Spread of Innovative Solutions for Sustainable Construction

Handbook

6 Active Solutions

IS-SusCon

Co-funded by the Erasmus+ Programme of the European Union

6 Active Solutions

Building technology system is a category that is made up of all mechanical, gas, electrical, sanitary, heating, air conditioning, ventilating, elevator, plumbing, life-safety, telecommunication and other service systems of a building.

There are essentially three ways to reduce the consumption of electricity and pipeline gas:

- When designing and building a house, we strive to ensure mini mum energy consumption - these are passive solutions.
- We use energy-saving equipment and household appliances, and we also operate them economically and consciously regarding the environment.
- We install and use renewable energy sources.

The latter two can be referred as building technology systems. These are not mutually exclusive solutions; the best option is to take advantage of all three options.

In the following chapter, we give a short overview of the most common building technical systems and their environmental relevance.

6.1 Heating, cooling, ventilation

a. Heating systems

A heating system is a mechanism for maintaining temperatures at an acceptable level by using thermal energy within a home. It is often part of an HVAC (heating, ventilation, air conditioning) system. A heating system may be a central heating system or distributed in each room.

Every heating system consists of two parts: the heat source and heat dissipator. In central heating systems the two parts are separated from each other. For example, in homes equipped with central heating system, heat is usually generated centrally by a gas boiler or a heat pump. This heat is then transferred as hot water in the pipes towards each room and it is dissipated by radiators or underfloor pipework.

In case of heat dissipators, the construction of radiators is usually simpler and therefore, faster and cheaper than that of surface heating. The cost of underfloor heating is much higher; however, it results in a much larger heating surface. On the one hand it is more comfortable, because there fluctuation in temperature is less temperature. On the other hand, it has lower operational costs as the heat generators (boilers, heat pumps) can operate more economically by needing lower water temperature.

In new family houses, the most common heat generators are condensing gas boilers, heat pumps and wood gasification or co-fired boilers.

Perhaps the most common heat generators are condensing natural gas boilers, which have an efficiency of at least 86% for new equipment according to standards. It recovers flue gas heat to preheat the cool water returning from the heating system. The cooler the returning water from the radiators, the better its efficiency. This is why condensing boilers work better with surface heating, such as floor, wall or ceiling heating. If this is not possible, at least efforts should be made to install radiators with a larger surface area than necessary, in order to lower the return temperature and thus more economical heating.

A co-fired boiler can be an economical choice in a rural location where cheap firewood is available. However, these boilers are being phased out as many people do not use them properly. The burning wet firewood or household waste results in the release of very harmful pollutants. Wood gasifiers require extra low moisture wood for proper operation. These boilers produce high temperature heating water - a good pairing for conventional radiators as heat emitters. If it is used for surface heating, the heating water must be mixed with the return water, so the efficiency will be reduced. Thus, installing an intermediate buffer tank between the heat generator and the heat emitter is absolutely necessary.

There is a growing interest in electric boilers among people who renovate their houses or plan to build new ones. These do not require complicated permitting processes for natural gas use, nor do they generate flue gas, which should be removed, and they are also suitable for radiator heating. Here, however, the main disadvantage is that electricity is the most expensive energy source.

In addition, there are heating systems where both the heat generator and the heat dissipation unit are located inside one single unit, for example air conditioners with heaters or oil-filled electric radiator space heaters. These are more common in places where the heat demand is small or casual such as cottages or regions with mild winters. Open fireplaces and heating fans usually serve only as complementing units.

More recently, low-cost heating cables, heating foils and infrared panels have also been introduced to the market. As they use electricity for heating, the user has to pay a much higher energy price than for natural gas or firewood. On the other hand, combined with renewable energy systems that generate electricity such as photovoltaics the operational costs can be competitive.

Heat pumps also use electricity but they are 3-4 times more efficient than other electric heating options. This is because heat pumps collect heat from the soil or the air, and concentrate it for use inside.

Condensing gas boilers

With some countries as exceptions, natural gas boilers are the most common heating systems in Europe. Now, only the most efficient condensing boilers are now used. It is also one of the best choices in terms of comfort and air pollution, and it is also one of the most economical solutions with adequate thermal insulation. Due to its low cost and reliability, other heating systems are almost only economical, if the installation of the gas boiler is not possible for some reason or requires very expensive renovation (e.g. a new chimney). A serious disadvantage is that natural gas is not a renewable energy source and, in addition, most of it must be imported from outside Europe. Its carbon footprint is higher than those of wood-fired or heat pump systems. Expecting a possible future rise in gas prices and for climate protection reasons, more and more people are choosing other heating systems instead. With regard to other pollutants, however, gas combustion is relatively clean compared to conventional coal or wood burning, as neither particulate matter, nitrogen oxides nor sulphur oxides are produced in large quantities.

Environmental impact during the life cycle

Production and installation include not only the manufacturing and installation of the boiler, but also other equipment required for the operation such as the chimney, combustion air supply and so on. Still, this section represents only a very small environmental impact compared to the operational phase. The operational phase includes the extraction, transportation and combustion of natural gas, maintenance and possible replacement of parts. From an environmental point of view, the most important part is the combustion of natural gas itself, as it generates high CO_2 emissions. Burning one cubic meter of natural gas releases approximately 2 kgs of carbon dioxide. In addition, natural gas has to be made available in our homes, and during the extraction and transportation of natural gas, some of it inevitably leaks into the atmosphere. This is a significant problem as one of the main components of natural gas is methane, which is about thirty times stronger gas in terms of greenhouse effects than carbon dioxide. At the end of its life, the disposal of equipment does not pose a major risk to the environment: most boilers and other ancillary equipment consists of easily recyclable materials, mostly metals.

Heat pump / air conditioner

Any machine that extracts heat from a colder place and transports it to a location with higher temperature is called a heat pump. This is how our everyday refrigerator and air conditioners work. When used for heating, heat pump acts as a “reverse” refrigerator: it draws heat from the outside environment and transports it to the inside of the house.

Depending on the design, some heat pumps can only be used for heating but there are also types available that are suitable for cooling in summer and for producing domestic hot water as well.

In a heat pump, the refrigerant liquid evaporates in a heat exchanger while absorbing the heat of the environment (e.g. from the water from pipes laid in the ground or from the outdoor air). It then releases its heat while condensing and returning to a liquid state. Then the cycle starts all over again.

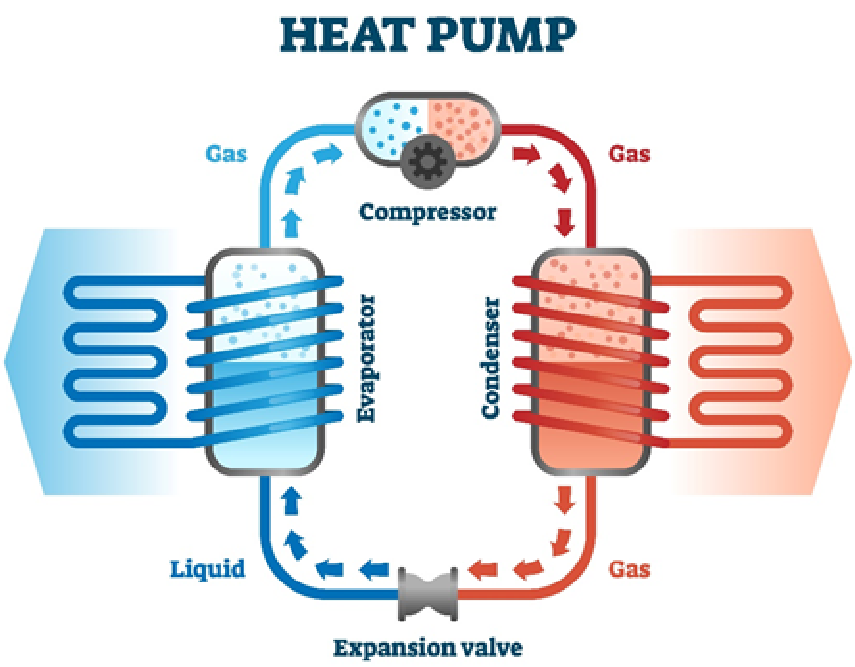


Figure 29: Schematic of a simple heat pump

The source of heat can be external air, soil or, if available, even surface waters such as a river or lake. A common feature of water-to-water heat pumps is that they utilise the heat of groundwater or surface water, and the heated medium is also water. Similarly, ground-to-water systems extract heat from the ground and air-to-water heat pumps extract the heat from the outdoor air. The heated medium can be water if the hot water is fed into a central heating system or the temperature can be set directly by blowing hot air in the rooms. In this latter case, we are talking about air-to-air, water-to-air or ground-to-air systems.

Several types of heat pumps are distinguished depending on the location of heat removal and its medium. There are three types of heat pumps: air-to-air, water source, and geothermal. They collect heat from the air, water, or ground outside your home and concentrate it for use inside. The most common type of heat pump is the air-source heat pump, which transfers heat between a house and external air.

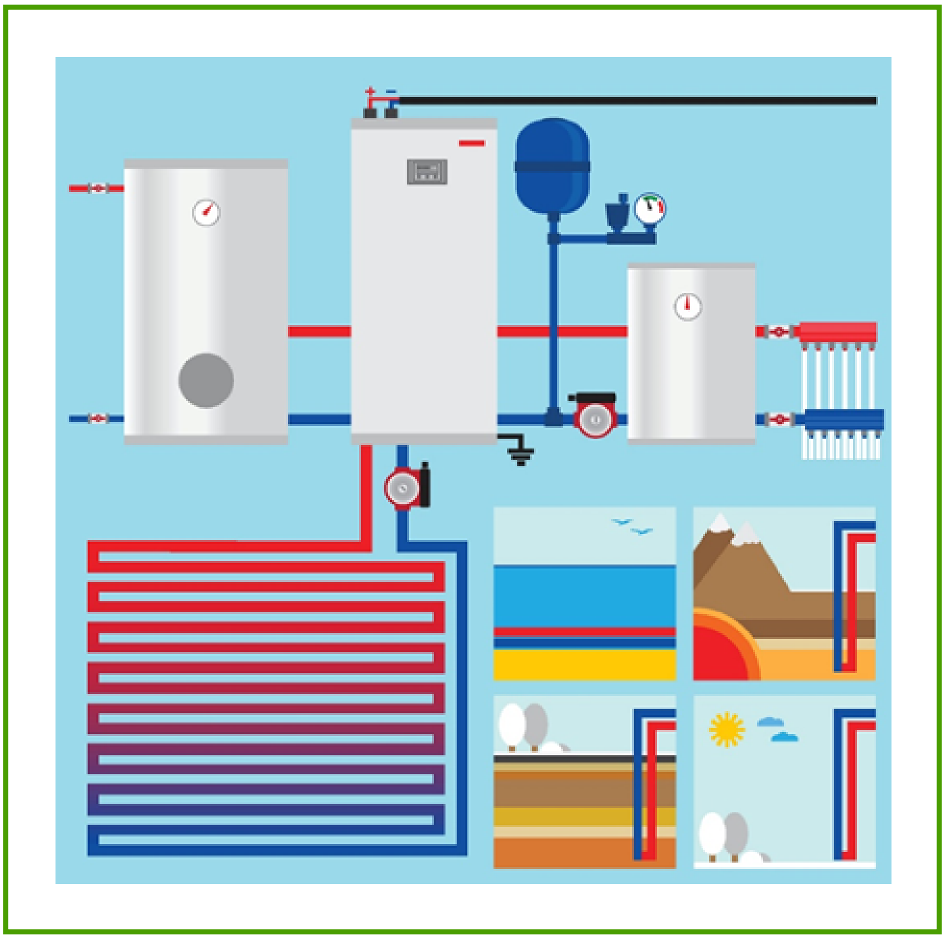


Figure 30: Diagram of a typical heat pump system, including buffer storage, pressure valve and electric pump. Source of the heat can be various, such as the air, the ground or a lake

Air-to-water systems are the most common today due to their relatively low investment costs.

Electricity is required for the heat pump to work. All heat pumps available on the market are given a COP ("coefficient of performance") value, which presents how much heat energy is produced by consuming a unit of electricity. The COP value is not constant throughout the year, as the larger the temperature difference it has to overcome, the worse the efficiency will become. For example, ground probe systems consume less in winter than an air source heat pump with the same heat output because the deeper layers of the soil never cool as much as the ambient air. Similarly, efficiency is higher if a lower temperature is sufficient for proper heating, such as in the case of underfloor heating.

Therefore, it is better to look for the SCOP ("seasonal coefficient of performance") value, which gives the efficiency for the entire heating season. This can be found on the energy efficiency label of heat pumps together with the SEER (" seasonal energy efficiency ratio") if the heat pump is capable of cooling as well. Both values are very important when selecting a heat pump, as the higher these numbers, the better the efficiency of the machines are. Production of heat pumps is also the most relevant in terms of mineral resource depletion because these machines contain a large amount of stainless steel, copper and other valuable materials.

Environmental impacts of heat pumps

Production and installation

The production of heat pumps and the refrigerant liquid is a material- and energy-intensive process, so it can be accountable for up to half of its the environmental impacts during its entire life cycle. The production and installation of ground-water systems that use more materials and involve more installation work are more harmful to the environment than air-to-water heat pumps, but they put less load on it during operation because they use less electricity.

Operation

Although no smoke is generated when using heat pumps they still present indirect emissions by using electricity. Although these emissions might not be apparent electric power still has to be produced in one way or another. Indirect emissions are highest in countries where most of the electricity comes from fossil fuels (such as coal or natural gas). In such cases, the overall environmental load of using a gas boiler may be less than heat pump. In contrast, where a large proportion of electricity is generated by renewable energy sources, such as solar, wind, or hydropower, the heat pump emits much less than a gas boiler. For this reason, if financially possible, heat pumps can be well paired with solar photovoltaic systems that provide renewable energy for the operation of the equipment. As the proportion of the renewables are expected to grow everywhere in the future, along with improvements of the heat pumps efficiency, it will certainly become one of the most environmentally conscious heating methods.

Refrigerant leak

All heat pumps are filled with approx. 1-2 kgs of special refrigerant. These refrigerant leaks very slowly over the years, so it may need to be refilled. Unfortunately, these refrigerants are powerful greenhouse gases, so a leak of only a few kilograms equals to hundreds or thousands of kilograms of carbon dioxide. Since, on average, half of the refrigerant leaks over the life of the equipment, this entails a very significant environmental impact, reaching up to a quarter of the total carbon footprint.

Dismantling and waste management

The main equipment of the heat pump is almost completely recyclable. Exceptions to this are plastic pipes, fittings, components that are either incinerated or disposed of at the end of their life cycle. Unfortunately, during disassembly and disposal, the remaining refrigerant may leak, so this can only be conducted by licensed companies.

Sources

1. Viral P. Shah, David Col Debella, Robert J. Ries (2007): Life cycle assess ment of residential heating and cooling systems in four regions in the United States.

2. Simona Marinelli, Francesco Lolli, Rita Gamberini, Bianca Rimini, Life Cycle Thinking (LCT) applied to residential heat pump systems: A critical review,Energy and Buildings, Volume 185, 2019, Pages 210-223, ISSN 0378-7788, https://doi.org/10.1016/j.enbuild.2018.12.035.

Wood gasifier boilers

Wood gasifier boilers provide heating by burning pelleted biomass, such as sawdust and other woody waste depending on their design. Compared to other heating systems the disadvantages may be that the quality of pellet varies and in some cases it has a more difficult controllability compared to other heating systems. In addition, it can be inconvenient to constantly refill the equipment with pellets and dispose the resulting ash. An environmentally important advantage is that the carbon content of the fuel has plant origin, i.e., it only emits as much carbon as the plant has sequestered over its lifetime. Thus, by burning pellets, it contributes much less to climate change than by burning natural gas. Yet it cannot be called "climate neutral" because timber extraction, pellet production and transportation all involve emissions. Furthermore, burning biomass results in the removal of valuable nutrients from forests and other agricultural areas. Combustion of pellets also produces other air pollutants: flue dust, sulphur oxides, nitrogen oxides, hydrochloric gas, etc. These emissions are significant because they occur in residential areas and thus have a detrimental effect on human health. Compared to conventional wood burning, on the other hand, it has better efficiency, lower emissions and it is a more controllable, more convenient system.

Electric heating

Direct electric heating is also possible, although it is most often it is only installed additionally to other heating systems. This is because operation costs can increase with three to four times compared to other heating methods. In return, however, it is easy to regulate, convenient, investment costs are low, and its construction is simple, if sufficient power is available from the grid. Maintenance needs are also minimal. It is often used outside the main heating season, for example in late spring, when only moderate additional heating is needed. In mild climates and well-insulated houses, it might as well supply the entire heat demand.

There are many types of electrical heating, e.g. infrared panels, oil filled radiator heaters, heating foils and heating cables for floor and wall heating, hot air blowing fans, electric boilers and stoves etc.

An apparent advantage of these is that no harmful air pollutants are generated at the place of use. The production of electricity, evidently, involves emissions but these occur far away from residential areas and are usually strictly controlled. Environmental impacts are thus largely determined by how electricity is produced. In contrast, the production and waste management of the heating equipment itself is of little importance. It also does not generally matter the type of system used (e.g. radiator, infrared panel, etc.) selected, the amount and source of electricity used is much more important in this aspect.

District heating

Modern district heating systems can be one of the most environmentally friendly solutions in densely populated urban environments. Its main environmental advantage is that heat can be obtained from a variety of energy sources, such as waste heat from power plants, waste incineration or natural gas or even using geothermal and solar energy.

Another important advantage is that large central heating plants can be controlled and its emissions can be reduced more easily than many small individual boilers.

For this reason, many major European cities are intensively developing their district heating systems. Much like electricity, the environmental impact of district heating is determined by the source of the heat.

Summary

It is a main characteristic of all presented heating systems that the production of heat generating equipment (boiler, heat pump, etc.) is almost negligible from an environmental point of view. It is a more important aspect how much heat should be generated during the use and from what source. Firewood and pellet combustion are beneficial from the viewpoint of climate protection, but unfortunately, they contribute greatly to local air pollution. It would be more appropriate to use them in district heating, as it is much easier to clean flue gases properly in large heating plants.

Natural gas combustion does just the opposite: it burns much more cleanly, so it makes only a small contribution to air pollution, but it is a non-renewable resource and its lifecycle involves significant CO_2 emissions.

Electric heating is relatively expensive to operate and beneficial only if the electricity comes mainly from renewable sources. Heat pumps are very efficient at converting electricity into heat, but unfortunately the escape of refrigerant partially offsets this, so they only compete with other energy sources in terms of environmental impact if the electricity used is largely produced by renewables.

It is important to remember – the best type of energy is the one that is not needed to be produced.

b. Ventilation

Nowadays, when it residential buildings are renovated and modernised, usually doors and windows are replaced, the roof and the facade are both insulated, and sometimes the old heating system is updated. There is little talk of ventilation, and many times it is not even planned.

Old wooden doors and windows let in some air even when closed, providing some sort of ventilation. New doors and windows are however completely air-tight. That is why we need to pay more attention to ventilation in case of renovated buildings.

Also, it is well known that nowadays, people spend much more time indoors than in the old days. 90% of the time we spend working, resting and leisure are usually spent indoors, in closed buildings from where we take the air we breathe. Therefore, the quality of the inhaled air has become very important. If a building is not properly ventilated - for example, if the windows are new but not opened frequently - the humidity in the air and the amount of pollutants can increase greatly indoors.

Depending on the habits of the occupants, the pollutants generated in an average dwelling can be of:

- water vapour from exhalation, kitchen activities, bathing, etc.
- carbon dioxide from exhalation
- other gases and vapours (e.g. smoking)
- other combustion products e.g. in the case of a gas stove,
- decomposition products of organic materials, evaporation products of building, materials,
- dust, suspended matter, pollens,
- viruses, bacteria, fungi and their spores in the
- odours from kitchen and restrooms.

Humidity is an essential component of air quality. For a healthy adult, humidity between 40 and 60 percent is optimal. By exhaling, in addition to the vapor, a fairly large amount of carbon dioxide is released into the air. Indoor air can be considered good if carbon dioxide levels remain below 1 ppm (parts per million).

Fungal spores are always present indoors, no matter what the conditions are. If other conditions are met (no ventilation, the wall corner or other thermal bridge cools below the dew point, condensation is present, the internal relative humidity rises above 75% - high internal moisture development), the appearance of mould is inevitable. With adequate ventilation, though, the chances of this can be reduced.

According to standards, the minimum fresh air requirement of a resting person performing sedentary or light physical work is 30 m3/ h / person. It can be higher in case of medium or heavy physical work. An average ventilation with a few minutes of window opening two to three times a day, calculating average for 24 hours equals to approx. 4 m3/ h air circulation. It is easy to see that if new doors and windows are installed, it is not possible to provide the right amount of fresh air just by opening the windows - especially if there are several people in the room. The new and renovated buildings nowadays, therefor need to be ventilated more, and mechanical ventilation is becoming more and more widespread.

Another argument in favour of mechanical ventilation is the following, by simply opening windows, we are often unable to improve air quality as external air is very polluted. In addition, there are more and more people living with allergic, asthmatic and other respiratory diseases, which also prohibits allowing simply external air of entering to their homes.

One possible way of ventilation is to build an air duct network with a central ventilation system. Ducted systems simply use ductwork. If a home already has a ventilation system or the home will be newly constructed, you might consider this system.

On the other hand, ductless applications require minimal construction as only a hole of three inches is required through the wall to connect the outdoor air vent cover and the indoor ventilator. Ductless systems are often installed in addition, when the ventilation of each room can be created separately.

Simpler, fresh-air mechanical ventilation systems provide only the necessary air exchange and air filtration but result is significant in terms of heat loss in cold weather. For this reason, the so-called energy recovery ventilation (ERV) systems are now often used. These use a heat exchanger to heat the incoming cool fresh air with the warmth of the indoor air, so that their use involves much less heat loss.

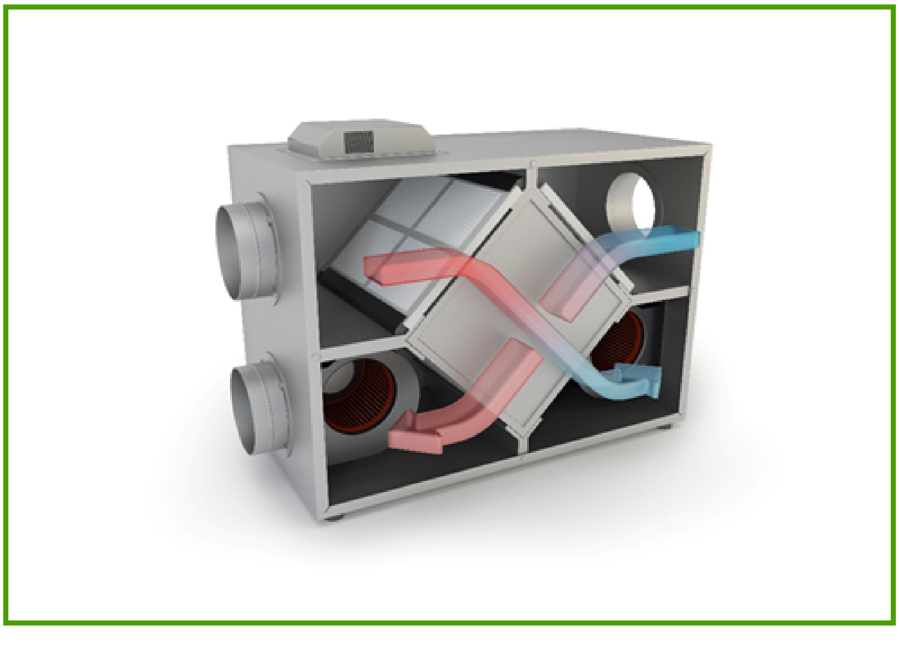


Figure 31: Ventilation system with built-in heat exchanger

Environmental impacts of ventilation

The production and disposal of ventilation systems are generally negligible compared to the energy required during usage. The only exception is mineral resource depletion as ventilators contain valuable metals such as copper, aluminium and stainless steel.

During the phase if use, energy consumption is the most important part. Energy consumption comes from two aspects: the electricity consumption of the equipment, and the thermal energy that is needed to offset heat loss during ventilation. For example, even if no electricity is used when we open windows, we still lose heat or cold that has to be replaced. In case of ventilation systems with energy recovery, heat loss is lower but in return some extra electricity must be invested in the operation of the heat exchangers.

6.2 Lighting

The design of lighting in an apartment is highly dependent on the style of the occupants. Many people want to determine the style and atmosphere of the interior lighting themselves. We would not want to take this beautiful, creative work away from anyone. However, in order for all the spaces in the apartment to receive optimal lighting (neither more nor less), it is also worth asking for advice of a lighting specialist or an interior designer. If you we wish to provide an environmentally friendly lighting, here are some tips to share and follow.

14% of the electricity consumption of an average European household is spent on lighting. This also means a significant burden on the environment. If we can reduce this with modern light sources and with the right design, it will be economically beneficial to the residents and the environmental impact of the house can be reduced as well.

Some lighting system quantities that are useful in choosing a proper light source.

We do not provide the adequate textbook definitions as they can be accessed with a few clicks. Rather, we would only show the buyer information worth knowing, the meaning of the data on the boxes, so that when we make a purchase, we can make a more informed decision.

- Luminous flux
- Efficacy
- Average lifespan
- Colour temperature
- Colour rendering index (R_A)

	Incandescent	CFL (Compact Fluorescent Lamp)	LED (Light Emitting Diode)
Efficacy (lm/W)	10-15	50-70	80-200
Lifespan (hours)	1000	8-12000	10-50000

Figure 32: Comparing light sources[59]

Luminous flux: All radiation emitted by a light source per unit time that can be perceived as visible light. Its calculation also takes into account the sensitivity of the human eye in the middle range of the visible spectrum (yellow - green). Unit: lumen [lm] (A 75 watt incandescent lamp emits approx 1000 lm.) (Spectrum: white light resolved by color or wavelength.)

59 Source: György Gröller

Efficacy:

The lamp converts electric energy into useful light radiation, and the rest into heat, sometimes invisible UV (ultraviolet), or IR (infrared) radiation. The efficacy shows how much luminous flux the lamp provides from 1 W of electrical power. This is the most important feature in the use phase of the life cycle.

Average lifespan:

It is also important from an economical and environmental point of view. Here we understand the concept "life" differently, LEDs do not suddenly break, their luminous flux decreases slowly. Life expectancy is defined as the luminous flux decreases to 70% of the original and is given as L70. The lifespan of LEDs can be significantly reduced if operated at higher temperatures.

Lamp comparison should be based on the quantified function, which also implies "for how long" the function is provided. For example, if we have to choose a 10,000-hour compact fluorescent lamp and a 20,000-hour LED we have to compare the price and production load of two fluorescent lamps with that of an LED. If we look at the lifespan of an LED for 20,000 hours, we have to buy about 20 incandescent bulbs during this time, and their energy consumption is about 10 times higher than that of an LED. That is why we cannot even buy a light bulb in the EU.

Color temperature (Tcc):

To put it simply, when a material is heated, it emits light at a higher temperature, and its color changes with temperature. It is initially red and the higher the temperature shifts towards blue. Thus, we can use temperature to characterize the shade of white that light sources shine with.

- warm white (T < 3300K)
- neutral white (3300K < T < 5500K)
- cold white (T > 5500K)
  This called "daylight" also, because the color temperature of the Sun is about 6000K.

It is recommended to use warm white inside the apartment, it is good to use neutral white at most in the bathroom and work areas. It is especially annoying when light sources with different color temperatures are mixed within the same room

Color rendering index (RA): It shows how faithfully a light source reproduces or distorts colors that are perceptible in natural light. Incandescent lamps are the best in this field (RA = 100), but RA values above 80 are already acceptable within the apartment. For LEDs, the price of better color rendering is slightly lower efficacy.

The features listed above shall be applied to light sources that can be found on the boxes of bulbs. In order to enjoy the right lighting in every part of the apartment, we need to place them well, we have to plan the general, local, direct, indirect lighting, the regulation (dimming) of the light sources. In other words, the right illuminance needs to be implemented. It is advisable to seek help of a specialist, as poor lighting makes the eyes unreasonably tired and impairs the feeling of comfort. Excessive lighting can also be annoying, but it is definitely a waste of energy and a burden on the environment.

Figure 33: Information on packaging. (The efficacy is: 1100lm/12W=91lm/W)

Illuminance

With our eyes we see the density of light, which means the rays of light projecting from a given object in the direction of the perceptual eye. Measuring and controlling this in a given space is quite difficult, therefore, we determine the light conditions indoors by measuring the amount of light falling on the objects. This is the illuminance, i.e. the luminous flux per unit area (lm/m^2 = lux [lx]). Lighting standards and recommendations - in parallel with several other lighting quantities - provide this to different areas. Within the apartment e.g. 100-300 lux in the living room, 300-500 lux for reading, 750-1000 lux for kitchen worktops or meticulous work. In addition to the given levels, the uniformity of the lighting is also important. Good and economical lighting can be combined with a combination of general and local lighting: e.g. in the living room with general lighting supplemented with a reading lamp, in the kitchen with counter lighting, desk lamp on the desk, etc.

Uniformity is easier to achieve if indirect lighting is used, if this is achieved with more light sources with less power, and if the reflection of the walls is higher. In well-lit areas, we can see the fine details of objects more accurately, work more efficiently, and we are less tiring of our eyes. Illuminance is not automatic, it depends on the luminous flux of the lamps, the light distribution of the light sources, the reflection of the surfaces and the natural light. Therefore, it is advisable to seek the help of a specialist for planning, as poor lighting unreasonably tires the eyes and reduces the feeling of comfort. Excessive lighting can also be annoying, but it is definitely a waste of energy and a burden on the environment.

Lighting 101

Daylight

It is the cheapest and the least environmentally damaging. If it is possible to let natural light in with proper orientation and the use of reflective, shading surfaces, we can save significant lighting energy. A sunny, bright apartment has a positive effect on our mood but even on our ability to work. Of course, if it is too much, it causes glare, so it is important to think about its regulation and shielding. Also, one should keep in mind that the thermal insulation of the windows is 2 to 3 times weaker than that of the walls, so we gain from lighting with windows that are too large but heating energy demand may increase.

With the solution shown in the picture, natural light can be introduced into the less illuminated spaces of buildings, even a few levels down. Through the chimney with a reflecting wall inside, the sunlight reaches the apartment with little loss. Due to its price, it is used even more in public buildings today, but in a newly built apartment it can help if you have to place a study or kitchen on the north, shady side of the house. At present prices, investments of around € 500 - 1000 are unlikely to reduce significantly the electricity bill but due to the lower environmental load and the aforementioned freedom of arrangement, it may be an interesting alternative.

Figure 34:
Solar tube, part on the roof

Light sources

There are three types of lamps for home lighting: incandescent, compact fluorescent and LED. From the listed types, incandescent lamps can no longer be marketed in the EU due to their economic, technical and environmental parameters. The efficacy of compact fluorescent lamps is already significantly better but no more serious development is expected and its marketing will be banned in the near future due to its Hg content. LED is the only option left, and anyone planning new lighting for their home today is not worth looking for anything else. The rare convenient situation is that we do not have to compromise because of our environmental goals, LED is not only the most environmentally friendly but also the best from an economic and technical point of view. It also gives designers more freedom to implement beautiful, interesting, and unique solutions.

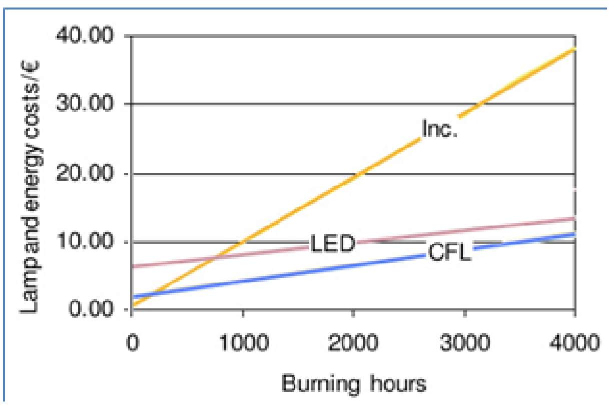
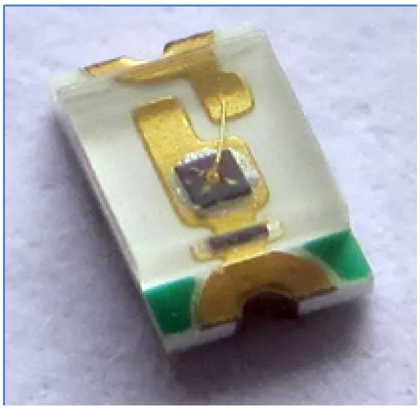


Figure 35: The cost of purchasing and operating a 500 lm light source as a function of time. (1 kWh ≈ 0,2€)[60]

60 Source: György Gröller

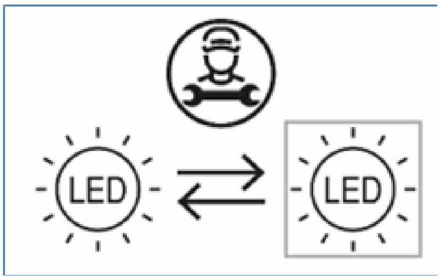
In order to confirm the above, the top diagram shows the evolution of lighting costs over time. The incandescent lamp produces an increasing energy bill after the low cost. The starting price of the other two light sources is higher but due to lower consumption, the total cost in a few hundred hours is less than that of a light bulb. The switching time between an LED and a compact fluorescent lamp depends on the efficacy of the LED. With today's 150 lm / W lamps, this happens after just a few thousand hours.



LED itself is a few mm diode by connecting several of them we can get an effective light source. The diodes operate on low voltage (12 - 24 - 48V) DC. It can be connected to the mains voltage via a power supply. There are separate and integrated power supplies with LEDs. So, when calculating the environmental impact of LEDs, the power supply should always be included in the calculation as well.

Retrofit lamps

These bulbs are similar in appearance and usage to conventional incandescent bulbs, they can be screwed in a place, and have a similar luminous flux to 25 to 100 W incandescent bulbs. The power supply is also clamped in the socket. This is a weaker solution in terms of both circuit and heat dissipation, so the efficiency and lifespan of these lamps are both also less than compared to a good LED lighting. In practice, this means an efficacy of 80 to 110 lm/W and a lifespan of 10 -20 000 hours. Its advantage is that it can be screwed into old chandeliers and sockets, and it does not require further investment.



Integrated LED

The potential of a new light source can be best exploited if the luminaire, LED panel, drive electronics and cooling are designed together and made up in a single unit. This refers to the design, many beautiful, elegant solutions are visible and also to efficiency, 130 - 180 lm / W and a service life of 50,000 hours are available today. So, it is designed for 20 to 30 years, so more noble, time and corrosion resistant materials have to be used which makes it more expensive. The disadvantage is that it is difficult to repair, the components are rarely replaced. Unfortunately, consumers have to count with the most failures regarding the other types. Many poorly designed, carelessly executed dumped goods that break down after a few weeks or months cannot be repaired. In principle, it would be possible to replace the panel or power supply but it is very difficult to persuade manufacturers to use standard components. The EU recommends using pictograms or similar on the packaging to indicate the interchangeability of components.

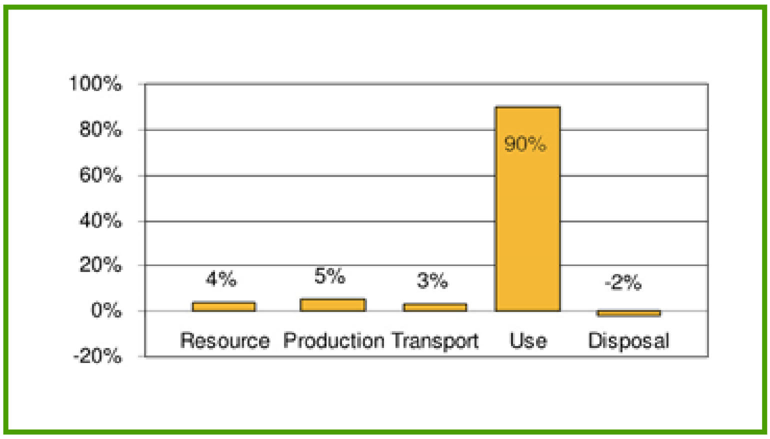
LED stripes

Ideal for indirect lighting of rooms and extra lighting of work areas. Coloured ribbons are suitable for unique decorations. It can also be a challenge for those who consider electricity their hobby. For long-term use, an aluminium rail with a plastic cover is required, so the environmental effects of it must also be added to the load on the power supply and the LED strip.

Lighting and the environment

The environmental impact of most light sources is significant during the use phase of the life cycle. Due to the small weight of the lamps, the production, transport and end of life (waste scenario, recycling) barely reach 10% of the total load.

Figure 36: Greenhouse gas emission of a retrofit LED at major stages of its life cycle. The other impact categories (e.g. Eutrophication, Ecotoxicity, Resource depletion, etc) also give similar results.[61]



What can the customer do in order to reduce the environmental impact of lighting?

Choosing light source

LED technology is still in the rapid developmental stage, the efficacy, lifespan and stability are still spectacularly improving. So, we need to know that new products are not only more expensive but are indeed better in the above-mentioned terms. When buying, it is definitely worth paying attention to the luminous flux, efficacy, colour temperature and lifespan of the lamp. The above parameters are usually found on the box of retrofit lamps, less often on integrated LEDs.

Use

We plan general and, if necessary, local lighting for our rooms. It is not a problem if we also have some scarcely used light sources, as it is not the production, but the use that presents the greater burden on the environment. General lighting should be dimmable/adjustable. The controllability of the lighting is important, on the one hand, as different lighting levels are suitable for different tasks, and on the other hand, individual people have different needs. In old age, higher illuminance levels provide the same level of visual comfort. Around the age of 40 approx. twice, over 60 approx. we require three times higher levels of illumination than in younger ages.

61 Source: György Gröller

Luminous flux control can be solved with individually dimmable (e.g. rotary knob) switches but there are control systems that automatically adjust the lighting for the lighting conditions and presence. The best known is the DALI system (Digital Addressable Lighting Interface). This can be part of smart home solutions. With this and similar systems, we can control the lighting in our home, remotely, or as a function of natural light or according to a specific program. Installation requires some extra wiring as well as dimmable light sources - this is usually marked on the packaging.

A long life of the LED is guaranteed if the lamp is not permitted to overheat. Therefore, LED chips are mounted on a good thermal conductive surface and they are not placed in a tight, non-ventilated space.

The environmental impact of the use phase depends to a large extent on the sources of the electricity consumed. Where the proportion of fossil fuels is high, the load is higher at the same consumption. That is why it is useful to cover as much of our energy needs as possible from our own solar source or from the other green energy.

The rebound effect

Switching to LEDs can also reduce the environmental impact and cost of lighting by 30 to 50%. Cheaper operating costs can lead to a more careless use, and it makes it easier to leave lights switched on in empty rooms, over illuminating rooms, which can neglect the environmental benefits of better light sources. In addition to conscious use, good planning and automatic control help. Then one must just pay attention to the money saved this way should not be spent on hobbies that are not environmentally friendly (referred to as an indirect rebound effect).

The end of life

According to the EU WEEE Directive, used light sources are classified as electrical waste to be collected (except for incandescent light bulbs). Therefore, it is essential and we kindly ask the reader to return waste lamps to one of the collection points. With today's technology, they can process the metal content of LEDs, especially aluminium, glass and plastic parts. For the time being, phosphors and semiconductor materials are being deposited. Compact fluorescent lamps will be in use for a few more years, although they will no longer be available for sale in the EU after 2021. Because of their mercury content, it is even more important that they are processed in a professional recycling plant at the end of their life.

Figure 37: Global rebound effect

6.3 Renewable energy sources

A national or European electricity mix includes some mixture of renewable and non-renewable sources. In most countries, the proportion of natural gas, oil and coal is still close to 50%. As can be seen in the diagram - and it is well known - their impact on the climate is more than an order of magnitude greater than that of renewables, and the trend is similar in other environmental impact categories. If we can decouple our house from this, it is a serious step towards an environmentally friendly, carbon-neutral home.

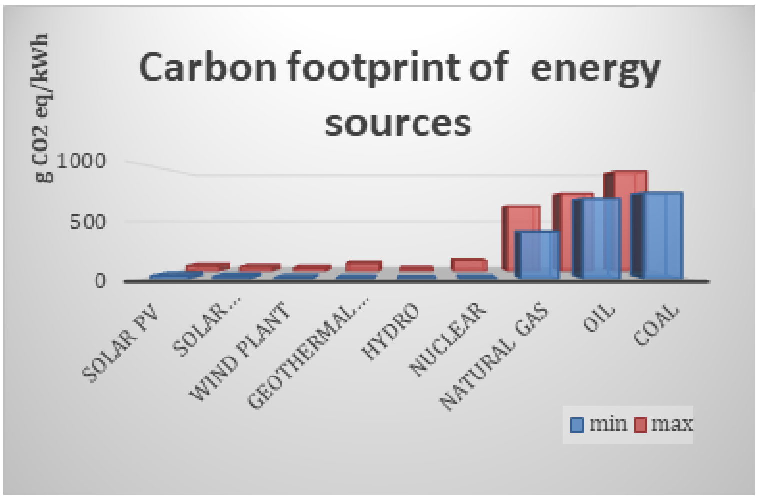


Figure 38: Carbon footprint of energy sources[62]

In the size of a residential building, solar panels, solar collectors and heat pumps using geothermal energy are the possible, suitable solutions, therefore, we summarize the characteristics of those.

a. Solar Thermal collectors

Solar collectors/ panels convert the radiant energy of the Sun into thermal energy that can be used to produce hot water and heat in homes. In a simple installation, we can obtain heat energy economically and with good efficiency. The downside is that it produces less energy in winter, when we also want to heat homes with it, and the surplus generated during summer cannot be stored. Otherwise this is referred to as a sizing problem, it is not worth installing more panels than the summer hot water demand because we cannot use the heat energy produced. Thus, in winter, we cannot expect heating assistance. Some might be able to equilibrate this energy variation of extra summer energy by heating their swimming pool but we do not wish to analyse the environmental impact of such a scenario.

62 Source: György Gröller

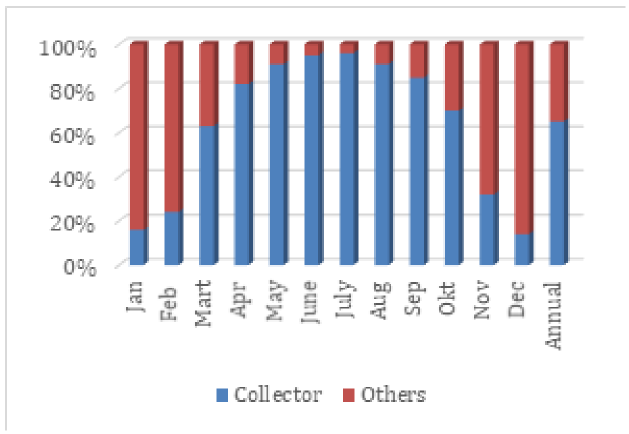


Figure 39: Distribution of energy sources required for the production of domestic hot water in one year[63]

Flat plate collector:

Under the cover glass run liquid-filled tubes that are in close contact with the absorber, which is a dark-surfaced metal (copper or aluminium) for good heat transfer. Below this plane is a thicker thermal insulation layer that prevents the liquid from cooling.

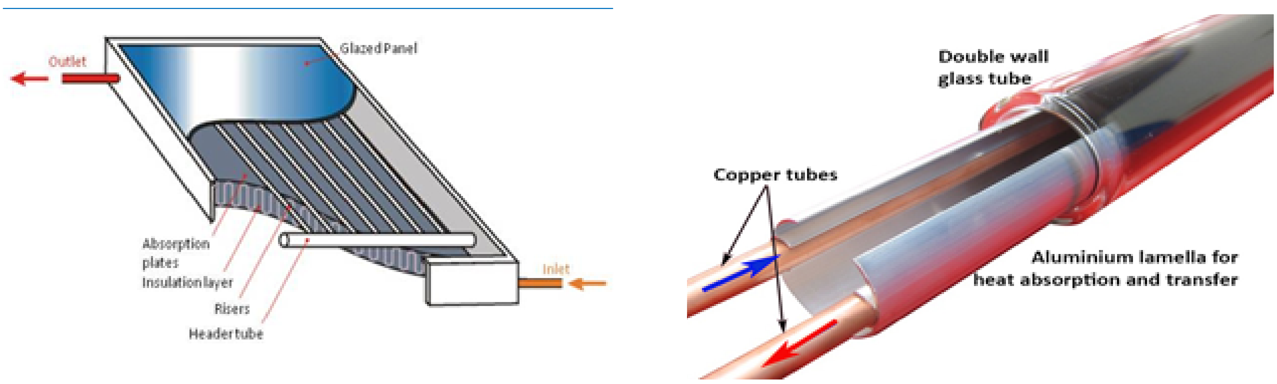


Figure 40: Structure of the flat plate and vacuum tube collectors

63 Source: György Gröller

Vacuum tube collector:

The heat transfer fluid here flows inside a double-walled glass tube (jacketed pipe), and the absorber is located within it. The thermal insulation of this construction is better than for flat plate collectors, therefore, they can efficiently heat water, even in winter cold. Their price is also higher, approx. we can count with an increase of one and a half times as of investment, but the price depends a lot on the particular construction.

In both types, the outermost protective layer is glass, but it is a hard borosilicate glass that has very good mechanical resistance, good light transmission, excellent heat and radiation resistance, so it has a good chance of protecting our collector for the expected 20-30 years.

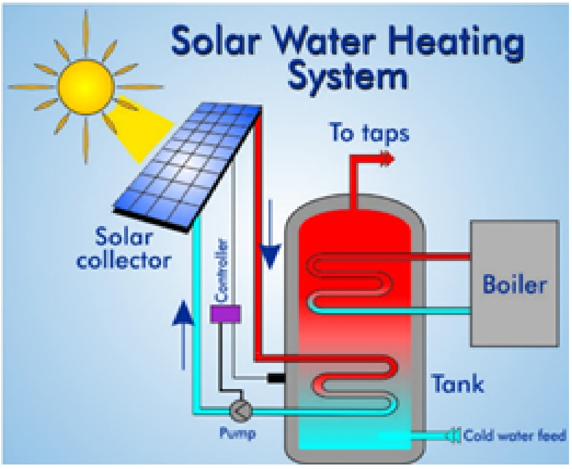


Figure 41: Schematic of the solar water heating system

Both types convert solar energy with good efficiency, although here efficiency cannot be given as exactly as e.g. for solar cells because it is very dependent on outside temperature, irradiation angle, etc. Some manufacturers promise 80 - 90% efficiency, this is also valid for the optimal case, but depending on the time of day and season, it can go down to 30% (unfortunately, it works with less efficiency in winter, energy-poor times).

A person uses approximately 50-60 liters of hot water per day. It requires 2.5 kWh of thermal energy. With a solar collector of 1 square meter, 2-3 kWh of solar energy can be utilized daily in half a year (summer) and 0.5-1.5 kWh in winter. Thus, with a solar collector of 1-1.5 square meters per person, a significant part of the required amount of hot water can be produced.

In case of detached houses, it is advisable to install 2-3 solar collectors for the production of hot water, and 4-5 solar collectors for larger water consumption. If we supplement it with heating, we can count on a collector surface of 2 - 3 m^2 / person. There is also a need for a relatively large hot water tank, usually 200-500 liters. The larger and well-insulated hot water tank is suitable for storing hot water produced by collectors during the day for evening and morning water consumption.

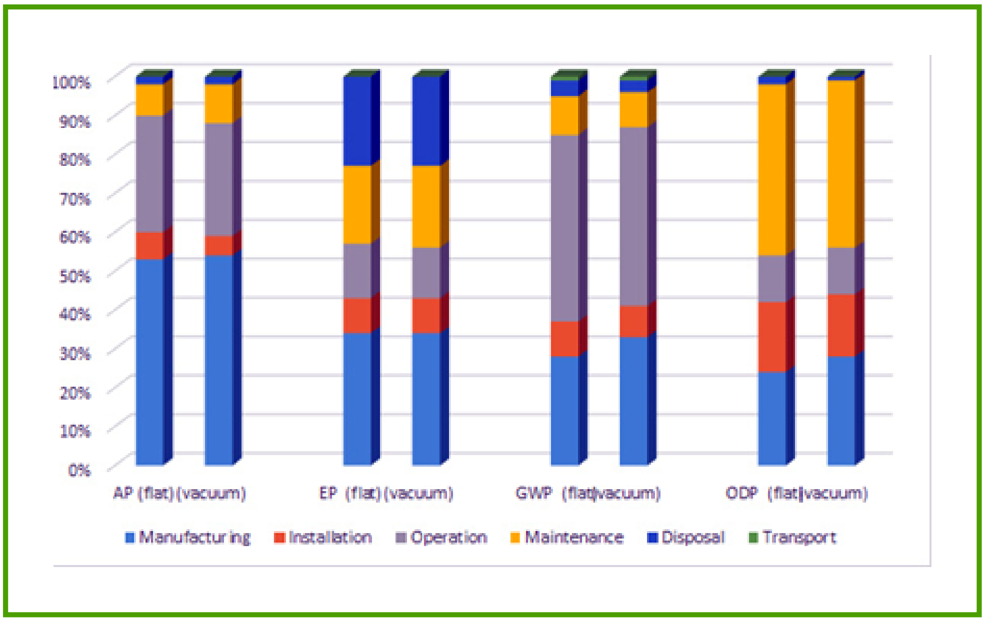
The average price of household-sized collectors is 300 – 900 €, depending on the size and manufacturer. The entire system is around 900 – 1800€, but this does not include the costs of installation.

Environmental assessment

The environmental balance of the collectors is clearly positive.
Following the life cycle:

- Raw materials: iron / steel, copper, aluminium, glass. Their production has a significant impact on the environment but not more than many ordinary industrial products. Fortunately, no special rare earths, precious metals, or severely toxic substances are needed. However, there is not much chance of finding other, more environmentally friendly substitutes.
- Production: The production technologies of the components do not include special steps with a serious impact on the environment. The elements contribute to the load on the system roughly in proportion to their weight, so the two most significant effects are the solar panel and the water tank, to a lesser extent the control electronics, the pipeline, the circulating pump and the mechanical fasteners.
- Transport, packaging: Much of the transport comes from the Far East - therefore, it is beneficial also for the environment, to choose a domestic, European-made product.

- Usage: During the use phase, the electrical energy consumption of the circulating pump must be taken into account, which is on average between 10 -45W depending on the load.
- End of life: At the end of life, practically all of its components can be recycled if they are dismantled separately. They do not contain hazardous substances, with the exception of the controller and the pump, these must be collected separately as E-waste, but most of them can also be recovered.



AP:
Acidification-Potential
EP:
Eutrophication Potential
GWP:
Global Warming Potential
ODP:
Ozone Depletion Potential

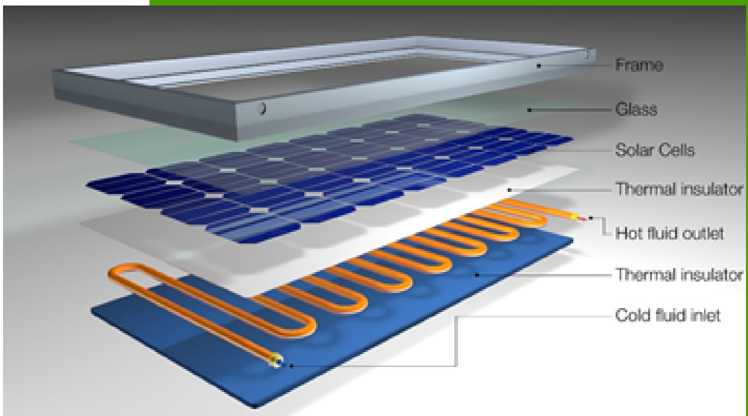
Figure 42: The environmental impact of different stages of life cycle in the light of four impact categories. The comparison only can be interpreted within a pair of columns, here we see the contribution of each stage to the overall environmental impact.[64]

64 Source: György Gröller

Some directions for development

We present two solutions that improve the usability and environmental values of the collectors.

a, Hybrid solar collector system: solar cells can only utilize a certain range of solar radiation, reflect a smaller part and transmit a significant part. This second part can be saved with a solar collector, which has a double advantage. On the one hand, we can produce more energy on the same surface, plus heat and electricity together, so that some conversion losses can be avoided. On the other hand, the collector cools the solar cell, which, being a semiconductor device, works better at lower temperatures. These devices are also available in the market but still at quite high prices.



b, Operation of a cooling system from a solar collector. It is known that the rapid increase in summer energy consumption is largely due to the use of air conditioners. In the absorption type air conditioner the cooling liquid is heated by electricity. This can be done in the same way with a heat exchanger from a solar collector, reducing electricity consumption to a fraction. Another advantage is that energy is produced almost in sync with the need for air conditioning. Thus, not only do we use the collector to produce hot water, we can cool it from the larger capacity in summer, and this capacity can contribute more to heating in winter. They are hardly available in the market yet but more skilful users can even make it at home.

https://www.youtube.com/watch?v=wzcfYVZ7G3w&pp=wgIECgIIAQ%3D%3D&feature=push-fr&attr_tag=0GqRi6YEmvqgXHLX%3A6

b. Solar panel

It produces electricity directly, making it the most popular and researched renewable energy source. Several semiconductor materials are capable of the so-called photovoltaic (PV) effect. Many of them are also available in the market as products, but in practice four varieties are present to a considerable extent. The important types:

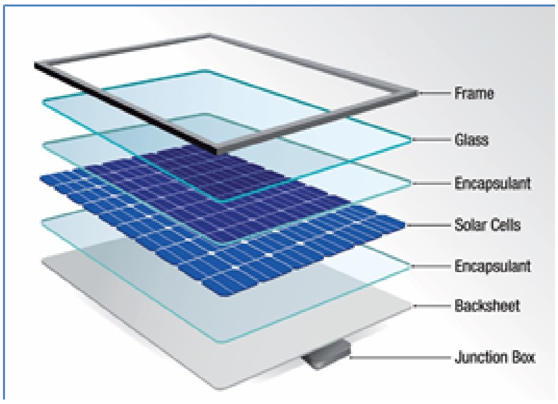


Figure 43: Structure of a crystalline Si solar PV panel

- **Monocrystalline silicon** (monocrystalline, mc Si), the most efficient (18 - 20%) and also the most expensive. Suitable for use in residential buildings.
- **Polycrystalline silicon** (poly Si), only a few% less in terms of efficiency and proportionally lower in price.
- **Thin-film solar cells:** several materials can be used here
    - **amorphous silicon (a Si), microcrystalline (μ-Si)**
    - Other semiconductor compounds: **cadmium telluride (CdTe), copper-indium diselenide (CIS) and copper indium gallium diselenide (CIGS).** Their efficiency can be between 8 and 16%, but eg μ-Si can reach 20%, however, their lifespan is shorter than that of crystalline Si panels. Therefore, they tend to occur in larger solar parks.

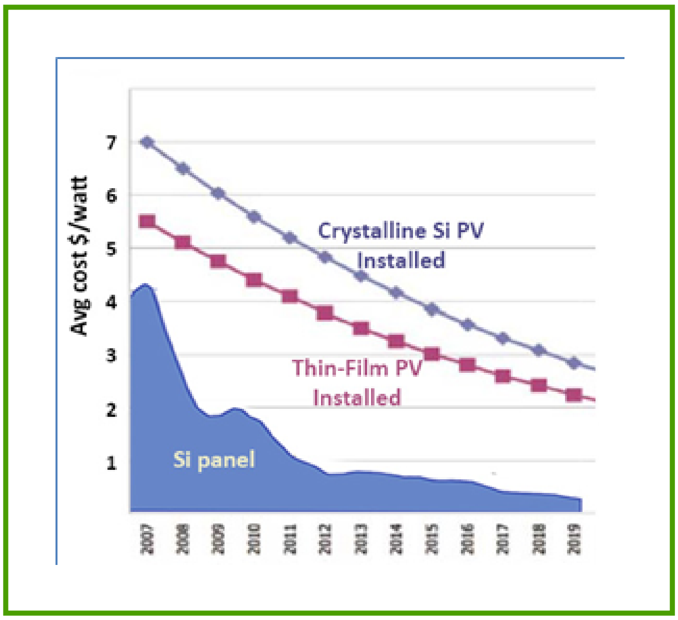


Figure 44: The decline in solar cell prices over the past decade[65]

There have been two main directions of development in recent decades. One of them is the improvement and simplification of silicon technology, as a result of which the price of the panels has greatly decreased, the service life has increased, and their efficiency has improved slightly. The other direction is to develop new, cheaper or more efficient materials. For the most part, the success of the first direction slowed the second one a bit. There are promising candidates, but these products are not seriously market-competitive products. The most interesting developmental directions that are already on the market:

Dye-sensitised solar cell: you can select the utilised wavelength range, which can be infrared, so it transmits most of the visible light and can be mounted on a window.

Polymer/organic solar cell: light, flexible, portable, their efficiency is relatively low (5 - 10%), but the panels are not proportionately cheaper

Perovskite: only a few years of development behind it, fast-improving results, efficiency already above 20% (measured in the laboratory).

All three can be made on flexible substrates, layers can be applied with cheaper printing methods, thus providing greater flexibility in both technology and use. For now, they have a few % of market share.

65 Source: György Gröller

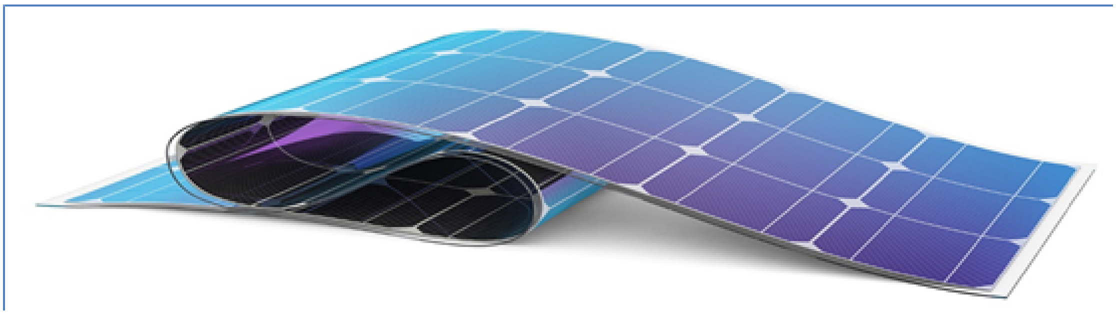


Figure 45: Solar cell on a flexible substrate

Elements of the household solar system

In a slightly expanded list, we present the supplementary elements needed to make the system function, primarily to see what else is needed to be considered in our environmental assessment of solar panels. For more information on the elements of the system, e.g. you can read here:

Panels: The voltage and current that can be obtained from an elementary cell are also very small. Therefore, several are connected in series (strings) and the strings are connected in parallel, from which a separate mounting unit, the panel, is built. The standard size of the panel is 1.5 - 2 m^2, weight 17 - 20 kg. The weight is mainly given by the glass and metal frame, the silicon itself is only a few tens of g.

Inverter: The solar cell provides a direct current (DC) of around 30 - 70 V, which is converted by the inverter to the standard 230 V alternating voltage (AC). This is how we can use it for our household appliances and thus export the surplus to the network. Its performance and size must be matched to the performance of the entire system. The inverter is also the central unit of the system, usually including the measuring unit and providing the possibility to access the data remotely.

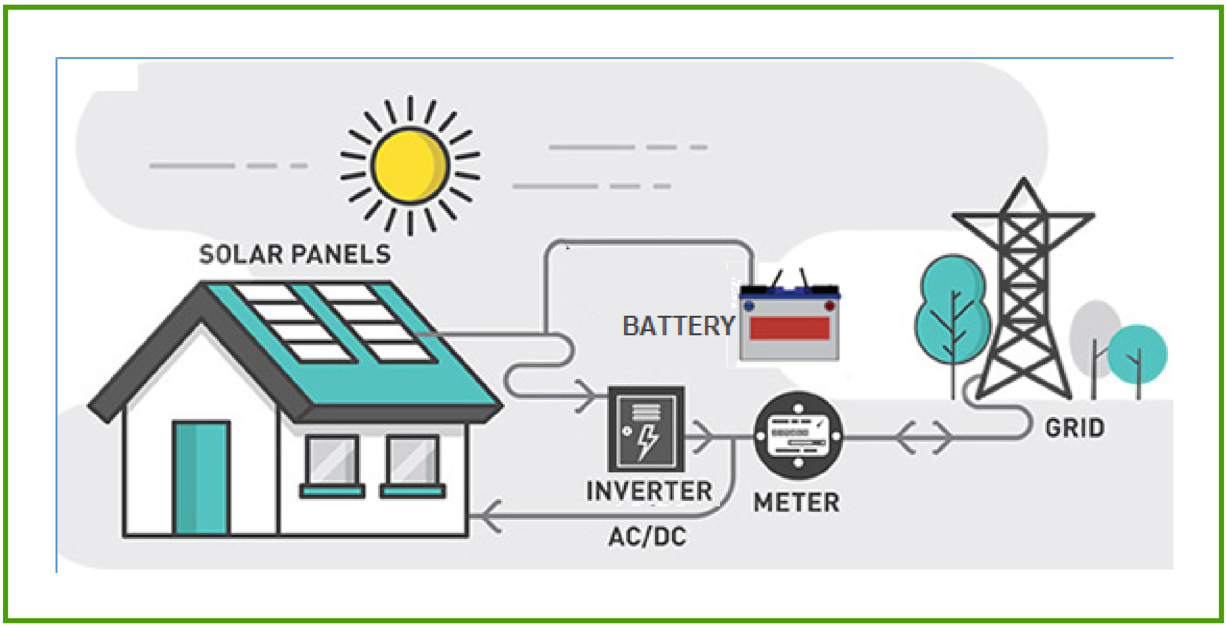


Figure 46: Elements of a household solar system

Measuring meter: If our solar system is connected to the grid, the exported- and imported current must be measured. In many cases, it is also necessary to log at what time of day the feedback occurred.

Battery: The unused generated electricity can be stored in batteries. In a net-worked system, this is an option but it is essential to use it in island systems.

Fasteners/Fixture: Mechanical elements made of iron or aluminium are required for fastening to the roof. On a flat roof, it comes with a sloping scaffold and concrete weight. All of these should be made of a material that will serve the solar cells for approx. 30 years lifespan.

Environmental assessment of solar panels

Let's review the life cycle of solar panels and the environmental loads worth mentioning at each stage.

- **Production of raw materials:** Silicon is made from quartz sand. It is abundantly available but the production of high-purity silicon requires a great deal of energy and special - often harmful - chemicals. Of the thin-film solar cell materials, cadmium (Cd) is very toxic, and tellurium (Te) and indium (In) have very low reserves on Earth. These all cause significant environmental load in different impact categories. Although the mass of the cells is only makes up of a few % of the total mass, it makes the largest contribution to the environmental impact of the entire system. In addition, the vast majority of the panels are made in China, where the source of energy needed for production is largely coal and oil.
- **Copper and silver** are used for **electronic interconnections**, tin and lead for soldering. (The use of leaded solder is exceptionally permitted in this area for long-term reliable operation.) In case of metals, especially precious metals, mining and metallurgy cause environmental damage. Lead is harmful to human health and the ecosystem, so its use in most electrical and electronic products is prohibited.
- **Inverter and other electronic components:** The main environmental loads in these are PCBs, copper conductors, precious metals, and rare earth metals in the iron core of transformers.

  Most of the mechanical structures are made of aluminium, the production of which also has a significant environmental impact, but it is well recyclable.

- **Transport, packaging, distribution:** Altogether, they account for only a very small proportion of the total load, we could almost say insignificant. From another point of view, however, it is by no means negligible, as it is important to reckon that millions of panels arrive in Europe every year, and transporting them already means serious fuel consumption, CO_2 emissions and seawater pollution. We know that this is not specifically a problem of solar panels, but stems from the current structure of the world economy.
- **Usage:** The service life is approx. In 30 years, there is almost nothing to do in terms of maintenance with solar panels, possibly sometimes to clean the surface but all in all, there is no environmental impact.
- **End of life, recycling, disposal:** The life expectancy of silicon solar cells is 25-30 years that of thin film panels is 10-15 years. Slightly different recycling methods have been developed for the two types. In all of them, the recycling of metal parts and the supporting structure can be considered simple, this can be practically be entirely solved. It is much more difficult to process the panel itself, as here it is needed to disassemble a sandwich structure that has been glued together to last for 30 to 40 years. The glass is almost completely recyclable, the conductor, contact and solder metals (Al, Cu, Ag, Pb, Sn) can be separated. There is no industrial-scale technology for the economical and environmentally friendly recovery of silicon, but the dismantling of the first panels is only just beginning. There are several possibilities for recycling, it depends on the purity of Si. Nowadays, this is an important research topic. One interesting solution may be that, given in the anode of the Li cells, it improves the capacity of the battery. Recycling technology is also available for semiconductor materials in thin film cells.

https://www.pv-magazine.com/2020/05/27/solar-panel-recycling-turning-ticking-time-bombs-into-opportunities/

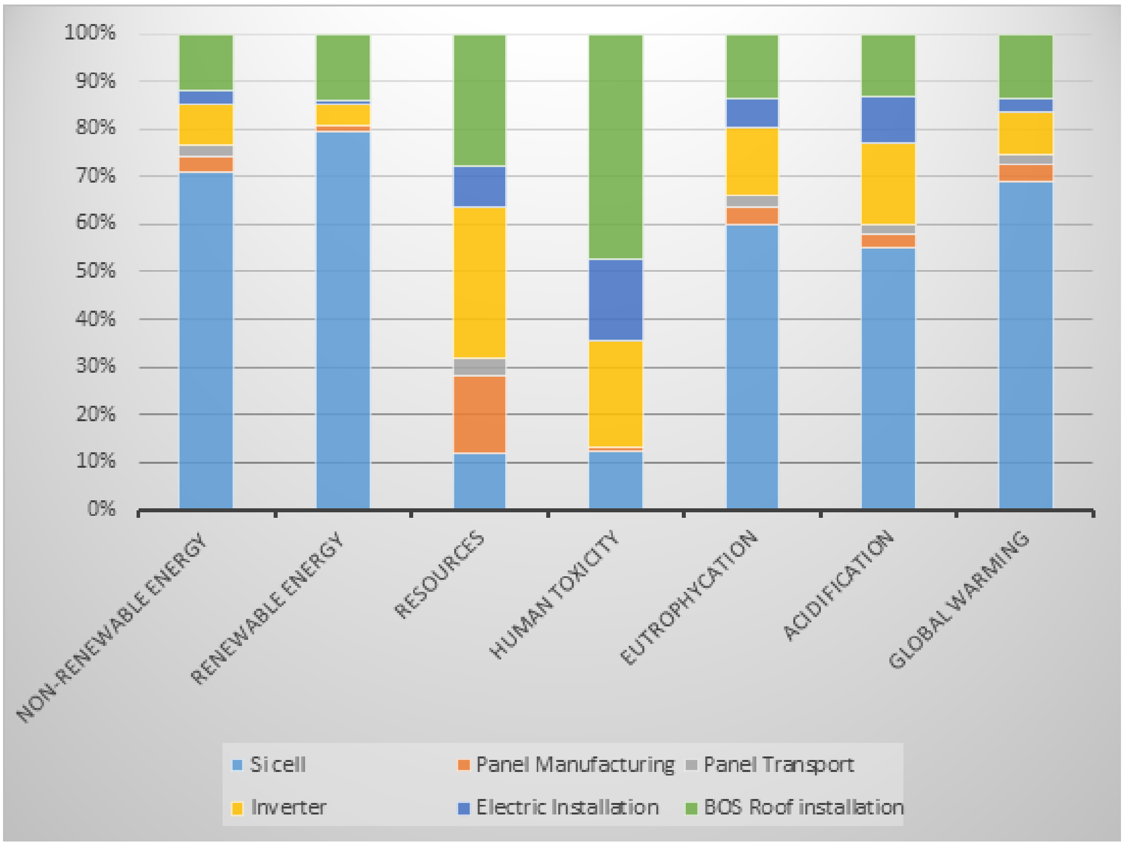


Figure 47: Environmental load of the elements of a crystalline Si solar system in seven different impact categories. The biggest effect is the production of the Si cell, followed by the inverter and the support structure. (BOS: Balance of System) In this representation mode, comparisons can only be made within each effect category, not between categories, because each is normalized to 100%.[66]

Important technical, environmental and economic characteristics

- Power, efficiency
- Spectral sensitivity
- Lifespan
- Energy payback time, cost payback time

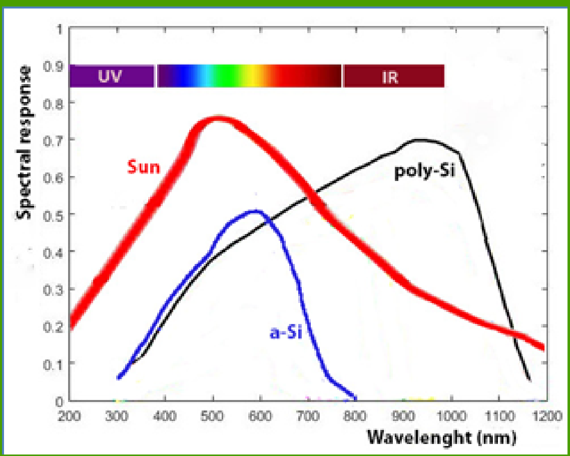
66 Source: György Gröller

Power, efficiency: The performance of the panels is measured under standard conditions and the peak power is given (Wp) This varies between 260 and 400 Wp, which is not enough to power an apartment. Therefore, multiple panels are connected into one system (in both serial and parallel connection, the power is simply added together). The current system output depends on several factors:

- the material of the cell, which determines the efficiency,
- the intensity of the radiation and its angle of incidence,
- temperature (higher at lower temperatures),
- the success of technological solutions to improve efficiency.

We can scale our system to be installed based on performance and average daily radiation. It is worth calculating in order to ensure our expected annual consumption with solar panels. Thus, the overproduction during the sunny days and the energy taken from the grid at other times will be almost the same. It is advisable to oversize the inverter by 30 - 50%, if one wants to expand the capacity of the system later, one does not need to replace the inverter.

Efficiency is calculated in the usual way: transmitted electrical power/absorbed radiated power. The special factor in this case is getting useful energy from a free and unlimited source, so the efficiency decides how much surface area one can get from the required output. If the panel is cheaper (and its production is not very environmentally harmful), it is not a problem if the efficiency is slightly lower, we can safely choose that one as well. In other words, that is why it was a good direction of development over the last 10 years, when the main goal was price reduction. The price has indeed has decreased to a third, while efficiency has increased by only a few percent (a threefold increase in efficiency had no realistic chance).



Spectral sensitivity: The semiconductor materials used here can only utilize a certain wavelength range (= spectrum) of the light falling on them and convert its energy into electrical energy. The figure shows the sensitivity curves for amorphous and crystalline Si. According to this, the utilisation (sensitivity) of **crystalline Si** cells is best between 700 and 1000 nm and is already decreasing in the visible range. The sensitivity of the **a-Si** in the thin layer cell is lower, but it covers the visible range better, so these cells perform better in cloudy weather. If we want to broaden the utilized spectrum, we can make a so-called tandem cell with two active layers of different materials with different sensitivities. With these, an efficiency of 45% was achieved in the laboratory.

Lifespan: The lifespan of these devices usually does not end with a one-time failure, but rather presents a slow decrease in efficiency. That is half to one percent each year, and when performance drops below 70 to 80 percent, it's worth thinking about replacement, perhaps expansion. Essentially, due to a manufacturing defects or accidents, it occurs that panels are damaged earlier but with a very limited instances. Crystalline Si panels have a life expectancy of 25 to 30 years, while thin-film solar cells have a life expectancy of only 10 to 15 years. Inverters are less long-lived, typically operating for 10 to 15 years. If a battery is included with the system, it may be replaced after 5 to 15 years.

Energy Payback Time (EPBT): Suitable for expressing energy gains. It calculates how long all the energy used in the pre-use stages of the life cycle is "repaid" by the solar cell. (Consumption of all additional energy is also included here.) This is a rather reassuring figure, approx. after a year and a half of operation, the "debt" is already settled by the solar cell, from where we really get the electricity cleanly. On a similar principle, we can calculate a **Cost Payback Period**, i.e., how long it takes for the cost of ownership to be recovered from unpaid energy bills. It depends on several factors, e.g. current state support, the price of residential electricity, the number of hours per day in the given area, the orientation of the roof, the amount of electricity exported to and imported from the network. Such an estimate can usually be obtained from the installation company or calculated by automatic calculators, the result can be between 5 and 10 years. The uncertainty significant due to the above variables.

Recommended sites:

https://www.solarguide.co.uk/solar-panel-payback-time#/ (last visited: 2021 April)

https://energyinformative.org/solar-energy-pros-and-cons/ (last visited: 2021 April)

6.4 Smart home

Today it is unimaginable to have a new or renovated home without any level of automation, electronic monitoring system. Almost every function of the flat has an existing control equipment measuring, and controlling systems that are controlled by an integrated IT and remote monitoring system. A detailed environmental analysis would go beyond the scope of our handbook. There are only a few LCA study in the literature, they do not examine complete systems, only a few details. We try to draw attention to some important aspects related to their installation and use.

Somewhat arbitrarily, we divide the devices used in smart house technology into three groups.

- Elements of the measuring and control system used for the energy management of the apartment
- Security systems
- Comfort and luxury solutions

Tools for energy management

By function, they belong here

- Thermometers, temperature controllers, switches required to control the heating and cooling system.
- Operation of the renewable energy sources belonging to the house, control of storage and recharge.
- Smart connectors connected to different consumers, which measure the consumption data of the devices (display, store, transmit) and switch the device on / off based on the received signals.
- Light meters, presence detectors and luminous flux controllers required for the operation of the lighting system.

Essentially, each can be implemented in different stages, from installing a couple of thermometers and heating controlled by those, to using smart meters and transmitting their data to a computer, processing them to control the heating, cooling, ventilation, lighting, shielding and any other functions. By solving all this with the help of the Internet, it can be ensured that residents can also send instructions for operation from a mobile phone, adapting to their current needs.

If we look at the environmental impacts, it is expected that the production, continuous operation and, finally, the waste management of many electronic devices, computers will mean significant energy consumption and environmental impact. In contrast, energy savings achieved in the household with these are the same in value. The life cycle analysis carried out on the topic showed that only in the case of the simplest construction can we achieve a load reduction of around 2-3% in the various environmental impact categories. If we build a complete sensor, monitoring and automatic control system, we can expect an increase in the environmental load between 6 and 16%. It improves the negative overall picture a bit with the fact that we are able to manage the operating time of large household consumers with smart systems so that we can smooth out the fluctuations in the load on the power supply system. This means that during low-load periods of the day, mainly basic power plants operate (e.g. nuclear) with minimal environmental impact, while during peak hours, gas, oil and coal-fired power plants also have to be started up. So, if we can divert the water heating, heat storage stove heating, electric car charging, possibly washing, and washing dishes to the time of the deep valley, it is both environmentally and economically advantageous. Smart systems can solve this with finer tuning, taking advantage of smaller valleys during the day.

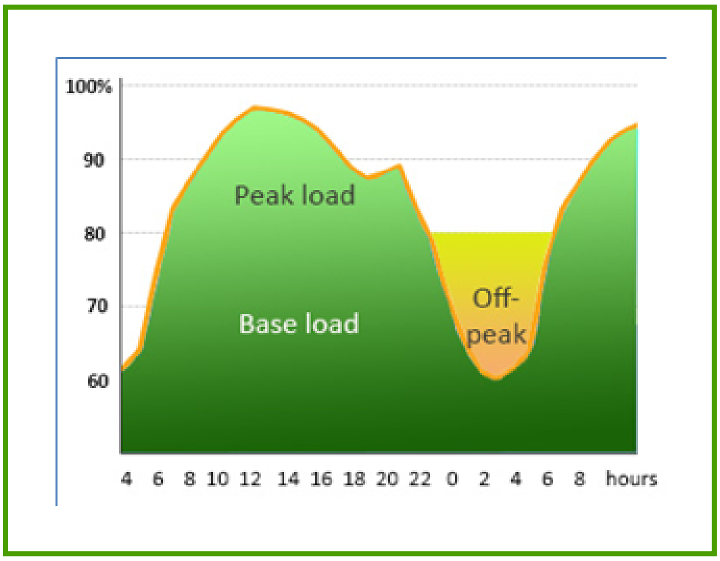


Figure 48:
Daily fluctuations in power consumption on an average summer day[67]

Another invaluable benefit of these tools supporting our house's energy management is to better focus our attention on energy conservation. Instead of 1 - 1 electricity and gas bill a year, we can have hundreds of data on our consumption every day. It is worthwhile to analyse these data from time to time, and based on this, to think about how we can operate our home in the most ecological way, based on our way of life and the characteristics of our house. One of the templates one can set up may not be the best. It is important to involve our family members, and especially our most environmentally sensitive children, in the analysis.

67 Source: Mavir, Portfolio.hu

Security systems

This includes security equipment, alarms, cameras, security power supplies, etc., and even in terms of cost and environmental impact, the proportion of the security company that operates the security system of our house provides remote monitoring. In addition to these, it is also worth installing fire, smoke and carbon monoxide detectors, safety lights for the safe night movement of our older family members.

It is acceptable that safety considerations will be a priority in this area. Environmental considerations can come from choosing between several systems with similar capabilities.

Convenience and luxury tools

These are not specifically environmentally friendly equipment. For those who have the need and opportunity and wishes to reconcile the usage with their environmentally friendly approach, we can suggest two things: to solve the energy supply from their own renewable source and to ensure the professional recycling of end-of-life equipment.