have substantially increased in recent years. It would be a good outcome for both residents and the environment to a) group parking places for cars in a way that leaves sufficient place for and around playgrounds and pedestrian areas, and b) provide easy-to-access space for bikes and baby carriages, ideally next to the entrances. Adequate and safe bike stalls can make it more attractive and efficient to quickly grab the bike instead of the car.
- The amount of impenetrable groundcover in the urban area (cement roads and walkways) limits the infiltration of water into the soil and then into the roots of plants. That infiltration represents an important contribution to lessening the formation of urban heat islands by ensuring the evaporative cooling effect, and also by providing the necessary water for the tree root growth which leads to fuller and denser tree canopies.
- The treatment of rainwater can lead to new ideas for the environment, if it is used actively as a design element. Approaching and adopting a storm water management system based on water-sensitive design solutions (centralized and semi-decentralized) can help create a healthier environment.

41. Building equipment and appliances

41.1 Introduction

Any improvement of the building envelope, as described in the previous chapters, can only pay off if it is possible to regulate the heating system. If it is only possible to regulate the temperature by opening the window, the improved envelope will not lead to energy savings. However, it is now possible to measure the real consumption of energy. Knowing about the individual consumption is one of the most efficient steering for planning an energy upgrade.

The following sections explain some basic principles of typical heating systems in residential buildings. This should help to understand the problems of outdated systems and how they can be improved during a refurbishment process.

This chapter starts with the basic description of the heating systems as they relate to refurbishment measures. It describes the heat supply from the heater to the power plant. The measures described are based on the general understanding of the refurbishment process. More details about the efficiency of heating systems and elements (e.g. pumps, heaters, etc.) are given in Study Guide 9 on heating, ventilation and cooling.

One extra section deals with systems for hot water supply, which deserve attention, as they help achieve increased efficiency and better living comfort.

41.2 Heating devices

The main element to heat a flat is the heater. Heaters are designed to transfer heat from a heat carrier to the building. In residential buildings the most common heat carrier is water. The main characteristic of the heater is its power or heat load, defined by the calculation of thermal balance for each of the heated rooms.

Requirements for heating devices

These are the minimum requirements for heating devices:

- Thermo-technical requirements, which consist of efficiency of heat transmission from the heat carrier to the room through a certain area of the outer surface of the device;
- Aesthetic requirements;
- Economic demands, caused by cost of devices;
- Sanitary-hygiene requirements related with dust reduction, its decomposition at high temperatures and ease of cleaning. For this

purpose the surface temperature of the heater is limited: the surface must be sufficiently smooth and easy to clean;

- The devices must be mechanically strong, convenient for transportation, high temperature-resistant and leak-proof. [3]

In addition to these minimum requirements, the method of regulation of heaters (e.g. thermostat valves) must be considered. The options to open and close, or to better regulate the heater depend on the distribution systems inside the house.

Pipes of heating systems are designed for supplying and leading the heat carrier to and from the heating devices. Steel, heat resistant metal-plastic and polymeric pipes are used. The most common distribution systems in residential buildings are single- or double-pipe heating systems.

Single pipe systems

In a single-pipe system the heaters are connected in series. Therefore, the cooling of the heat carrier by moving through successive heating devices has to be taken into account. Single-pipe heating systems are used in one of two variants: flowing or with closing contours.

In a flowing single-pipe heating system the heat carrier passes sequentially through all radiators of a heating chain. Regulation valves on single-pipe systems may not be installed without additional bypasses that allow continuous water circulation in systems. Otherwise the flow would be blocked.

In a single-pipe system with closing contour, the heat carrier flow is channeled into two directions - to flow through the short closing section (bypass) and to the heat device. After being cooled from the heat device, the heat carrier goes back into the riser.

Double pipe systems

The double-pipe heating system provides a parallel connection of heating devices. The heat carrier goes to a heating device by one pipe and returns by another. Separation by devices is carried out through the use of collectors. The double-pipe system is considered more effective than a single-pipe one but is more expensive due to the greater number of heating pipes. Balancing and adjustment of this system is more complex than for a single pipe. The advantages of a double-pipe heating system are 1) more equal distribution of a heat carrier in the network and 2) the possibility of more precise adjustment of heating units on the floors and rooms.

41.3 Types of heating systems

Following the distribution of the heat carrier in the residential building, the question arises - where and how is the heat carrier itself heated up? Heat can be produced in the following ways:

Individual vs. central heating

- Individual heating plants, which are used to serve a single user (the whole building or a part of it), are usually located in a basement or technical area of the building (as part of decentralized heating system);
- Central heating plants, which are used to serve a group of buildings, are usually located in a separately placed building (part of a centralized heating system).

A central heating system is most commonly used for heat supply in the existing building stock. In this case, two main types of connection between the house and the grid can be distinguished:

- The open (dependent) scheme of connection provides direct delivery of a heat carrier from a heating network to the heat supply system of a building (Figure 41-1). In the open scheme, water in the networks is not only used as a heat carrier, but also as a source of hot water consumed in the building. A dependent heating system usually is transformed into an independent system during the refurbishment.
- In the improved closed (independent) scheme of heat supply, the heated water in a network is used only as a heat carrier and is not used by a consumer. In this scheme, the heat carrier passes through the heat exchanger installed in the consumer heat unit, where it heats the secondary heat carrier, which is used in a building heat supply system.

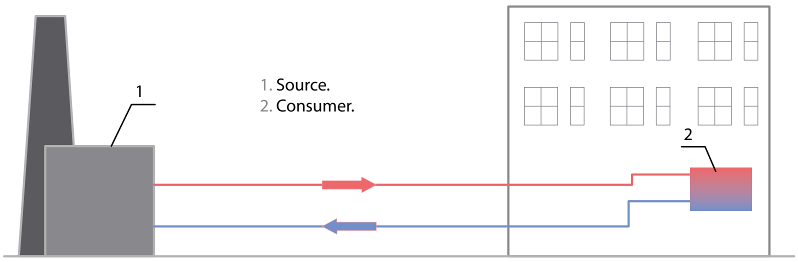


Figure 41-1: Simplified scheme of an open centralized heating system

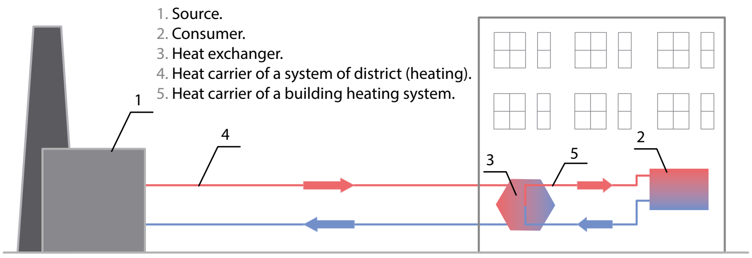


Figure 41-2: Simplified scheme of a closed centralized heating system

Centralized heating systems have both strengths and weaknesses. The application of centralized systems in dense urban areas tends to be economically justified. Further, it is possible to combine electricity and heat production with a high overall efficiency factor when the heat source is

Combine heat and power plant (CHP)

a large scale combined heat and power plant (CHP). Disadvantages of this system are heat losses on the service pipes (thermal networks), the need for repairs, complexity of regulation of a hydraulic regime and heat supply to consumers.

Module 9 gives more information about centralized and decentralized heating systems.

41.4 Possibilities to improve heating systems

The previous sections helped to explain the types of heating systems. Based on these descriptions, it should be easier to distinguish which existing system has a potential for improvement and which has to be changed completely in the process of a refurbishment.

Table 41-1 gives an overview of the main activities to be carried out in a refurbishment. In the first column typical problems are listed; the second column suggests possible solutions. This may help to prioritize the most immediate concerns as well as additional possible measures.

Problems	Measures	Remarks
Need to change from centralized to decentralized system, due to too many losses in the distribution from the power plant to the building	Installation of mini-CHP	Check legislation and contracts
	Installation of independent boilers for the house	
	Installation of independent boilers for each flat	
Hot water is directly supplied by the district heating, without an exchanger in between	Replacement of the closed, independent system by installation of a heat exchanger	See measures for the heat water supply system
	Installation of individual heating units	
The heating system can only be regulated by opening the window	Improve the single-pipe system by installation of by-passes and thermostat valves	Adjustable heating devices lead to average savings of about 20%, according to experience in Germany
	Replace the single-pipe system with a double-pipe system	
	Install regulation devices in each flat. Options can be found in the section about automatic regulators.	

The pipes are blocked with limestone after decades of use	Replacement of the complete pipeline	The life-time of pipes is estimated to be 20-30 years depending on material and type (annex 2)
	Convert to a double-pipe system	
The heaters are outdated or oversized	Replacement of heaters	The life-time of heaters is estimated to be 15-40 years depending on type and material (Annex 2)
	Upgrade heaters to align with improvements of the energy performance of the building after refurbishment	
Data on individual consumption is not collected: it is not possible to pay according to real consumption	Install improved metering devices in each building or each flat	See the measures for hot water supply
	Installation of metering devices at each heater	
Additional measures to improve the efficiency of the heating system		
Balancing the system (hydraulic balance)	Installation of balancing valves	Estimated saving potential of 5%
Increasing the efficiency of the heaters	Installation of reflection screens behind the heaters	
Insulation of all pipes in unheated areas		Estimated saving potential of 5%
Installation of efficient circulation pumps		

Table 41-1: Overview of problems and possible measures to improve heating systems.

41.4.1 Improving heat regulation

The precondition of heat regulation is that the distribution allows closing or regulating one flat or one heater. The distribution systems should be improved in a way that the following measures can be undertaken.

Automatic regulators

Automatic regulators allow setting the required room temperature and the level of air exchange in the apartment separately for day and night time. Temperatures can also be reduced during long absence of tenants. If there is a mechanical ventilation with heat recovery of exhausted air, automated systems can also combine these functions with regulating the level of air exchange (Figure 41-3).

Figure 41-3: Automatic regulator of air exchange and flat heating.

Block valves

Block valves can be installed to connect or disconnect a flat or a riser from the heating system:

- When the temperature in the apartment is below the value set by the resident, the system automatically opens the block valve of the unit, providing the flow from the heating system to the flat heaters.
- When the temperature in the apartment exceeds the value set by the resident, the system automatically closes the block valve of the unit and disconnects the apartment from the heating system of the building (Figure 41-4).

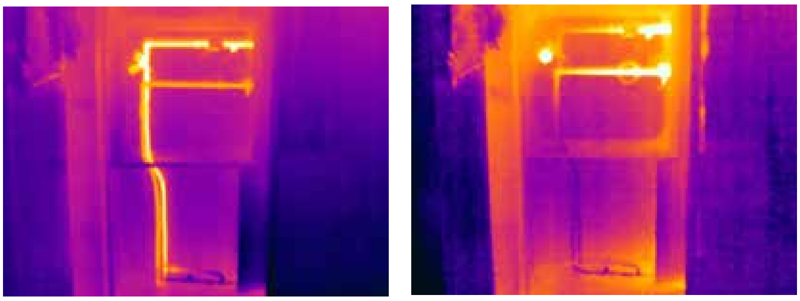


Figure 41-4: Work of the block valve of a residential heating system. Left side: valve is opened. Right side: Valve is closed

Additional air temperature regulation in the room can be achieved by application of thermostatic valves on the heating devices.

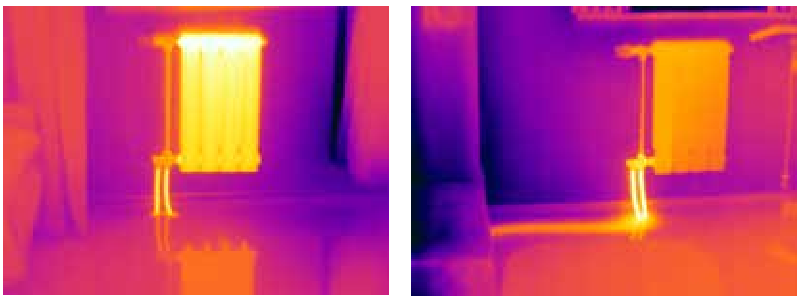


Figure 41-5: Work of the thermostatic valve on the heater. Left side: valve is opened. Right side: Valve is closed.

The combination of metering every apartment and the regulating heat consumption creates maximum opportunities for energy conservation in residential buildings. Consumers can manage the consumption of thermal energy.

When reconstructing residential heating systems, automatic control of air temperature in each flat or room should be provided by the installation of individual meters for heat consumption.

Heat meters

Heat meters in apartments are devices with a diameter of canals of 15-20 mm and a measuring range of heat carrier temperature of 5 - 150°C.

Regulation of heat consumption can be central, local, individual or performed at each radiator. Qualitative regulation in the water heating system is carried out by changing and maintaining the temperature of the water directed to the devices, which provides a required temperature regime in a room. Quantitative regulation of heat flow of a heating device is provided by changing the amount of a heat carrier (water).

Automatic control of the heat carrier temperature in the thermal unit of the building is carried out either by a change in outdoor temperature (in most cases) or room temperature. Individual control systems are designed to maintain the desired temperature in a room. For individual manual control of a heat flow, heating devices and valves are used.

Automatic thermal regulators are installed on the supplying leads of heating devices and water entrances in the heating devices during the reconstruction of heating systems in order to regulate the indoor temperature (Figure 41-6).

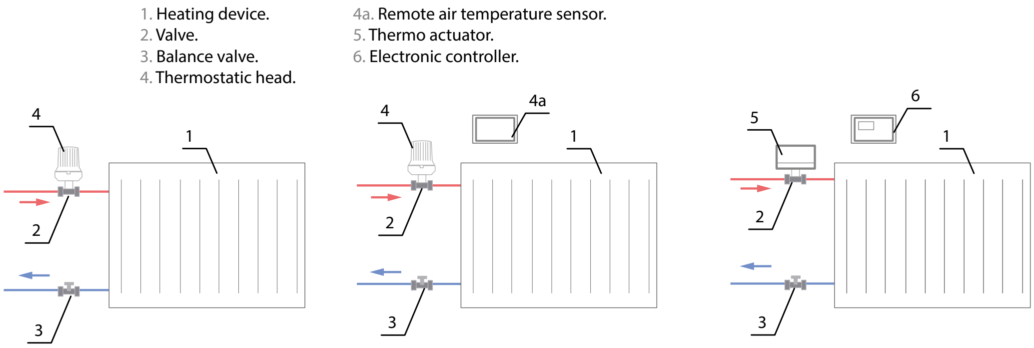


Figure 41-6: Examples of thermal regulators.

The heating system should be balanced during a refurbishment. This involves placing balancing valves, valves on risers or heating devices, depending on how they are connected. Examples of installation are shown in Figures 41-7 - 41-8.

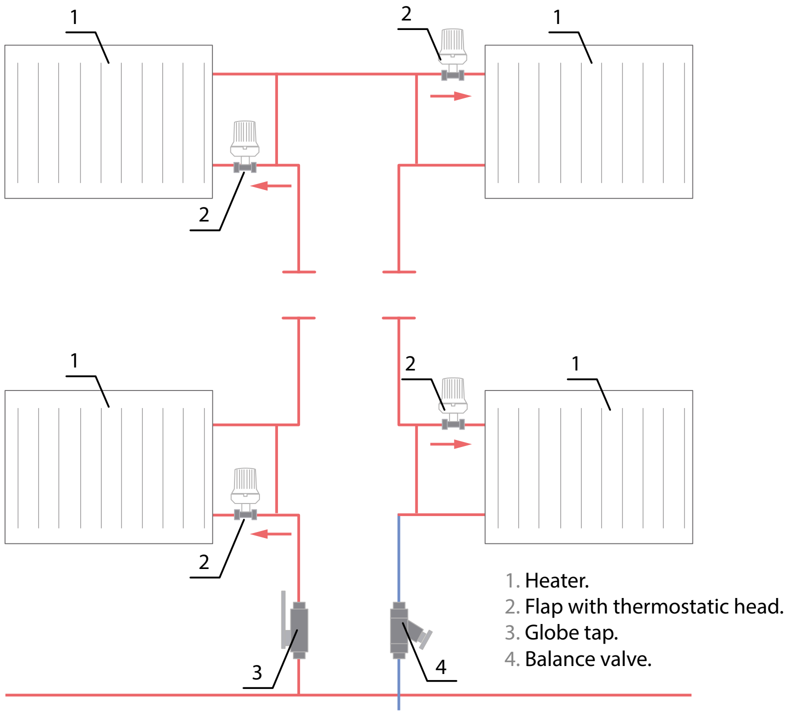
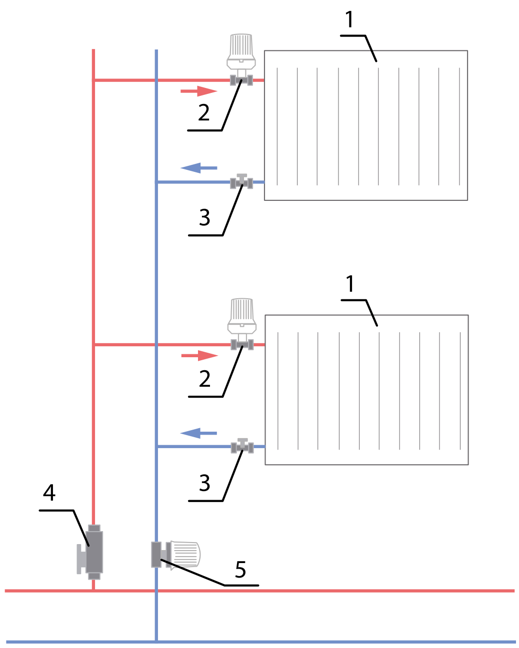


Figure 41-7: Example of a unit of thermostats and control valves in the single-pipe heating system with examples of thermal regulators (based on [2]).



1. Heater.
2. Flap with thermostatic head.
3. Balance valve of the heater.
4. Block valve.
5. Differential pressure regulator.

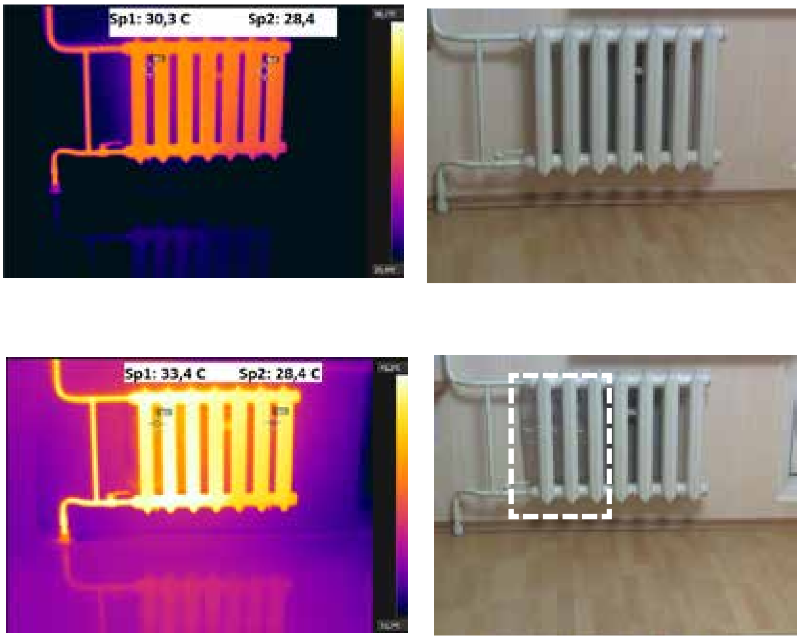
Figure 41-8: Example of a unit of thermostats and control valves in a double-pipe heating system.

As a rule, individual heat meters are installed while reconstructing residential heating systems. Meters can be installed on each device (Figure 41-9) or installed in the housing thermal unit.

Figure 41-9: Heat cost allocator installed on heating device

41.4.2 Installing heat-reflective screens

For reduction of heat loss during refurbishment of buildings, a cheap and effective measure is the installation of heat-reflective screens made from foil materials behind the heaters (Figures 41-10 and 41-11).



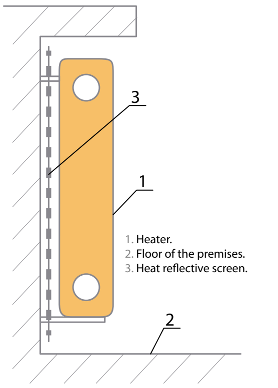


Figure 41-12: Scheme of installation of heat-reflective screen

Figure 41-10: Effect of installation of heat-reflective screen. Upper left: Thermogram without screen, upper right: Heater without screen, down left; Thermogram with screen, down right: Heater with screen (marked area)

41.5 Generation of hot water

41.5.1 Types of internal systems of hot water supply

There are different types of internal systems for hot water supply. A hot water supply system is a complex of devices to provide consumers with hot water for domestic purposes. Hot water is supplied to the same devices as the internal system of cold domestic and drinking water supply (except cisterns). The quality of cold and hot water, which is supplied for drinking needs, should meet the requirements of health standards for drinking water. The temperature of hot water in the draw-off should be in the following ranges:

Temperature of hot water

- between 60°C and 75°C - for centralized hot water supply systems, which are connected with open heating systems;
- between 50°C and 75°C - for centralized hot water supply systems, which are connected with closed heating systems [6].

According to the location of the source of hot water supply systems, there are centralized and decentralized systems.

In centralized systems hot water reaches the large group of consumers through external heating networks from a CHP, district boiler houses or from its own boiler houses. The water is heated in hot water boilers, water or vapour heaters.

With decentralized hot water supply, the water is heated directly at the place of consumption and provided to one or more devices in the contiguous premises. Water is heated by vapour, fuel combustion or electricity. An example of a decentralized hot water supply system could be water heating in the running type gas water heaters or in capacitive automatic water heaters installed in apartments. The advantages of decentralized hot water supply are its autonomy, small heat losses and the possibility of an independent repair.

Types of hot water systems

Depending on the method of water preparation, centralized hot water supply systems can be operated in the following ways:

- with the local boilers;
- with heating of hot water in central heating units or individual heating units in the closed scheme of heating;
- with direct water draw-off from heat networks (open heating scheme).

Closed hot water supply systems are fed directly from the cold water pipe through pressure of pumps of its system as shown in Figure 41-11.

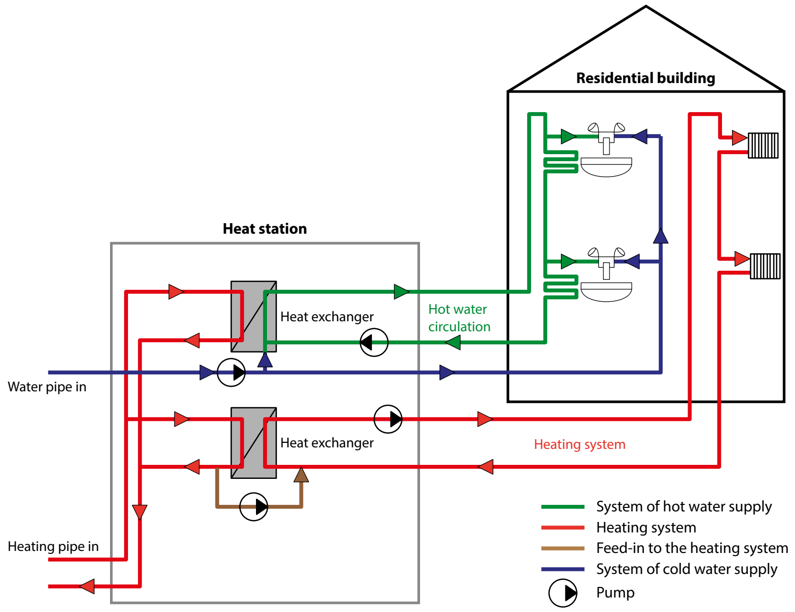


Figure 41-11: Closed hot water supply system in independent scheme of heating system.

Automatic regulators of a hot water supply system should provide the required temperature of the water in the system. To reduce thermal energy consumption it is recommended to decrease the temperature of hot water at night.

41.5.2 The main elements of hot water supply systems

The main elements of the hot water supply system are water heaters, pipes, an armature and circulation system.

Storage water heaters (boilers) and flowing heaters are used most commonly for heating water. Water heating in the storage water heater (boiler) is carried out by means of the heat exchanger, which is located inside the boiler. The heat carrier of a heating system moves through the heat exchanger. Water heating occurs through the walls of the heat exchanger. With the consumption of hot water, the water level of the boiler is automatically restored from the cold water pipeline and is heated to a determined temperature. Storage water heaters combine two functions in one unit - water heater and the heat accumulator.

In flowing water heaters a small amount of water is quickly heated to a determined temperature by a high-powered heat source. A gas water heater (geyser) is an example of a flowing heater. It consists of a metal body containing a burner that heats water passing through the heat exchanger. Safe operation of the burner is ensured automatically. When you open the tap to get water, the valve is opened and the gas goes into the burner. Combustion products of gas are removed through the chimney; hot water goes to the consumer through the pipe. The required temperature is independent from fluctuations in water pressure. Circulation of water in the hot water system allows supporting constant water temperature in draw-off points at any time and avoids draining cooled water in the pipes to the sewer system. For the removal of cooled water from supplying pipelines, with minimal or no water pumping, circulation lines are arranged. Circulation of water in the system is carried out by a circulation pump [8].

Towel risers

In bathrooms and shower rooms towel-risers are provided: these are separately constructed rails of hot water pipeline designed for drying towels and maintaining the required air temperature. Towel dryers can be made of steel, brass, or stainless steel with decorative covering and can be connected with circulation pipelines.

41.5.3 Reconstructing the hot water supply system

Table 41-2 provides an overview of the main activities to be carried out during reconstruction of a hot water supply system. The first column lists typical problems; the second column gives possible solutions. This can help to prioritize the most necessary and possible additional measures.

Boilers and heat exchangers

Problems	Measures	Remarks
The hot water from the pipe comes directly from the power plant – a lot of thermal energy is lost during the water's transit from power plant to the residential building	Replacement of the closed, independent system by installing a heat exchanger	See measures for the heating system
	Installation of individual heating units	
Pipes are outdated	Replacement of the pipes	The life-time of pipes is estimated to be 25 years (for hot water)
It takes a long time to get warm water due to lack of circulation pumps	Installation of circulation pumps	This measure not only increases the living comfort, but also the efficiency of the system. Saving potential is about 20 %
Individual consumption is not known; it is not possible to pay according to real consumption	Installation of metering devices in each flat	See the measures for heat supply system

Additional measures to improve the efficiency of the hot water supply system
Insulation of all pipes in unheated areas
Installation of efficient pumps
Use of solar thermal devices for hot water supply
Replacement of isolation valves at the entrances to the building, at the junctions of sections, at the base of water pumping and circulation risers, on the supply line to each apartment, at the water heater inlets and outlets;

Table 41-2: Overview of problems and options for updating a hot water supply system

References module 7

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Annex 1 Short overview on commonly used insulation materials

In order to compare different insulation materials, their characteristics have to be known. A colour code has been established to indicate good, moderate and bad characteristics. This can give you a first impression about sustainability of the construction material. However there can be other materials on the market with either better or worse performance.

good moderate bad

For the 10 construction materials selected, the following items are described and evaluated:

Type/Name: This includes the insulation material group, the application and the term in English. Material groups, for example, can be composed of natural fibre insulation materials or polystyrene; they can be used as injectable loose-fill insulation, blankets or matting and boards or panels.

Production/Resource: This information mentions the raw materials or the most important composites used to produce the insulation material.

Primary energy content: This figure indicates the energy used in the production chain, for example, for manufacturing or transporting. It is measured as kWh/m^3.

Environment/Sustainability: This category provides information on the availability of the resources.

Health: This category indicates whether the material is harmful or harmless or if a suspicion exists that has or has not yet been proven.

Application and delivery: This information describes how the insulation product appears in construction, e.g. as cavity wall insulation, between rafters or as interior insulation or external façade-boards. Furthermore, the most common building elements, locations for insulation are included, for example, wall, ceiling, etc. The pictograms give a further impression as to where the material can be applied.

EIFS: EIFS stands for Exterior insulation finishing system, which can be described as ETICS Exterior thermal insulation composite system as well.

Thermal conductivity λ: Thermal conductivity appears if heat flows through a material with a specific thickness in a direction normal to the surface. It is measured as W/(mK). Thermal conductivity is not the same as U-Value (W/m^2K) where the thermal conductivity is divided by the layer thickness (m). The λ-values are mostly used for single layers of materials while U-values are used for building elements such as whole walls.

Thermal storage capacity: Thermal storage capacity describes the ability to store heating energy in a material. This is especially important during off-peak times at night. It is measured as J/(kgK).

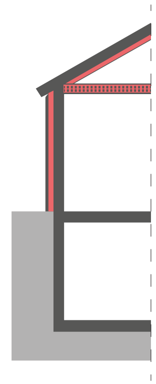
Water vapour diffusion resistance: Water vapour diffusion resistance describes the water diffusion ability of a material. If the resistance is high, the material is less permeable to water vapour. It has no dimension (the unit is 1).

Density: The density describes the specific weight of a material. A high density generally has a high thermal storage capacity. It is measured as kg/m^3.

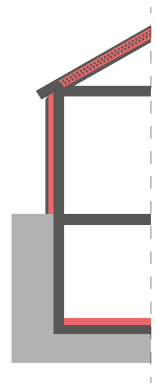
Construction material class: The construction material class describes the construction material classes according to German legislation and indicates inflammability of a material, e.g. class "A" is non-inflammable and class "B3" is easily inflammable material.

Costs: This category estimates rough costs, considering western European prices. Specific values are not shown.

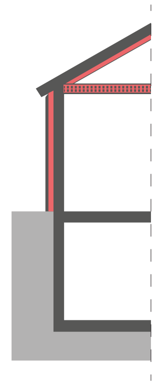
Type/Name	
Cellulose insulation material – cellulose flakes loose-fill insulation, injectable (recycled newspaper)	
General information	
Production/Resource:	Recycled newspapers
Primary Energy Content:	50 - 80 kWh/m^3
Application and delivery:	Cavity wall insulation, ceiling
EIFS possible:	No
Accessories for EIFS:	Holes to be sealed with a plug
Environment/Sustainability:	High resource availability
Costs:	Lower costs
Physical properties	
Thermal conductivity λ:	0,039 W/(mK)
Thermal storage capacity:	1600 - 2100 J/(kgK)
Water vapour diffusion resistance:	1 - 2 μ
Density:	30 - 65 kg/m^3
Construction material class:	B2
Health:	Harmless



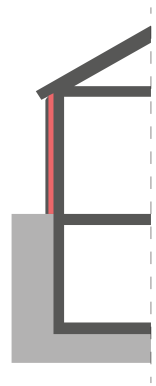
Type/Name	
Mineral wool insulation materials – mineral fibre blanket/matting	
General information	
Production/Resource:	Recycle glass, limestone, binder
Primary Energy Content:	100 - 700 kWh/m^3
Application and delivery:	Roof between rafters, wall
EIFS possible:	Yes
Accessories for EIFS:	Substructure necessary
Environment/Sustainability:	High resource availability
Costs:	Lower costs
Physical properties	
Thermal conductivity λ:	0,035 W/(mK)
Thermal storage capacity:	840 - 1000 J/(kgK)
Water vapour diffusion resistance:	1 - 2 μ
Density:	10 - 200 kg/m^3
Construction material class:	A2
Health:	Suspicion of problematic fibres during the manufacturing stage, not proven

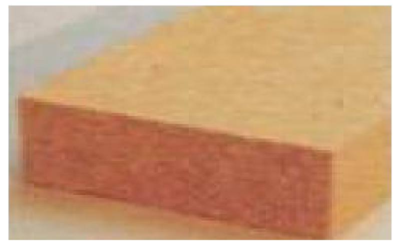


Type/Name	
Mineral wool insulation materials – rock wool loose-fill insulation, injectable	
General information	
Production/Resource:	Natural stone, binder
Primary Energy Content:	150 - 400 kWh/m³
Application and delivery:	Cavity wall insulation, ceiling
EIFS possible:	No
Accessories for EIFS:	Holes to be sealed with a plug
Environment/Sustainability:	-
Costs:	Lower costs
Physical properties	
Thermal conductivity λ:	0,040 - 0,045 W/(mK)
Thermal storage capacity:	840 J/(kgK)
Water vapour diffusion resistance:	1 - 2 µ
Density:	35 - 120 kg/m³
Construction material class:	A1
Health:	-

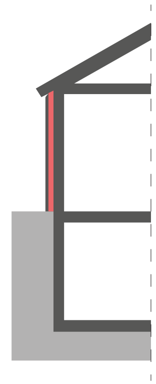


Type/Name	
Natural fibre insulation materials – multiple-layered straw panel	
General information	
Production/Resource:	Straw
Primary Energy Content:	182 kWh/m³
Application and delivery:	Façade-boards
EIFS possible:	Yes
Accessories for EIFS:	Substructure and fixing
Environment/Sustainability:	High resource availability
Costs:	Lower costs
Physical properties	
Thermal conductivity λ:	0,0942 W/(mK)
Thermal storage capacity:	1300 J/(kgK)
Water vapour diffusion resistance:	35 - 40 μ
Density:	340 kg/m³
Construction material class:	B2
Health:	Harmless

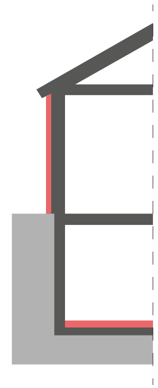


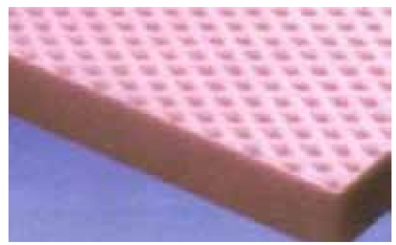


Type/Name	
Natural fibre insulation materials – wood fibre board/panels	
General information	
Production/Resource:	Softwood, paraffin
Primary Energy Content:	645 kWh/m^3
Application and delivery:	Façade-boards, matting
EIFS possible:	Yes
Accessories for EIFS:	Substructure and fixing
Environment/Sustainability:	High resource availability
Costs:	Medium costs
Physical properties	
Thermal conductivity λ:	0,040 - 0,043 W/(mK)
Thermal storage capacity:	2100 J/(kgK)
Water vapour diffusion resistance:	5 μ
Density:	110 - 200 kg/m^3
Construction material class:	B2
Health:	Harmless

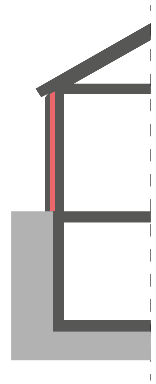


Type/Name	
Polystyrene insulation materials – expanded polystyrene foam board	
General information	
Production/Resource:	Polystyrene, crude oil
Primary Energy Content:	400 - 1050 kWh/m^3
Application and delivery:	Mostly boards
EIFS possible:	Yes
Accessories for EIFS:	To be glued or plugged
Environment/Sustainability:	Resource availability dependent on crude oil
Costs:	Medium costs
Physical properties	
Thermal conductivity λ:	0,040 W/(mK)
Thermal storage capacity:	1500 J/(kgK)
Water vapour diffusion resistance:	20 - 100 μ
Density:	10 - 60 kg/m^3
Construction material class:	B1, B2
Health:	Manufacturing is harmless, if the insulation catches fire toxic gases can develop

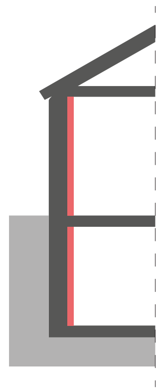




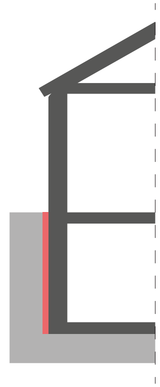
Type/Name	
Vermiculite and perlite insulation materials – perlite loose-fill insulation	
General information	
Production/Resource:	Perlite
Primary Energy Content:	200-240 kWh/m^3
Application and delivery:	Cavity wall insulation
EIFS possible:	No
Accessories for EIFS:	Filling up
Environment/Sustainability:	-
Costs:	Medium costs
Physical properties	
Thermal conductivity λ:	0,050 W/(mK)
Thermal storage capacity:	1000 J/(kgK)
Water vapour diffusion resistance:	3 μ
Density:	85 - 145 kg/m^3
Construction material class:	A1
Health:	-



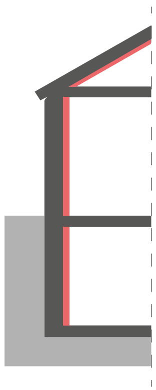
Type/Name	
Cementitious insulation material – fibre cement board	
General information	
Production/Resource:	Lime silicate, Cellulose fibre
Primary Energy Content:	800 - 1200 kWh/m^3
Application and delivery:	Boards, wall, internal Insulation
EIFS possible:	Yes
Accessories for EIFS:	To be glued or plugged
Environment/Sustainability:	-
Costs:	High costs
Physical properties	
Thermal conductivity λ:	0,060 - 0,067 W/(mK)
Thermal storage capacity:	850 - 1000 J/(kgK)
Water vapour diffusion resistance:	5 - 20 µ
Density:	200 - 240 kg/m^3
Construction material class:	A1
Health:	-



Type/Name	
Polyurethane rigid foam	
General information	
Production/Resource:	Polyether, -methane, crude oil
Primary Energy Content:	800 - 1500 kWh/m^3
Application and delivery:	Mostly boards for roof, wall
EIFS possible:	Yes
Accessories for EIFS:	To be glued or plugged
Environment/Sustainability:	Resource availability dependent on crude oil
Costs:	Medium costs
Physical properties	
Thermal conductivity λ:	0,028 W/(mK)
Thermal storage capacity:	1200 - 1500 J/(kgK)
Water vapour diffusion resistance:	40 - 200 µ
Density:	>30 kg/m^3
Construction material class:	B2
Health:	Manufacturing is harmless, if the insulation catches fire toxic gases can develop



Type/Name	
High technology insulation - vacuum panels	
General information	
Production/Resource:	Compressed silica, film
Primary Energy Content:	Very high energy content
Application and delivery:	Boards for roofs, walls, internal insulation
EIFS possible:	Yes
Accessories for EIFS:	to be glued, no holes, no cuts
Environment/Sustainability:	High resource availability
Costs:	High costs
Physical properties	
Thermal conductivity λ:	0,007 W/(mK)
Thermal storage capacity:	800 J/(kgK)
Water vapour diffusion resistance:	Infinite μ
Density:	150-210 kg/m^3
Construction material class:	B2
Health:	Harmless



Annex 2 Minimum life time of the basic elements of heating and water supply systems

Element	Life time before replacement in years
Piping, including pipes for cold water:	
zinced water-gas pipes	30
neozinced water-gas pipes	15
polymeric tubing	50
hydrants, water taps	10
hydrometric sites	10
Piping with hot water from the water-gas zinced pipes with heat supply schemes:	
closed	20
open	30
Heated towel rails:	
ferrous pipes	15
zinced pipes	30
nickel-plated tubes	20
pipe insulation of mineral wool plates	10
Heating	
Cast iron (steel) radiators:	
with closed circuits	40 (30)
with open circuits	30 (15)
steel heaters	15
convectors	30
Piping (standpipes)	
with closed circuits	30
with open circuits	15
Pipelines (home lines):	
with closed circuits	20
with open circuits	15
pipeline insulation	10

Source: Technical Code of Established Practice 45-1.04-14-2005 (for Belarus) Technical exploitation of residential and public buildings and constructions

8

Walls, windows and doors

WHAT WILL YOU LEARN IN THIS MODULE?

The following chapter is dedicated to the components of the building shell: walls, windows, doors, roof and cellar. Together these elements separate the inner from the outer environment of a physical structure. Whereas the building shell is intended to protect the dwellers from negative climatic influences such as wind, rain or heat, it must also allow for sufficient ventilation in order to provide fresh air and to let out trapped moisture. These considerations form the background of the following module. It is structured according to the main components of a typical building shell i. e. walls, windows, doors, roof and basement. Every component is described according to its basic characteristics, variations and types. Questions of thermal insulation of the respective element are then answered and proposals and advice for refurbishment are specified. The last section of this module examines the problem of mould, a central question arising from the interrelation of insulation and ventilation: mould as a consequence of excessive indoor humidity and approaches to prevent its occurrence.

42. Walls

42.1 Typology, common structures

Walls are one of the most important elements of buildings and structures. Walls not only isolate the premises from external environment and transmit heat, air, moisture, but also are exposed to effects of human activity: cooking, breathing, washing, etc. Walls should have the necessary durability, resistance against atmospheric forcing and corrosion; should have the necessary heat-, water-, air- and sound-insulating qualities; should be long-life and fire-resistant, and should provide a beautiful appearance and cost-effectiveness for renovation of residential buildings. Moreover, the choice of wall construction is a primary design issues, as it represents a significant part of the total building costs.

Types of walls

Wall materials include stone, wood, concrete and combinations of those; depending on the nature of the construction: big blocks, panels and fragments (small-sized) stone materials may be used. From the viewpoint of thermal insulation, there are two types of external walls: single-layer and multilayer.

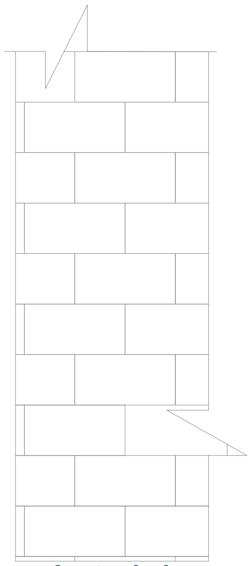


Figure 42-1: Construction of a single-layer concrete wall

Single-layer walls

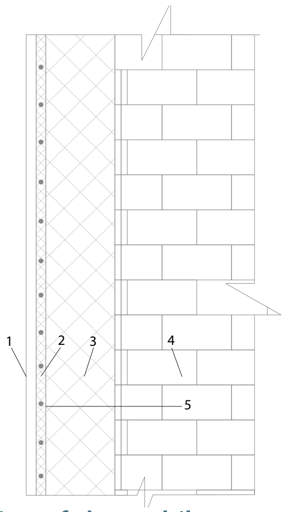
Single-layer walls are made of structural heat-insulating materials and products (brick, for example, porous, i.e. warm and durable), which combine heat-transfer and heat-protecting functions. Single-layer walls are more commonly used by designers and builders: they provide ease of construction and operation. Single-layer walls, as a rule, are made of homogeneous material. Their characteristic feature is that the material has load-bearing, as well as heat-protecting functions.

For the production of single-layer enclosing structures in constructing practice there are widely used and diverse kinds of brick and concrete (e.g.) honeycomb structure. A feature of modern single-layer enclosing structures is that they can be built of concrete with density that does not exceed 600-700 kg/m3 or clay brick with sufficient thermal characteristics.

42.2 Multilayer walls

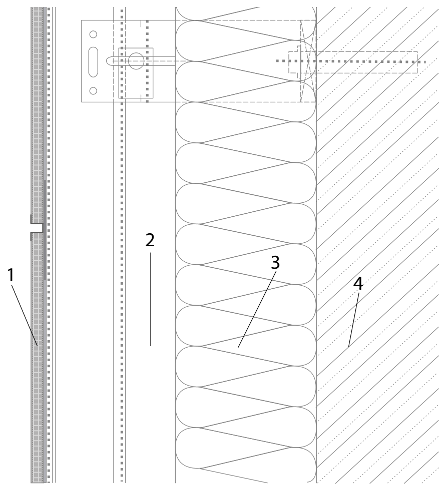
Multilayer walls

In multilayer walls (walls with several layers, for example, concrete, insulation, plaster, air gap), insulation is preferably located outside. There are two variants of the outer insulation: systems with an outer cover layer without a gap and systems with an air gap between the outer facing layer and insulation. It's not recommended to use heat insulation inside because of the possible accumulation of moisture in the insulating layer (see the module on building physics), however if such an application is needed (e.g. in listed/historic buildings) the inner surface should have continuous and long-life vapour barrier .



1. Plaster layer.
2. Coil mesh.
3. Insulation.
4. Main layer-brick.
5. Plate dowel.

Figure 42-2: Construction of the multilayer wall without ventilated gap



1. Ceramic granite cladding.
2. Ventilated gap.
3. Insulation.
4. Main layer-brick.

Figure 42-3: Construction of the multilayer wall with ventilated gap

The main advantage of structures with an air gap is the presence of naturally ventilated air space that allows condensation and 'as built' moisture to leave the construction. Furthermore, it protects the heat insulation materials against atmospheric precipitation; it keeps the insulation in a dry condition that allows applying semi-rigid mineral wool and fiberglass plates. The disadvantage of this design solution is its relatively high cost.

42.3 Thermal insulation needs

Walls play an important role in energy saving of buildings. Heat losses through the walls cause high heating costs - sometimes more than half the total. The more thermal insulation of external structures, the smaller the heat losses through the building envelope.

Legal requirements to heat insulation

Thus, heat losses depend on the level of insulation. All countries have legal requirements regarding the level of heat insulation of external structures; they differ depending on the climatic conditions of the country and its public policy on energy conservation. Constantly rising prices of energy resources and the related phenomenon of tariff growth for thermal energy, as well as reduction of reserves of non-renewable hydrocarbons (oil, gas), mean that standards of energy consumption of buildings are constantly decreasing in most developed countries of the world; therefore the requirements for the level of thermal insulation of walls is increasing.

The most important indicators of thermal protection (thermal insulation) are:

Indicators for thermal resistance

- reduced thermal resistance of a building envelope – this value indicates the extent to which a wall/door/roof cannot pass heat from the house to the outside and vice versa, cold from the outside into the house;
- specific heat consumption for heating of a building – how much heat is required for heating one cubic meter of a building when the temperature changes by one degree.

Walls must protect from direct moisture such as rain or snow but must also be constructed in a way that condensation and mould is avoided. Walls need to be soundproof. During the reconstruction of houses, the soundproofing of walls can be improved to reduce the noise from neighbouring rooms and from the street. In addition to all these requirements, walls must, of course, meet the basic demand as load- bearing elements, providing enough carrying capacity to the building.

Currently, no wall materials effectively meet all these requirements. So if walls are made of good thick concrete, the strength of the walls will be provided at the smallest wall thickness of 10-15 cm, however, the required thermal resistance (the ability to save heat) will not be achieved. The thickness of concrete walls needs to be increased up to 3-6 m in order to create the necessary thermal insulation of a building. If a wall is constructed of insulation material - light, porous, such as polystyrene - the necessary thermal insulation can be achieved at a thickness of 10-20 cm, however, the requirements for strength will not be met. Walls made of such material cannot be bear sufficient weight. Thus, the building envelope (walls, windows, doors, etc.) are multi-layers. The layers consist of materials that have multiple properties: each performs its particular function.

If the material has high strength, its insulating properties are low. With substantial heat transference through walls, the building becomes energy inefficient. Conversely, materials with good heat retention are too low in strength. Excessively high heat transfer of a material can be reduced by the injection of regularly distributed pores (air), but the replacement of solid material by air inevitably leads to a decrease of strength. However, there are materials that combine low, but sufficient strength and considerable porosity, and are therefore satisfactory for thermal insulation. These materials are used for load-bearing walls and are called walling materials. They include brick and masonry stones (ceramic and silicate, including gas-silicate), blocks and panels of lightweight concrete (aerated concrete, foamed concrete, concrete with porous aggregates), natural stones, etc.

42.4 Practical solutions and recommendations for refurbishment

In order to carry out qualitative, good reconstruction and renovation of residential buildings, walls need to be insulated. Regulations must be followed and construction must meet certain recommendations.

Usually it is recommended that building walls made out of brick and ceramic stones are designed with pointing masonry joints on the façade (except walls with air streaks and walls panelled with brick). When using stones of the porous ceramic, it is recommended to provide a cladding (an outer layer on the exterior) layer of brick with anchors of stainless steel or fiberglass to bind to the primary masonry.

Guidelines for the design of walls with unventilated air layers

The following guidelines should be noted when designing walls with an unventilated air layer:

- The height of the unventilated air layer shall not be higher than the storey itself and shall not be more than 6 m. The thickness of the layer shall not be less than 40 mm (10 mm with heat insulation);
- Air layers up to 3 m in area, must be separated with sealed layers of non-combustible materials;
- Air layers should be located close to the cold side of the wall.
- The following guidelines should be noted when designing walls with ventilated air layers (walls with a ventilated facade):

- The thickness of the air layer should be not less than 50 nor more than 100 mm, and should be placed between the outer layer and the insulation;
- when calculating the reduced thermal resistance to heat transfer (value, which indicates how a wall collects heat) all thermal bridges should be taken into account - elements of material which conduct heat out into the street, as well as fasteners, usually metal, such as nails, which are used to attach the insulation layer to the wall. In the module on building physics, a sample calculation demonstrates the effect of attachments on thermal resistance.
- the outer layer of the wall should have ventilation holes, including around windows;
- the lower ventilation holes usually should be located near the socles, preferably incorporating the functions of ventilation and removal of moisture;
- the upper ventilation holes usually should be combined with eaves;
- to apply tough thermal insulating materials with density of at least 80 - 90 kg/m3 , the use of soft thermal insulation materials is not recommended;
- when using natural or artificial stones as the outer layer of slabs cladding, horizontal joints must be open (must not be filled with a condensing material) .

Thermal insulation of exterior walls should be designed as a continuous stream on the facade of a building. Elements such as ventilation ducts and nails that attach the insulation must not destroy the integrity of the insulation layer. Air ducts, ventilation ducts and pipes, that partially go through a wall, should be placed next to the warm surface of the insulation. If flammable insulation is attached to the building envelope, windows and other openings should be framed with non-flammable mineral wool insulation strips of minimum 200 mm in width, with minimum 80 - 90 kg/m3 density.

These structures must have permits for use from the federal fire control authorities.

KEY POINTS TO REMEMBER FROM CHAPTER 42

- **Depending upon the type of construction, there are various types of materials for walls: stone, wood, concrete and combined materials which are available in the form of big blocks, panels and small-sized stone materials**
- **From the viewpoint of thermal insulation there are two types of external walls: single-layer and multilayer.**
- **Heat losses through the walls of the building (transmission heat losses) may be more than half of all heating costs**

Some very important indicators for the calculation of building energy efficiency are:

- **reduced thermal resistance of a building envelope – the extent to which a wall, door, window or roof prevents passage of heat from the house to the outside and vice versa, cold from the outside into the house**
- **specific heat consumption for heating of a building – how much heat is required for heating one cubic meter of a building when the temperature changes by one degree.**
- **Important requirements for the walls include water permeability, soundproofing, and carrying capacity of the walls. However, currently, there is no wall material that effectively meets all these requirements.**

43. Windows

It was noted earlier that enclosing structures such as windows, balconies and doors plays a major role in energy saving. Transmission losses of enclosing structures depend not only on the characteristics and condition of the facade material, but also on the type and condition of window, balcony and door blocks, as well as the quality of their installation.

43.1 Typology, common structures

A window is an element of the wall or roof structure, designed for connecting interiors with the surrounding space. It allows natural lighting and ventilation, and protects from weather and noise. Currently, glass unit PVC window frames are installed both in new construction and in building renovation. PVC windows have a range of advantages, but they are not the only option. Other window units on the market have frames and boxes made from the following materials:

Materials used for window frames

- wood (glulam);
- aluminium;
- polyvinyl chloride (PVC);
- fiberglass (glass composite);
- steel;
- a combination of materials (wood-aluminium, wood-polyvinyl chloride, etc.).

43.2 Thermal insulation needs

Disadvantages of wooden window frames

Two-leaf wooden window frames with double glazing are common in houses built in past decades. They have disadvantages: sensitivity to external influences and changes in weather conditions (wood swells, cracks; frames fade in the sun, as they are not resistant to ultraviolet rays), and have low heat and noise insulation characteristics ; they are susceptible to physical deterioration, air leaks, leading to gapping of window elements and the occurrence of cracks. The width of the wooden window block is several times greater than the width of modern windows. The lifetime of these window units is 15 years.

Thus, it is recommended to replace these old wooden window frames with modern windows which provide 20-25% more efficiency due to improvements in both frames and glazing.

Double- or triple-glazed window panes have been available on the market for many years. Each layer of glass will reduce the U-value by about 2,0 W/(m^{2}K). However, for a truly energy efficient buildings such a reduction is not enough.

The wider the space between the panes, (typical distances between the panes: 12 mm, 16 mm) the better is the insulation effect. Window panes, where the space between the panes is sealed airtight, have even better insulation properties.

Additionally, windows can have a coated glazing which increases their insulation properties. Coatings are used to minimize heat transmission from the inside to the outside.

Modern window frame design allows changing the number of glass unit chambers: they use glass that provides optimal operating conditions in different regions and climatic zones, as well as reducing installation costs. The width of the profile and number of chambers (glass) of a glass unit depend on the climatic conditions, and if necessary, energy-saving coating is applied to the glass and the thickness of the glass is increased (from 4 to 6 mm) to improve the sound insulation.

Furthermore the design of the frame aims to lower the heat transmission losses of the frame itself.

The following figures illustrate a modern PVC window:

Appearance of PVC window constructions

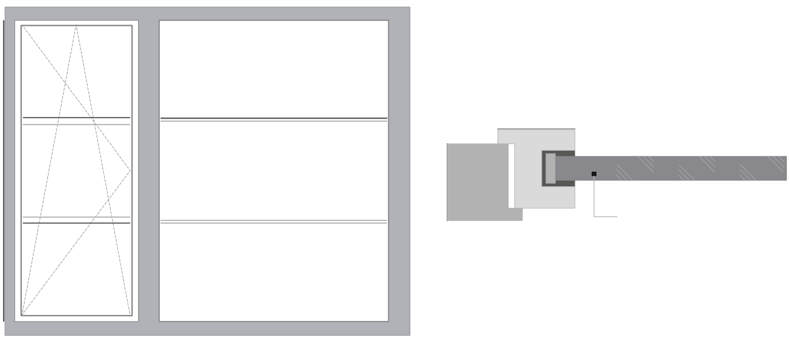


Figure 43-1: Window construction, front view (left side) and top section (right side)

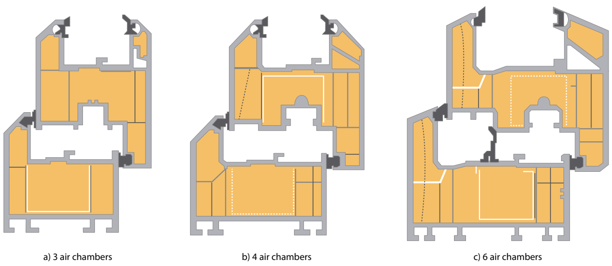


Figure 43-2: Frame sections: 3 air chambers (left side), 4 air chambers (centre), 6 air chambers (right side)

43.3 Practical solutions and recommendations for refurbishment

The most common products for mass construction which meet the requirements of modern windows are made with PVC frames. PVC window units are produced in many cities and regions and correspond to the climate conditions. To determine the optimal characteristics it is recommended to consult with a dealer (representative) in your area.

Great attention should be paid to the technology of installation of window units. Both the operating characteristics of window units and also the thermal insulating characteristics depend on the quality of installation. Picture 6 illustrates an installation example in a sectional view.

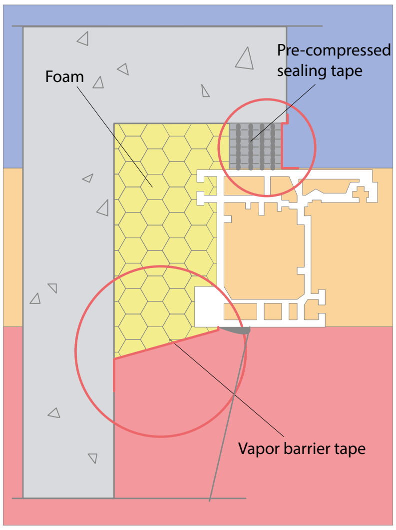


Figure 43-3: The constituent elements of PVC frames insulation

Figure 43-4: Vapour seal tape (foiled tape, left) and installation wedges, fixed with foam (right)

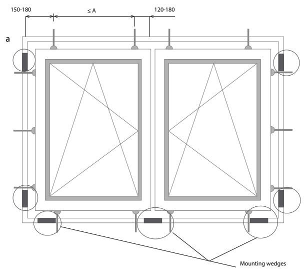


Figure 43-5: Location of installation wedges

Window frames should be set strictly on the level with the help of installation wedges, in the horizontal and vertical planes (see figure 43-5). Then, gaps are filled with foam (Picture below, left)

Figure 43-6: Installation foam (left), vapour seal (right)

The excess installation foam is cut off with a special knife after it has dried (figure 43-6, right). The section of the porous foam that is visible is smoothed with plaster or closed with a decorative plastic angle.

It is possible to reduce heat loss through the windows further by insulating the glass with heat- conserving ceramic IR tape. In summer, the IR tape limits penetration of UV (ultraviolet) rays into a room, preventing objects and furniture from heating, which not only creates more comfortable conditions but can also reduce air conditioning costs. In winter, IR tape reduces the thermal conductivity of glass, thereby keeping heat inside the heated room.

Once new windows are installed properly, air exchange becomes an important topic. If the former natural ventilation is now interrupted by the new airtight windows, moisture and mould may occur (see modules 2 on building physics and 9 on heating and ventilation). It is important to think about a ventilation concept. There are modern windows on the market with artificial gaps.

KEY POINTS TO REMEMBER FROM CHAPTER 43

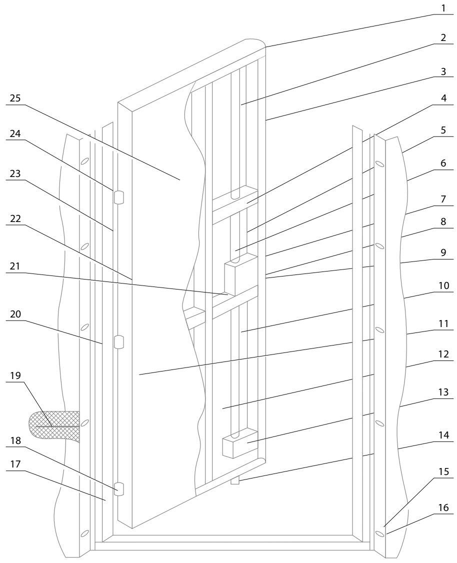
- **The following materials are used for the production of window frames: wood (glulam), aluminium; polyvinyl chloride (PVC); fiberglass (glass composite); steel; combinations of materials**
- **Old window frames are less durable and 20-25% less effective than modern windows**
- **PVC frame design allows changing the number of glass unit chambers and uses glass with characteristics that provides optimal operating conditions in different regions and climatic zones, and reduces costs of implementation**
- **The use of ceramic IR tape to increase insulation around windows will prevent additional heat loss**
- **New airtight windows may interrupt the natural air exchange The "ventilation concept" should be reconsidered.**

44. Doors

44.1 Typology, common structures

Types of doors

Doors not only provide heat conservation, affect the aesthetic appearance of the building, provide interior comfort, but can also protect rooms from moisture, dust, cold and drafts. Entrance doors are often exposed to external loads, protecting the house from bad weather and intruders. Doors are components of balcony blocks. Wooden door blocks are made of various materials such as wood, steel, aluminium, and plastic. Plastic is the most preferred material because it is more universal and is able to meet the needs of almost any user, combining affordable price and easy maintenance.



1. Top locking beam.
2. Top traction of the main lock .
3. Leaf frame (welded steel profiles).
4. Places of attachment of the internal "flap".
5. Bolt.
6. Places of attachment of the upper traction.
7. Beams of a bolt of lever lock.
8. Latch.
9. Bolt of a cylinder lock.
10. Low traction of a main lock.
11. Places of attachment of finishes.
12. Inner cavity for a filler.
13. Directing of a vertical traction.
14. Lower locking beam.
15. Mounting "ear".
16. Threshold.
17. Hole for the anti-removable beam (pin).
18. Anti-removable passive beam (pin).
19. Mounting anchor.
20. Box (frame).
21. Combined lever - cylinder lock.
22. Internal steel sheet.
23. Outer steel sheet.
24. Loop knot.
25. Peephole.

Figure 44-1: Door construction

44.2 Thermal insulation needs

Importance of proper door insulation

In contrast to windows, door units are operated daily throughout their service life. Thus, an inefficient door unit of an entrance door is able to significantly reduce the energy efficiency of a building. Currently there are many different types of designs and materials of door units. Among street door blocks the most common are steel blocks and PVC double-glazing units. The installation of door units is similar to the technology of installing windows: high-quality workmanship is needed to effectively insulate and strengthen the joining points of the door unit and building.

44.3 Practical solutions and recommendations for refurbishment

A lobby between the front door and an unheated stairwell, with the addition of a thermal curtain, is able to substantially increase the energy efficiency. A lobby is a passageway between doors, which is used to protect against cold air, smoke and smells when entering the building, stairwell or other premises.

KEY POINTS TO REMEMBER FROM CHAPTER 44

- **Door blocks are made of various materials such as wood, steel, aluminium, plastic**
- **Plastic is the most preferred material for door blocks because it is able to meet the needs of almost any user, combining affordable price and easy maintenance**
- **Proper door insulation can significantly contribute to a building's energy efficiency**
- **A lobby between the front door and an unheated stairwell, plus installation of a thermal curtain at the entranceway will increase energy efficiency.**

45. Roofs and cellars

45.1 Typology, common structures

There are two popular types of roofs - pitched and flat. Usually, roofs with an attic are left without insulation - they remain cold; the attic slabs (attic floor) are insulated instead.

If an attic or garret is intended as living space (warm attic), the slopes of the roof should be insulated to reduce heat loss and heating costs.

Flat roofs

Flat roofs are rarely used for low-rise construction in continental climatic conditions, but are quite popular in industry and recently in civil engineering. In addition to its direct purpose - protection from the cold and precipitation - flat roofs of such buildings can serve as gardens, playgrounds, terraces of residential or public buildings and even as parking space. A flat roof can be fitted with an attic room, though more often it is designed without it (combined covering).

The main advantage of flat roofs is that they are inexpensive; the main drawback is the impossibility to regularly monitor the technical condition of the thermal insulation layer and the water tightness of the waterproofing carpet. Damage is revealed only when leaks appear on the ceiling. Flat attic roofs are a bit more expensive, but they do not have this disadvantage.

Technical cellars are cellars that contain lower pipe routing of a heating system, hot water supply and pipes of water supply and sewage systems.

The cellar, being the lowest (underground) part of the building houses various equipment and building systems. Temperature conditions are quite stable due to the heat-insulating properties of the earth and the lack of natural sunlight.

The basement has several entrance doors and windows. In most cases with an individual heating unit, networks of hot water supply and heating are located or go through the basement, providing warmth to the first floor slab in the cold season. It is nonetheless recommended to properly insulate the pipes and the cellar ceiling.

45.2 Thermal insulation needs

Modern roof requirements

When insulating any building, the greatest attention should be paid to the roof, as this part of the building is the most vulnerable to thermo-physical parameters. Statistics show that at least 25-40% of heat escapes through the roof. A modern roof must withstand temperatures down to -50°C, or even lower, and also have a high heat resistance: roof temperature can reach almost 100°C in summer. The roof also must be resistant to frequent temperature drops and transitions across 0°C, and ultraviolet radiation.

Roof and cellar insulations

Roof insulation is provided by a layer of material that has low thermal conductivity and good water resistance. Requirements for biological stability are high: materials should not support mould and mildew growth, they should not release substances hazardous to the human body, and should comply with fire safety requirements.

It should be noted that during the insulation of slabs over cold cellars, the diffusion of water vapour through slabs, as well as through all external structures separating zones of warm and cold air, occurs. Cellar ceilings should be insulated with proper material.

It is necessary to provide ventilation of cellars in order to prevent moisture in insulation materials and avoid dampness, mould and mildew. For this purpose, special openings and arranged air holes, through which water vapour will be removed outside with ventilated air, are made.

Waterproofing of cellar

It's important to remember to waterproof basement walls and floors. In spring, the ground water level rises considerably and reaches the earth's surface as the snow cover melts, so exterior waterproofing of basement walls, covering their full height, is strongly recommended.

Perimeter insulation

When cellars are warm, perimeter insulation is required. The building perimeter is in rather unfavourable humidity conditions, being subject to both ground and rain water. For this reason, materials that have zero water absorption and can protect thermal insulation properties in a damp environment are used for perimeter thermal insulation. Extrusion foam plastic with closed pores fully meets these requirements.

45.3 Practical solutions and recommendations for refurbishment of the roof

A roof with a cold attic floor interior space should be ventilated with outside air through special openings in walls. The attic space of a pitched roof made of piece-materials (asbestos-cement sheets, tiles) is ventilated through the gaps between its sheets.

In a roof with a cold attic floor, heat insulation is laid on the attic slab. An insulating layer around the perimeter of the attic should be installed up to least 1 m in height to protect it from moisture and to avoid thermal bridges. Ventilation ducts and air releases that go through a cold attic must be insulated.

In a roof with a warm attic floor, attic space with insulated exterior walls and insulated roof covering is heated by warm air that comes from the exhaust ventilation of the house. One exhaust shaft for each section should be used to remove air from the attic space. Attic space should be divided into isolated compartments by use of walls. Doorways in walls, providing pass-through in the attic, should have sealed rabbet ledges.

Combined roofs, i.e. roofs without an attic, can be constructed as ventilated or unventilated. Unventilated roofs are acceptable in those cases when moisture does not accumulate in the cold season, thanks to vapour barriers, etc. Ventilated coverings are needed when structural measures cannot guarantee good humidity conditions.

Combined ventilated roofs are recommended for residential and public buildings. The recommended design of a ventilated roof covering without an attic floor (combined roof) may contain the following layers, starting from the lower surface:

- bearing structure;
- vapour-sealing layer;
- heat insulating layer;
- ventilated layer that serves to remove moisture from the roof structure or for cooling;
- base for waterproofing (screed coat or roof slab with ventilated gap interlayers);
- multilayer waterproofing roofing carpet.

Fibrous insulating materials in ventilated coverings must be protected from exposure of vented air by vapour permeable membranous coatings.

Draining air layers and channels should be located above the thermal insulation or in its upper zone. The minimum cross-sectional size of these layers should not be less than 40 mm. Air supply inlets should be arranged in the cornice parts, exhaust outlets - on the opposite side of the building or in the ridge. The total cross section of both air supply inlets and exhaust outlets is recommended to set within 0.002 - 0.001 of the horizontal projection of the coating.

45.4 Practical solutions and recommendations for refurbishment of the basement

During the insulation of plate socle slabs, heat insulation is laid on the bearing plates, placing it among the beams mounted on a reinforced concrete slab through the layers of roofing material, asphalt felt or other waterproof material.

A vapour seal, which prevents wetting of heat insulation by water vapour of internal air, is arranged above the insulation. The fabric of the vapour seal material is rolled with an overlap of at least 100 mm, and then joints are glued with a special tape or duct tape to ensure impermeability. When using foil vapour seal materials, they are set with the shiny surface facing into a warm room. In this case, there is a need to provide a small air gap between the vapour seal and a floor base. Holes (100x100) - (150x150) mm in size are set to arrange basement ventilation: they are placed every 4-5 m on the perimeter of the basement. Moisture will be able to evaporate to the outside, and the basement will not smell of damp and mould.

It is possible to insulate the existing socle slab by attaching the insulation plates to the slab from the basement side. For this purpose the hard insulation is glued to the reinforced concrete slab by adhesive mastic and is then plastered on a grid.

The need for insulating an existing basement slab can appear during maintenance of the house. It is not necessary to disassemble the floor on the first level; it is better to insulate the slab from the basement side.

Many homeowners are worried about cracks in the walls and misalignment of external structures, which usually appear in spring. This unpleasant phenomenon is due to the deformation of foundations caused by frost soil expansion. Ground is good at absorbing water, which increases in volume while freezing. This leads to an increase in the volume of soil which is under the foundation. These processes push out the foundation from the ground. In addition, water-saturated soil becomes more ductile and less durable during melting. This causes subsidence of foundations and, as a consequence, misalignment and cracking of walls.

Traditional measures aimed at reducing the impact of forces of frost exposure, provide an arrangement of sand pillow of at least 100 mm in thickness under the foundation and the use of backfill of sand rather than exposed soil. These measures partially solve this problem, but complete elimination of the consequences of frost exposure is possible only by the elimination of their causes - freezing ground - by insulation of the perimeter of the building's foundation. This can be done by a thick layer of sand (200 mm) on which slabs of extruded polystyrene are laid.

It's better to remember that the heat loss through the exterior corners is much greater than the heat loss through the flat surface, so insulation in corners should be 1.4-1.5 times thicker than along walls. The top insulation layer is surrounded with sand not less than 300 mm in thickness.

KEY POINTS TO REMEMBER FROM CHAPTER 45

- **The most popular types of roofs are flat and pitched**
- **The main advantage of flat roofs is their low cost. But the main disadvantage is the impossibility of permanent monitoring of the technical condition of the thermal insulation layer and water tightness of the waterproofing carpet. Damage is revealed only when leaks appear on the ceiling**
- **While insulating a building, great attention must be paid to roof insulation. Statistics show that at least 25-40 % of heat escapes through the roof**
- **Roof insulation is provided by a layer of material that has low thermal conductivity and good water resistance. Materials used must also have biological stability**
- **It is important to provide proper cellar insulation and ventilation; waterproofing is essential.**

46. Mould prevention

46.1 Typology, common structures

Mould can arise when residents start to insulate walls and seal windows in order to save heat. Without additional measures, this decreases the ventilation drastically and about 8 - 15 litres of water vapour can start to accumulate in the flat each day.

During the design and construction of residential buildings, a system of natural ventilation is designed in such a way that the volume of air that enters the apartment is sufficient for the residents and can be heated by the existing heating system. Thus besides special ventilation holes in apartments, there are also other ways to provide proper air exchange: all interior doors in the apartment, as well as clearance under the doors of the bathroom and toilet, usually not less than 2 cm, allow some air flow.

Natural ventilation

Natural ventilation has its own advantages, primarily, its simplicity and lack of required maintenance.

When the natural ventilation system is disrupted, mould can occur. The ideal temperature for mould to grow and spread is 20°C when humidity exceeds 95 percent. Poor air exchange, high humidity and air stagnation promote the growth of mould. Mould can spread extensively - on the plaster, concrete, plastic, wood, fabric base of linoleum, rubber, carpet, painted surfaces, books, etc. Flower pots provide good conditions for mould growth. Microspores climb up through the ventilation from damp cellars. Fungus spores multiply quickly in moist and cool premises, and where there is poor air circulation. Improper heating also can lead to arising of moisture. Abrupt changes of air temperature can transform water vapour into moisture that condenses on the walls.

46.2 Practical solutions and recommendations for preventing mould

The most important thing to remember is to keep the humidity low. Water vapour should not enter the rooms, for example from boiling kettles or cooking, or from drying wet clothes in the apartments. With central heating, drying things on a radiator releases a lot of moisture. Excess water can be removed by airing rooms intensively for a short time. All the windows and doors must be opened. Such brief, intensive airing is not conducive for heat loss of the walls. Windows that are open just slightly (outward-opening or in top-tilt position) do not adequately/fully remove moisture and cause the flat to cool down. Air conditioners also reduce humidity. Also recommended are air cleaners which are equipped with special filters.

Especially in colder climates, proper heating must be provided and the heating system must be kept in good repair. If the heat network deteriorates, district heating might not be enough to heat all flats. In such cases, additional heating of premises is required. It isn't recommended to turn off the heating at night, since moisture on the walls can increase when the room cools. Covering cold and wet walls with carpets is not recommended: the air stagnation under the carpet creates a big difference in the temperature of the air in the centre of the room and under the carpet. Water vapour penetrates through the carpet and settles on the wall in big spots, causing the wall/paper behind the carpet to turn black from fungus. Furniture should be arranged in a way that bulky objects are not set directly against the wall, so that the airflow is not restricted. Leaking taps should be repaired in a timely manner. If humidity persists, tenants should consider reducing the number of houseplants.

Air temperature throughout the apartment should be uniform. If only one room is heated, warm vapours will escape through the gap in the doorway and condense to moisture in the cold room. As the result the cold room will also become soggy.

Technical options to improve the ventilation of flats are discussed in the module on heating and ventilation.

KEY POINTS TO REMEMBER FROM CHAPTER 46

- **Poor air exchange, high humidity and air stagnation promotes the growth of fungi/mould**
- **Improper heating can lead to moisture. Abrupt changes of air temperature can lead to the transformation of water vapour into moisture that settles on the walls**
- **The higher the humidity in the room, the higher the dew point and closer to the actual temperature of the indoor air**
- **Controlling air humidity is the best way to prevent formation of mould in a room.**

47. Thermographic imaging

Thermographic images can help identify thermal bridges and transmission heat losses through windows, doors and other openings. They allow the detection of errors in the design and construction. The following illustrations show some examples of such mistakes.

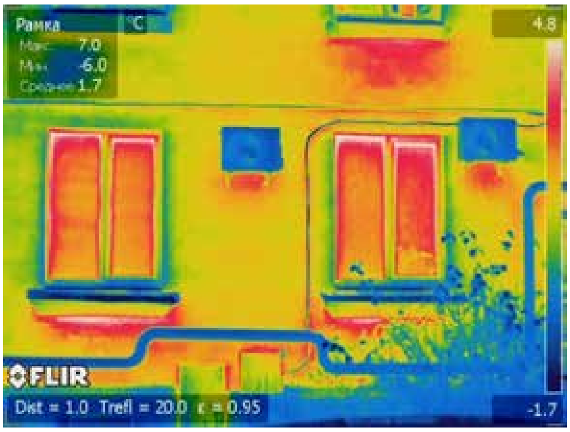


Figure 47-1: **Heat leakage through the joints of walls and improperly installed windows units and air conditioners**

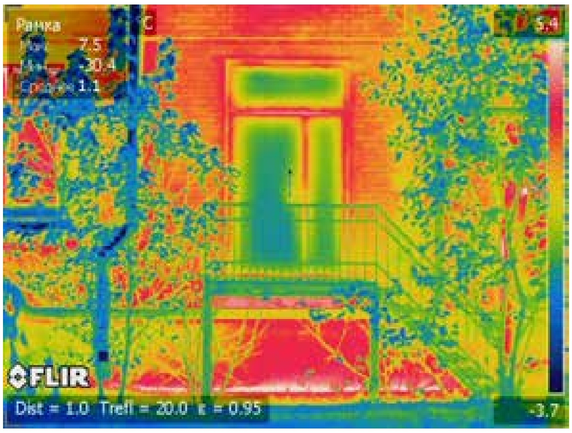


Figure 47-2: **Heat leakage through the joints of walls and improperly installed door unit**

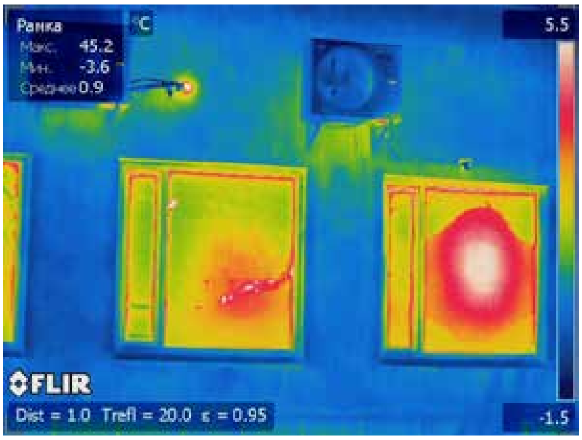


Figure 47-3: **Heat leakage through the joints of walls and improperly installed windows units and air conditioners**

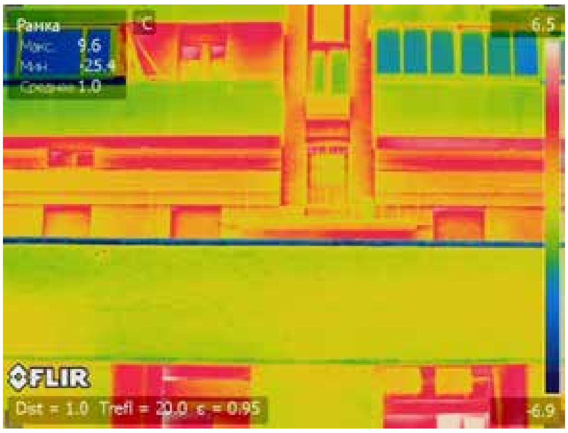


Figure 47-4: **Heat leakage through the joints of walls and improperly designed balcony slab**

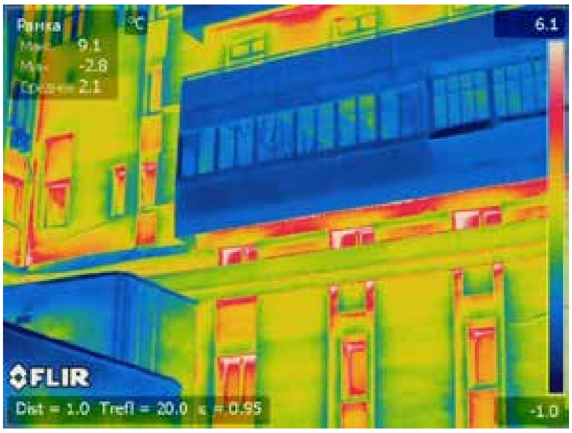


Figure 47-5: **Heat leakage through the joints of walls and improperly designed balcony slabs**

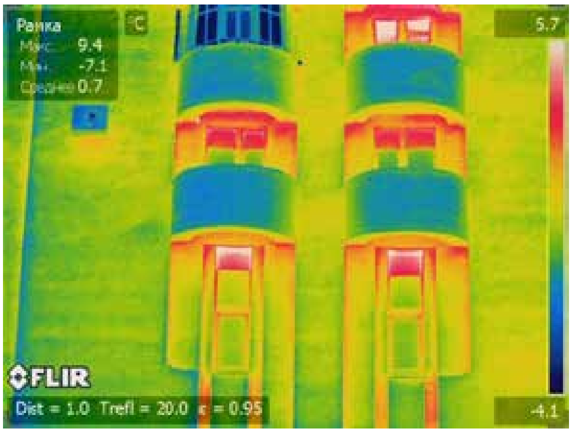


Figure 47-6: **Heat leakage through the joints of walls and improperly designed balcony slabs**

9

Heating, ventilation and cooling

WHAT WILL YOU LEARN IN THIS MODULE?

Indoor comfort is largely dependent on temperature. In our climate zone, we experience annual temperature differences between winter and summer of up to 50 degrees and our buildings must be equipped to ensure a pleasant indoor climate in cold winters and hot summers. In this module we will explain how heating systems work, what types of ventilation systems exist and how cooling can be ensured on warm at hot days. Especially passive and active cooling methods will become more important in the future as climate change will increase the likelihood of extreme weather events amongst them heat spells in summer.

48. General introduction: Typical Situation before refurbishment

48.1 Weakness of existing system, no regulation, no individual metering, losses in distribution system

A large part of the existing building stock was constructed in the period between the late 1950s and the late 1990s. During that time, the main goal was to provide apartments for inhabitants as fast as possible without any respect to energy efficiency. The oil, gas and coal prices were so low in many countries around the Baltic Sea that there was no need for additional heat insulation of the building envelope or for efficient heating and ventilation systems. The situation was similar in Western and Northern Europe until the 1970s when the energy prices forced governments to introduce energy saving ordinances. In order to optimize construction time in times of shortage of flats, one-pipe systems were widely used in Central and Eastern Europe and the Baltic States. Due to the lack of low-noise circulation pumps and the absence of individual heat regulation in apartments, the possibilities to adapt the individual thermal comfort were limited. Consequently, many apartments were overheated and the temperature was regulated by opening the windows. In those times there was no heat metering of the real consumption, either per apartment or apartment building as a whole. The tenants paid for heat per square meter according to a specific methodology.

Before the 1990s the centralized heating systems in Central and Eastern Europe were typically constructed with the use of external centralized heat substations and four pipe systems. In addition, pipes were placed in special concrete channels and were poorly insulated which resulted in high heat losses. The external centralized heat substations provided the hot water and heat supply for up to 20 buildings (figure 48-1).

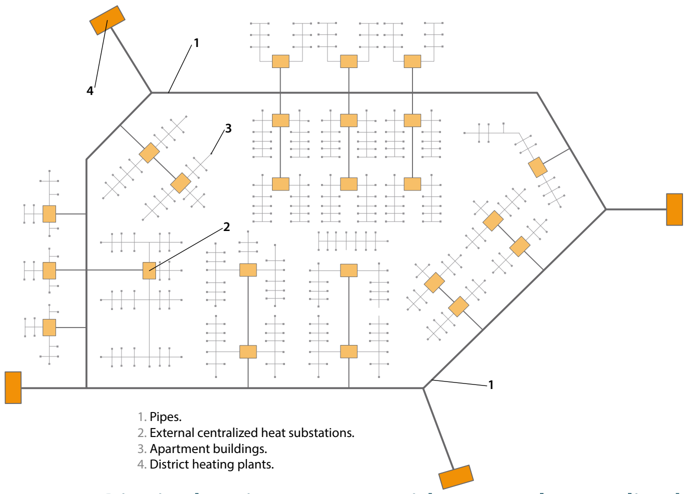


Figure 48-1: District heating systems with external centralized heat substations (used before 1990s).

Modern buildings have individual heat substations which ensure hot water preparation inside the building and provide heat metering per building. Some new apartment buildings may have heat metering per apartment in addition to the common heat meters of the entire building.

Buildings constructed before the 1990s have often been equipped with mandatory natural ventilation systems. The fresh air in such buildings flows in through the gaps between window frame and window carcass. The exhaust air leaves through the vents, which are situated in kitchens and bathrooms. Nowadays, during the construction of new buildings and the renovation of existing ones, the mechanical exhausts from kitchens and bathrooms are commonly used and natural air supply is provided through simple air inlets in bedrooms. In many cases, after the renovation, the only natural exhausts persist in bedrooms, and ventilation is possible only by opening the windows.

The average heat consumption by an apartment building constructed before 1990 is often 220 – 280 kWh/m2. In some cases, heat consumption reaches up to 350 - 400 kWh/m2. The heat consumption depends not only on the building insulation level but also on maintenance. Proper operation of heating and hot water systems can significantly reduce heat consumption. Simple and inexpensive measures such as balancing heating and hot water systems, supply/return water temperature control and insulation of pipes, minimize room overheating, consequently improving total building energy efficiency.

49. Centralized system of energy supply

49.1 District heating system: generation and distribution

A typical district heating system consists of a heat generation plant, a network of pipelines and individual heat substations installed in each building. Individual heat substations ensure the hot water preparation and the optimal temperature regime of heating systems according to the building specifics and the requirement for thermal comfort.

Heat generation plants

Heat generation plants can be classified into boiler houses and co-generation stations. Boiler houses produce heat, which is distributed to the end-users for space heating and hot water preparation. The average efficiency of boiler houses is up to 60%. The co-generation stations produce electricity as well as heat: electricity is the main product and heat, a sub-product. The efficiency of co-generation stations is up to 90%.

The special pre-insulated pipes are used for heat distribution between the generation site and the end user. The pre-insulated pipes usually have polyurethane foam (PUR) heat insulation and a high-density polyethylene (HDPE) covering. In order to detect water leakages, special wires are integrated between the steel pipe and its covering. Some typical underground pipe installations are shown in figure 49-1.

Figure 49-1: Modern pre-insulated pipes for district heating systems

District heating can efficiently use a variety of different energy sources, especially local renewable energy sources such as wood waste, sewage sludge, etc.

49.2 Distribution inside the houses

49.2.1 General description

Heating systems for buildings consist of pipes, shutoff valve, balancing valve, heating elements, room thermostats and a local heat source or, in the case of a centralized heating system, an individual heat substation.

Heating system elements

Nowadays, heating systems for buildings are assembled using steel pipes and/or copper pipes. Due to the working temperature of PEX (Cross-linked Polyethylene) pipes which is limited to 70°C, they are widely used for radiant heating (warm floor and/or warm walls)

There are two main types of heating elements: radiators and convectors. Different types of heating elements are presented in Figure 2. Radiators exchange the heat with the room mainly by radiant heat exchange; the convectors take advantage of natural convection (air movement). Radiation or radiant heat exchange means the heat transfers from warmer to colder objects by infrared heat radiation. Convection is the heat transfer from the warmer to colder objects by air circulation.

Nowadays, panel radiators which combine benefits of convectors and radiators (figure 49-2e) are widely used

Figure 49-2: Heating elements: a) convector b) convector used before 1990 c) radiator d) modern column radiator e) modern panel radiator

The amount of heat supplied by a heating element depends on the surface area of the element and the temperature difference in supply and return water. All manufacturers provide data on the heat capacity of the heating element for a range of temperature differences. When refurbishing a building, it is strongly recommended to exchange all old heaters because the building heat losses are reduced; the flow temperature inside the heating system can be smaller as well. Furthermore, after decades of use, limestone accumulates in the pipes, decreasing the efficiency of the system.

Importance of a modern heater

There are two main types of building heating systems:

- Single pipe system;
- Double pipe systems.

The principal schemes of single and double pipe systems are shown in figure 49-3.

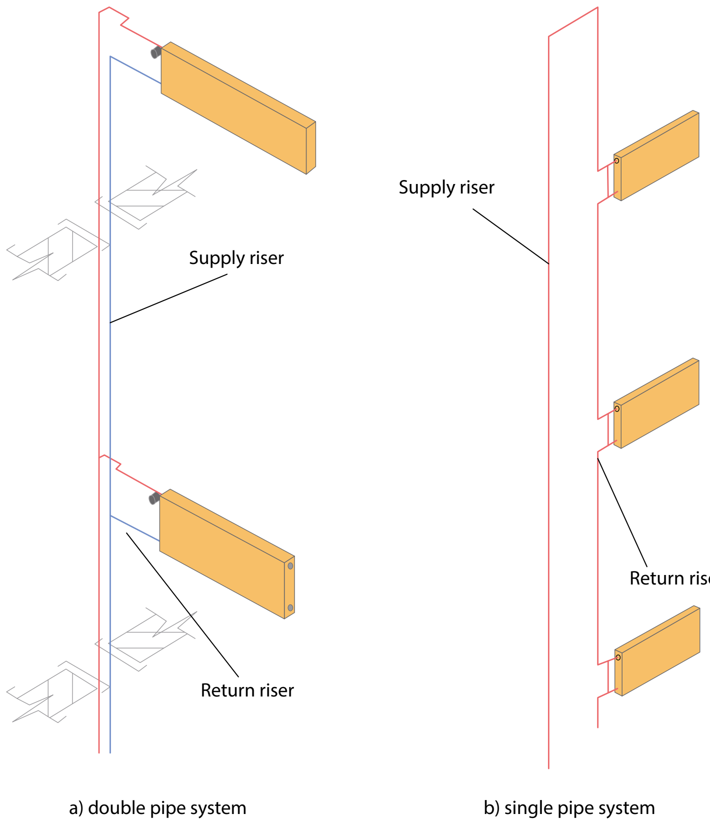


Figure 49-3: The principal schemes of single pipe systems and double pipe systems

49.2.2 Single pipe heating system

Single pipe heating system

Nowadays, single pipe systems are no longer widely used for new apartment buildings. Such systems should be evaluated in terms of existing building renovation. The principal scheme of single pipe systems is shown in figure 49-4.

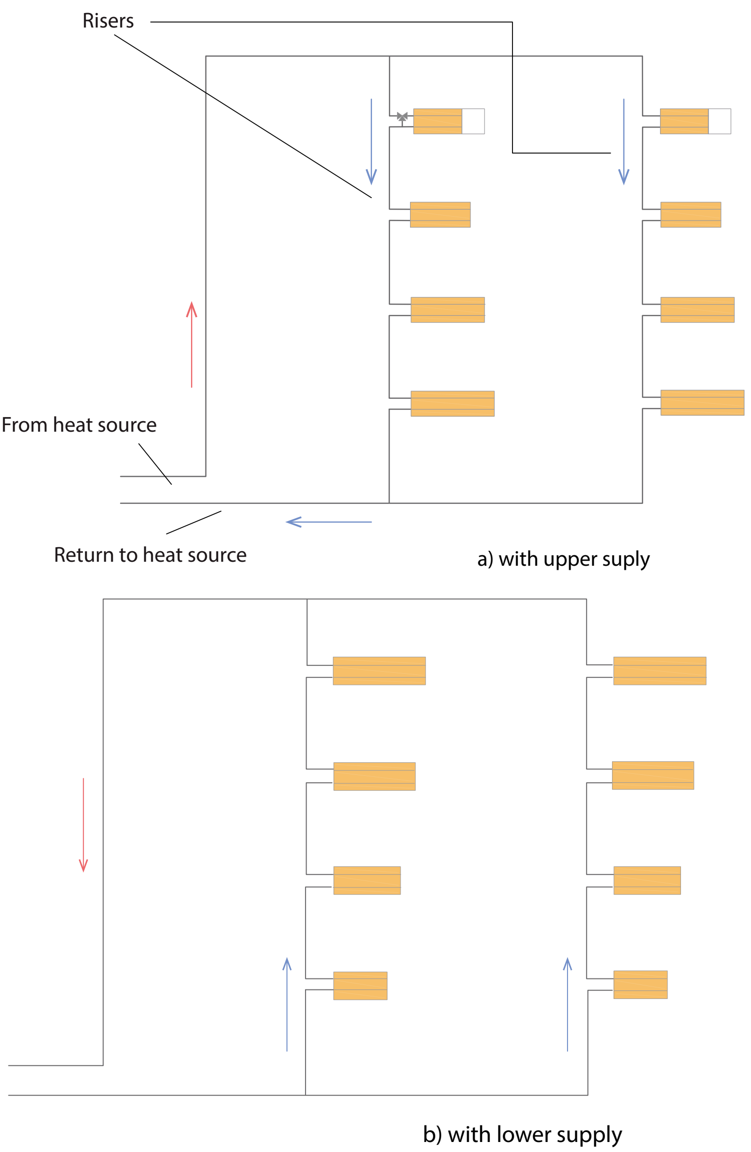


Figure 49-4: Single pipe heating system

Upper and lower water supply

Single pipe systems can have either upper or lower water supply. The temperature of the supply water passing through the heating system decreases due to heat exchange in the room. Consequently each consecutive heating element receives less heat. That is why the size of heating elements varies according to floor and heat supply scheme. Systems with upper supply can have a larger heating element on the top floor due to additional heat losses through the roof.

Old heating elements

The majority of old heating systems are unable to regulate the valve installation on heating elements. Regulation valves on single pipe systems may not be installed without additional bypasses that allow continuous water circulation in systems (Figure 49-5a). In some cases, old heating systems have 3-way valves, which allow for manual water flow regulation in each heating element without blocking water circulation in heating systems (figure 49-5b and 49-5c).

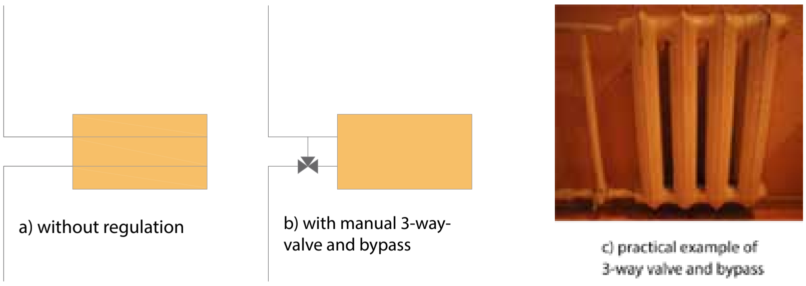


Figure 49-5: Heating elements connection widely used pre-1990s

Depending on indoor air temperature and heat gains, the solution presented in figure b and c might not allow for automatic water flow regulation.

The bypass line in combination with a regulation or shut-off valve can be used for improvement of existing heating systems without blocking the water flow circulation. A possible solution with bypass and shut-off is shown in figure 49-6.

Figure 49-6: Panel radiator connection to existing single pipe system with bypass and shut-off valve

49.2.3 Double pipe system

Double pipe systems

Double pipe systems ensure a uniform distribution of heat within the building and allow for individual temperature regulation. Some general schemes of double pipe heating systems are shown in figure 49-8.

The loop system

The loop systems are widely used in construction of new apartment buildings. The main benefits of such systems are a) individual heat metering in each apartment, b) easy system maintenance without blocking the heat supply to other apartments, and c) low temperature drop in risers, etc.

The loop system can be implemented during renovation of existing buildings. But the practical implementation of such a heating system is limited by extensive construction works in apartments, reduction of

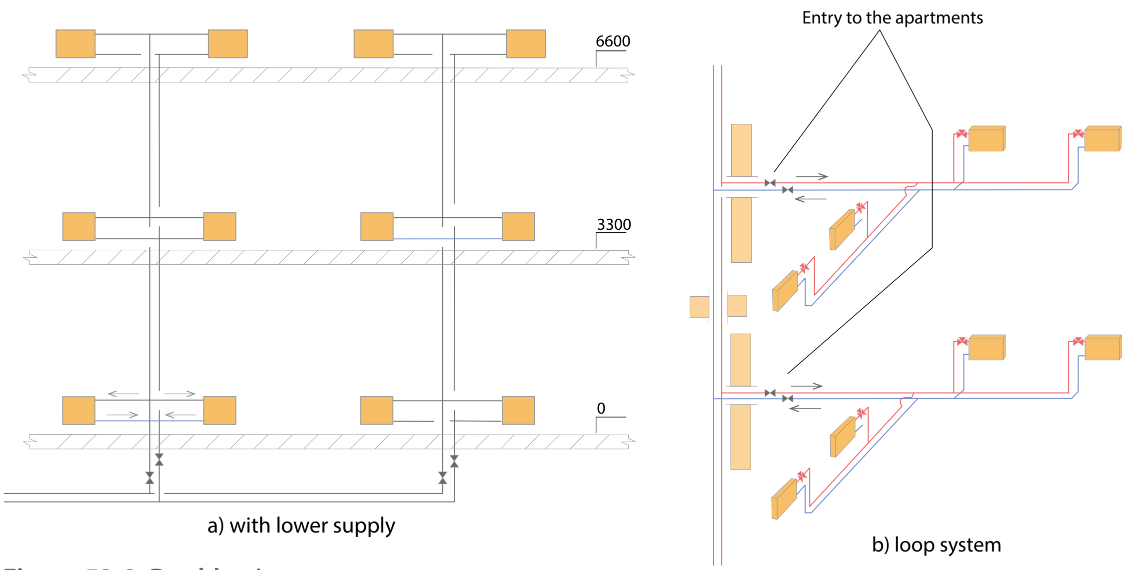


Figure 53-8: Double pipe system

space due to new pipes which are usually placed along the walls, and bigger initial investments.

KEY POINTS TO REMEMBER FROM CHAPTER 49

- **Individual heat substations ensure hot water preparation and the optimal temperature regime of heating systems, depending upon the building specifics and the requirement for thermal comfort**
- **Heat generation plants can be classified as boiler houses (production of heat and hot water) with 60% efficiency and co-generation stations (heat and electricity) with 90% efficiency**
- **Local renewable energy sources can be efficiently used for district heating**
- **The amount of heat supplied by a heating element depends on the surface area of the element and the temperature difference in supply and return water**
- **During a refurbishment, it is strongly recommended to exchange old heaters, as it will lead to the reduction of buildings´ heat consumption**
- **A double pipe heating system ensures uniform distribution of heat within the building and provides the possibility for individual temperature regulation**

50. Decentralized systems

50.1 Pros and cons of changing to a decentralized heat supply system

One of the main benefits of a decentralized heat supply system is the absence of an extended network of heating pipelines. Consequently, the building heating system's heat losses are minimal. Decentralized buildings heating systems are widely used in construction of new buildings when there is no centralized city heating system and existing gas pipes network. The gas pipes network has to ensure sufficient gas pressure in order ensure an optimal working regime of all gas boilers.

Main benefits of centralized heat supply systems:

- can be efficiently maintained by housing company;
- better control of CO_2 emission;
- minimal number of chimneys (usually max. 2) and natural ventilation shafts;
- more available space in apartments;
- safe operation due to absence of wide network of gas pipes in building.

Main benefits of decentralized heat supply systems:

Benefits of decentralized heating systems

- no heat supply breaks in building in the case of individual boiler breakdown;
- minimal heat loss from pipes;
- independent operation in each apartment;
- length/timing of heating season can be controlled (in accordance with individual needs of apartment's inhabitants.)

50.2 Types of decentralized systems

Implementations of decentralized heating systems

There are not too many ways to implement decentralized heating systems in multi-apartment buildings. The two main possibilities are installation of individual gas boilers or small flat heat substations in each apartment. Both solutions significantly reduce the length of distribution pipes for heating and hot water systems.

50.2.1 Low temperatures boilers

Low temperature boilers

Even in modern high-efficiency boilers, waste heat in the exhaust gases is lost to the atmosphere via the boiler flue. Water vapor is one of the exhaust gases. In classic boilers this water vapor condenses in the chimney and is drained away. The condensing boilers have extra heat exchanger surfaces to extract heat from exhaust gases and supply it to heating systems (figure 50-1).

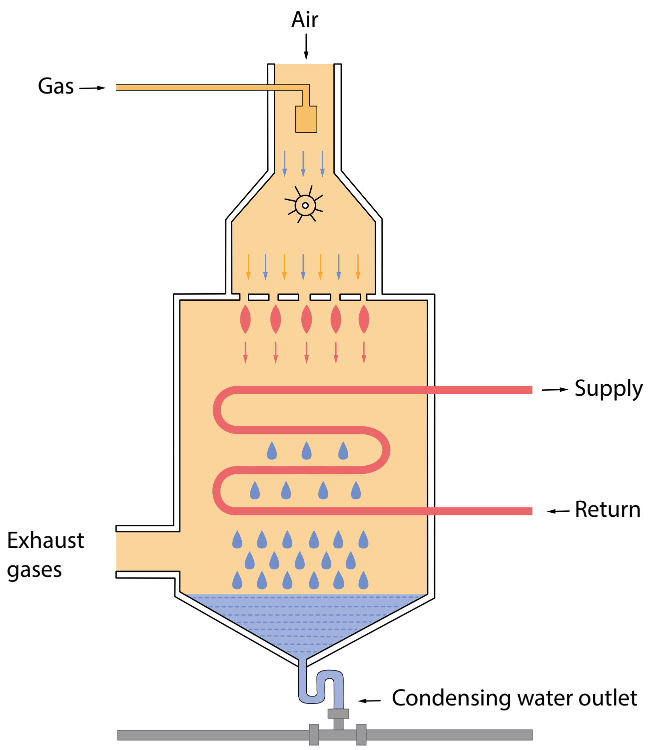


Figure 50-1: Principal working scheme of condensing boilers (Source: http://www.junkers.lv/)

The best efficiency of condensing boilers can be achieved in combination with low-temperature under floor heating. This allows achieving 97% efficiency.

50.2.2 CHP

The heat and electricity can be generated simultaneously by cogeneration stations. The combined production of heat and electricity ensures rational use of primary energy as well as having a positive effect on the release of greenhouse gases and particles into the environment. **CHP**

The main benefits of Combined Heat and Power systems are:

- Higher efficiency in comparison to boiler houses: up to 90% efficiency;
- Lower greenhouse gas emissions;
- Possibility to provide electricity.

Usually, CHPs are used for electricity and heat production at city or big-scale factories. It is possible to operate CHP using various resources such as natural gas, biogas, biomass, etc.

KEY POINTS TO REMEMBER FROM CHAPTER 50

- **Both centralized and decentralized heating systems have advantages. A centralized system is safer due to the absence of a wide gas pipe network; the decentralized system provides minimal heat loss from pipes and allows control of the heating season according to individual apartment residents' needs**
- **A decentralized heating system can be implemented by installation of either individual gas boilers or small flat heat substations**
- **CHP generates both heat and electricity and have up to 90% efficiency.**

51. Efficiency of technical equipment

51.1 Efficiency of distribution: Insulated pipes

Usually heating and hot water system pipes in buildings constructed before 1990 are poorly insulated or not insulated at all. However, steel is an excellent heat conductor. The thermal conductivity of steel is 17 W/(m^2·K), more than 450 times higher than that of heat insulation materials. As the result, in addition to heat losses through the building envelope, the existing non-renovated building has significant heat losses in its heating and hot water systems. The additional heat losses in pipes usually result in unnecessary overheating of unoccupied spaces, e.g. basement, staircases and attics.

Heat losses in poorly insulated buildings

Figure 51-1: Insulated pipes and non-insulated pipes

The heat losses through the one-meter steel pipes under different temperature difference between water and ambient air are shown in table 51-1. As you can see, the heat losses increase with the diameter of the pipe and temperature difference.

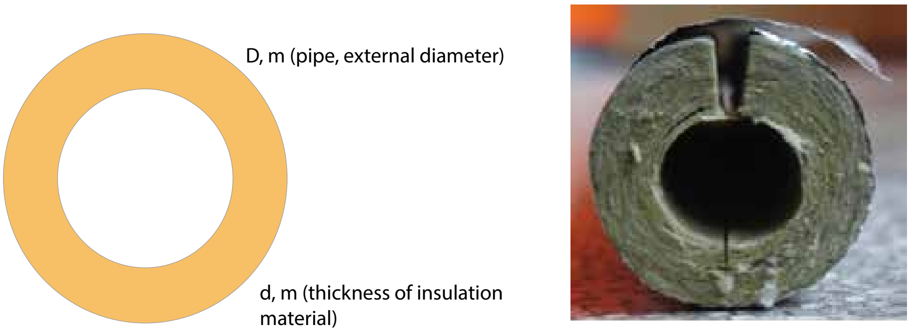
Heat losses and the resulting exploitation costs can be minimized by application of heat insulation materials on heating and hot water pipes. Special attention should be paid to spaces with low air temperature. Different types of insulation, similar to those used for the building envelope, can be used for heat pipe insulation. The most popular are mineral wool and expanded polystyrene foam insulation. A main criteria for choosing the best insulation solution is thermal conductivity and thickness of material. Some examples of pipe insulation solutions are shown in figure 52-2.

Pipes insulation materials

DN diameter	Temperature difference between water and ambient air (°C)											
	5	10	15	20	25	35	40	45	50	55	60	65
15	2	5	7	10	12	17	20	22	25	27	30	32
20	3	7	10	13	17	23	27	30	34	37	40	44
25	4	8	13	17	21	29	34	38	42	46	50	55
32	5	11	16	21	27	37	43	48	53	59	64	69
40	6	12	18	24	30	42	48	54	60	66	72	78
50	8	15	23	30	38	53	61	68	76	83	91	98
60	9	19	28	38	47	66	75	85	94	104	113	123
80	11	22	33	44	56	78	89	100	111	122	133	144

* the presented values are calculated for steel pipes with wall thickness 3 mm. The presented data may differ from other sources due to use of different calculation approaches and conditions of ambient air.

Table 51-1: The heat losses through the one-meter of steel pipes (W/m)



a) dimensioning

b) wool insulation with aluminium covering

Figure 51-2: Example of pipe insulation solutions.

For insulation of heat systems pipes, usually mineral wool insulation with aluminum covering (figure 51-2b) is used.

DN diameter	Temperature difference between water and ambient air (°C)											
	5	10	15	20	25	30	35	40	45	50	55	60
15	1	2	3	4	5	6	7	8	9	10	11	12
20	1	2	3	4	5	7	8	9	11	12	13	14
25	1	2	4	5	6	9	10	11	12	13	15	16
32	1	3	4	6	7	10	11	13	14	16	17	18
40	2	3	5	6	8	11	13	14	16	17	19	21
50	2	4	5	7	9	13	15	16	18	20	22	24
60	2	4	7	9	11	15	18	20	22	24	26	29
80	3	5	8	10	13	18	20	23	25	28	30	33

* the presented values are calculated for steel pipes with wall thickness 3 mm. Thermal conductivity of heat insulation material assumed as 0,04 W/(m·K). The presented data may differ from other sources due to use of different calculation approaches and conditions of ambient air

Table 51-2: The heat losses through the one-meter steel pipes with heat insulation with thickness 20 mm, W/m

51.2 Efficiency of circulation pumps

Circulation pumps

After the installation of individual heat substations, circulation pumps had to be installed to ensure the water distribution and circulation in the hot water and heating system of the building. The energy use of circulation pumps has an effect on the energy balance of the building. Using efficient pumps can decrease the energy consumption and can cut the costs for water circulation by half. Energy-efficient circulation pumps have a variable speed drive and a permanent magnet motor. Speed control enables the circulation pumps to adapt to the changing demands in heating systems such as individual radiator regulation, fluctuation of outdoor air temperatures, etc. (1). Circulation pumps should cover both peak demand and smallest possible demand. The peak demand lasts usually for two weeks per heating season, when outdoor air temperature drops to the lowest point.

In order to increase the efficiency of circulation pumps the heating system should be correctly sized with minimal friction losses. The pump dimensioning strongly depends on friction losses and the height of heating systems. System friction losses depend on water flow, amount of fitting, pipe diameters and pipe lengths. Each unnecessary pipe bend, valve or small pipe diameters increase total pressure drop in the system and should be compensated by circulation pumps. In other words, energy consumption by circulation pumps increases with unnecessary fittings, valves, reduced pipe diameters and excessive pipe lengths. Therefore, special attention should be paid to the design and construction quality of the heating system.

The use of modern energy-efficient circulation pumps with variable speed allows for reduced water circulation when there are lower heating system loads (for example: some radiators are turned off). Consequently, due to reduction of the necessary water circulation, the pump speed decreases, resulting in reduced electricity consumption by the circulation pump. The study (1) shows the difference between yearly energy consumption of different circulation pumps (table 51-3).

System Load Profile		Fixed speed before year 2005 Label C	New fixed speed after 2005 Label B	High efficiency (fixed speed) Label A	High efficiency (variable speed) Label A
Flow [%]	Time [%]				
100	6	18	14	10	8
75	15	45	34	26	15
50	35	101	76	60	26
25	44	123	93	76	27
total		287	217	171	76

* Calculations are based on a heating season of 285 days.

Table 51-3: Yearly energy consumption in kWh of different circulation pump options in a specific system (1)

Performances of circulation pumps

There are four different type of pumps, with increasing energy efficiency from left to right. For each pump type there is the same heating system load profile for one heating season: in this case the pump operates with full flow 6% of the time, with 75% of the flow during 15% of the time, and so on. You can see from the table that pumps with higher efficiency consume considerably less energy and will save operation costs.

Similar to many household appliances, circulation pumps have an energy consumption labeling scheme (figure 51-3). For example, energy consumption level may be from G (worst) to A (best).

Figure 51-3: Example of circulation pumps with different efficiency classes.

51.3 Efficiency of heaters

Performance different types of heating elemets

Efficiency of heating elements strongly depends on the quality of installation and connection types to the system. The main principles of proper installation of heating elements depend on heat exchange specifics between heating elements and environment. According to data (2), the approximate proportions of radiant and convective heat from the different types of heating elements are shown in table 51-4.

Heat exchange in the room

During the renovation of apartments, it is important to prevent any installation that would block the heat exchange. Use of decorative panels in front of radiators is not recommended because it blocks radiant heat exchange. Although radiant heat output for modern radiators is up to 50%, it provides better thermal comfort by increasing room mean radiant temperature. When using convectors, it is necessary to ensure air movement across convectors. Some 'good and bad practice' examples are shown in figure 51-4.

Possible solutions for radiator connections are shown in figure 51-4. The best solution ensures that water circulates through the entire radiator evenly; in a less efficient solution the water might not circulate sufficiently in the upper part of the radiator.

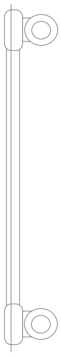
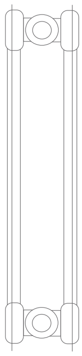
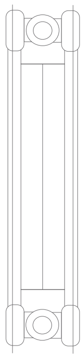
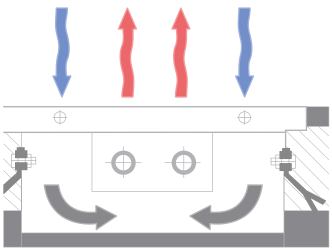
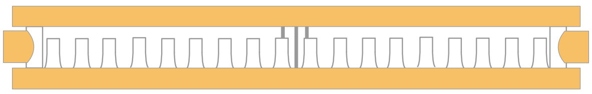
Type of panel	Principal scheme	Radiant output (%)	Convective output (%)
Single panel radiator		70	30
Double panel radiator		50	50
Triple panel radiator		30	70
Convector panel		......	100
Panel radiators		15-20	80-85

Table 51-4: Approximate proportions of radiant and convective heat from the different types of heating element

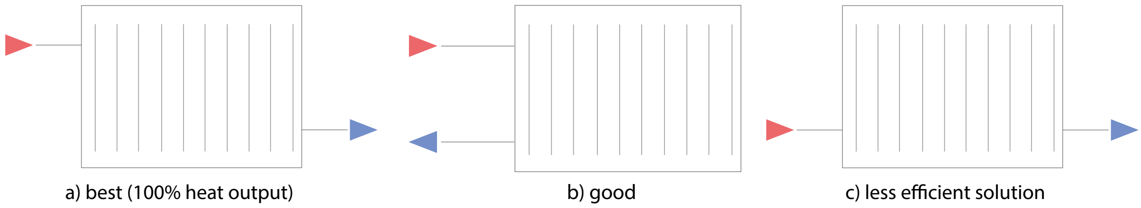


Figure 51-4: Possible connection solutions for radiators

51.4 Adjustable radiator thermostat valves

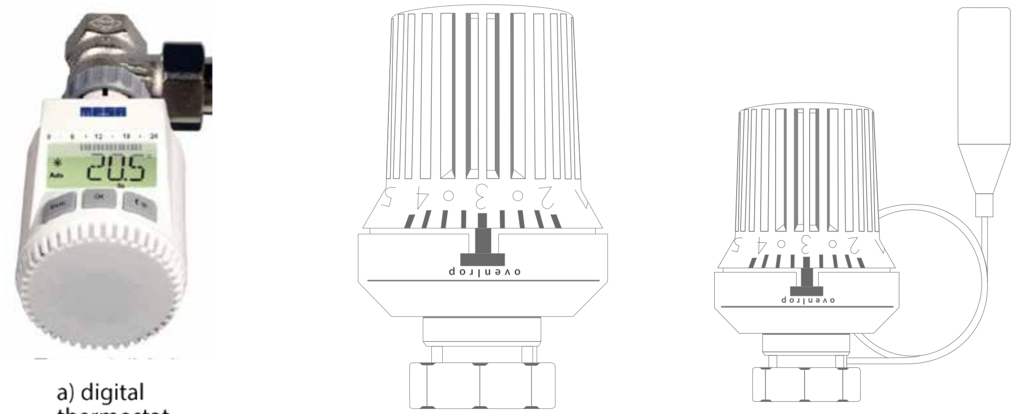
In order to control room temperature and to avoid unnecessary room overheating, each room should have a regulation device: simple, relatively cheap regulation valves can be used (figure 51-5). An advantage is that they do not block water flow to other apartments, however, regulation is possible only when the apartment is occupied. There is a great risk of water-freezing in radiators in case of rapid temperature reduction and/or long absence of inhabitants.

Figure 51-5: Valve for manual setting of water flow

Nowadays, thermostatic radiator valves (thermostats) are widely used for room temperature regulation. The thermostat includes two mandatory components – a thermostatic expansion valve and the thermostat or thermocouple.

Thermostat working position

The thermostat automatically reduces water flow through the radiator in case of internal heat gains such as solar gains, gains from household equipment, from lighting, inhabitants, etc. Consequently the overheating risk is minimized and heat loses are reduced. When room temperature drops below the set point, the water flow automatically increases. Modern thermostats have a special working position in order to prevent water freezing in radiators during a long absence of inhabitants or due to open windows. The "not-frozen" position will keep indoor air temperature at approximately 8 °C. Different types of thermostats are presented in figure 51-6.



a) digital thermostat

b) with remote sensor

c) standard

Figure 51-6: Currently available thermostats

Thermostats with remote sensors are used in the case of limited air circulation and hot or cold air pockets (for example, heavy curtains, low internal surface wall temperature or frequent, lengthy window opening).

Types of thermostats

A digital thermostat provides the possibility to program room temperature for long time periods (week, month) according to the inhabitants' need. It is possible to program automatic temperature reduction during the day and night. The digital thermostat automatically ensures temperature increase before apartment-dwellers wake up in the morning or return home from work in the evening.

Special thermostats which include a room temperature sensor are available for floor heating. According to the set temperature, the thermostat regulates heat supply. This kind of thermostat can be used in combination with the water system and the electric system.

51.5 Hydraulic balance

Hydraulic balance in heating systems

In practice, the heating elements are placed at different distances from the heat source. The pressure drop inside a heating system depends on the length and the diameter of the pipes and the water flow inside the pipes. Longer pipes have a bigger pressure drop than shorter ones. Loops with a smaller pressure drop provide better water circulation. Consequently, if the heating system is unbalanced, radiators which are closer to the heat source receive more heat than remote radiators. This can cause overheating in closets and colder temperatures in areas located far from the heat source.

In terms of water circulation, the long circulation loop creates a larger pressure drop than a shorter loop; therefore, better water circulation can be achieved through the short loop, due to the fact that is has smaller friction losses.

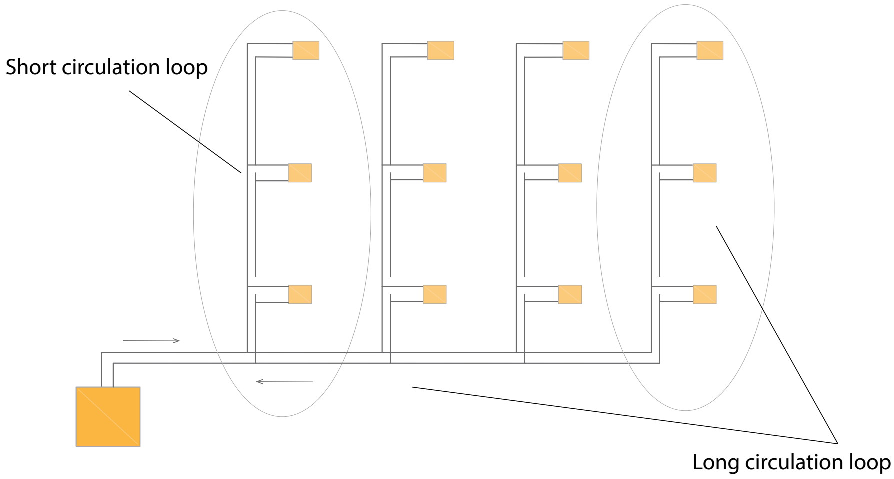


Figure 51-7: Heating systems scheme

Balancing valves

In order to insure uniform water distribution in systems, the pressure drop in all loops of a heating system should be equalized. Pressure drops are equalized by the use of balancing valves (figure 51-8), which adjust water flow. This ensures that the pressure drops in each loop are equal to the longest circulation loop. Balancing valves usually are placed on return riser pipes. Practical installation is shown in figure 51-9.

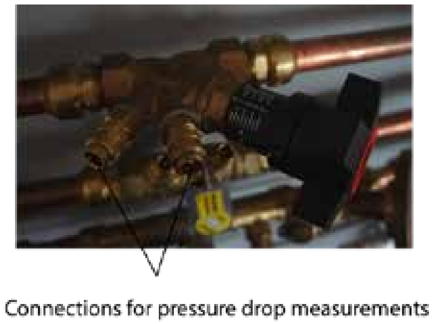


Figure 51-8: Balancing valve

Figure 51-9: Practical installation of balancing valves

Generally, the balancing valve on the remote riser should be fully opened and almost closed on the nearest riser. In order to ensure efficient operation of a heating system, both the system risers and the heating element within apartments should be balanced. Usually, radiator balancing is needed in two-pipe loop heating systems in order to ensure uniform water distribution within apartments. Practical installation of a radiator is shown in figure 51-10.

Balancing valves

Figure 51-10: Balancing of heating elements

51.6 Methods of metering

After installation of radiator thermostats, inhabitants are able to adjust the room temperature according to their personal needs. Heat consumption in apartments with lower room temperature will be smaller than in apartments with higher temperatures. Also, apartments with correctly installed radiators and proper operation of the ventilation system are more energy efficient. The implementation of heat metering in each apartment is a strong incentive for inhabitants to use energy more rationally. But the reduction of room temperature should be carefully evaluated in order to avoid water vapor condensation and mold growth. It is advisable not to decrease the indoor temperature below 16 °C in insulated buildings and 18 °C in non-insulated buildings.

Indoor climate regulation

The heat consumption in apartments can be measured by direct heat meters or heat cost allocators.

Heat cost allocators usually are used in one-pipe heating systems where heating elements in different apartments are connected to the common riser. Heat cost allocators do not measure real heat consumption but define each heating element's share in the building's total heat consumption. The total heat consumption of the building is measured by a direct heat meter (kWh, MWh) in the heat substation. The total costs are divided between all heat cost allocators according to their share. Modern allocators are electronic devices which must be attached to all heating elements in the building. The share of each heating element in the total heat consumption is calculated on the basis of temperature difference

Heat cost allocatiors

between the heating element and indoor air. A principal scheme of all heat cost allocators installation is shown in figure 51-11.

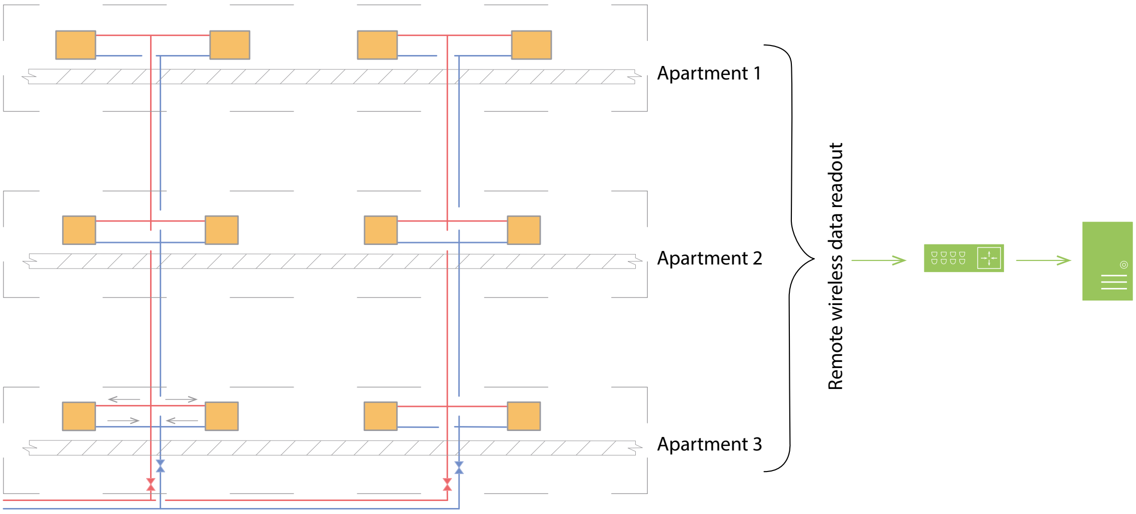


Figure 51-11: Installation of heat cost allocators

Direct heat metering can be implemented on double-pipe systems with loop distribution in apartments. Figure 51-12 presents practical installation of a direct heat meter in an apartment.

Figure 51-12: Practical installation of direct heat meter

Direct heat meters

Direct heat meters measure the amount of consumed heat by measuring the water flow and temperature difference between supply and return water.

Before installation of individual heat metering, the heat overflow between apartments as well as common heat consumption should be taken into consideration. Common heat consumption within a building includes heat consumption of staircases, technical rooms, and pipe and basement and heat losses. Heat flow specifics in multi-apartment buildings are shown in figure 51-13.

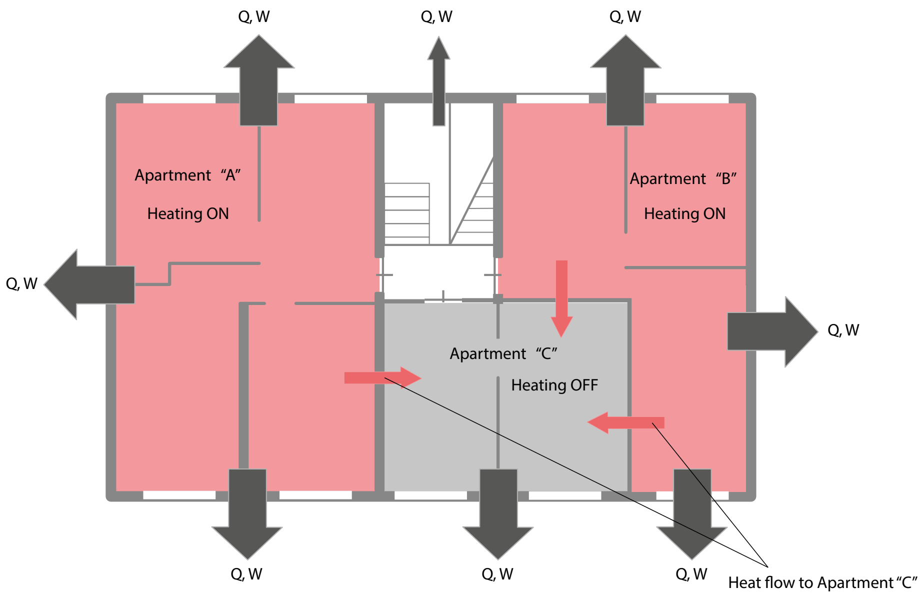


Figure 51-13: Heat flow specifics in multi-apartment buildings

Heat flow specifics

Note: Apartment "C" can receive heat through non-insulated internal walls and floors from neighboring apartments. Even with completely switched off radiators, Apartment "C" temperature will remain only a few degrees below that of neighboring apartments. If individual heat meters are installed in all apartments, the owners of apartment "A" and "B" will be charged more than apartment "C". This might be a small side-effect of installing meters.

KEY POINTS TO REMEMBER FROM CHAPTER 51

- **Usually, heating and hot water systems in the buildings constructed before the 1990s are poorly insulated or not insulated at all, which leads to significant heat losses**
- **A key criteria for choosing the insulation material for pipes is thermal conductivity and thickness of material. Some of the most popular materials are mineral wool (with aluminum covering) and expanded polystyrene foam**
- **Usage of efficient water circulation pumps can cut the costs by half**
- **It is important to insure air movement across heating elements and to prevent any installations that would block the heat exchange**
- **The installation of radiator thermostats allows adjustment of the room temperature according to personal needs**
- **Hydraulic balance in heating systems is important, since it provides the same amount of heat to each radiator.**

52. Ventilation

52.1 Importance of ventilation/air exchange

Indoor moisture generation and control

The main role of ventilation systems is not simply providing air for breathing but also to provide fresh air for removal of air pollutants such as carbon dioxide (CO_2), moisture and odors. On average, a person is able to survive 1,5 minutes without air. The human body needs only 6 liters of air per minute. But at the same time the average fresh air supply rate is 25 m^3 per hour per person for apartment buildings. This extra amount of fresh air is needed to remove pollutants generated by human activities. To achieve night cooling, ventilation can be used to remove the heat accumulated during the day. The carbon dioxide emission per person depends on the activity level. Doing normal work, the human body can produce up to 0,13 m^3/h of CO_2. The moisture production by human body is between 1 kg/day up to 3,1 kg/day according to data (3) (4). The moisture production from plants is up to 0,5 kg/day, personal hygiene (shower, hand wash) also adds up to 0,55 kg/day. Direct gas burning gives 1,1 kg per 1m^3 of natural gas (3).

The existing recommendation researches (5) (6) (7) on indoor air quality has shown that CO_2 concentration in indoor air should not exceed a level of 1500 ppm.

In general it could be recommended to keep relative humidity between 30% and 60% for indoor environments. Long periods of relative humidity below 30% can cause drying of the mucous membranes and discomfort for many people while relative humidity above 60% for extended time periods promotes indoor microbial growth.

The necessary amount of fresh air can be calculated taking into account data (8) approach on the basis of the formulas 52-1 – 3.

The necessary amount of fresh air in order to remove the excess amount of CO_2 is calculated as follows:

Formula 52-1

$$L = \frac{G}{c_{in} - c_{out}} \quad [\mathrm{m^3/h}]$$

where:

G – CO_2 production [kg/h]

c_{out} – outdoor air CO_2 concentration [$\mathrm{kg}_{CO_2}/\mathrm{m}^3$]

c_{in} – indoor air CO_2 concentration [$\mathrm{kg}_{CO_2}/\mathrm{m}^3$]

The necessary amount of fresh air in order to remove the excess amount moisture is calculated as follows:

Formula 52-2

$$L = \frac{W}{g_{in} - g_{out}} \quad [\mathrm{m^3/h}]$$

where:

W – moisture production [kg/h]

g_{out} – outdoor air moisture content [$\mathrm{kg/m^3}$]

g_{in} – indoor air moisture content [$\mathrm{kg/m^3}$]

The necessary amount of fresh air in order to remove the excess amount of heat gains is calculated as follows:

Formula 52-3

$$L = \frac{3,6\ Q}{\rho \cdot c \cdot (t_{in} - t_{out})} \quad [\mathrm{m^3/h}]$$

where:
ρ – air density [kg/m^3], (1,2 kg/m^3 at air temperature 20 °C)
c – specific heat of air [kJ/kg], constant: 1,005 kJ/kg
Q – heat gains [W]
t_{in} – indoor air temperature [K]
t_{out} – outdoor air temperature [K]

As it can be seen from formulas 52-1 – 3, the amount of fresh air strongly depends on the amount of water vapor, excess heat and CO_2 and difference of indoor and outdoor air parameters. In practical terms, it means that, in general, buildings in green suburban areas need less fresh air than buildings in a city center.

52.2 Methods of ventilation / air exchange concepts

52.2.1 Window / shaft ventilation

Fresh and exhaust air regulation

Almost all existing apartment buildings have natural ventilation systems. Fresh air flows into apartments through gaps between the window frame and the window itself or by opening the windows. After the installation of air-tight windows, the natural ventilation is significantly reduced and must be compensated by regular ventilation through opening the windows.

Thermal gravity effect

Exhaust air leaves through the vents, which are situated in kitchens and bathrooms. The driving force for air movement is the pressure difference between indoor and outdoor environments. Pressure difference depends on the wind speed and the density difference between indoor and outdoor air. The density difference between indoor and outdoor air is called 'the thermal gravity effect'. Thermal gravity is the main driving force for air exchange in shaft ventilation. The thermal density is caused by the temperature difference between the indoor and outdoor air. The thermal gravity effect at the ventilation shaft can be calculated as follows:

Formula 52-4

$$\Delta p = 9,81 h(\rho_e - \rho_i) \quad [\mathrm{Pa}]$$

where:
h – height of ventilation shaft [m]
ρ_e – outdoor air density [kg/m^3]
ρ_i – indoor air density [kg/m^3]

The aerodynamic resistance of ventilation systems

The aerodynamic resistance of ventilation systems must be lower than available gravity pressure. The thermal gravity is effective if the outdoor temperature drops below 5 °C.

The aerodynamic resistance of ventilation systems depends on duct friction losses and fitting losses. Friction losses per one meter of ventilation duct under different air volume is shown in table 52-1. The smaller the duct and the higher the air volume that flows through the duct, the higher friction losses will be.

Air volume m³/h	180	360	720
80	18	70	…….
100	6	22	80
125	2	7	25
160	0.6	2	7
200	0.2	0.7	2.5
250	…….	0.25	0.9
315	…….	…….	0.28

Table 52-1: Friction losses per one meter of ventilation duct (Pa/m) based on ASHRA data (9)

Friction losses depend on diameters of ducts and air volume. If it is not possible to ensure air exchange by thermal gravity effect, electric fans are used. The power and energy consumption of fans depends on aerodynamic resistance of ventilation systems. Electricity consumption will be higher for systems with bigger aerodynamic resistance. The optimal ventilation system solution is based on construction costs, operating costs and available space for ducts.

The air exchange rate in shaft ventilation systems is limited by indoor and outdoor air temperature difference. This type of ventilation system works efficiently in winter time when the temperature difference between outdoor and indoor air reaches up to 40 °C. In summer time there is no temperature difference; air exchange through shaft ventilation stops.

52.2.2 Cross ventilation

In order to remove air pollutants and heat gains, cross-ventilation can be efficiently used in summer time. The principle of cross-ventilation is shown in figure 52-1.

Cross ventilation in practice

Implementation of cross-ventilation can be especially efficient in office buildings for night cooling. During the day, the air exchange rate should be kept in a comfort range avoiding draught; during the night, the air exchange rate should be significantly increased in order to remove heat accumulated by building construction during the day. The main limitation for implementation of cross-ventilation is specific to wind directions and wind speed in the location. Leaving the windows open during the night can pose a safety risk (birds, burglars, etc.).

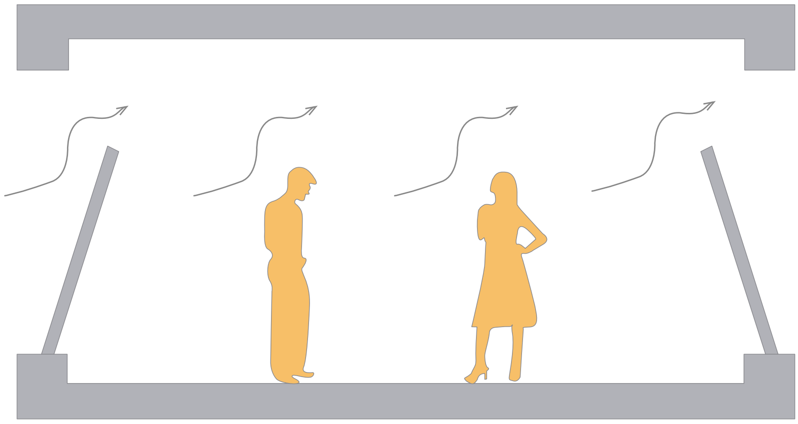


Figure 52-1: Principal scheme of cross-ventilation

The practical implementation of cross-ventilation in apartment buildings, aside from the wind conditions, is limited by floor planning. As figure 52-2 shows, the cross- ventilation scheme can be easily implemented in apartments which have windows on opposite facades.

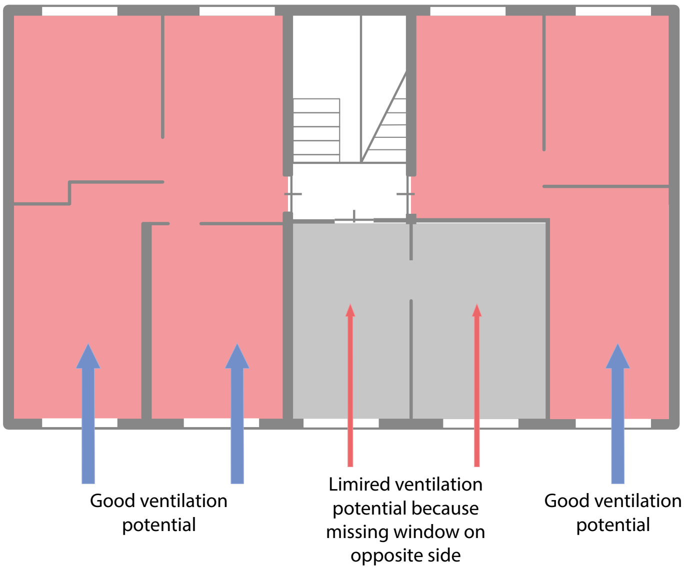


Figure 52-2: Apartment building floor plan

The effect of cross-ventilation can be reinforced by building proper orientation towards the direction of prevailing winds.

52.2.3 Controlled mechanical ventilation (room-wise and house-wise)

Mechanical ventilation

Mechanical ventilation systems ensure an optimal air exchange rate. They are independent of the inhabitants' behavior. A simple ventilation system of an apartment building consists of central mechanical exhausts from kitchens/living rooms, and natural air supply in bedrooms through regulated air inlets (figure 52-3). The flow level through air inlets is regulated manually, or by automatic regulation of the relative humidity level.

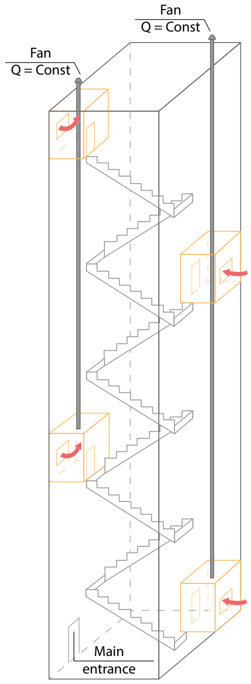


Figure 52-3: Principal scheme of ventilation systems of apartment buildings

Some solutions for air inlets currently available on the market are presented in figure 52-4.

During the renovation of multi-apartment buildings, the exhaust fans can be installed on existing ventilation shafts and wall air supply units can be installed in bedrooms.

Figure 52-4: Currently available air inlets solutions

Controlled mechanical ventilation without heat recovery

The main benefits of such systems are the absence of ducts and a low noise level. Dimensions of wall air supply units are shown in figure 52-5. The operation of exhaust fans can be programmed according to building specifics. Exhaust fans can be operated 24 hours per day or can be programmed to work during specified hours (for example morning/evening hours and weekends).

A similar system can be installed separately in each apartment. In that case, individual operation can be introduced on the basis of CO_2 or relative humidity level. The main limitation for practical implementation of systems in each apartment is the lack of space for exhaust ventilation ducts in order to ensure individual exhaust for each apartment.

It should be mentioned that, unfortunately, such a solution doesn't provide heat recovery.

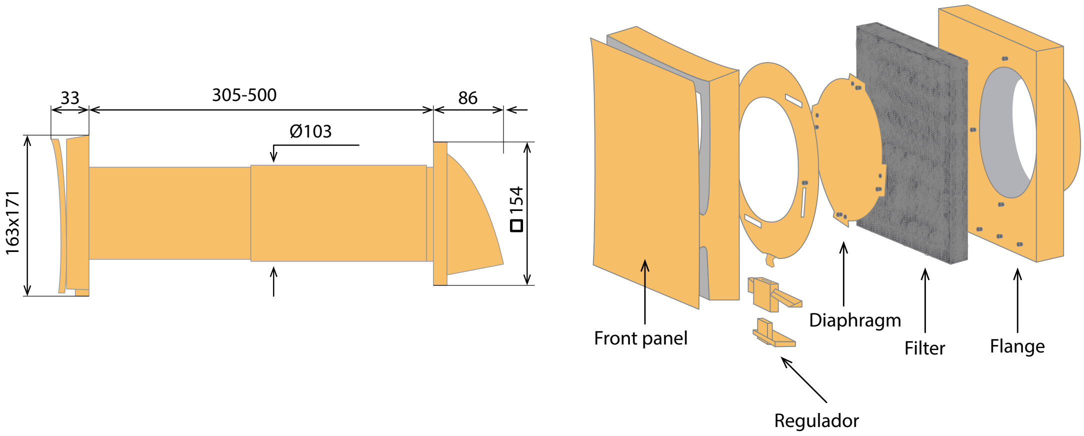


Figure 52-5: Wall fresh air supply units (Source: http://www.ventilation-system.com/cat/356/

52.2.4 Controlled mechanical ventilation with heat recovery

After the building renovation, a low level of energy consumption can only be achieved by complex solutions including proper thermal insulation, efficient windows, increased air tightness and installation of a ventilation system with heat recovery. Nowadays, controlled ventilation systems with heat recovery are popular in single family houses and can be easily implemented in multi-apartment buildings.

Controlled mechanical ventilation with heat recovery

Cross-Flow, Rotary and Counter-Flow heat exchangers are usually used for ventilation of apartment buildings.

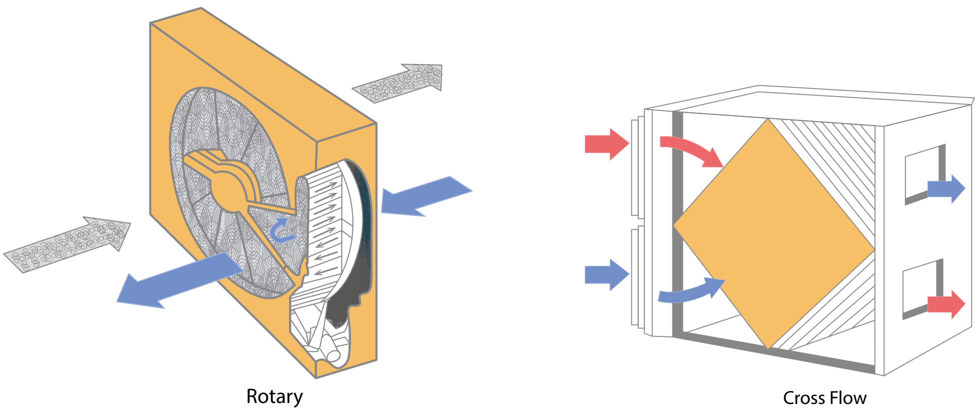


Figure 52-6: Principal schemes of air heat exchangers

Efficiency of heat exchangers can be calculated as follows (10):

Formula 52-5

$$\eta = \frac{W_s(t_1 - t_2)}{W_{min}(t_1 - t_3)}$$

where:

t_1 – supply air temperature into unit (outdoor air temp.) [°C]

t_2 – supply air temperature out of unit [°C]

t_3 – exhaust air temperature into unit (room temp.) [°C]

W_s – supply flow rate [m^3/h]

W_{min} – minimum flow rate (supply or exhaust) [m^3/h]

Usually supply or exhaust air flow rates are the same, so the supply air temperature after the heat exchanger can be calculated as follows:

Average efficiency of a cross flow heat exchanger is 55%, rotary heat exchanger – 70% and counter-flow heat exchanger - 85% . In addition to heat recovery, the rotary heat exchanger regains humidity during winter.

Example 1. Calculated supply air temperature for different kinds of heat exchangers.

Indoor temperature +22 °C, outdoor air temperature – (-10 °C).

For the cross flow heat exchangers supply air temperature:

$$t_s = 0{,}55 \cdot (22-(-10))+(-10)=7{,}6\ °C$$

For the rotary heat exchangers supply air temperature:

$$t_s = 0{,}7 \cdot (22-(-10))+(-10)=12{,}4\ °C$$

For the counter-flow heat exchangers supply air temperature:

$$t_s = 0{,}85 \cdot (22-(-10))+(-10)=17{,}2\ °C$$

KEY POINTS TO REMEMBER FROM CHAPTER 52

- **Ventilation systems provide fresh air for breathing and for removal of air pollutants such as carbon dioxide (CO_2), moisture and odors**
- **The pressure difference is the main driving force for air movement between indoor and outdoor environments**
- **It is recommended to keep relative indoor humidity between 30% and 60%. Humidity above 70% can provoke indoor microbial growth**
- **After the installation of air-tight windows, the natural ventilation is significantly reduced and must be compensated by regular ventilation through opening the windows**
- **Cross-ventilation is very efficient for removing air pollutants and heat gains, but can only be implemented in apartments which have windows on opposite facades**
- **Controlled mechanical ventilation systems ensure an optimal air exchange rate; the efficiency of mechanical ventilation can be improved by heat recovery application**

53. Cooling

53.1 Overheating in summer time

Overheating

Typically it is assumed that overheating starts at an indoor air temperature above 28 °C. Up to 28 °C, an individual dressed in light clothing and working moderately is comfortable in such a temperature. In addition, a fan can increase the comfort. Overheating in summer time is mainly caused by the external heat gains, in particular, solar heat gains. In contrast to office buildings, internal heat gains have a smaller impact on the total heat gains in apartment buildings. The main source of internal heat gains in apartment buildings is human activity, while in offices it is computers, printers and copy machines.

The human body produces, on average, 127 watts doing moderate work, 74 watts, sleeping, and up to 450 watts doing hard work. Household activities such as using an oven have a significant impact on overheating; avoiding active cooking during the hottest times of the day is recommended.

53.2 Passive methods to prevemt overheating

In order to reduce overheating, appropriate shading should be used. External shading devices are much more efficient than indoor shading.

There are more than 10 different types of shading. The main types are:

- External and internal venetian blinds;
- Roller blinds;
- Curtains;
- Folding arm awning.

Shading

Natural shading elements such as trees can also be used efficiently. The choice of the type and size of shading devices depends on Solar Geometry. Solar Geometry describes the relationship between the sun and earth during the year. Figure 53-1 presents effects of shading on heat gains in summer time.

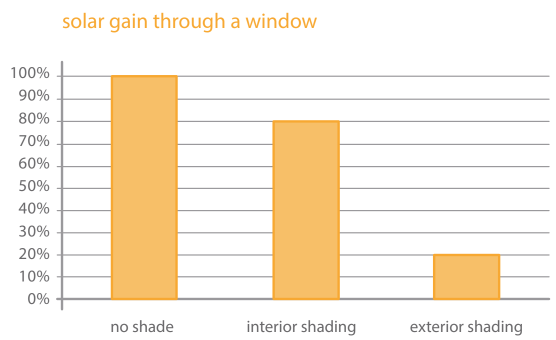


Figure 53-1: Effect of shading on heat gains in summer time (source: Norbert Lechner presentation http://balticenergy.info/web/page.aspx?refid=32)

Principles of Solar Geometry for different latitudes are shown in Figure 53-2.

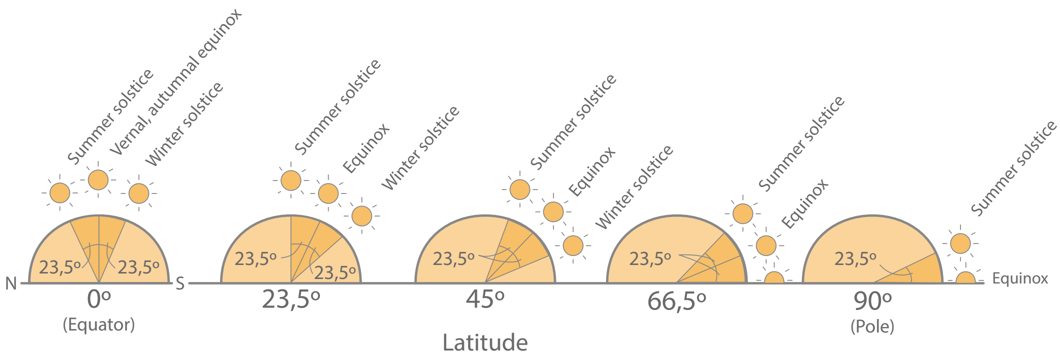


Figure 53-2: Principles of Solar Geometry (11)

The solar angle close to the equator is higher than the solar angle at the North Pole. That makes shading design more complicated at higher altitudes. Lengths of overhang on south façade for latitude 60N and 23.5 N are shown in figure 53-3.

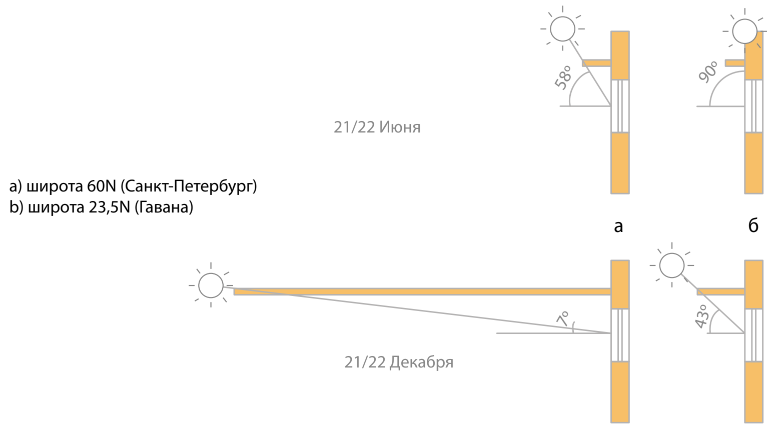


Figure 53-3: Lengths of overhang on south facade

Calculation for a 24 m^2 room with a southern-oriented window had shown the significant effect of external shading at latitude 56 °C. Window area is 5,2 m^2. Figure 53-4 presents energy consumption for room cooling with different shading strategies.

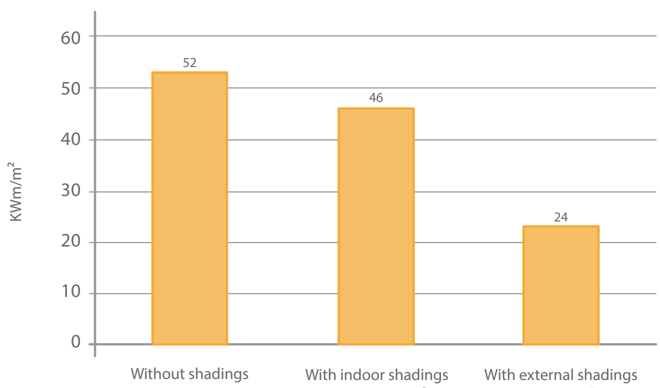


Figure 53-4: Room energy consumption for cooling with south oriented window

53.3 Efficient active methods to prevent over-heating

Usually, the traditional air conditioning systems with compressor and halocarbon refrigerants are used for space cooling in summer time. Nowadays, the new cooling methods such as direct and indirect evaporative cooling systems have become more popular. Direct evaporative cooling reduces temperature by spraying water directly to the indoor air or in supplying air in ventilation systems (Figure 54-5). During the direct evaporative cooling process, indoor air becomes colder but, at the same time, moisture content significantly increases, possibly causing condensation and mold problems. Direct evaporative cooling is used efficiently in regions with hot and dry climate, where it is possible to reduce air temperature by 8 - 12 °C. In humid climates, the possible temperature reduction is only a few degrees but can provide acceptable thermal comfort.

Direct evaporative cooling

Figure 53-5: Examples of direct evaporative cooling in a restaurant in Istanbul

For cold and humid climates, indirect evaporative cooling can be an efficient way to provide indoor cooling. The main principle of the operation of indirect evaporative cooling is direct moisturizing of exhaust air and heat exchange with supply air at the heat exchanger (figure 53-6). So by direct evaporative cooling, the exhaust air becomes colder and wet while the supply air is cooled through the heat exchanger without moisture increase.

Indirect evaporative cooling

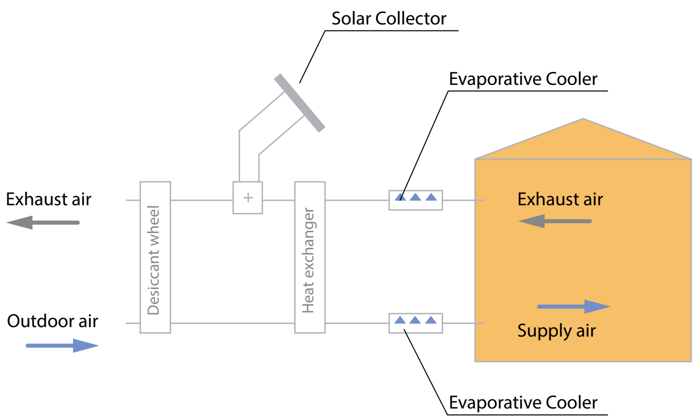


Figure 53-6: Simple scheme of indirect evaporative cooling

As shown, one additional advantage of indirect evaporative cooling is solar energy utilization in summer time. The heat is necessary to increase supply temperature air and remove initial moisture that later allows for cooling of air by moisturizing. There are many modifications of indirect evaporative cooling systems. For example, the moisture absorbers can be used in order to increase temperature reduction by evaporative cooling. An example of modern indirect evaporative cooling equipment is shown in Figure 53-7.

Direct evaporative cooling

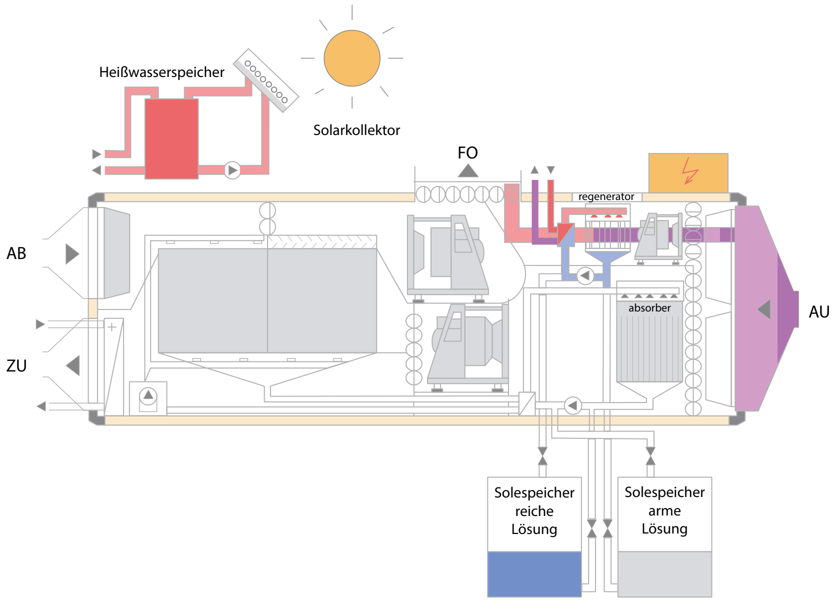


Figure 53-7: Principle scheme of modern indirect evaporative cooling equipment (source: www.menerga.lv)

Indirect evaporative cooling

KEY POINTS TO REMEMBER FROM CHAPTER 53

- **Typically it is assumed that overheating starts at an indoor air temperature above 28 °C**
- **On hot summer days proper shading can prevent overheating**
- **External shading devices are much more efficient than indoor shading. The main types of shadings are: external and internal venetian blinds, roller blinds, curtains, and folding arm awnings**
- **Direct evaporative cooling is used most efficiently in regions with hot and dry climate, while indirect evaporative cooling is efficient for cold and humid climates.**

54. Additional active cooling methods

The passive and efficient active methods described so far usually imply major structural interventions that require investments and a longer preparation time. In the extremely hot summers of recent years, temperatures in homes and workplaces often rose well above 28°C. In these phases, solutions were needed that could quickly provide relief. Thus, in many cases, small, preferably mobile, electrically operated devices were purchased, such as fans or mobile air-conditioning units. These, in turn, may solve the problem of overheating in the short term, but in the long term they continue to contribute to CO2 emissions and thus exacerbate the problem.

If active cooling methods are found essential, equipment should be used and operated as efficiently as possible. Some solutions are described below.

54.1 Fans

Fans as floor-standing or table-top or so-called tower units are the most flexible and cost-effective devices. They do not cool the air, but the draught generated makes temperatures seem more comfortable. However, the relieving effect is only perceptible in direct proximity to the unit.

Ceiling fans are less flexible, but they can also make a difference in larger rooms. As a small electrical device, a fan again contributes to a small extent to internal heat gains. Compared to other active flexible devices, the unwanted heating effect as well as the energy consumption is low, however.

Figure 54-1: The most classical active cooling device

54.2 Mini coolers

The method of "direct evaporative cooling systems", see previous chapter, is basically used in mini coolers. These small devices are about as big and mobile as small electric fan heaters.

Water is atomised and blown into the room by a fan. As with fans, the cooling effect is only noticeable in the immediate vicinity of the device. The temperature in the room is not lowered with this method either and the cooling effect is only caused by the evaporation of the water droplets. The power of such units is low, but so is the energy input and the waste heat.

54.3 Single room air conditioners

If there is no other method to reduce the heat load in a room and a fan is not sufficient, air-conditioning systems with compressors and halocarbon refrigerants can be considered for the most affected rooms. So-called split systems consist of an outdoor and an indoor unit. They are connected by a refrigerant tube that must be routed through the masonry.

Typically, the indoor unit is mounted just below the ceiling or as a ceiling cassette on the ceiling, while the outdoor unit is mounted on the façade or on the roof. The outdoor unit discharges the waste heat and disturbing noise to the outside.

Figure 54-2: Outdoor unit of a single room air conditioner

The installation of the outdoor unit requires at least the permission of the owner. Thus, the installation of such a unit is time-consuming and so costly that further structural passive measures could be realised with comparable effort.

Air-conditioning units are labelled with energy labels. These should definitely be taken into account when purchasing. While an appliance in energy efficiency class A consumes around 500 kWh per year (assuming an operating time of 500 hours), an A++ appliance makes do with around 350 kWh. Please be aware that only appliances within one class/type should be compared.

54.4 Mobile air conditioning systems

Mobile air conditioning systems are mounted on wheels and can be moved from one room to another as needed. However, they also have at least one hose that has to be led out of the window or into a canister. Warm air can in turn get inside through a gap. Compared to split units, a larger part of the warm exhaust air remains in the room and must be cooled again.

The cooling capacity of these units is lower and the energy input higher than with split units. However, the purchase costs are significantly lower. There are no costs for installation. According to research by the German Federal Office of Economics and Export Control (Bafa), the costs until a mobile unit is put into operation are at least two-thirds lower than for a split unit system. The cost of operation is quoted at 24 cents per hour compared to 17 cents for a split system (reference year 2021).

Similar as with split systems, energy labels should be observed when purchasing. Note that comparing the efficiency classes of a mobile unit with a split unit is misleading.

If it seems essential to purchase an active air conditioner or to use an existing one, the following tips should be taken into account:

- Only cool down rooms that are actually used.
- Do not start using the units when the room is already overheated.
- Position mobile units in the room so that the air can circulate freely.
- Close the blinds during the day to avoid direct sunlight.
- Ventilate only at night or in the morning hours.
- If possible, avoid unnecessary heat sources (cooking, lighting, but also TV sets, computers, etc.).
- Keep the difference between room and outside temperature as small as possible (also for health reasons). It should not be more than 7 °C.
- For mobile devices: Seal the window gap well through which the cooling hose passes.
- Clean the air filters of the air conditioner regularly.
- Do not lower the humidity too far. A range of 35 to 65 percent is generally recommended.
- So as not to disturb your sleep unnecessarily with cooling noises: Run the air conditioner before going to bed and switch it off overnight.

54.5 Coefficient of performance and Energy Efficiency Ratio

The coefficient of performance (COP) is a measurement of the energy efficiency of the air-conditioning unit's heating performance. The energy efficiency ratio (EER) is the ratio of a unit's cooling output relative to its input electrical power. Manufacturers must specify the EER. The higher the performance figure, the better. Devices of energy efficiency class A must have an EER of at least 2.6, those with a value of 8 are recommended. However, usually only a maximum recommended room size (in m^2) is given for consumers. This does not take into account which additional heat gains can be expected in this room, e.g. through south-facing windows or appliances that heat the room. Nevertheless, usually only the output in watts, the recommended room size and the efficiency class are given.

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10

Adapting to climate change when refurbishing buildings

WHAT WILL YOU LEARN IN THIS MODULE?

This module will show some typical risks that climate change poses to urban areas in the Baltic Sea Region as well as the different scales and regulation levels (e.g., national/federal, regional) that influence their implementation. While laws and regulations help steering adaptation measures over wider regions, in the context of this module, the most important adaptation measures are those that can be realized by owners and inhabitants in the framework of new building or capital renovation. Therefore, these measures will be discussed more in detail. Examples for typical measures on site are roof or facade greening or water saving measures. The measures discussed in this module mainly target the reduction of negative impacts from excess temperatures and rainfall. Both technical aspects of implementation of measures, as well as broader aspects of land use planning are discussed.

55. Impacts of climate change in the urban environment

The housing sector is one of the most critical sectors when it comes to combatting climate change. However, decreasing energy usage in the housing sector is not the only challenge. Adaptation to the inevitable consequences of climate change is an increasingly important topic that requires attention. The built-up land and the urban heat island effect will intensify the consequences of the predicted rise in temperature and more extreme weather events. In addition, the high concentration of infrastructural, economic, and social assets often makes urban areas more vulnerable to climate change than surrounding landscapes. Despite their intrinsic vulnerability, given the planning of new settlements and building of new houses, it is possible to implement innovative measures for adaptation and mitigation options – and explore synergies between them – to address the risks of climate change.

Adaptation measures in the urban environment depend on the nature and magnitude of ongoing and projected climate change impacts. A brief overview of the climate change impacts most relevant for urban areas in the Baltic Sea Region (BSR) can be found in the CAMS project report "Mapping climate adaptation options in energy efficiency projects". The following is a summary based on this text.

The text was gathered from two key sources, namely Räisänen (2017) on exploring the evolution of climate change in the BSR and its associated environmental impacts; and a report prepared by the Union of the Baltic Cities (UBC) on cities adaptation actions to extreme weather events. In addition, it is important to highlight that research on the effect of climate change in the Baltic Sea countries has been funded by several research and cooperation projects supported by the European Union EU. The potential future climate changes in the Baltic Sea region and the environmental impacts of the changes are comprehensively discussed in the first and second BACC assessments (BACC Author Team, 2008), (BACC II Author Team, 2015). This sub-chapter summarizes the finding in Räisänen (2017), which is in turn based on the BACC assessments.

Potential climate change trends in the BSR

Potential climate change trends particularly in the Baltic Sea Region (BSR) have been explored in several studies. It is assessed that in the Baltic Sea Region temperature will increase during winter, particularly in the northern parts of the region.

The warming will be accompanied by a general increase in precipitation in the winter in the form of rain, while snow is likely to decrease following more frequent episodes of midwinter snowmelts. In summer, projected change in precipitation may either increase or decrease with a higher chance of drying in the northern parts of the BSR. Short term summer precipitation extremes are also likely to become more severe, even in the areas where the mean summer precipitation remains stable. Finally, while changes in the average wind speed over the Baltic Sea are rather uncertain, the water temperature and salinity of the Baltic Sea are expected to increase, while ice cover is projected to decline (Räisänen, 2017).

Urban climate change related risks are increasing

According to the Fifth Assessment Report of IPCC, urban climate change-related risks are increasing. This includes rising sea levels and storm surges, increases in heatwave and extreme precipitation events, more pronounced inland and coastal flooding, landslides, drought, increased aridity, water scarcity, and air pollution. These climate-related stressors often come with associated negative impacts on people (their health, livelihoods, and assets) and on local and national economies, as well as ecosystems (Revi et al., 2014). The BSR region is - and will increasingly be - exposed to some of these risks. The UBC report on cities' adaptation actions to extreme weather events (Paju, 2019) synthesized the main expected weather events and adaptation results in 25 cities in the BSR: Estonia, Finland, Germany, Latvia, Lithuania, Norway, Poland, and Sweden. The following table summarizes the climate hazards as described in Paju (2019) according to five categories of climate-related variables: precipitation; temperature; flood and sea-level rise; storm and wind and water scarcity.

Climate-related variable	Changes in variables	Impacts in urban areas
Precipitation	More extreme precipitation, such as heavy rainfall, rainstorm, fog, heavy snow.	• Heavy water run-off affects every aspect of urban life – from transport and logistics to the residential sector and public health. • Damage to the city infrastructure and properties due to flooding.
Temperature	More heatwaves and extremely hot days.	• Increases in temperature and heatwaves exacerbate the heat-island effect that includes: melting asphalt; increased asphalt rutting due to material constraints: thermal expansion affecting bridge joints and paved surfaces; - damage to bridge structure materials. • Increasing demand for public health services for the elderly, children, people with chronic diseases and of low socio-economic background to cope with the heatwaves. • Energy demand, residential and transport sectors will be affected by the heatwaves.
Storm and wind	More windy weather events (severe wind, storm surge, lightning, thunderstorms; tornados and extratropical storm)	• Damages to road infrastructure (fallen trees on roads and power lines). • Increased maintenance costs. • Danger to inhabitants.

Climate-related variable	Changes in variables	Impacts in urban areas
Flood and sea-level rise	More coastal flood, flash/ surface flood or river flood	• All areas of the urban infrastructure are affected – from transport to the well-being of the local inhabitants. • Damage to infrastructure, building walls and basements. • Disruptions to accessibility. • Floods can cause the mixing of sewage and drinking water. • Erosion and risk of landslide.
Water scarcity	More drought, lower groundwater levels	• Affects the well-being of a city: from food production to biodiversity and ecosystem services in the urban areas and water supply.

Table 55-1: Impacts of climate change in urban areas (Adapted from "UBC cities' adaptation actions to extreme weather events" (Paju, 2019))

56. Adaptation measures in buildings and settlements

The above-mentioned climate hazards are challenging for urban areas. Facing these hazards, carrying out adaptation measures on building sites or in the immediate vicinity of buildings are only a small a small cog in the adaptation machine. There is a need for national and regional strategies how to cope with possibly more frequent extreme weather events and sea-level rise and how to protect and decrease the vulnerabilities of buildings and infrastructure. Furthermore, adaptation to climate change will be only successful, if there will be a general change in behaviour towards a sustainable treatment of soil, rivers, landscape, agriculture, and forestry.

Adaptation measure on different scales are mutually dependent. On the one hand, small measures will contribute to the overall resilience of the entire system. On the other hand, local or regional policies can set the frame – e.g. through modified land use plans – and adaptation strategies will usually list a number of preferred or supported on-site adaptation measures. In the building context, these policies aim at more resilient settlements and urban areas. In this module we will focus on measures thar respond to precipitation, water scarcity and rising temperatures.

Before looking at the measures in detail, it is wise to briefly think about how to deal with the uncertainty associated with climate change projects. Since the exact consequences of climate change cannot be forecasted and predictions of changing climate parameters are usually given by a likely range, we are faced with an uncertainty of how to adapt to climate change best. The following triad of measures can serve as a decision guideline when dealing with uncertainty.

Dealing with uncertainty

- No-regret or low-regret measures: This refers to measures which are worth implementing regardless of what happens or which only require little investments that are justified in the face of uncertainty of the scale of climate change
- Flexible measures: Flexible measures are measures the are able to respond to a range of possible impacts of climate change.
- Win-Win measures: Such measures contribute to adaptation whilst also having other benefits in other sectors, e.g. the social or economic sector or they contribute to the mitigation of climate change.

57. Instruments on different levels to install adaptation measures

In the construction sector - including new construction and major renovation – mainstreaming adaptation is more effectively done via building regulations, building permits or certification systems. Usually, buildings and construction activities must follow at least two sets of regulations regarding:

- hazard prevention on the construction site and the completed building,
- and plans for the urban development for site and surroundings.

The compliance of building/renovation design to both principles must be proved in the process of granting construction permission. With these sorts of instruments, it is possible to steer construction activities into the direction of climate mitigation and adaptation.

Hazard prevention

About hazard prevention

- Any building must be constructed according to regulations of hazard prevention, fixing rules for fire protection, stability, the use of proved materials and fix minimum spaces between the buildings etc. These regulations are normally set by state or federal state in building codes, norms, or guidelines.
- Building codes contain regulations on how to avoid overheating in summertime. For example, in Germany it is mandatory to calculate heat gains und steer against too high solar gains in summertime, that means a building with a complete glazed wall directed to the south without any blinds would not pass the permission procedure.

- Proper planning, selection of heat resistant materials, checking of fact sheets of manufacturers etc., should be state of the art.
- Includes the development or adaptation of rain or snow load maps, to design roofs, roof drainage, gutters etc.

About land-use planning

- Any building must follow municipal regulation and planning as municipalities have the right to define or plan the future land use of their territory.
- Certain general - or masterplans define zones of land use, e.g., farming, industry, living quarter, infrastructure etc. for the whole municipal territory.
- For new settlement activities, more detailed urban plans must be provided e.g., in a scale of 1:1000 indicating number of building storeys, the density, building lines etc.
- The scope of the municipal planning activities is set by national law in most countries.

Increasing reslience

The figure below shows an example of a land-use plan typical in Germany with the identification of flood prone areas where future construction is not allowed. It is the task of the municipality to define flood risk areas and to limit or ban settlement activities in these areas. Safeguarding building against hydro-meteorological hazards is not only about excluding construction from risk prone areas but also about taking action to make settlements and their surroundings more resilient to the increased amount and frequency of precipitation. Steps towards more sustainable rainwater management could be soil saving developments, retention areas, permeable roads and squares, protection and creation of green areas etc. It is possible for municipalities to develop climate maps to protect cold air corridors on their territory. Some municipalities, e.g., in Germany, go further and enact rules which state that even private gardens in front of the house must not be sealed.

Figure 57-1: Example of a German land use plan with the fixation of a flood risk area near the river Elbe (noted as Ü in the map)

More resilience against the overheating of urban areas can be achieved with similar measures to improve water management: the protection and development of green areas. Furthermore, protecting or replanting of street trees can help preventing heat islands by shading and evaporation. Adequate placement of buildings to allow for cool air corridors in urban areas to flow freely – as illustrated in the figure 57-2– can also be considered as a viable adaptation option.

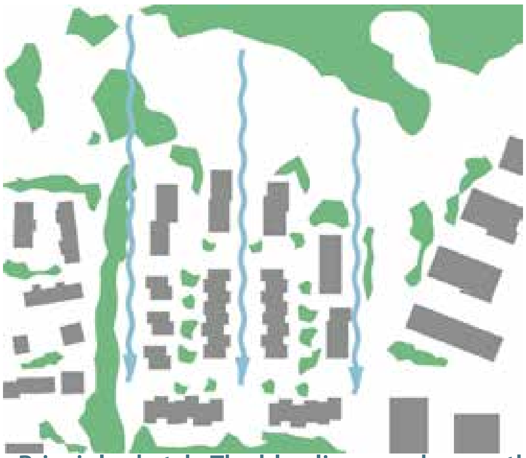

Figure 57-2: Principle sketch: The blue lines mark areas that are to be kept free of buildings in order keep the cold air corridors (sketch of the air corridor principle in a new settlement in Germany, 30657 Hannover Bothfeld

The implementation of adaptation measures regarding buildings and built environment takes place in the context of multi-level instruments (from municipal or national to local). The following table maps adaptation measures in relation to these instruments and the relevant climate risk.

Risks		Level	Measures
Precipitation	More extreme precipitation such as heavy rainfall, rainstorm, fog, heavy snow	Municipal level: General – or masterplan	Hazard prevention: Definition of flood risk areas Improving resilience: permeable roads and squares, saving of green areas Soil saving urban development
		Municipal level: Detailed urban planning	Definition of density and compactness of settlement Definition of sealed areas Binding (possibility to set binding rules in all countries?) rules for permeable car parks surrounding the building
		Municipal level:	Incentives for measures on site, like grants for roof greening
		On site	Hazard prevention: Use of construction according to local situation, ground water level etc. e.g. entrance to underground car park located higher, to avoid problems with strong rains. Sustainable stormwater systems integrated into the design of the building, such as rain gardens Green roofs (retention)

Risks		Level	Measures
Water scarcity	More drought, lower groundwater levels	Municipal level:	Setting of rules to save water, e.g., restrictions on the use of drinking water for irrigating the garden or car washing
		On site	Installation of water saving devices Reuse of water, grey water treatment Change of behaviour
Temperature	More heatwaves and extremely hot days	Municipal level: General – or masterplan	Climate maps Protection of natural cool air corridors
		Municipal level: Detailed urban planning	Soil saving measures, development and protection of green areas, street trees
		On site	Hazard prevention: Calculation of frequencies of overheating in summer time, Passive shading measures Green roofs Façade greening

Table 57-1: Adaptation measures for buildings according to level and climate risk

58. Measures on site

58.1 Introduction

Some of the adaptation measures in the building sector that can be carried out on site are aimed at changing behaviour such as the efficient use of drinking water. However, most of the measures focused on within this chapter refer to small or larger construction projects, such as the installation of a green roof. These projects require comprehensive information, planning, and cost-benefit-accounting for their execution. The following descriptions do not replace the need for comprehensive gathering of the necessary information to decide on the viability and impact of the measure. The example of the production of green roofs shows that a market has emerged and that modular systems for green roofs are now available. These come as a package of coordinated materials, fixation, drainage which is financially advantageous. From a holistic environmental point of view, such ready-to-go solutions may turn out to have other disadvantages. Some products still operate with PVC-containing sealing membranes, which are associated with negative consequences for the environment.

Therefore, it is recommended to search for independent information about products and take a closer look if further environmental aspects are to be considered. Note that product fact sheets cannot replace independent information gathering in a fast-moving market. Another example relates to rain or grey water cisterns. Independent services and manufacturers provide tools to approximate the required size. A quick test of some of these tools showed that the results are within a range of recommended sizes, sometimes unnecessarily large volumes were recommended. Therefore, a comparison of different services is advisable.

Importance of independent Information about products

In this study guide, references to life span and primary energy can be indicative at best. Not all products have undergone a life cycle assessment. Information about the "grey energy" of a product, i.e., the primary energy that is needed in the process of manufacturing, is not always easy to find. Where available, the information is given. Furthermore, short descriptions of potential first steps towards realization are included and an indication as to whether a permit of the building authorities is required. This must then be clarified with the local authorities.

58.2 Roof greening

Buffering precititaion and extreme temperatures through green roofs

While on normal roofs around 80% to 100% of the precipitation is channelled into the sewer system, on green roofs, 70% to 100% of precipitation is caught in the vegetation layer and released back into the air through evaporation. Green roofs release the precipitation with a time delay and in doing so they alleviate the pressure on urban drainage systems during intense rainfall. As a result, the overall risk of flooding is reduced. Below you will find typical discharge coefficients for different surfaces and varying installation heights of green roofs. More rainwater is caught in thicker installations.

Information box:

The discharge coefficient describes the percentage of the precipitation that runoff, i.e., H. the ratio between the effective (effective) precipitation and total precipitation.

The amount of effective precipitation depends on various area parameters. These include above all the slope of the terrain, the land use, the permeability and pre-moisture of the soil, any retention by natural hollows, lakes or artificial storage, the intensity and duration of the precipitation event as well as the air and soil temperatures (snow storage, snowmelt, ground frost).

Type of surfaces	material	discharge coefficient (H)
Pitched roof	Tiled roof	0,9 -1,0
Green roof	Installation height < 10 cm	0,3
	Installation height > 10 cm	0,1

Type of surfaces	material	discharge coefficient (H)
Roads, car parks etc.	Asphalt	0,9
	Gravel	0,6
	Infiltration capable paving	0,4
	Paving with widened joints	0,4
	Gras paver	0,15
Green areas,	Garden, meadows	0,0 -0,1

Table 58-1: Typical values of discharge coefficients

In addition to lowering the pressure on water drainage systems, green roofs also provide a positive thermal effect by reducing temperature extremes over the year. While gravel roofs and black bitumen cardboard heat up to around 50°C to over 80°C even in Central Europe, the maximum temperatures for green roofs are around 20°C to 25°C. On clear winter nights, the temperature of unplanted roofs drops to as low as -20°C. The annual temperature fluctuation is thus approximately 100 degrees. Green roofs only cool down to a little below 0°C in winter, so that here the annual fluctuation is only about 30 degrees.

Intensive and extensive green roofs

A distinction should be made between intensive and extensive green roofs, depending on the type of plants used and required maintenance. When constructing an extensive green roof, the selected plants must be insensitive to frost and drought and tolerant towards a low supply of nutrients. Various types of sedum have proved particularly successful when supplemented with dry-resistant herbs. These plant species from the spectrum of rare lean grasses need little care and yet offer a good contribution to biodiversity. In contrast, intensive roof greening offers a wide range of design options and can be used as a roof garden. The substrate layer is correspondingly higher and there are requirements for the irrigation of plants.

Figure 58-1: Extensive green roof

Figure 58-2: Intensive green roof

Different functional layers are necessary for all types of green roofs, e.g., for water storage, drainage, aeration, nutrient supply, and anchoring.

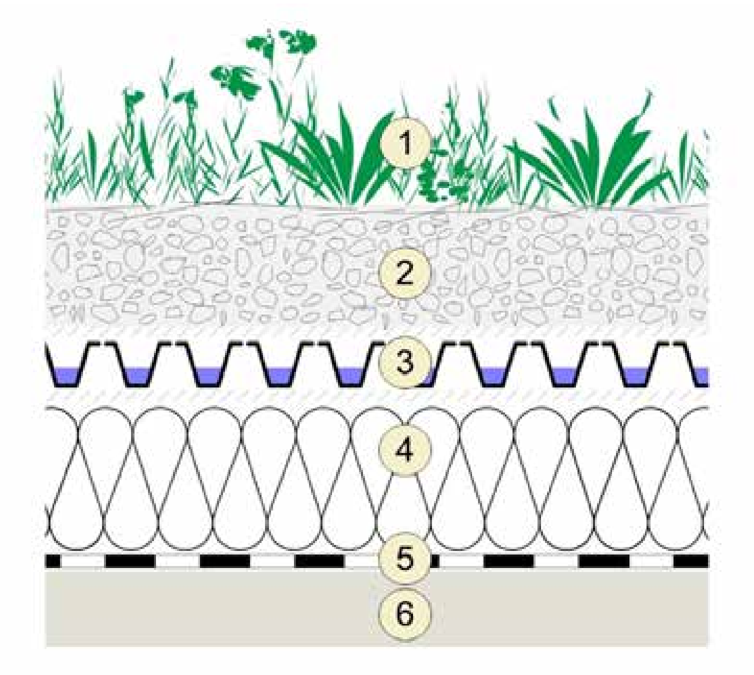

Figure 58-3: Construction layers of a green roof: 1 Vegetation 2 Vegetation support/substrate layer 3 Filter- and Drainage layer 4 Insulation 5 Sealing 6 Sub construction

Construction layers of green roof

The vegetation support layer of a green roof usually does not consist of naturally occurring soil, but of a substrate. In addition to naturally occurring materials (e.g., lava or pumice), recycling materials (e.g., clay bricks and compost) are increasingly used as the basis for vegetation substrates.

The drainage layer diverts the excess water from the roof to avoid undesirable water accumulation and to store rainwater to supply the plants. It consists of natural bulk materials, such as lava, expanded slate or expanded clay, or plastic elements, so-called solid-state drains. It has a height of about 1 to 15 cm. The most important functions of the drainage layer are to quickly lead any excess water from the green roof structure towards the roof drain and the drainage system or to store.

This leads to the question: Which type of roofs are recommended for roof greening? Principally roof greening is possible at flat and pitched roofs.

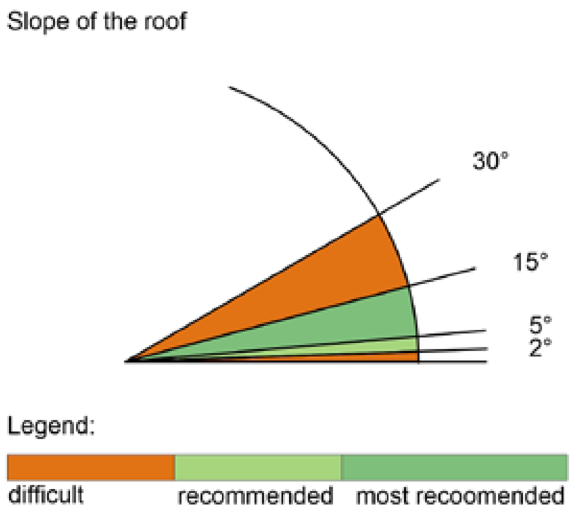

Figure 58-4: Recommendations concerning the slope for roof greening

A minimum of 2° slope of the roof is recommended to avoid puddles. In case of flat roof greening, a minimum slope should be given by sub construction. An angle of 5° to 15° is the most recommended range for pitched roofs.

For pitched roofs with an angel greater than 15°, additional measures are required. For example, an additional wooden slatted frame serves as an installation aid and protection against shearing forces.

Attention: Comparable to other building elements, manufacturers are offering complete construction packages containing the functional layers. This is advantageous due to liability questions and normally the materials of the layers and fixations fit together. But it is not easy to check, if all layers are really "eco-friendly". For example, foil/slide/layer can be made of PVC. Furthermore, there is no indication of the "grey energy" of a green roof as such. (Remember: the grey energy of a product is the primary energy required for production, transport, storage, sale and disposal.) To overall to maintain a good eco-balance of a green roof, processability and longevity of the materials should be considered. Figure 58-5 shows that a green roof cannot compete with the average life span of a pitched tiled roof. For flat roofs, the greening is a very good alternative, however. There have been campaigns to support green roofs for buildings with flat roofs like large panel or commercial buildings.

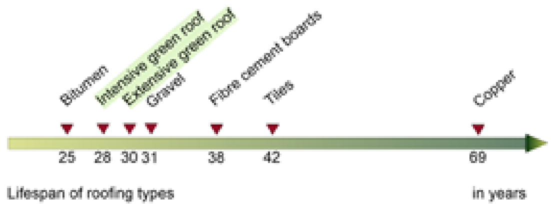

Figure 58-5: Life span of roof types

Initial conditions and first steps

The first step towards a roof greening is to check building permit requirements with the local building authority. Contact a structural engineer to check load assumption, shearing forces, anchoring in case of strong wind etc. In some countries or municipalities, roof greening is supported by grants or loans. Some incentive programs exclude PVC-containing products.

58.3 Facade greening

Buffering extreme temperatures through facade greening

In summer, largely sealed urban spaces heat up because of the lack of evaporation, so-called heat islands. As mentioned in chapter 3, street trees can help prevent heat islands by shading and evaporation. Wherever the urban density is too high and there is no space to plant trees, the greening of the facade is an alternative. The positive thermal effect of this measure mainly relates to the reduction in temperature extremes. A dense green facade contributes to air humidification and thus to local cooling through its evaporation capacity. The local temperature in front of a green facade is around 0.8 to 1.3°C cooler than in front of a non-green façade (Wong 2010). Furthermore, the greening of the facade naturally contributes to biodiversity in urban areas. Birds find nesting places, bees find nectar here, butterfly worms find nourishing leaves etc.

Additional benefits of facade greening are:

- Improvement of the thermal insulation of the building
- Reduction of infiltration heat loss due to wind braking
- Cooling effect through evaporation
- Cooling effect through absorption and reflection of the sun's rays in the foliage
- Moisture production through evaporation

Further, a distinction should be made between ground-based and facade- based greening as these two options carry distinct advantages, disadvantages, and technical requirements. We provide details on the two approaches below.

58.3.1 Ground-based greening:

With the variant of ground-based greening, the climbing plants are planted directly in the ground in front of the wall. In this variant, plants absorb water and nutrients from the soil, requiring little maintenance and care, and it is usually quite easy to implement. The plant types of Ivy (Hedera helix), wild grapevine (Parthenocissus quinquefolia), among others, are self-climbing plants and are commonly used in green facades. They form "sticky feet" with which they can climb out on the wall. Honeysuckle (Lonicera periclymenum) or wisteria (Wisteria sinensis) need climbing aids such as ropes or sticks on which they grow upwards. It is important to consider that some plants can cause damage to the building substance if they are not cut back. For example, ivy shoots can grow through a brick roof.

Figure 58-6: Ground based greening, wild grapevine

58.3.2 Façade-based greening:

Façade-based (or wall-bound) greening is also called vertical gardens. Without contact with the ground, the plants are dependent on complex systems to be supplied with water and nutrients. This makes it possible to green entire facades or certain surfaces to set design accents. Manufacturers offer complete systems, from substructure to ready mixtures of plants, adapted to the orientation of the building

Figure 58-7: Examples of facade based greening system

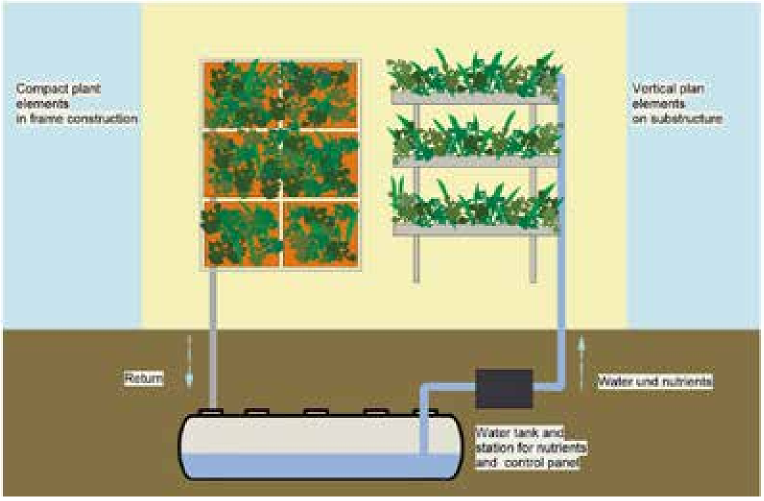

Figure 58-8: Sketch for vertical garden system with compact or vertical plant elements (the circulation of water and nutrients and the return is required for both systems).

Vertical gardens

The figure above shows the principle of two variants of vertical gardens. Left, compact elements made of textiles in a frame construction. The wall can be completely covered with greenery. Right, vertical elements on a sub construction. Both variants depend on a technical system containing a water tank, pumps, control panel, pipes for a nutrient system, and return pipes, and both require maintenance, e.g., the frost protection of the water system. The loads - including wind load - of the whole material must be calculated beforehand to achieve a sufficiently strong fastening, e.g., a system with compact plant elements can reach a maximum weight of 30 kg/m^2 in fully overgrown water-saturated state. Finally, it is important to consider that point-shaped thermal bridges may occur due to subsequent fastening of the sub-construction.

The design of a vertical garden is not comparable to planting trees or climbing plants. Rather, it is a complex construction measure. Their "grey energy", longevity, maintenance efforts etc. should be considered, when opting for such a measure. Therefore, it is unfortunate that, so far, there is no indication of the "grey energy", processability and longevity of a vertical garden as such. For the technical equipment similar warranty periods are assumed, as for grey water systems see the chapter on water saving measures.

Initial conditions and first steps

If the building is surrounded by private areas, such as the garden and the front yard, it is unlikely that any country will ask for a permit for greening the facade. The situation is different if the building is adjacent to public land. Then the building authorities must be involved. In the case of wall-based solutions, a civil engineer should check load assumptions, and proper planning is mandatory. In some countries or municipalities, façade greening is supported by grants or loans.

58.4 Flood protection measures for buildings

Anyone constructing, renovating, or refurbishing a building in a flood-prone area must consider which parts of the building can get in contact with water. The protection concept for the building begins with considering how the affected parts can be protected or used to minimize damage. If the basement is affected, higher-quality use can easily be avoided. The floor and walls can be covered and clad with water-resistant materials. Solid built-in furniture should be avoided in case they are not water resistant. Sensitive utilities such as electrical distribution or telecommunications equipment should be housed in parts of buildings that are not threatened by flooding.

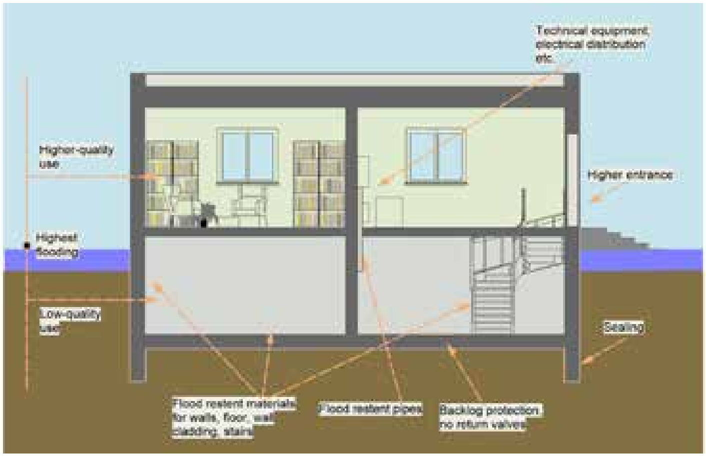

Figure 58-9: Sketch showing how flood prone building parts can be protected

Technical and structural planning should be undertaken to prevent water from entering the building. Entrances, doors, garage entrances etc. should be located higher than the expected highest flooding. The outer walls that get in contact with the water should be made of waterproof materials, like waterproof concrete, or sealed accordingly. Pipe penetrations with press seals, multi-line building entries or formwork struts with a water barrier offer adequate protection. The water also shouldnot enter the building through the sewer system. For this purpose, back log protection/no return valves should be installed. Information on particularly flood-resistant (construction) materials and vice versa unsuitable materials is provided below.

Flood resistance of building elements

Building elements	Flood-resistant materials	Unsuitable materials
Floor slab	Waterproof concrete	
Flooring	Epoxy resin surfaces Artificial stone Natural stone (granite, dolomite)	Wooden pavement cork linoleum marble Solid wood Parquet / laminate Sandstone Textile coverings (carpets, carpets)

Building elements	Flood-resistant materials	Unsuitable materials
Walls	Concrete Fired solid brick Glass blocks Sand-lime bricks Clinker	Wood (boards, chipboards, partitions) light partition walls (plasterboard)
Outer shell	Mineral plasters (cement, hydraulic lime) Stoneware tiles Water-repellent insulation, XPS Polystyrene extruder foam (XPS) is a closed-cell, hard insulating material made from polystyrene. The extrusion produces a large number of small, closed cells, which ensure high mechanical strength and high resistance to moisture.	Fiber insulation materials
Plaster	Special plaster (hydrophobized)	Gypsum plaster
Painting	Lime paint Mineral paints	Dispersion paint
Wall cladding	Tiles	Plasterboard Wood cork Wallpaper textiles

Table 58-2: Examples of flood-resistant materials according to building element

Initial conditions and first steps

The protection concept starts with the consideration of which parts of the building could be affected by the flooding. What needs to be done to prevent water from entering? What needs to be done to minimize damage caused by possible water ingress? These considerations result in a list of necessary construction measures which should be carried out during planning or renovation. All measures should be planned and carried out according to the state of the art.

58.5 Water saving measures

58.5.1 About drinking water consumption and water saving

Increase in water consumption

Water consumption in households can be reduced both by change of behaviour and by technical measures, therefore, we start with a few introductory words. In Germany, increasing prosperity and urbanization was associated with increases in water consumption from the 1950's onwards. The values in figure 58-10 refer to the quantities of water consumed in the household. When this is added to water consumption from industry and agriculture, the consumption is significantly higher. Drinking water consumption in households reached its peak in 1990 at 145 litres per capita and day. Since then, consumption has been slowly falling, stagnating at around 125 litres per capita and day in the 2000s.

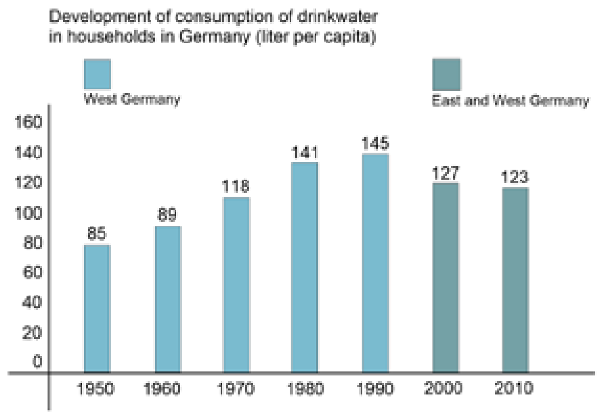

Figure 58-10: Development of drinking water consumption in households in Germany (one value per decade). Values are based on data of: Pistohl (1999)

Reasons for a decrease in consumption could be the installation and use of more water-saving devices. e.g., efficient toilet flushing and washing machines or flow restrictor sets. In the former socialist countries, drinking water demand has also declined in recent decades, probably due to more economical use, as incentivized by the introduction of water meters. The slight decrease in drinking water consumption does not change the fact that precious drinking water is also used for activities where drinking water quality is not required. Drinking water could be replaced by rainwater or so-called grey water for those activities. Figure 58-11 shows the share of household activities, requiring drinking water or non-drinking water quality for household activities in Germany.

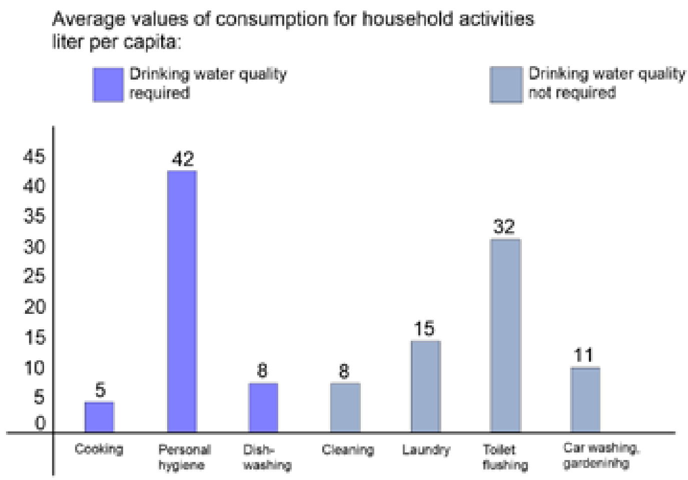

Figure 58-11: Water consumption for household activities in Germany Based on data of: Pistohl (1999)

In dry and hot periods more water is consumed, for showering or irrigating the garden. Since the statistics are only available up to 2016, there is no indication yet whether the particularly hot years (2018, 2019) have interrupted the slight decline in consumption. In fact, in the dry periods in some regions (in Germany), calls for water-saving behaviour have already been necessary. Presumably, there are very limited numbers of households left in the Baltic Sea region where savings buttons are completely absent. Toilet facilities without a savings button have disappeared from the market today. Therefore, water-saving behaviour means more effort than the installation of small technical devices.

58.5.2 Learning from Cape town

Saving water in times of scarcity

After three years of drought, in 2018 a critical situation arose in Cape Town which led to profound behavioural changes. Drinking water consumption per person had to be reduced below about 50 litres per capita and day. Dirty cars became a status symbol, musicians created songs of two minutes to measure the "allowed" time in the shower. It was suggested that drinking water should only be used where strictly necessary. After a long period of drought, the use of rainwater in cisterns is no longer an option. What remains is to reuse the water or to use grey water.

Figure 58-12: Sketch of a toilets with washbasin insert. Principle sketch after an idea, recommended in Cape town

58.5.3 Grey water treatment

After showering or washing hands, the wastewater is fed into the grey water system, treated, and temporarily stored. Kitchen sewage or wastewater from the toilet is not treatable as grey water. It is still discharged as wastewater and not collected. The remaining grey water is treated without chemical additives, just by filtering. The processing takes place in several steps: undissolved (hair, fluff) and dissolved substances (oils, soaps) as well as bacteria, microorganisms and germs are filtered out. Residual materials are discharged into the sewer system. With the treated process water, toilet flushing can be supplied directly from the system. If the process water supply is insufficient, drinking water is automatically added.

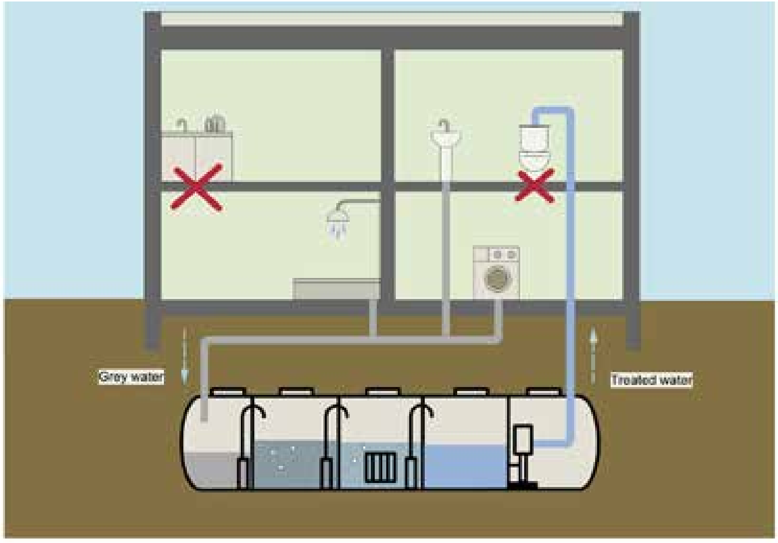

Figure 58-13: Principle sketch for a grey water system: first part: biological treatment by oxygen enrichment, second part: filtration, third part: Storage of grey water for operation

Function of grey water systems

According to drinking water ordinances, a pipeline system separate from the drinking water network must be provided for the grey water: the wastewater should be collected via separate pipes and fed into the plant (source Based on Grauwasser nutzen und doppelt sparen – bauen.de). For single-family houses, there are small systems on market with a treatment volume of 300 litres or more per day. The collecting tank, filter and pump are integrated into the compact systems. They can be set up in the basement or buried in the garden to save space. Large-scale facilities for apartment buildings, hotels, camping places etc. are possible and have been in operation for years. It is recommended to obtain information about the efficiency of the technical equipment in advance (e.g., the different pumps in the circulation).

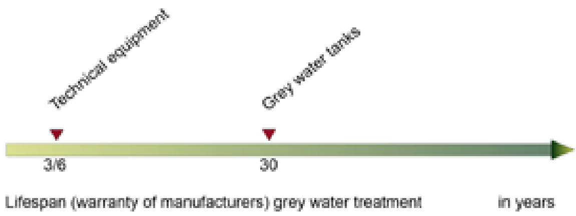

Figure 58-14: Warranty of manufacturers e.g., www.graf-online.de. To change components of the technical equipment is possible in frame of maintenance

Initial conditions and first steps

Introducing measures for the water treatment of a building normally requires a building permission. In the case of new buildings, the question of water treatment is part of the permission procedure. In some countries or municipalities, grey water treatment is supported by grants or loans.

58.6 Sustainable rainwater management

Buffering heavy rains by rain water management

Like the green roofs, any measure of sustainable rainwater management releases the precipitation with a time delay. In case of heavy rain, the urban drainage is relieved considerably, and the risk of flooding is reduced, if the rainwater remains on site.

Infiltration basin and pond/rain garden

The easiest way to keep rainwater on site is to feed it into a rainwater basin/infiltration basin. The properties of the soil must be known to properly plan location, size, and layers of the pit. A rough orientation is shown in figure 58-15. As a rule, it is assumed that an infiltration basin should occupy about 10-20% of the area to drain. For a roof area of 150 m2, a hollow of 15 - 30 m2 in size is needed. The better the permeability of the soil, the smaller the trough can be. In practice, it is well designed ifit empties itself after a rain within a day. If the soil is not that permeable, the water can also be collected in a pond/rain garden. It must be ensured that overflowing water can be safely discharged.

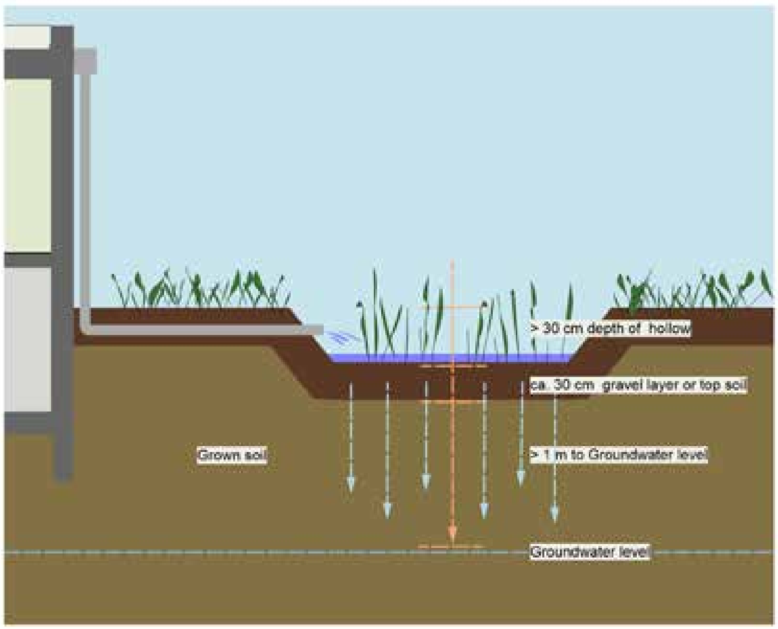

Figure 58-15: Rainwater infiltration basin

Rainwater cistern

Another way to keep the water on the property is to install a rainwater cistern. The water flows from the downpipe into the cistern which functions as buffer in case of heavy rain. Moreover, the rainwater can be used, for example, for irrigating the garden or flushing the toilet. In this way, as seen in chapter 4.5, the consumption of drinking water is reduced. If the rainwater is to be used for toilet flushing, the corresponding pipes must be completely separated from the drinking water network.

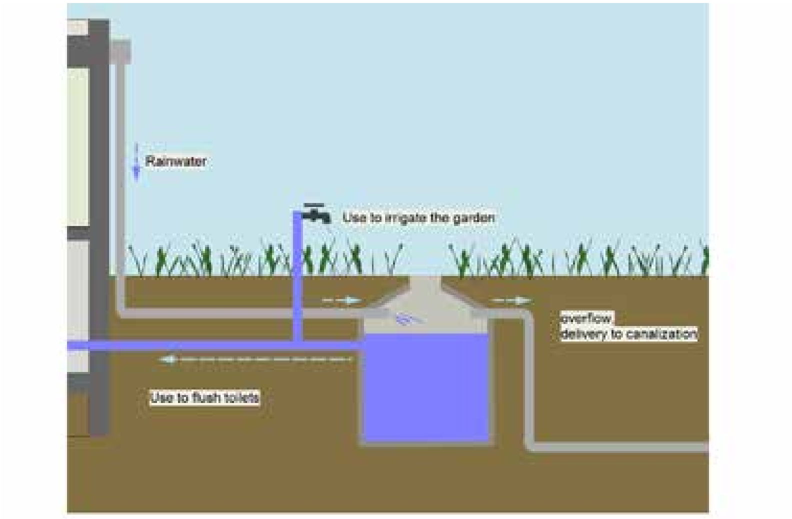

Figure 58-16: Sketch of a rainwater cistern made of concrete

Determining the size of cisterns

The size of the cistern must be carefully determined. If it is too big, it too rarely overflows. Regular overflow has cleansing effect. If it is too small and too often dried out, too much drinking water must be used in the system i.e., fed directly into the cistern. Both manufacturers and independent services provide tools which roughly calculate the appropriate size. It is recommended to compare the results of different calculation tools. In a first step, the yield of rainwater from the roof or other sealed surfaces is calculated and in a second step, the approximate consumption of rainwater of the household or the group of households is estimated.

- The yield is calculated from the size of the roof or sealed area, the discharge coefficient (see info box earlier) und a value for the medium precipitation, like indicated in rain maps.
- The consumption is calculated by the number of inhabitants and the estimated behaviours of flushing the toilet, irrigating the garden or washing the car.

The more parameters (e.g., type of water saving toilets, intensity of gardening) can be included in the calculation, the more realistic the result will be. See below for a practical example for the rough estimation of the size of a cistern.

1. The yield: Taking the previous example of a roof of about 150 m^2: water yield can be calculated from the size of the roof, its discharge coefficient, and the average precipitation of the location according to a rain map (in this case values for Northern Germany): Yield = 150 m^2 x 0,9 x 600 l/m^2 = about 81.000 litres per year)
2. The consumption: Taking 4 inhabitants, using nearly 60 litres per capita and day, compare with figure 58-11 in chapter 58-5 water saving measures (attention: rainwater is not suitable for the laundry, but for toilet flushing, watering the garden etc., here plus some buffer) Consumption = about 86.000 l/year for irrigating the garden and flushing the toilet plus some buffer

3. The selected size: The size can then be determined by dividing the consumption by a factor equal to 30/365 to account for the balancing/buffer dry periods. Before selecting a certain vessel, it should be double checked with the yield. Double check with the yield = 150 m^2 x 0,9 x 600 l/m^2 = about 81.000 litres per year; Selected size = 86.000 x 30/365 = about 7000 l

That means the cistern is not too big, so a cleansing effect by overflow will occur. An example for the size of a 7000 l cistern is: 2933 x 1980 x 2408 mm.

Materials for cisterns

Cisterns made of concrete (water resistant concrete) or plastic (Polyethylene (PE) or Fiberglass reinforced) are available in sizes of 3000 – 10.000 l. Although comparable warranties are given for concrete and plastic cisterns, concrete cisterns are considered more long-lasting.

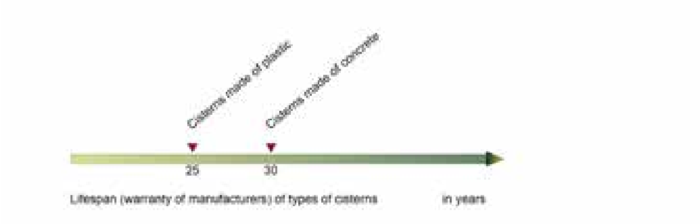

Figure 58-17: Lifespan/warranty of manufacturers for cisterns

However, it is more expensive to install concrete cisterns. The excavation needs to be deeper and in addition its installation requires the support of a crane. In an area with a high groundwater level, a plastic cistern could float due to its reduced weight in its empty state. Contamination of groundwater and wastewater does not as yet appear to be caused by any of the materials. It is recommended to obtain information about the efficiency of the required pumps.

Initial conditions and first steps

To decide on one or other variant of rainwater treatment, pond, infiltration basin or cistern, a soil assessment is required. Thus, the properties of the soil, related to its seepage capacities can be assessed. Introducing measures for the water treatment of a building normally requires a building permission. In the case of new buildings, the question of water treatment is part of permission procedure. Strangely, it is possible, but not recommended, to order cisterns from large international companies. Before ordering such a large vessel, the aforementioned preliminary considerations, calculations and planning are required! This includes exploring if a building permit is required. For tanks above a certain size, this could be the case, for example for a tank bigger than 5000l.

58.7 Water permeable surroundings

Buffering extreme temperatures and heavy rains through water permeable surroundings

As previously mentioned, some municipalities enact rules, which state that gardens in front of the house must not be sealed. There are some good arguments for this policy. Compared to the natural soil, a sealed surface carries significant negative impacts to the surrounding microclimate and the wider environment.

- Negative impacts associated with sealed areas:
- heat up in summer, risk of "heat islands"
- prevent the penetration of precipitation water
- the air is drier and dustier, as there is no plant evaporation.
- less water to be supplied to the groundwater
- less soil filtration to cleanse the water

Therefore, as little space as possible should be sealed on the property, in gardens, courtyards, in front of houses etc. Of course, access to the entrances should be easily walkable. But many surfaces could be unsealed without a loss in comfort or accessibility. If a surface must be used as a parking place, fire brigade driveway, or other reasons, there are many possibilities to adopt a water-permeable construction. However, paving and sub-structure must be frost-proof and able to absorb the respective loads of cars, fire trucks etc. Joints and all required layers of the sub construction must also be water permeable. Figure 58-18 shows two sketches of water permeable pavement and sub construction with good infiltration. The thickness of the gravel layer must be dimensioned according to the ground quality and assumed load.

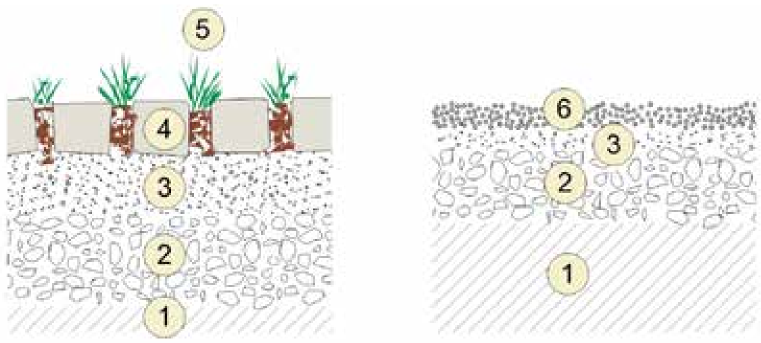

Figure 58-18: Sketch of two types of water permeable paving and sub construction: 1 grown soil, 2 crushed rocks, 3 crushed stones, sand 4 cobblestone 5 widened joints, filled with substrate, 6 gravel

Despite the relative advantages of permeable pavement compared with sealed surfaces, not all materials used have as good a discharge coefficient as the natural soil, see the part of the list of typical values on the table below:

Type of surfaces	material	discharge coefficient
Roads, car parks etc.	Asphalt	0,9
	Gravel	0,6
	Infiltration capable paving	0,4
	Paving with widened joints	0,4
	Gras paver	0,15

Type of surfaces	material	discharge coefficient
Green areas	garden, meadows	0,0 -0,1

Table 58-3: Discharge coefficients for different materials

Gravel

The gravel covering impresses with its simple and well-priced construction. This type of surface is not suitable for heavy vehicles, like fire trucks. Some maintenance, like sweeping is needed to maintain the gravel layer.

Figure 58-19: Parking lot with water-permeable gravel surface

Infiltration capable paving:

In the meantime, there are pavements in which not only the joints, but also the paving stones themselves are permeable to water – typically concrete blocks with an open-pored character. The water seeps through the pores of the stone itself and they can be laid without particularly large joints. This allows for a quieter, easier-to-walk surface. It would be appropriate to check the fact sheets of the manufacturers, where the discharge coefficients should be indicated, and compare them to those in table 58-3 to have an idea of their relative advantage in permeability compared with other materials. These stones are softer than other pavement and cannot be driven on by heavy vehicles. Regular cleaning of the paving is required to keep the pores open and protect them against sludge. Nevertheless, according to the available research, the infiltration capacity decreases significantly after a short time following installation.

Figure 58-20: Concrete blocks with open pores structure

Paving with widened joints:

Joints alone do not fully make paving infiltration capable. The surface in figure below is beautiful but is considered sealed, as the joints are too narrow and filled with impermeable material.

Figure 58-21: This surface is still considered as sealed

Hard coverings like paving made of concrete, clinker and natural stone are suitable for infiltration-capable constructions if they are laid with widened seepage joints. The joints (widths of up to 3 cm in practice) are filled with suitable material. In some products the right distance between elements is kept through small bulges, serving as spacers, see sketch below. If the substructure is correspondingly strong, the surface can be driven on by heavy vehicles.

Figure 58-22: Water permeable surface of a car park: Paving with widened joints (ca. 3 cm) and principal sketch of a stone (1) with a small bulge (2) serving as spacer

Gras pavers:

These structures have a very good discharge coefficient. This is due to the share of joints and recesses in this building material to approx. 40 - 50%. If the substructure is correspondingly strong, this surface can be driven on by heavy vehicles. In Germany, fire brigade driveways are often executed in this way

Figure 58-23: Gras paver to fix a fire brigade driveway for a multifamily house

Initial conditions and first steps

Even these few examples show that there are different construction methods to meet many requirements, with which a sealed surface can be replaced or avoided. However, these coverings cannot meet all requirements at once, e.g., a smooth surface that can be used with heavy vehicles. So, careful considerations are required at the beginning. All measures should be planned and carried out in a state-of-the-art manner. A complex renovation is an opportunity to improve the surroundings of the building.

58.8 Shading and passive cooling

In the urban environment, measures against overheating are of particular importance. The bundle of measures from planning of trees or unsealing the soil near buildings, to façade and roof greening can be continued with passive cooling measures inside the buildings. More information is given in module 9.

Figure 58-24: Different types of exterior shading elements

KEY POINTS TO REMEMBER FROM MODULE 10

- **Measures on site can contribute to the overall resilience of the system**
- **Most adaptation measures are construction projects, requiereing proper planning and execution**
- **Weather extremes can be buffered by roof and facade greening rain water management water permeable surroundings**
- **Flood protection starts with a protection concept at the very beginning**
- **Water saving starts with behavior chance up to technical solutions how to use grey water**

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