RENEWABLE HEATING & COOLING REPLACEMENT TECHNOLOGY BRIEFS FOR END CONSUMERS

replace

Making heating and cooling for European consumers efficient, economically resilient, clean and climate-friendly

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EXECUTIVE SUMMARY

The aim of the REPLACE project is to motivate and support people in target regions of nine different countries to replace their old heating systems with more environmentally friendly alternatives or to implement simple renovation measures that reduce overall energy consumption of the buildings.

In order to support consumers in making the right replacement choice, this report provides a practical guide to end-users who are considering replacing their heating system or undertaking an energy efficiency measure in their home. The report will give them useful information on the economic, environmental and social benefits of replacing an old and inefficient heating system with an innovative low-carbon and renewable one. Additionally, the report advises on the steps that every informed consumer should take before and during the replacement process and answers the most common questions that end-users ask in this context. Finally, the report presents a comprehensive list of the renewable heating and cooling technologies currently available on the European market through concise and illustrated technology factsheets.

Today there is a myriad of heating solutions that you can choose from: while non-renewable technologies running on fossil fuels exist and are still available on the market, this report only covers and addresses heating & cooling systems which make use of renewable energy sources.

This report is part of the activities of Work Package 4 “Preparation of instruments for replacement campaigns” of the REPLACE project and will be also available on the REPLACE website in 10 languages.

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GLOSSARY

AC	air conditioning system
CHP	Combined Heat and Power
COP	Coefficient of Performance
DH	District Heating
EU	European Union
GHG	Greenhouse gas
HVAC	Heating, Ventilation and Air Conditioning
H&C	Heating & Cooling
kW	Kilowatt
kW_{el}	Kilowatt Electricity
kW_{th}	Kilowatt Thermal
PV	Photovoltaic
PV/T	combined photovoltaic and solar thermal collectors
(R)HC	(Renewable) Heating and Cooling
RES	Renewable Energy Source
SPF	Seasonal Performance Factor

INTRODUCTION TO THE REPLACE PROJECT

REPLACE is a European project with the aim of informing and motivating people in nine different countries to replace old and inefficient heating systems in residential buildings with environmentally friendly alternatives. Funded under the EU Horizon 2020 programme for three years (2019 – 2022), REPLACE develops and implements boiler and oven replacement campaigns to support changes towards achieving the climate targets and making Europe independent of oil, coal and natural gas.

Half of Europe's energy consumption is used for heating or cooling. However, two thirds of the heating systems installed in Europe (80 million units) are inefficient. Usually, these outdated heating systems are only replaced when they fail completely during use or are about to fail. This often leaves no time for informed decisions or for a change of the energy source. The challenge is that the amount of information required for a switch is high: many questions have to be clarified and different actors need to be consulted. Often, people have difficulties to afford the high initial investment costs of low-CO_2 systems, even if the life cycle costs are already significantly lower and much less risky than for systems running on conventional energy sources.

REPLACE wants to tackle those and other local challenges and barriers by developing and testing locally adapted, tailor-made replacement campaigns across ten European pilot regions with a total population of 8 million. Specifically, the project targets consumers, investors/owners as well as intermediaries, like installers, chimney sweepers, energy advisors and consultants, and helps them to make well-informed decisions. Simple renovation measures that pay-off quickly as they reduce overall space heating consumption for a low investment and which are implemented as coordinated community actions are also part of the programme

REPLACE develops efficient and strongly service-oriented campaigns as well as user-friendly information tools. It identifies requirements for the implementation of actions concerning infrastructure, regulations and legislation by investigating stakeholders' mind-sets and their needs. Lessons learnt from previous projects are taken into consideration and action plans for each pilot region are being implemented.

The replacement campaigns are to be launched and supported by the project partners and by local working groups, bringing public authorities, end consumers, installers, chimney sweepers, energy consultants, equipment manufacturers, energy supply companies, policy makers and other key players to one table. Together, they will design comprehensive, locally adapted effective action packages tackling the main barriers and challenges end consumers and installers face when boilers or ovens shall be replaced.

REPLACE's primary objectives are to:

- understand the heat markets as well as the mind-sets and needs of end consumers, intermediaries (like installers, chimney sweepers, energy advisers) and investors,
- identify and reduce market barriers and to foster an enabling environment as well as better and trustworthy services,
- improve framework conditions, planning and investment security,
- better inform all stakeholders of the benefits of a heating or cooling system replacement, according to their information needs and preferred formats,
- enable consumers to take informed decisions, encouraging sustainable energy behaviour,
- strengthen the trust of end consumers in intermediaries and in the reliability of renewable HC systems and related (service) suppliers,
- transfer know-how from more advanced to less advanced countries in this field, e.g. by training of installers in South-Eastern European countries,
- create and implement locally adapted, tailor-made replacements campaigns addressing and overcoming replacement barriers in ten European pilot regions, while also testing, steering and improving them on-site, and
- to make the project's findings available for replication in other countries and regions.

REPLACE also addresses fuel poverty and gender issues and reduces the risk of a heating crisis by supporting the use of regional renewable energy sources (such as solar, ambient heat or biomass) and HC equipment produced within the EU (biomass boilers, heat pumps, solar collectors etc.).

1. WHY SHOULD I REPLACE MY HEATING SYSTEM?

Whether it's to reduce your carbon footprint on the planet and cut your CO2 emissions, or to save money on your energy bill, or to become more independent from energy supply and the rising energy costs, or to be a frontrunner and get the latest available technology, there are many reasons which would justify the switch from an old and inefficient heating system to a modern renewable one at home.

While at the dawn of the renewable energy era, the technology options were limited and expensive, today you are spoiled for choice. There is in fact a multitude of affordable and flexible options available on the market, capable of adapting to everyone's building type and energy needs.

Before exploring all the available options, let's look together at the benefits you will grasp from replacing your heating system with a modern renewable technology or from adopting building refurbishment measures.

Saving energy may the best option to reduce your carbon footprint and minimise the negative impact on the environment. Therefore, before any change of your energy system, you should always consider the option of energetic refurbishment of the building. To further reduce your carbon footprint, your heating & cooling solutions should use renewable energy sources instead of fossil fuels such as oil, coal or natural gas.

With an efficient renewable system at home, you will help your region, country, and even the whole European continent, to reach the ambitious climate and environmental objective of carbon neutrality in the coming years.

At the same time, you will contribute to the improved air and life quality of your neighbourhood and city, thus positively affecting health conditions of your fellow citizens.

Economic benefits

If the environmental benefits are not enough to convince you to switch to an efficient renewable energy system right now, are you aware of all the money you could save on your energy bill by installing such a heating system in your home? The installation of a new and modern renewable energy solution avoids using fossil fuels and uses energy in the most efficient way possible. This means that in order to heat your place, you will consume less energy, while keeping the same level of warmth and comfort (and often even improving it). And the lower your energy consumption, the higher your economic benefits.

Renewable heating and cooling systems can reach very high efficiencies. Not only because of their innovative features and technologies, but also because they are often decentralised energy solutions. Theis means that they produce the heat you need directly at the place of consumption (or very close to it) and thus reducing to the minimum all energy losses, which inevitably happen during the transport of energy from the production point to the consumption point.

Because of their decentralised nature, renewable heating systems can also decrease your reliance on imported energy such as coal, oil and natural gas.. This would translate into increased independence from the uncertaincosts of energy in the future and from imports of fossil fuel from politically unstable regions.

Similarly, many European countries are preparing legislation on carbon pricing systems and on the phase out of fossil energy sources for residential heating by the end of this decade, or even earlier. This means that if this is the case in your country, buying i.e. an oil condensing boiler, even if efficient, would turn up in a short-sighted investment. A renewable heating system will be instead a safer investment, together with all the advantages which come with it.

And if all of this isn't enough yet, improving the building shell of your house or equipping it with a renewable heater, will bring your house to a higher energy efficiency class, thus increasing the value of your property.

Looking at the big picture, supporting small scale renewable heating systems will not only benefits your pockets, but would support the European industry at a whole. Small-scale renewable installations are in fact major job providers and key drivers of the European energy transition. Firstly, the installation, maintenance and operation of renewable systems are

important creators of highly skilled jobs that will make the green economy a local reality[1]. Secondly, they empower territories by creating local jobs, contributing to rural development, and allowing SMEs business activities, local communities and citizens to supply their heat needs from local energy sources. By choosing a renewable heating system for your home, you would therefore help the European Union fulfil its ambitious objective to become the world Number #1 in renewables.

And if the upfront investment required for buying a renewable heating system might look scary, you are probably not aware of the many incentive schemes available in your region or country on RES technologies. Such incentives, coupled with the savings on your energy bill, will contribute to pay back the initial costs of purchase and installation. Have a look at our REPLACE project technology factsheets or contact your local installer to get to know more about incentives you can benefit from.

Social benefits

Last but not least, the installation of a modern decentralised heating technology, empowers energy consumers (households, but also hospitals, public buildings and hotels) to produce their own sustainable heat from renewable energy sources such as sun, water, biomass, etc. You will no longer be a passive consumer, but a 'prosumer' (a combination of the words 'producer' and 'consumer'), actively contributing to the challenge of decarbonising buildings and to the energy transition in Europe.

Installing an innovative renewable energy system at your home might make you a frontrunner in your village or town and you might lead by example convincing other fellow citizens and even policymakers to adopt a similar solution i.e. in the town hall, in a public school or hospital.

In terms of comfort, modern systems heat your home more evenly and better hold the temperature in the rooms. They also operate at lower noise levels, so you can enjoy peace and quiet while staying warm.

Additionally, the latest heating technologies are complemented by innovative and useful features, which help you make the best use of your system and save more energy, time and money. For example, today you can control your system directly from an app on your smartphone, indicating the temperature you would like in each room of your home, or you can programme the system so that it switches on just before you come back home from work and switches off when you go to bed – isn't this just cool?

So, what are you waiting for? You can read more about the renewable heating and cooling technologies available on the market and find out which ones suit best your building type and your energy needs on the REPLACE project website.

1 Small is Beautiful Declaration, "Call for a «de minimis» approach on the framework for small renewables & cogeneration installations" (https://www.solarpowereurope.org/wp-content/uploads/2018/08/112017-SMALL-IS-BEAUTIFUL-Declaration.pdf)

2. HOW DO I REPLACE MY HEATING SYSTEM?

Replacing your heating system is easier said than done. The replacement process can in fact be long and twisty because of the many competing technologies available on the market today and of the countless factors to consider, ranging from legislation in your region to energy prices in your country.

There is no silver bullet solution and no system is better than all the others: what is the best option for you, always depends on your building type, on your energy needs, and on a multiplicity of other factors and conditions.

This practical manual will guide you step by step through the whole process, advise on how and where to collect reliable information, and help you to take the best decision for your home and for your energy needs.

1. Get familiar with the technologies available on the market

There are so many technologies available on the market today to choose from! Not always an easy task to choose "the one". None of them is the best of all the others: what is the best option for you, always depends on your local conditions (e.g. possibility to connect to a district heating grid or to have wood pellets delivered), building type, on your energy needs, and on a multiplicity of other factors and conditions. For this reason, we recommend you read the REPLACE technology factsheets to get to know which are the renewable heating options you can choose from. The factsheets explain the basics of how they work, tell which building type they suit, and list their main benefits. Once you acquired familiarity with the ABC of all the alternatives, you can move on to the next step!

2. Check whether a total or partial insulation of the building shell is needed on top of a heating system replacement

Replacing your heating system is not always the only and best solution. Sometimes, heating system replacement goes hand in hand with the insulation of your building's shell (or of parts of it) or with other renovation measures. Sometimes, comprehensive building refurbishment measures might make the replacement of the heating system even useless. In other cases, renovation measures are made mandatory by the law and you have no other option than to carry the required measures out. Check with your energy advisers what is the best option for you, but always remember to take insulation measures into account – especially a thermal insulation of the uppermost ceiling and, in case of strong wind, a refurbishment of windows.

3. Get in touch with an energy adviser

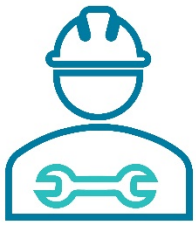
If you do not have the necessary technical expertise (no worries – who has it?!) to understand all the technicalities of a heating system replacement, then you might want to ask an expert for his/her recommendations. The advice of someone with technical expertise will not only make your life easier, but it will above all ensure that you're taking the right choice. Heater replacement is in fact not always the only and the best option: an energy adviser will be able to assess whether in your specific case a refurbishment of your building would be a more convenient action instead and will provide you with reliable information. The REPLACE technology briefs include a list of energy advisers in your region – just get in touch with them for a preliminary consultation.

P.S. To make your life even easier, you can also take this step as the first one of the whole replacement process to save time and energy!

4. Estimate the benefits and costs

To understand what technology suits best your energy needs and building type, you can calculate the costs you will incur and the benefits you will grasp. Costs include i.e. purchase and installation costs of the system, operating costs, while benefits consist of i.e. expected savings on the energy bills compared to your current heating system, incentive schemes applicable to your new system in your region, etc. This will help you understand what technology is the most advantageous in economic terms in your specific case. You can easily estimate costs and benefits by using the REPLACE project calculator.

5. Contact an installer



Once you have made your choice on the new heating system to install at home, contact a local installer (and possibly more than one) for a quote for the purchase of the product and for the installation costs. The REPLACE technology briefs include a list of useful contacts in your region. Get in touch with few of them in order to compare their offers, their experience with renewable energies, and to listen to different experts' views.

6. Apply for regional/national incentives

Some countries, regions or municipalities offer special incentive schemes to encourage the market uptake of renewable heating system. These incentives may take the form of reductions on the purchase cost of the system, or of tax deductions, etc. They will allow to save money on your up-front investment or on the operating costs of your new system. Check the REPLACE project technology briefs to find out what schemes are available in your region for each renewable heating system and how to apply for them. Your energy adviser or local installer will help you going through the administrative steps required in order to benefit from such public incentives.

7. Go for it, enjoy and tell others how nice it is!

Once you have taken your decision, buy the product you have chosen from your installer, get it installed and enjoy the warmth and comfort of your home! And as you can be very proud of your choice, don't forget to tell others about your story and to show them your system.

3. FREQUENTLY ASKED QUESTIONS (FAQs) FROM CONSUMERS

The following pages will answer the questions most frequently asked by consumers undergoing the process of replacing their heating system or of implementing measures to improve the energy performance of their house or building.

The questions that will be answered are the following ones:

1. Can I combine multiple heating systems?
2. Is it better to replace my heating system or to insulate/renovate my building?
3. In which cases is improving the energy performance of my building compulsory?
4. What alternative do I have beyond replacement of heating system and building shell refurbishment?
5. What can I do if my heating system suddenly breaks down?
6. What can I do if I am a tenant or if there are multiple owners in my multi-family house?
7. Why should I invest in a new heating system if I can hardly afford to run my old one?
8. Heating with infrared panels: is the cheapest solution also the best one?
9. Renewable heating systems require much higher up-front costs. Why shouldn't I buy a fossil fuel system instead?
10. When replacing my heating system, why should I choose a different technology than the one I had before?
11. I am heating with electricity. What alternative options do I have, if there is no chimney and no heat distribution system in the house?
12. Is heating with natural gas better than heating with coal or oil?
13. How can behavioural changes impact my energy consumption?
14. Is biomass sustainable?
15. Is an old inefficient wood stove better than a modern efficient oil boiler?

If you have questions not addressed in this section, you can always contact your local energy adviser or installer, who will provide you with recommendations on the best option for your energy needs.

CAN I COMBINE MULTIPLE HEATING SYSTEMS?

When it comes to heating, there are so many solutions out there, that the decision to go with one heating system or another is not an easy one. Each technology and each energy source have their own advantages as well as downsides. This has led manufacturers to consider the feasible combinations of existing technologies and energy sources, in order to maximise their benefits and offset their weaknesses. The combination of multiple products can in fact be hugely beneficial for end users because it maximises the overall system energy efficiency, thus reducing energy consumption and operating costs.

When multiple heating technologies partner together, we refer to hybrid heating, defined as "an appliance or a system of appliances which combine at least two different energy sources and whose operation is managed by one control[2]". Among the hybrid systems, many combinations are possible. For example, an electric heat pump can be combined with a solar thermal installation, delivering a significant proportion of a property's hot water, whether or not the sun is shining and thus reducing the electricity demand on the heat pump.

Among the hybrid appliances, one of the most common mix is the combination of a solar thermal system, complemented by a biomass boiler. This mix combines the use of free solar energy, which comes at no cost on your energy bill. If the sun does not shine, a biomass boiler such as pellet, logwood or woodchips will guarantee that your home is warm.

You can check all the possible options of renewable "mix and match" in the REPLACE project's technology briefs.

Solar thermal collectors installed on the roof of a single-family house

2 EHI, "Heating Technologies: Hybrids" (http://www.ehi.eu/heating-technologies/hybrids/)

IS IT BETTER TO REPLACE MY HEATING SYSTEM OR TO INSULATE/RENOVATE MY BUILDING?

Whether it's the installation of a new renewable heating system to replace an old inefficient one or of energy-efficient windows, there is no right or wrong when adopting an environmentally friendly measure.

There are many benefits of improving energy efficiency of your building and using renewable energy efficiently to heat your home. These include lower energy costs, greater living comfort, a higher property value, as well as the valuable contribution to climate change mitigation.

Nevertheless, the reduction of energy losses and of heat demand, to be achieved via an improvement of the thermal quality of the building, should sometimes take priority over other actions, such as the heating system replacement. For your heat supply at home to be cost-efficient, it might in fact happen to be of primary importance to first realise the full potential of energy savings. This could be achieved i.e. by insulating the building envelope (top floor ceiling, basement ceiling and facade) and replacing the old windows[3].

Sometimes, the building's envelope refurbishment measures go hand in hand with the replacement of the heating system. In these cases, the energy performance of the house is clearly further improved. It has been demonstrated that a comprehensive modernisation of older buildings' energy systems can reduce their energy consumption by up to 80%.[4]

In conclusion, even if we can say that the increase in renewable energy use for heating and the refurbishment of the building stock into energy-efficient buildings are equally important, it is key to always ask for the expert's advice on what is the measure which best suit your building and energy needs.

For a better idea of what is the optimal solution for your building, contact your local energy adviser.

Photovoltaic panels integrated in the façade of a building

3 Klimaaktiv, „Renewable Heating" https://www.klimaaktiv.at/english/renewable_energy/renewable_heating.html)
4 Institute for Energy and Environmental Research Heidelberg et al. (ifeu) (2011), excluding transport.

IN WHICH CASES IS IMPROVING THE ENERGY PERFORMANCE OF MY BUILDING COMPULSORY?

Regulations governing the design, construction, management and renovation of buildings vary from country to country in Europe. Nevertheless, all European Member States are subject to the provisions of the European Performance of Buildings Directive (EPBD)[5], including the obligation to prepare their own long-term renovation strategies.

Based on the requirements of the EPBD, all EU countries must in fact establish a long-term renovation strategy to support the renovation of their national building stock into a highly energy efficient and decarbonised building stock by 2050. The strategies shall include, among others, policies and actions to stimulate cost-effective deep renovation of buildings and to target the worst performing buildings[6].

You can contact a local energy adviser to get to know the current legislation in your country regulating the built environment and find out whether the energy performance of your building is subject to compulsory improvement measures. The REPLACE project technology factsheets provide you with a list of useful contacts in your region.

Refurbishment works for insulation of the rooftop of a single-family house

5 Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG)
6 European Commission, "Long-term renovation strategies" (https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en)

WHAT ALTERNATIVE DO I HAVE BEYOND REPLACEMENT OF HEATING SYSTEM AND BUILDING SHELL REFURBISHMENT?

The individual refurbishment of your building shell and the replacement of your heating system are just some of the options you have to reduce the energy consumption for your space heat, and not necessarily the best ones. Comprehensive refurbishment measures can in fact be disruptive and long-lasting, and the purchase and installation of a renewable heating system can at times be expensive.

Concerted and collective actions can be less costly and still effective alternatives, with shorter pay-back times compared to those of the up-front investment in a renewable heating technology. These actions could consist i.e. in collective purchase of pellets, establishment of energy cooperatives, regular checks of the heating system, hydraulic balancing by installers, thermal insulation of the uppermost ceiling of your building, etc. and are to be targeted collectively with the other occupants of the building and/or neighbouring buildings. Read the REPLACE project report for consumers to find out more about these options.

Delivery truck supplying wood pellets to a house

WHAT CAN I DO IF MY HEATING SYSTEM SUDDENLY BREAKS DOWN?

Prevention is better than healing. If we were all living in an ideal world, everyone would replace their heating system before it breaks down. The lifetime of every heating system is limited and as our heating system gets older, it is recommended to increase the frequency of the periodic checks and to listen to the expert's assessment when advising to replace our system because it is likely to breakdown soon.

But we do not live in the ideal world and sometimes our heating system suddenly breaks down, leaving us and our home in the cold. What can we do in such situation? The most straightforward approach (and the most common one) is to replace it with a new model of the same technology. The new version of our old heating system might likely be more efficient, but it does not necessarily mean that this is the best and an environmentally friendly option for our home.

If you had more time to choose, perhaps you would consider a new technology and a fuel switch, you would collect more information on the available options on the market in your country, better assess what your needs are, consult few energy advisers and installers, compare several offers, apply for national or local incentives, and then buy your preferred technology and get it installed. But in the case of a sudden breakdown, you would not have the time to tick all the recommended items of this checklist (even less so if the breakdown happens in wintertime). Luckily, nowadays in some countries and regions the market offers you the chance to get a mobile space heating and domestic hot water preparation device, an innovative heating unit which temporarily replaces your broken heating system.

Mobile space heating devices range from small units running on electricity to mobile plug-and-play containers running on the fuel stored in the building, or on pellets or other fuels.

A mobile space heating and domestic hot water device does not only avoid emergency uninformed replacements and a lock-in effect towards fossil fuel technologies, but it also allows you to take your time to make the best choice for your household, based on your building type and your needs, while keeping your home warm and comfortable. In fact, the mobile device ensures that the disruptions linked to the replacement of your boiler and the interruption of heating and hot water do not last more than just a few hours (less than the time it takes for the building to cool down), meaning that it would allow you a replacement even during wintertime.

At the same time, the mobile space heating device also alleviates the problem of the shortage of professionals skilled with installation of renewable heating solutions, allowing them more time to satisfy all the requests of their customers, while ensuring they do not suffer any disruption.

WHAT CAN I DO IF I AM A TENANT OR IF THERE ARE MULTIPLE OWNERS IN MY MULTI-FAMILY HOUSE?

Replacing an old and inefficient heating system with a modern renewable one is clearly a long-term investment which may require significant upfront costs and long-lasting payback times.

Tenants renting an apartment or a house for a limited amount of time are therefore often reluctant to commit to such investment, similarly to the landlord owner of the building, who is normally supposed to bear the costs for the replacement of the heating system of his/her property, without directly reaping the benefits of such replacement.

Nevertheless, they probably do not know that the replacement of the heating system would be beneficial for both parts. On the tenants' side, they would benefit from lower energy bills, while the owner would see an increase in the value of the property, led by an increase in the energy class of the house. Last but not least, everyone would benefit from the equally important environmental and social benefits listed in Chapter 1 of the REPLACE project report for consumers. For all these benefits, the tenant shall accept an increase in the rent costs, if the owner decides to invest in renewable and efficient heating measures.

A similar stalemate problem occurs in multi-family houses and buildings. Some actions, such as the thermal insulation of the uppermost ceiling, the improvement of the building shell, hydraulic balancing simple boiler checks and building refurbishment measures in general are collective actions whose costs are to be born by all the occupants of the building and which therefore shall be agreed by everyone in advance. Like the replacement of the heating system, these collective measures also bring improved energy efficiency of the building and energy savings, from which all the occupants will benefit in economic and environmental terms.

Dialogue between tenants and owners and among all the owners of a multi-family house is therefore key to ensure that everyone properly understands the benefits coming from the adoption of environmentally friendly measures related to heating and cooling.

Wood pellets boiler for a single-family house

WHY SHOULD I INVEST IN A NEW HEATING SYSTEM IF I CAN HARDLY AFFORD TO RUN MY OLD ONE?

The average product lifetime of a heating system in Europe is assessed at 24 years[7]. When the system gets too old, it might become more convenient to replace it with a new one instead of spending money in reparations, still running the risk of a sudden and definitive breakdown in winter.

If on the one hand it is true that buying a new heating system can be very costly, on the other hand it is also true that modern heating systems are much more efficient than the old ones: new systems can heat the same space by consuming less energy, thus resulting in lower energy bills. This decrease in the energy costs will ensure that in a few years' time the initial investment is paid back.

On the contrary, old and inefficient heating systems can be the cause of energy poverty. Energy poverty, defined as the "inability to keep homes adequately warm[8]", is a widespread issue in Europe, affecting between 50 and 125 million people, and one of its causes is to be found in the high energy costs of inefficient and old heating systems at home, which consume high amount of energy to heat, therefore resulting into higher energy bills.

On top of the lower energy costs and of the payback, many countries and regions across Europe offer special incentives to end-users willing to buy a renewable heating system (i.e. tax returns, feed-in-tariffs, etc.) which can lower the up-front cost and reduce the payback time.

Some frontrunners countries are even considering establishing public funds to take over liability for bank loans to socially vulnerable households, for whom subsidies are not enough to finance the initial investment and who would otherwise not get access to those loans.

Check out the REPLACE's projects technology briefs to find out what are the incentive schemes available in your region for heating systems replacement.

7 European Commission, "Space and combination heaters – Ecodesign and Energy Labelling Review Study: Task 2 Market Analysis", July 2019 (https://www.ecoboiler-review.eu/Boilers2017-2019/downloads/Boilers%20Task%202%20final%20report%20July%202019.pdf)
8 European Commission, "Energy Poverty" (https://ec.europa.eu/energy/content/share-households-expenditure-electricity-gas-and-other-housing-fuels_en)

HEATING WITH INFRARED PANELS: IS THE CHEAPEST SOLUTION ALSO THE BEST ONE?

Every heating system has advantages and disadvantages and there is no one-size-fits all solution which can be elected as the best of all in absolute terms. What is the best technology for your home depends on the type of building, on your energy needs, on the region where you live, on the costs of energy fuels in your country, and on many other factors.

As all the heating technologies available on the market, also infrared panels have their pros and cons[9]. Infrared heaters are electrical resistance heaters. This means that they convert electricity into radiation energy, which is absorbed by the objects and persons in the room. Among the advantages of infrared heating panels, we can list the following ones:

- Low investment costs: the infrared heating panels require a much lower upfront cost compared to other renewable or highly efficient heating technologies.
- Quick installation: the panels are a plug-and-play heating solution and there is no need for any pipework. They can be mounted on the wall or on the ceiling, even without the intervention of an expert.
- Very little maintenance required: there are no moving parts and there is no motor to wear out or air filters to replace, which also means that infrared heating panels are very quiet in operation and can be used in bedrooms.
- No fireplace or storage space required: infrared heating panels save space in the room because they are preferably mounted on the ceiling or on the walls.
- High efficiency and no significant distribution losses within the building: infrared heaters can achieve a share of heat radiation of up to 60%, compared to the 20% to 40% of conventional radiators.

If all the above points hold true, the disadvantages of infrared heating panels are not missing though:

- As infrared heating panels run on electricity, operating costs can be significantly higher than for systems with central heat generators.
- Losses in the generation, storage and transportation of electricity.
- High carbon footprint, depending on how the electricity they run on is generated (whether it is renewable electricity or not).

9 Energie Tirol, Richtig Wohnen: Infrarotheizung (https://www.energie-tirol.at/wissen/richtige-heizung/infrarotheizung/)

- Infrared heating panels are usually not a stand-alone technology: an additional system for space heating and for the production of domestic hot water is needed.
- High temperature of the plates: infrared heaters can heat up to 100°C, thus causing risk of burns.

Before replacing your heating system, you should always collect information on what is the best option for your household and possibly consult your local energy adviser or installer for the expert's advice.

Read Chapter 2 of the REPLACE project report for end consumers to find out what are the steps to follow when installing a new heating system.

Infrared heating panels mounted on the wall of the living room

RENEWABLE HEATING SYSTEMS REQUIRE MUCH HIGHER UP-FRONT COSTS. WHY SHOULDN'T I BUY A FOSSIL FUEL SYSTEM INSTEAD?

One of the reasons why consumers hesitate to buy a modern renewable heating system, can be explained by the higher up-front investment required by the purchase and installation of a renewable technology compared to one running on fossil fuels. Nevertheless, modern and renewable heating systems reach high levels of energy efficiency, thus providing you with the same level of warmth and comfort as those of a non-renewable heater but in many cases using less fuel.

At the same time, relying on renewable energy to heat your home decreases your dependency on the uncertain but rising costs of fossil fuels, as your system will run on a cheaper (and greener) source of energy.

The decrease in energy consumption will translate into a decrease of costs in your energy bills.

The savings on the energy bills will pay-off the initial investment for the purchase and installation of the renewable system normally in few years time.

The pay-back time can vary depending on many factors: initial capital cost of the product, energy costs in your region, energy consumption, etc. It can be accelerated by the availability of incentive schemes in your country, region or municipality, which can i.e. reduce the up-front costs of purchase and/or installation or reward you with a tax deduction.

When considering a long-term investment like the purchase of a new heating system for your home, you should not forget the legislative measures planned in your region for the near future. The lifetime of a heating system spans between twenty and thirty years, but there are more and more countries in Europe preparing legislation on carbon pricing or to ban residential heating running on fossil fuels by the end of this decade, or even earlier. i.e. if your country is planning to phase out oil or natural gas for residential heating, you might want to reconsider the choice to buy i.e. a natural gas or an oil condensing boiler now. A renewable heating system will be instead a safer investment, together with all the advantages which come with it.

To get more familiar with the benefits of a renewable heating system compared to a fossil fuel one, you can read Chapter 1 of the REPLACE project report for end-users.

WHEN REPLACING MY HEATING SYSTEM, WHY SHOULD I CHOOSE A DIFFERENT TECHNOLOGY THAN THE ONE I HAD BEFORE?

It frequently happens that the replacement of the heating system in households is done in emergency situations because of a sudden breakdown of the old system. Therefore, the residential heating sector experiences a tendency for a lock-in effect towards technologies running on fossil fuels. It means that in case of an emergency replacement, households tend to replace their old heating system with a new model of the same technology (i.e. old gas boilers are often replaced by new gas boilers, etc.). This lock-in effect clearly disincentives the uptake of renewable technologies for residential heating. But there are many reasons why you should prefer a renewable heating system to a non-renewable one. You can find a comprehensive list of reasons related to environmental, economic and social benefits in Chapter 1 of the REPLACE project report for end-users.

In case you lack the time to document yourself on the best renewable heating option for your home because of a sudden and unexpected breakdown of your heating system, you can temporarily resort to a mobile space heating and domestic hot water device. Mobile space heating devices range from small units running on electricity to mobile plug-and-play containers running on the fuel stored in the building, or on pellets or other fuels. The mobile device ensures that the disruptions linked to the replacement of your boiler and the interruption of heating and hot water do not last more than just a few hours (less than the time it takes for the building to cool down), meaning that it would allow you a replacement even during wintertime. You will find additional information on these units in the factsheets of the REPLACE project report for consumers.

And probably, one of the reasons for which you did not choose a renewable heating system ten years ago is also that back then heating systems running on renewable energy sources were much less widespread on the market and much more expensive. Nowadays things have changed: the large-scale deployment of renewable heating systems brought the production costs and consequently the prices for consumers down. You can now buy a renewable heater for a reasonable price, benefit from public incentives, and grasp benefits of economic, environmental and social nature.

Old inefficient wood-burning stove

I AM HEATING WITH ELECTRICITY. WHAT ALTERNATIVE OPTIONS DO I HAVE, IF THERE IS NO CHIMNEY AND NO HEAT DISTRIBUTION SYSTEM IN THE HOUSE?

In many countries there are single-family or multi-family houses that are equipped either with electrical storage heating systems for space heating (with night-time heat storage or electric radiators with fireclay storage cores or water-filled cores) and domestic hot water preparation with electricity-heated decentralized hot water storage or with instantaneous water heaters near the respective water taps.

The principle of modern electrical heating system is very simple: using a storage device, e.g. of a fireclay storage core inside the electric heater, the external radiators made of steel (partly also enameled) are evenly heated. Night-time storage heaters are also widespread in old buildings, but their use has decreased over the years because of the detrimental effects on health of asbestos – which is commonly found in night-time storage heaters. Additionally, nowadays electricity in the secondary tariff or at night is often no longer as cheap as in the past, when night storage heaters (also from an energy point of view - to support band-type electricity generation from large power plants) were still subsidized.

The initial investment costs of direct electricity heating systems are rather low, because it does not require a water-based heat distribution and delivery system in the house (i.e. piping and radiators). However, depending on the thermal quality of the building envelope and on the climatic conditions, it can result in very high electricity consumption and, consequently, high heating costs. In addition, during the heating season high electricity loads are required from fluctuating renewable sources (such as solar or wind power, or also hydropower, which is generally scarcer in winter due to lower water flow). If to meet the peak demand, the electricity is generated from coal, oil or natural gas (still very common, especially in winter), then the carbon footprint of direct electricity heating is extremely high, and it results in harmful emissions of greenhouse gases and other pollutants.

As an alternative to direct electricity heating, there are two options for homes without a fireplace and a chimney: a district heating connection, or a heat pump.

In both systems, however, it will be necessary to install a hot water distribution system to distribute the heat to the heat dissipation systems. In the case of heat pumps, in particular, it is important to ensure that the upper temperature level is as low as possible in the heat output system (e.g. using subsequently installed underfloor heating or radiators with a correspondingly large surface). This is particularly important in the case of air heat pumps, as the lower the temperature difference between the heat source (outside air) and the room temperature, the higher is the efficiency.

From an ecological and economic point of view, entire or partial renovation of the building envelope is recommended in both cases. Individual components should in any case be thermally improved, where this

can be carried out cost-effectively, such as on the top floor ceiling or if it is also for comfort purposes (i.e. drafty windows) convenience. In the case of a good building envelope and milder climatic conditions, individual (possibly also connected) rooms can be heated using fan coils in the case of a heat pump (also without radiators or surface heating or in addition to these). In warmer climatic zones, a heat pump has the advantage that the heated rooms can also be air-conditioned in the summer. In the case of the outdoor units of air source heat pumps, attention must be paid to the creation of noise at the place of installation (e.g. external facade in the inner courtyard or roof area) and compliance with the standards, as well as the prevention of related neighborhood conflicts. If the on-site conditions allow it, groundwater or soil (surface collector or deep borehole) can also be considered as a heat source for the heat pump. These variants are more expensive to buy but can be cheaper in terms of operating costs (due to higher efficiency).

An example of a gas boiler which was replaced by an air heat pump in a multi-apartment building can be found in the report on best practice examples of the REPLACE project (see heat pump in Zagreb's Upper Town courtyard). Measures like those implemented in this example should be carried out also in the case of a replacement of a direct heating system.

If in addition to the hot water distribution and heat dissipation system, the installation of a fireplace and chimney is considered (e.g. on the outside of the facade, if possible under building regulations), then the building's own central heating systems, e.g. on the basis of pellets, logs or wood chips, can be used as a replacement for direct electricity heating. In this case, it is advisable to examine a comprehensive or at least partial thermal renovation of the building envelope.

Finally, it is always recommended to consult an independent energy consultant or an installer for more detailed and case-specific information.

Building's connection to a district heating network with a heat exchanger

IS HEATING WITH NATURAL GAS BETTER THAN HEATING WITH COAL OR OIL?

Natural gas, coal and oil are all fossil fuels and all non-renewable energy sources. In boilers running on gas, coal, or oil, normally heat is produced by a process of combustion of the fuel. Fossil-fuel combustion is also one of the main sources of the emissions of greenhouse gases and other pollutants that drive climate change[10].

When replacing your heating system, the biggest environmental benefits cannot be grasped by switching from a fossil fuel to another, but only switching from a fossil fuel to a renewable one.

Even if it is sometimes stated that the whole lifecycle carbon emissions of natural gas is lower than that of other fossil fuels, this is sometimes also questioned in the scientific discussion. In any case, the environmental footprint of a renewable heating system is generally lower than that of other competitors running on fossil fuel. This clearly means that switching to a less emissions-intensive fossil fuel (i.e. from coal or oil to gas) does not provide a long-term answer to climate change. This answer is only provided by renewable energy.

Crude oil pump in operation

10 "Fuel combustion and fugitive emissions from fuels (without transport)' was responsible for 54 % of EU-28 greenhouse gas emissions in 2017.": Eurostat, Greenhouse gas emission statistics – emission inventories, 2019 (https://ec.europa.eu/eurostat/statistics-explained/pdfscache/1180.pdf)

HOW CAN BEHAVIOURAL CHANGES IMPACT MY ENERGY CONSUMPTION?

Energy savings do not always require significant investments of capital. Sometimes, it is enough to follow some simple tips and to adopt environmentally friendly habits to save up to 20% on your energy consumption for home heating[11].

Few examples from our list of recommendations include the following[12:]

- Adjust the room temperature: it is enough to lower the temperature of just one degree in the room in order to achieve 6% energy savings.
- Get the right humidity level in the room: at equal temperature levels, dry air is perceived as colder than moist air. The optimal level of humidity in the room should be between 30% and 55%.
- Close the doors to not disperse the heat into colder rooms and close shutters, which are an additional heat protection, especially in buildings with bad windows.
- Lower the temperature at night, especially if your home gets warm again quickly in the morning.
- Do not heat cellars and garage: they are usually poorly insulated and that is why the energy consumption in there is usually three to four times that of a living room. If the rooms are not used, you should avoid heating them.
- Ventilate the room by opening the windows, during the right time. Ventilate minimum 10 minutes, preferably during the day in winter and during the night in summer. When more people are at home, longer ventilation times are suggested. This allows fresh air to enter the room and avoid cooling: the colder the outside temperature, the shorter the ventilation time.
- Install seals or replace the old ones: old windows and doors can be the cause of drafts and heat losses. Installing gaskets saves energy costs and increases comfort.
- When and where possible, install thermostats and control systems, like valves on the radiators to set the desired temperature, radiator thermostats which quickly react to temperature changes in the room, radiator thermostats with time programming functions and/or individual to each room.
- Remove objects which might cover the radiators (i.e. curtains on a wall radiator, carpets on the floor heating) and regularly clean the radiators from dust.

11 Energie Tirol, „20% Heizkosten sparen“, (https://www.energie-tirol.at/uploads/tx_bh/energie_tirol_handbuch_heizkosten_sparen.pdf)
12 Ibidem.

- Vent the heating if you hear a gurgling in the pipes or radiators. You may be able to do this yourself with a ventilation key or, if in doubt, have the installer do it for you. Venting can also be carried out on underfloor heating manifolds.
- Pay attention to whether some rooms do not get warm enough, even when the radiators are at their maximum power. This can be an indication of a lack of hydraulic balancing of the heating system, which can be carried out by an installer and which alone can save a good 15 percent or more of energy costs.
- Urgently call your installers if the valves can no longer be opened or closed.
- Carry out a professional inspection of your heater once per year to ensure good maintenance and prevent undesired failures.

Simple, isn't it?

Heat pump installed on the wall of a house and storage of logwood on the floor

IS BIOMASS SUSTAINABLE?

Like sun, wind and water, biomass is a renewable source of energy too.

Some may argue that biomass is not sustainable because in the production of heat or electricity from biomass, the combustion process is not eliminated. Nevertheless, one of the elements which make biomass sustainable is that biomass extracts carbon dioxide (CO_2) from the atmosphere during its growth (photosynthesis). CO_2 is the main greenhouse gas of the combustion processes and the one mainly responsible for global warming. Carbon dioxide is emitted during combustion of fossil fuels (e.g. lignite, hard coal, oil, natural gas), but also of biomass. The difference, however, is that the extraction of CO_2 from the atmosphere, makes biomass "more carbon neutral" compared to fossil energy sources.[13]

Some others may think that the production of bioenergy is contributing to the deforestation. In central Europe, forests are usually managed sustainably. Furthermore, biomass does not only consist of wood from forest. Biomass consists of all the biological sources available on a renewable basis, including woody biomass (forestry and wood industry residues), agricultural biomass (crops and residues) and biowaste (solid municipal biowaste, manure and sewage)[14]. In addition, sustainable forest management secures long-term fuel supply and balances ecological, economic and socio-cultural aspects[15]. Sustainable forest management is essential to ensure that biomass used for energy purposes is sustainable: i.e. making careful choices about the type of biomass we harvest for fuel and how we harvest it.

When looking at the material flows of a typical sawmill, about 40% of the mass of a tree trunk is saw-mill byproducts, that are partly used for energy purposes, e.g. wood pellets or industrial woodchips, or for paper, pulp and paperboard production. Sustainable forest management ensures that the absolute amount of biomass in a given region does not diminish over the years, but on the contrary it increases, despite the harvest of wood for material and energy usage (forest as a carbon sink). Since 1990, not only the EU's forest area has increased by 14 million hectares, but also the EU's wood stock has grown by 8 billion solid cubic meters, with Central Europe being one of the regions with the highest wood reserves in the world[16].

Sustainable forest management is ensured by national legislations, international commitments as well as voluntary certifications[17]. Bioenergy is also the only form of energy with a guarantee of sustainable

13 "Biomass energy sources are not entirely CO2-neutral, as fossil energy sources are still used for the preparation and utilisation of biomass (e.g. for harvest and transport)", Dimitriou and Rutz, 2015
14 Bioenergy Europe, "About Bioenergy" (https://bioenergyeurope.org/about-bioenergy.html)
15 BioVill, "Pellets Heating Systems", 2017 (http://biovill.eu/wp-project/uploads/2017/07/Pellets_infosheet_en.pdf)
16 Food and Agriculture Organisation of the United Nations (FAO), July 2020, "Global Forest Resources Assessments" (fao.org/forest-resources-assessment)
17 Bioenergy Europe, "Forestry" (https://bioenergyeurope.org/policy/forestry.html)

sourcing, irrespective of the geographic origin of the biomass and guaranteed by the sustainability criteria set by European legislation[18].

In conclusion, bioenergy is usually sustainable in economic, social and environmental terms. The use of wood for heating fosters rural development, it creates jobs and, being cost-effective, it contributes to a sustainable future, fair to our societies and environment.

Wood in the forest

18 Bioenergy Europe, „What is Bioenergy? The Essentials" (https://bioenergyeurope.org/article/196-bioenergy-europe-essentials.html)

IS AN OLD INEFFICIENT WOOD STOVE BETTER THAN A MODERN EFFICIENT OIL BOILER?

Even if it is true that wood is a renewable energy source, while oil is a fossil fuel, it is also true that using energy inefficiently, be it renewable or not, is never an environmentally sustainable option.

When using energy, we always have to make the best possible use of it, especially in the case of energy from woody biomass: an inefficient use of biomass from forestry could easily lead to an uncontrolled forest management, which would not only be unsustainable on the long term, but it would also end up seriously harming the environment.

The best way to use energy efficiently at home is to explore refurbishment options for your building or to replace old and inefficient heating systems with modern ones, which can reach a very high level of energy efficiency, thus lowering your energy consumption, which also means reducing your environmental footprint and energy bills.

Modern and efficient logwood stove in the living room of a house

4. WHAT ARE MY REPLACEMENT OPTIONS?

While in the past, the choice of the heating system to install at home was an easier one, today this is no longer true because of the multitude of different technologies and brands available on the market. While the market still offers alternatives running on fossil fuels, it has been explained in the previous chapters how the best investment in environmental, social and economic terms together is ensured by the purchase of a renewable heating system for your house.

This chapter will provide you with a comprehensive list of options of renewable heating systems available on the market in your region at the time of writing. A short and concise technology factsheet is dedicated to each system, providing some basic notions and illustrations of their functioning, their main benefits (and potential downsides), incentives available in your region to promote them, and some figures and interesting facts.

The information provided in these factsheets are limited. Have also a look at the website of the REPLACE project, where you will find the heating matrixes, a region-specific guide which shows which renewable energy based heating system best fits to your building type and to your energy demand, as well as the "REPLACE your system Calculator". Via application of the heating matrixes and based on case-specific aspects like site conditions (e.g. possibility to connect to a district heating grid, availability of biomass storage space etc.), economic, comfort and environmental considerations, the Calculator will show you the best renewable heating system for your house. You will be able to find out more about the best options recommended to you by the Calculator, by reading the factsheets in this report, also available on the project website.

For consultation services and recommendations, we encourage you to contact an energy adviser or your local installer, who can assess what is the best option for you based on your specific case (i.e. building type and energy needs). Useful contacts from your region are provided in the factsheets.

Beyond the technologies that you will find in the factsheets, there are some other options which might be worth considering when planning the replacement of your heating system or the improvement of the energy performance of your building, illustrated in chapter 5 of this REPLACE project report. Enjoy the reading!

FACTSHEET

BIOMASS BOILERS FOR WOOD PELLETS

Building type: single-family houses, multistore houses, large buildings, micro-grids, district heating

How it works

Biomass heating systems use wood materials to provide heat and hot water. Burning wood in a boiler provides a renewable and sustainable source of heat.

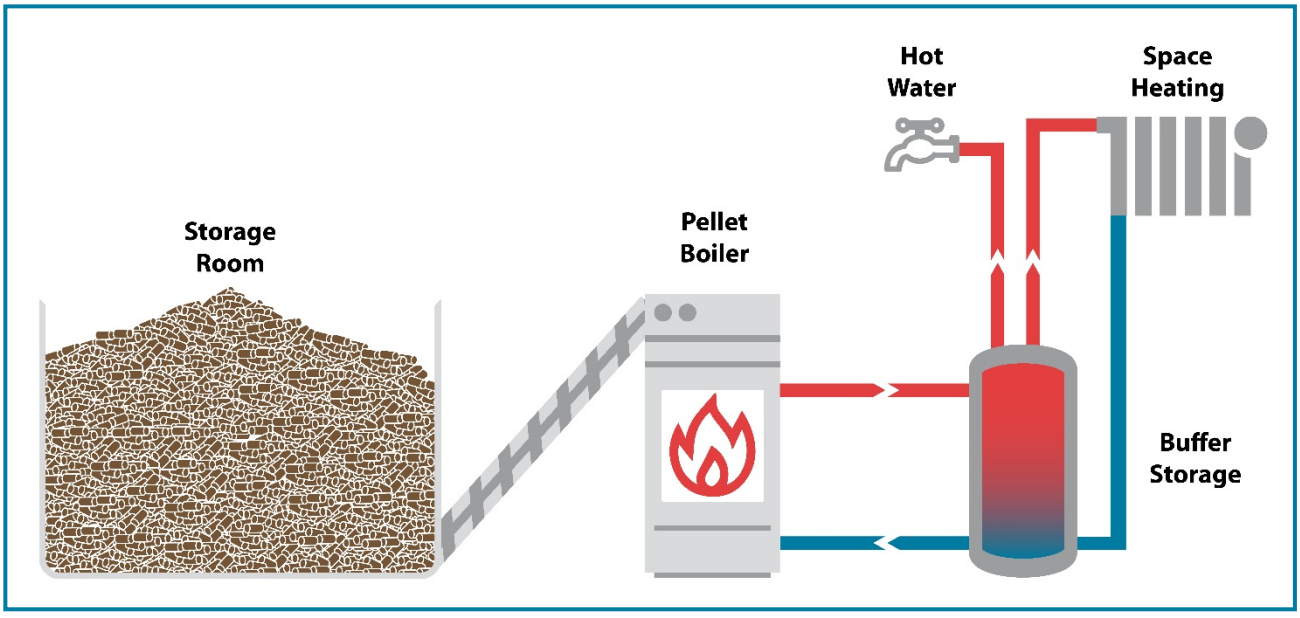
While biomass stoves are generally used as heaters for a single room, biomass boilers are suited to heat an entire house, and biomass district heating systems entire neighborhoods!

The functioning of a biomass boiler does not substantially differ from that of a conventional fossil fuel boiler: in both cases, water is heated up by the combustion process and then circulated to the individual rooms to provide the heating requirements for a building. They can therefore easily be used for an existing heat distribution system, as well as being installed as part of a brand-new heating system.

While there is a wide range of materials that can be classified as biomass fuel, the most common sources for biomass boilers are logwood, wood pellets or wood chips. The best option for you also depends on the surface to be heated.

Wood pellets are a biomass fuel made from compressed sawdust, produced as a waste from sawmills. Unlike log systems which normally require manual filling, when connected to a bulk fuel store a pellet biomass boiler will be completely automated.

Wood pellets can run a **biomass central heating system** of small or medium size, which provides heat for single-family houses and even for multistore houses or commercial buildings (thus replacing your old



Did you know?

*In order to ensure efficient burning and high energy yields, the biomass fuel should be of **good quality (dry, clean and of the right size) and properly stored**. Different certification schemes help to ensure good quality of the fuel.*

Good quality pellets have a low moisture content (<10%), a low ash content (<2%) and a low fine material portion (<1%). In most countries, only such good quality pellets are available on the market.

heating system). A modern pellet central heating system runs with high comfort and cleanliness. The fuel is delivered by a tank truck, blown into the pellet storage, and automatically transported from the storage to the boiler. Ignition, control, boiler cleaning and ash removal are fully automatic. All that remains to be done is to empty the ash box, usually about twice a year.

Some state-of-the-art biomass boilers can alternate between running on wood pellet and on wood chips or logwoods, depending on the availability of the fuel and on the personal needs.

A pellet boiler supplemented with a Stirling engine, using the micro-combined heat and power (micro-CHP) technology, can provide not only heat, but also simultaneously generate electricity.

Furthermore, **pellet boilers with condensing technology** are available on the market. In a house with a low temperature heating system, (i.e. with floor or wall heating) the flue gas of the pellet boiler can potentially be cooled down and the withdrawn heat can be captured via a heat exchanger and utilized for heating purposes. However, because the water in the flue gas condenses, the installation of a stainless-steel tube in the chimney is needed to collect the condensing water. Besides an efficiency gain of about 10% (i.e. less fuel is needed), less dust particles are emitted, because they remain in the condensate.

Pellets are also used to fuel **stoves** heating single rooms and complementing the central heating system. Pellets are sometimes also used **in micro-grids and district heating**, although the most common fuel for larger systems are wood chips. In such cases, it is recommended that normal pellet boilers efficiently deliver the summer load (domestic hot water demand), because the larger wood chip boilers should not be run too much in lower part load operation, but rather in winter.

In general, a biomass boiler should be combined with a **hot water buffer heat storage**, which avoids stop-and-go operations and supports a high degree of intervals of high energy efficient full load operation, thus significantly contributing to lowering avoidable dust (fine particle) emissions.

Why should I install a boiler for wood pellets?

- **Good value for money**: The prices of wood pellets are usually lower and less volatile compared to the prices of fossil fuels.
- **Efficient boilers for every house type and size**: Today industry offers a wide range of boiler sizes, fuel types and combinations of wood fuels. Regardless of the boiler size and fuel, modern systems operate with a high energy efficiency and low dust emissions.

- **Clean, comfortable and efficient heating**: Modern pellet heating systems are clean and, because of their high efficiencies, they bring the energy bills down, without decreasing the comfort at home.
- **Wood is a regional resource**: if the wood for the pellets is produced locally, as it is often the case, transport distances are reduced and the revenues stay within the local community.
- **Sustainability**: Sustainable forest management secures long-term wood supply as well as balanced ecological, economic and socio-cultural aspects. Wood pellets are by-products of sawmill operations, part of a sustainable forest management. In sawmills, about 60% of the mass of a timber trunk can be processed for material usage purposes (construction, furniture, etc.). The remaining 40% is by-products. Those by-products are used for both material purposes (paper, pulp and wood panel industry) and energy purposes (wood pellets and industrial wood chips). A very good and locally widespread source of wood pellets are wood dust and shavings, as they have a particularly low carbon footprint.
- **Energy security**: Regardless of the season, wood is normally available within the region and its prices do not depend on economic and political developments. As long as timber and sawmill industry are in operation, there will be sufficient amounts of pellets available. Furthermore, wood pellets can be stored and transported over large distances via ship and train. Large storing facilities are also available, as pellets are produced around-the-clock and people tend to buy it as fuel just shortly before the heating season.
- **Wood is climate friendly**: The CO_2 emitted while burning woody fuel equals the amount of CO_2 that the tree assimilated during its growth.
- **Perfect for off-grid locations**: with biomass heating you don't need to be connected to utilities. Biomass boilers and stoves are a perfect off grid solution for both heating and hot water.
- **Wood pellets can reach nearly every house**: Pellets can be delivered not only by 4-meter-high heavy-duty vehicles but also, if necessary, by 3.5-meter-high trucks and can be easily pumped over a distance of 30 meters to the in-house storage. With special vehicles, pellets can be pumped even up to 15 meters high or via hoses, up to 60 meters long.
- **Wood pellets are dust free and smell good**: The delivery, as well as the wood pellets, are dust-free. Any wood dust is sucked back into the truck and recycled to pellets. Wood pellets for most people smell good, which is not the case with oil fuel.
- **Wood pellets are neither dangerous nor harmful to your house**: There are rumours that wood pellets would emit dangerous gases or would make walls collapse if they get wet. Building and fuel standards ensure that wood pellets and storages are totally safe, even in case of flooding. Instead, in the case of oil fuel, a flooding can make a severe damage to the house and to the environment (water pollution). The smell of leaked oil can hardly be removed from the flooded cellar walls, without comprehensive deconstruction measures.
- **The availability of a biomass storage space might be a hurdle, but there are alternative solutions**: Biomass boilers fit best in houses where a fuel storage room already exists, like in the case of formerly heating systems with oil fuel or where a room can be made free, e.g. in the cellar. Otherwise, alternative solutions include storing pellets underground in the garden or under a car parking lot. Wood pellets have around half of the energy density of oil fuel, and because of their efficiency, smaller amounts are needed compared to oil fuel.

Boilers for wood pellet match with…

Wood pellet boilers can **completely replace existing fossil fuel (gas, oil, LPG) boilers** and provide all your space, underfloor and water heating requirements but can also be integrated with other systems.

Wood pellet boilers can be easily integrated in existing central heating systems with **buffer storage tanks**. An additional buffer tank stores the heat generated from burning and ensures a demand-driven supply of heat (e.g. night/day or seasonal differences).

Biomass heating systems are ideally combined with a **solar collector system**, which provides domestic hot water in summer, or can even partially cover space heat demand in transitional seasons (before and after summer). They can be also combined with **heat pumps.**

Boiler for pellets Overview[19]

Boiler nominal power	11 to 22 kW_{th} (generally possible from 5 kW_{th} to IN MW range)
Pellet consumption	3.06 to 6.12 tons per year
Acquisition costs (purchase and installation)	27,000 to 34,000 € (incl. VAT)
Acquisition costs (with deduction of 45%)	14,850 to 18,700 € (incl. VAT)
Annual savings on running costs (including fuel costs)	350 to 770 €/a
Greenhouse gas emission reduction (gg. oil heating, minus GHG emissions from the climate-friendly system under consideration)	4.4 to 8.94 tons of CO_2 per year (based on heating oil consumption of 1,500 and 3. 000 L/a [15,000 or 30 000 kWh] → Emissions in t CO_2 per year for emissions of pellets 29 g/kWh vs. heating oil 327 g/kWh)
Operating volume	The mechanics of the feeder can be audible; this is generally unproblematic, as the plant is in a separate room; soundproofing measures such as soundproofing bottom can reduce noise.
Building requirements	Space available for pellet storage (e.g. for sack silo), access for trucks up to 25 m distance.

[19] To calculate the figures of the below table, a base case from the Bavaria Oberland region in Germany has been used as a best practice. Figures from other countries across Europe (Austria, Bosnia and Herzegovina, Bulgaria, Croatia, North Macedonia, Serbia, Slovenia and Spain) are available on the REPLACE project website at www.replace-project.eu.

FACTSHEET

BIOMASS BOILERS FOR LOGWOOD

Building type: single-family houses, multistore houses

How it works

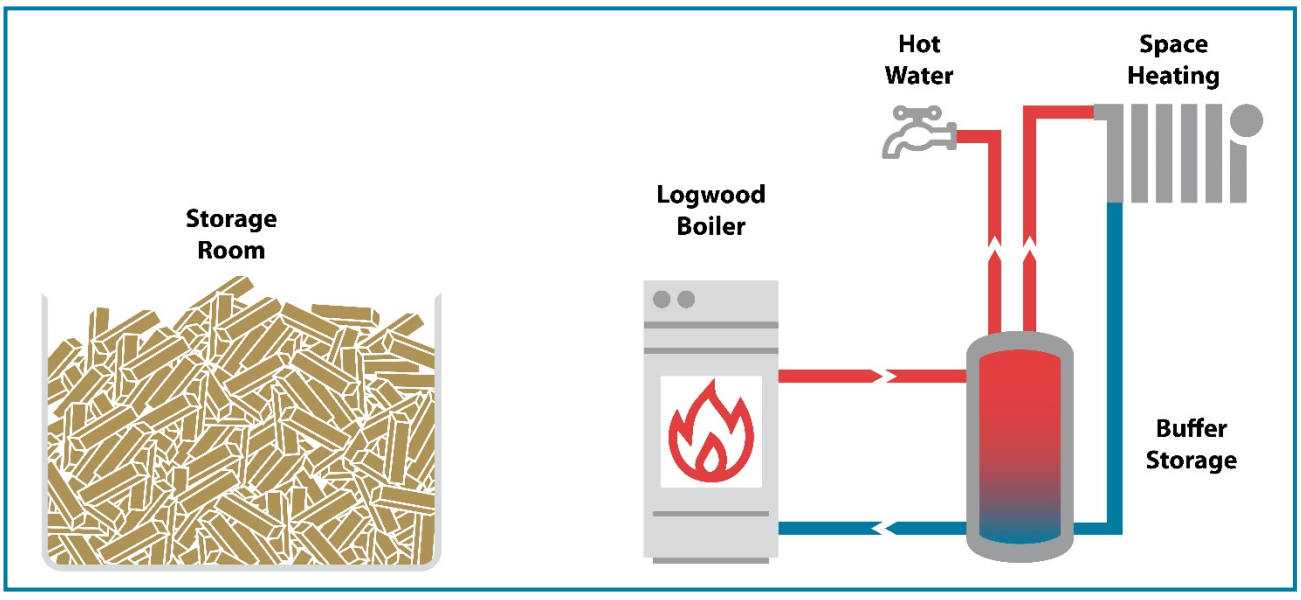
Biomass heating systems use wood materials to provide heat and hot water. Burning wood in a boiler provides a renewable and sustainable source of heat.

While biomass stoves are generally used as heaters for a single room, biomass boilers are suited to heat an entire house, and biomass district heating systems even entire neighborhoods!

The functioning of a biomass boiler does not substantially differ from that of a conventional fossil fuel boiler: in both cases, water is heated up by the combustion process and then circulated to the individual rooms to provide the heating requirements for a building. They can therefore easily be used for an existing heat distribution system, as well as being installed as part of a brand-new heating system.

While there is a wide range of materials that can be classified as biomass fuel, the most common sources for biomass boilers are logwood, wood pellets or wood chips. The best option for you also depends on the surface to be heated.

Logwoods are a popular and one of the cheapest choices of fuel for those who have either access to own wood sources or who like to handle wood. Logs are normally manually loaded into the boiler, so direct interaction is required from the owner. Depending on the season and on the used technology, usually loading the boiler every day or every two days may be required in the cold season. Modern wood boilers are often also called **wood gasification boilers**. They are very efficient and have fewer emissions. These



Did you know?

In order to ensure efficient burning and high energy yields, the biomass fuel should be of ***good quality (dry, clean and of the right size) and properly stored****. Different certification schemes help to ensure good quality of the fuel.*

In the case of logwood, air-dried logwood requires at least 2 years of storage to reach a moisture content of less than 20%.

boilers are characterised by two burning chambers. In the gasification chamber, the wood is decomposed to charcoal and to gas which is burned in the second chamber.

The higher the efficiency of the boiler, the dryer the log woods. Ideally, the water content should be around 20%, which can be achieved when logs are stored split and stacked for at least half a year, exposed to sun and wind (jacked up, not touching the ground and covered by a rain protection).

Logwoods can run a **biomass central heating system** of small or medium size, which provides heat for single-family houses and even for multistore houses or commercial buildings (thus replacing your old heating system). Some state-of-the-art biomass boilers can alternate between running on pellet and on logwoods, depending on the availability of the fuel and on the personal needs.

Logwoods are also used to fuel **stoves** heating single rooms and complementing the central heating system.

In general, a biomass boiler should be combined with a **hot water buffer heat storage**, which avoids stop-and-go operations and supports a high degree of intervals of high energy efficient full load operation, thus significantly contributing to lowering avoidable dust (fine particle) emissions.

Why should I install a boiler for logwood?

- **Good value for money**: The prices of wood are usually lower and less volatile compared to the prices of fossil fuels. More precisely, the costs for logwood are among the lowest ones of all technologies based on renewable energy sources.
- **Clean, comfortable and efficient heating**: Modern wood heating systems are clean and, because of their high efficiencies, they bring the energy bills down, without decreasing the comfort at home. However, logwood is more labour-intensive, compared to other wood fuels.
- **Wood is a regional resource**: if wood is produced locally, as it is often the case, transport distances are reduced and the revenues stay within the local community.
- **Sustainability**: Sustainable forest management secures long-term wood supply as well as balanced ecological, economic and socio-cultural aspects.
- **Energy security**: Regardless of the season, wood is normally available within the region and its prices do not depend on economic and political developments.
- **Wood is climate friendly**: The CO_2 emitted while burning woody fuel equals the amount of CO_2 that the tree assimilated during its growth.

- **Perfect for off-grid locations**: with biomass heating you don't need to be connected to utilities. Biomass boilers and stoves are a perfect off grid solution for both heating and hot water.

Boilers for logwood match with…

Logwood boilers can **completely replace existing fossil fuel (gas, oil, LPG) boilers** and provide all your space, underfloor and domestic water heating requirements but can also be integrated with other systems.

They can be easily integrated in existing central heating systems with **buffer storage tanks**. An additional buffer tank stores the heat generated from burning and ensures a demand-driven supply of heat (e.g. night/day or seasonal differences).

Biomass heating systems are ideally combined with a solar collector system, which provides domestic hot water in summer, or can even partially cover space heat demand in transitional seasons (before and after summer). They can be also combined with **heat pumps**.

Boiler for Logwood Overview[20]

Boiler nominal power	11 to 22 kW
Annual wood consumption in cubic meters [m^3]	8.4 or 16.7 cubic meters per year
Acquisition costs (purchase and installation)	22,400 to 26,800 €
Acquisition costs (with deduction of 45%)	12,320 to 14,740 €
Annual savings on running costs (including fuel costs)	Approx. 850 to 1,090 €/a
Greenhouse gas emission reduction (gg. oil heating, minus GHG emissions from the climate-friendly system under consideration)	4.5 to 9.1 tons of CO_2 per year (based on heating oil consumption of 1,500 and 3. 000 L/a [15,000 or 30 000 kWh] → Emissions in t CO_2 per year for logs emissions 25 g/kWh vs. heating oil 327 g/kWh)
Operating volume	Negligible
Building requirements	Sufficient space available for wood storage, uncomplicated access to the wooden warehouse.

[20] To calculate the figures of the below table, a base case from the Bavaria Oberland region in Germany has been used as a best practice. Figures from other countries across Europe (Austria, Bosnia and Herzegovina, Bulgaria, Croatia, North Macedonia, Serbia, Slovenia and Spain) are available on the REPLACE project website at www.replace-project.eu.

FACTSHEET

BIOMASS HEATING SYSTEMS WITH WOODCHIPS

Building type: multistore houses, large buildings, micro-grids (connecting several single-family houses), district heating

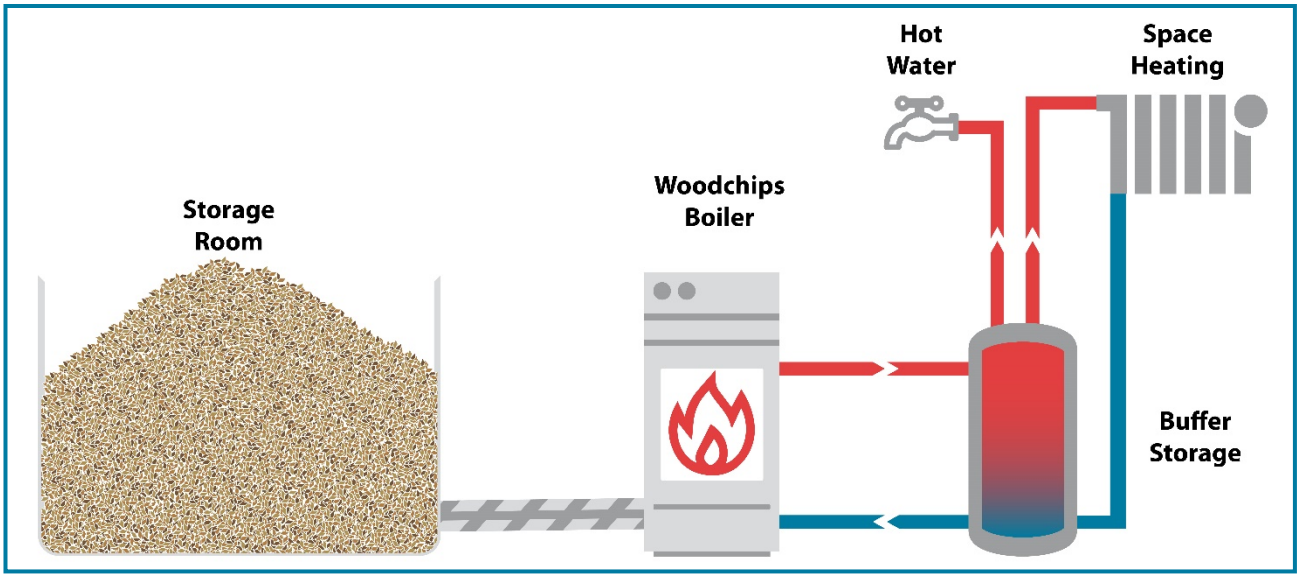
How it works

Woodchips are small pieces of wood which have been chipped to produce a suitably sized fuel for wood chip boilers.

A woodchip boiler integrated in a central heating system produces hot water which is then circulated in the building to where heat is needed. This heating system usually consists of two parts: the **fuel transport system** and the **boiler**. The system offers high comfort and is comparable to heating with fossil fuels.

Due to efficiency reasons and fuel storage requirements, woodchips heating systems are suitable for centralized heating systems in **medium to larger buildings** (un-refurbished, larger single or double family houses, apartment blocks, agricultural buildings, etc.) or in **micro grids** with a central heating station or container (connecting several buildings via a heating grid), but often also in industrial applications. Sometimes, farmers and/or forest owners operate these boilers in communities. The boiler size starts at about 20 kW nominal power. Many thermally un-refurbished single or double family houses need such a power range, but not modern, energy efficient, new houses. Larger boilers for mass production can have 100 kW nominal power. Tailor-made wood combustion plants start at 400 kW and range up to several MW of nominal power. They can burn practically every biomass source with limited water content, even low-quality fuels with high shares of impurities.

The **storage of woodchips** requires considerable space. Woodchips are usually delivered by trucks or by



Did you know?

*Using **waste or recycled woodchip** in biomass boilers can increase fuel savings even further as well as helping some companies benefit from the elimination of disposal costs.*

Waste or recycled woodchip can be purchased through some fuel supply companies at a lower cost than virgin chip, but the greatest financial returns are made when companies "produce" waste wood as a byproduct of their day to day activities and re-use it as a fuel, instead of disposing of it.

farmers' tractors with a trailer and directly filled into the storage room. Heating of single-family homes is also possible but requires a suitable storage capacity or regular delivery.

Ideally, wood chips should be very dry, homogenous, free of impurities, of high quality (low fractions of fine particles, bark and of green material). The water content of wood chips used in the residential sector should not be higher than 30%, as a higher water content would lead to biodegradation process with self-warming. Therefore, the original wood material should be sufficiently naturally dried (by sun and wind), before it is chipped.

The majority of woodchip boilers are classified as **"multi-fuel"** as they are also able to run on pellets, and in some cases on wood dust or energy crop by-products like corn spindle or elephant grass, though the vast majority are run on chip. This gives owners great flexibility as well as security as multiple types of fuel can be used in the system.

In general, a woodchip boiler should be combined with a **hot water buffer heat storage**, which avoids stop-and-go operations and supports a high degree of intervals of high energy efficient full load operation, thus significantly contributing to lowering avoidable dust (fine particle) emissions.

Why should I install a woodchip heating system?

- **Good value for money**: The prices of woodchips are usually lower and less volatile compared to the prices of fossil fuels.
- **Efficient boilers for every medium** to larger house type and size: Today industry offers a wide range of boiler sizes, fuel types and combinations of wood fuels. Regardless of the boiler size and fuel, modern systems operate with a high energy efficiency and low dust emissions.
- **Clean, comfortable and efficient heating**: Modern woodchip heating systems are clean and, because of their high efficiencies, they bring the energy bills down, without decreasing the comfort at home.
- **Wood is a regional resource**: if wood for the woodchips is grown locally, as it is often the case, transport distances are reduced and the revenues stay within the local community.
- **Sustainability:** Sustainable forest management secures long-term wood supply as well as balanced ecological, economic and socio-cultural aspects. Farmers' wood chips normally stem from sustainable forest thinning and cleaning operation, stabilizing resilience of forests and increasing their yield in terms of timber for material usage.

- **Sanitary forest measures and market stabilisation**: In recent years woodchips proofed to be a good mean to support sanitary forest measures: calamities such as storms, snow, ice breakage and bark beetle infestation have significantly increased, thus destabilising forests and the functioning of wood markets. Woodchips for burning is the only cost-effective way of utilising wood assortments damaged by the many calamities caused by climate change.
- **Energy security:** Regardless of the season, wood is normally available within the region and its prices do not depend on economic and political developments. Given the increasing calamities caused by climate change (see above), a shortage of wood chips for the residential sector is unlikely.
- **Wood is climate friendly**: The CO_2 emitted while burning woody fuel equals the amount of CO_2 that the tree assimilated during its growth.
- **Perfect for off-grid locations**: with biomass heating you don't need to be connected to utilities. Biomass boilers and stoves are a perfect off grid solution for both heating and hot water.

Woodchip heating systems match with…

Woodchip boilers can **completely replace existing fossil fuel (gas, oil, LPG) boilers** and provide all your space, underfloor and water heating requirements but can also be integrated with other systems.

They can be easily integrated in existing central heating systems with **buffer storage tanks.** An additional buffer tank stores the heat generated from burning and ensures a demand-driven supply of heat (e.g. night/day or seasonal differences).

Biomass heating systems are ideally combined with a **solar collector system**, which provides domestic hot water in summer, or can even partially cover space heat demand in transitional seasons (before and after summer). They can be also combined with **heat pumps.**

The basis for the quantitative data in the following table is a larger building, which is still heated with oil. The cost-orientation values assume building 3,000 l/a heating oil consumption. This corresponds to a woodchips amount of 46.5 srm/a (cubic meters per year). Cubic meters is the poured wood parts. Instead of being layered tightly, they are simply poured, which leaves significantly more air in a cubic meter of wood than with proper layering. Annual savings are offset against the operating costs of a comparable oil heating system, at a fixed price of 80 cents per liter of heating oil.

Woodchip Heating System Overview[21]

Boiler nominal power	From 22 kW
Annual wood consumption in cubic meters [m^3]	46,5
Acquisition costs (purchase and installation)	Approx. €30,000
Acquisition costs (with deduction of 45%)	€16,500
Annual savings on running costs (including fuel costs)	Nearly 1,300 €/a (1,290.50 €)
Greenhouse gas emission reduction (gg. oil heating, minus GHG emissions from the climate-friendly system under consideration)	9 tons of CO_2 per year (based on fuel oil consumption of 3. 000 L/a [30 000 kWh] → Emissions in t CO_2 per year at woodchips emissions 26 g/kWh vs. heating oil 327 g/kWh)
Operating volume	In case of incorrect installation, noise is caused by uninsulated iron
Building requirements	Sufficient space for wood chip storage (storage room, silo or earth bunker), space for buffer tanks.

[21] To calculate the figures of the below table, a base case from the Bavaria Oberland region in Germany has been used as a best practice. Figures from other countries across Europe (Austria, Bosnia and Herzegovina, Bulgaria, Croatia, North Macedonia, Serbia, Slovenia and Spain) are available on the REPLACE project website at www.replace-project.eu.

FACTSHEET

MODERN WOOD STOVES

Building type: individual rooms, , but also single- or two-family houses, or other small buildings

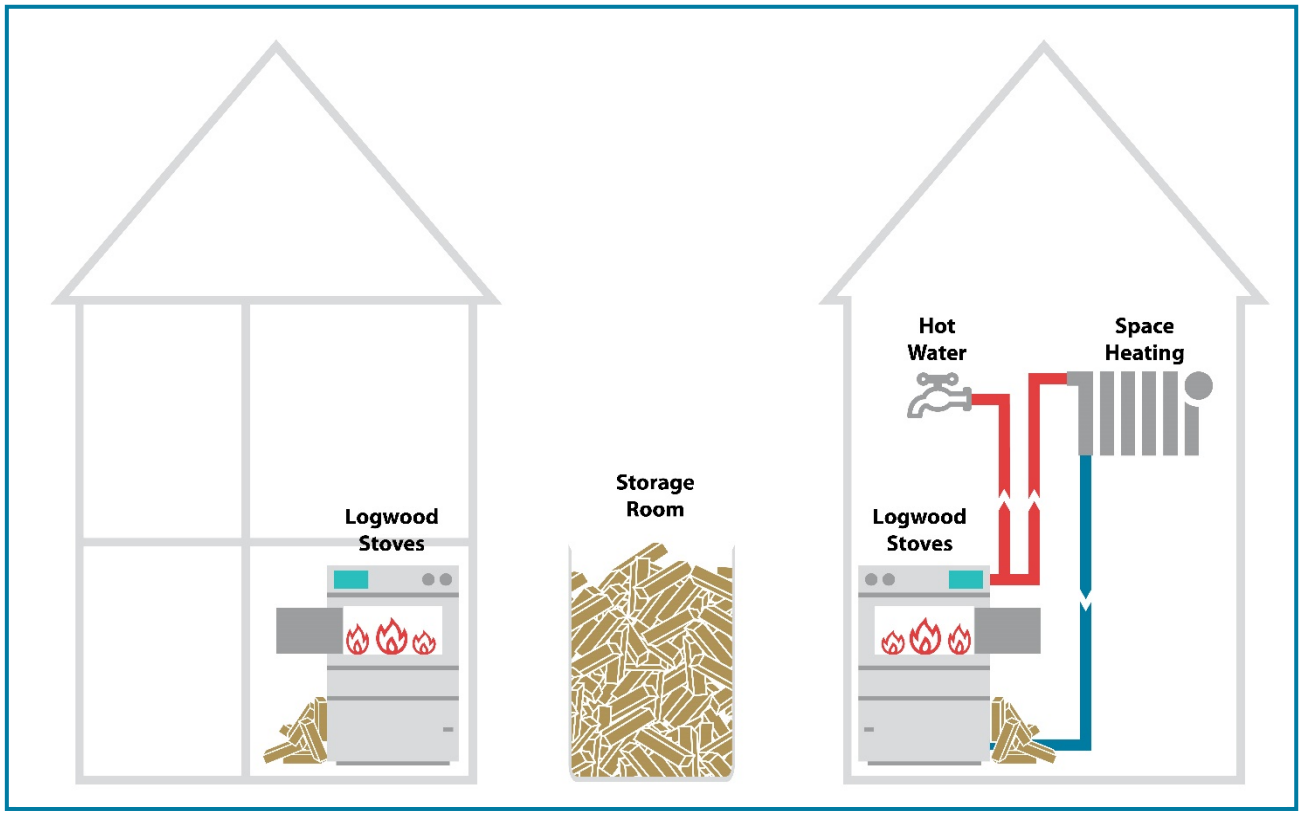
How it works

People love the coziness and warmth of fire in winter, but fireplaces and old wood stoves usually rely on a relatively inefficient burning process to generate heat. Nowadays, modern and efficient wood stoves, made out of cast iron, ceramic (tiled stoves) or steel, replaced their inefficient and polluting predecessors. They are generally used as heaters for a single room. More advanced systems can heat up to a whole building!

Wood stoves for heating the whole-house are equipped with a water pocket that is connected to the water cycle of the central heating system. They can also provide the heat for hot water.

It is important that the place of installation and the ratio of radiant and heating energy are chosen correctly, so that overheating of the room is avoided. It is necessary to ensure combustion regardless of the room air, because buildings are usually so densely built that not enough combustion air is available, or that a ventilation system would be disturbed. The combustion air can be supplied either via a suitable chimney or via a separate supply pipe.

A contemporary wood burning stove is an easy device to understand. Wood is stacked in the firebox and lit



Did you know?

Biomass has been used as a source of energy since man first discovered fire to heat and to cook. Despite the well-known and highly publicised renewable energy sources such as solar, wind or hydropower, ***bioenergy is the oldest and by far the most used source of renewable heat,*** *with 87% of all renewable heat coming from biomass and heating 66 million households in Europe!*

to provide the initial flame. The ventilation into the unit brings in fresh air to fan the flames to the desired heat.

Why should I buy a modern wood stove?

- **Good value for money**: The prices of wood are usually lower and less volatile compared to the prices of fossil fuels. Some stoves also require very low initial investment; nevertheless, it is important to not be tempted by the purchase of the cheapest option, because it is likely also the most polluting and least inefficient system.
- **Clean, comfortable and efficient heating**: Modern stoves are clean and much more efficient than transitional fireplaces, without decreasing the comfort of a warm fire at home.
- **Wood is a regional resource**: if wood is produced locally, as it is often the case, transport distances are reduced and the revenues stay within the local community.
- **Sustainability**: Sustainable forest management secures long-term wood supply as well as balanced ecological, economic and socio-cultural aspects.
- **Energy security**: Regardless of the season, wood is normally available within the region and its prices do not depend on economic and political developments.
- **Wood is climate friendly**: The CO_2 emitted while burning woody fuel equals the amount of CO_2 that the tree assimilated during its growth. It is nevertheless important to only use certified pellets and properly store the wood.
- **Very easy installation use and maintenance**: stoves generally don't need complicated installing requirements like the traditional fireplace. Normally, they can be easily installed without the aid of a professional and require very low space and maintenance.

Wood stoves match with…

Wood stoves are usually used as heaters for a single room (i.e. the living room). In this case, they can complement any central heating system for additional space heating and for water heating, regardless of the technology and fuel used.

Nevertheless, modern stoves can also be connected to the water cycle, thus heating water which is then circulated to the whole house and radiating the heat via radiators or underfloor heating. In this case, stoves do not complement your central heating system, but fully replace it.

FACTSHEET

MODERN PELLET STOVES

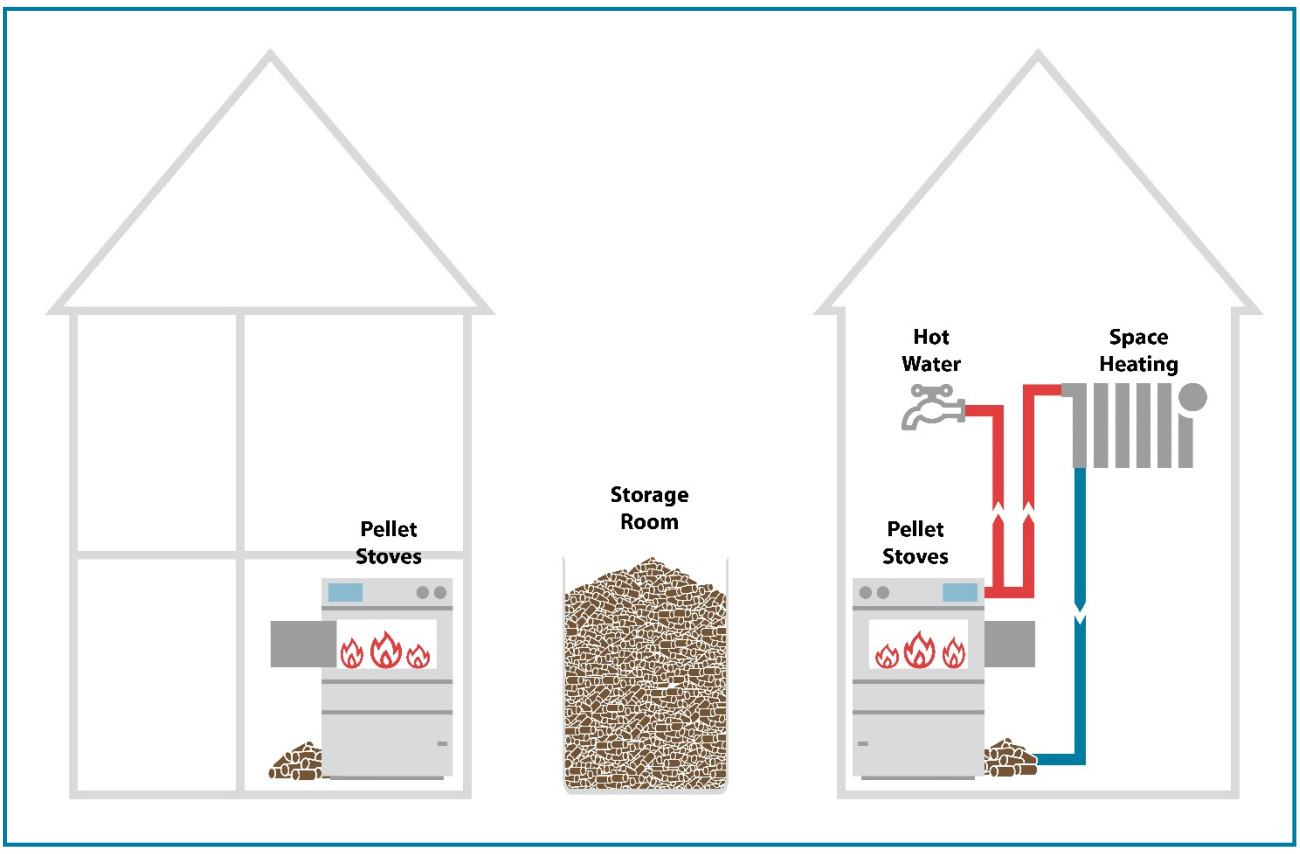
Building type: individual rooms, but also single-or two family houses or other small buildings

How it works

People love the coziness and warmth of fire in winter, but fireplaces and old wood stoves usually rely on a relatively inefficient burning process to generate heat. Nowadays, modern and efficient pellet stoves, made out of cast iron, ceramic or steel, replaced their inefficient and polluting predecessors. They are generally used as heaters for a single room. More advanced systems can heat up to a whole building!

Wood stoves for heating the whole house are equipped with a water pocket that is connected to the water cycle of the central heating system. They can also provide the heat for hot water.

It is important that the place of installation and the ratio of radiant and heating energy are chosen correctly, so that overheating of the room is avoided. It is necessary to ensure combustion regardless of the room air, because buildings are usually so densely built that not enough combustion air is available, or that a ventilation system would be disturbed. The combustion air can be supplied either via a suitable chimney or via a separate supply pipe.



Did you know?

Biomass has been used as a source of energy since man first discovered fire to heat and to cook. Despite the well-known and highly publicised renewable energy sources such as solar, wind or hydropower, ***bioenergy is the oldest and by far the most used source of renewable heat****, with 87% of all renewable heat coming from biomass and heating 66 million households in Europe!*

A pellet stove looks like a wood burner on the outside, but inside it is very different. Firstly, it requires electricity to function. Secondly, the fuel – wood pellets – needs to be continuously fed into the burn pot, thus requiring an auger. Pellets are stored in a hopper of varying sizes (depending on the output of the stove and generally fitting between 12 and 40 kg of pellets), which generally needs to be manually filled every two/three days.

When the stove is turned on, the pellets are automatically transferred by an automatic auger from the hopper where they are stored into the burn pot. Here the actual combustion takes place. As the pellets burn, more pellets are fed into the burn pot. Warm air is fed through an internal heat exchanger and is moved into the combustion room. A blower fan blows hot air around the fire to maintain a high temperature and enable the pellets to burn efficiently and evenly.

A flue is installed either on the back of the stove, or into an existing chimney. A little amount of ash comes out of the burning of pellets and falls into a collector under the burn chamber. Ashes can be cleaned with a hoover about once a week.

Technical refinements, such as the possibility to switch the pellet heating system or pellet stove on and off and to monitor it with a smartphone, increase the ease of use.

Why should I buy a modern pellet stove?

- **Good value for money**: The prices of wood are usually lower and less volatile compared to the prices of fossil fuels. Some stoves also require very low initial investment; nevertheless, it is important to not be tempted by the purchase of the cheapest option, because it is likely also the most polluting and least inefficient system.
- **Clean, comfortable and efficient heating**: Modern stoves are clean and much more efficient than transitional fireplaces, without decreasing the comfort of a warm fire at home.
- **Wood is a regional resource**: if wood is produced locally, as it is often the case, transport distances are reduced and the revenues stay within the local community.
- **Sustainability**: Sustainable forest management secures long-term wood supply as well as balanced ecological, economic and socio-cultural aspects.
- **Energy security:** Regardless of the season, wood is normally available within the region and its prices do not depend on economic and political developments.

- **Wood is climate friendly**: The CO_2 emitted while burning woody fuel equals the amount of CO_2 that the tree assimilated during its growth. It is nevertheless important to only use certified pellets and properly store the wood.
- **Very easy installation use and maintenance**: stoves generally don't need complicated installing requirements like the traditional fireplace. Normally, they can be easily installed without the aid of a professional and require very low space and maintenance.

Pellet stoves match with…

Pellet stoves are usually used as heaters for a single room (i.e. the living room). In this case, they can complement any central heating system for additional space heating and for water heating, regardless of the technology and fuel used.

Nevertheless, modern stoves can also be connected to the water cycle, thus heating water which is then circulated to the whole house and radiating the heat via radiators or underfloor heating. In this case, stoves do not complement your central heating system, but fully replace it.

FACTSHEET

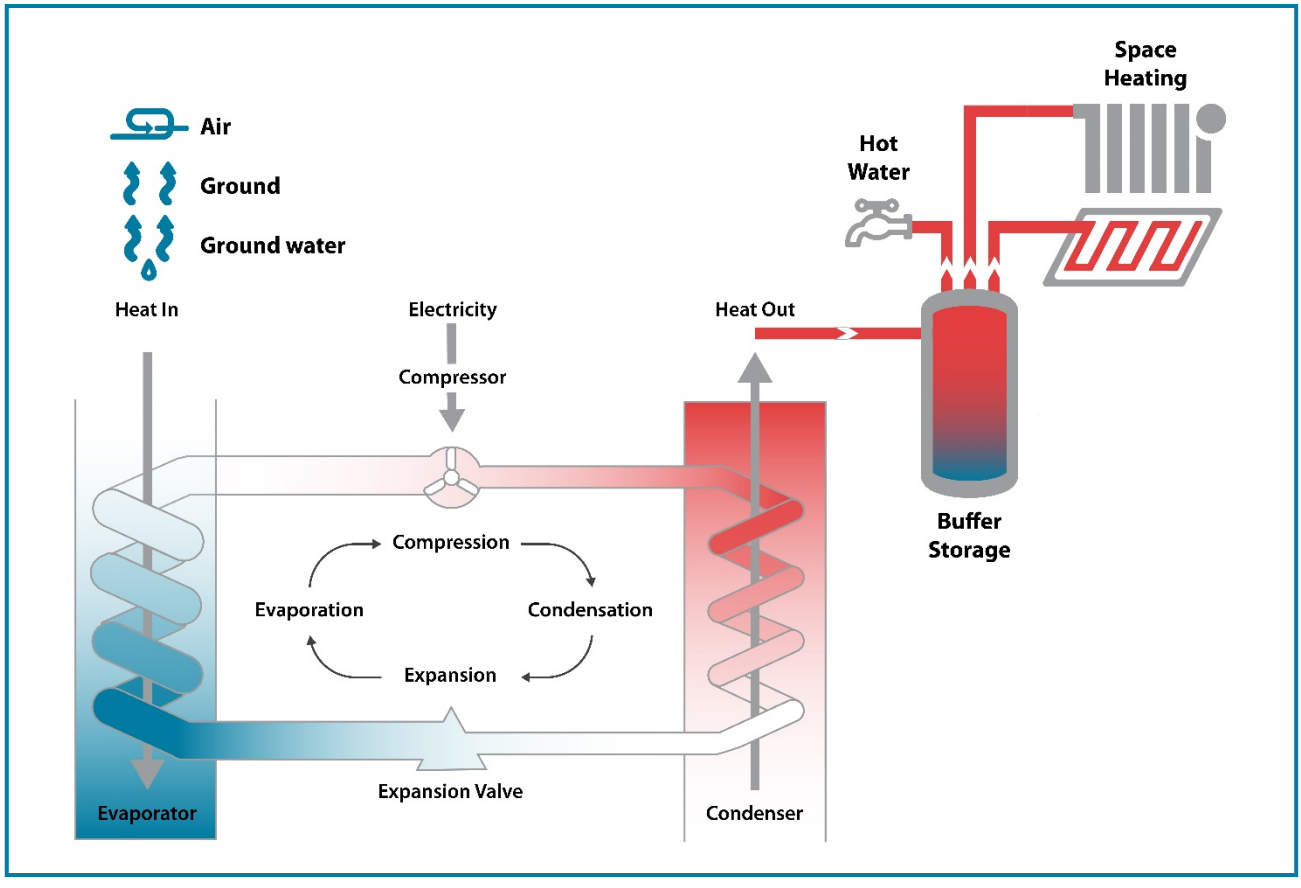
ELECTRIC HEAT PUMPS

Building type: new and existing buildings, well-thermally insulated buildings equipped with a low temperature heat delivery system, single- and two-family houses

How it works

A heat pump is a device that can provide heating, cooling and sanitary hot water for residential, commercial and industrial applications. It does not generate heat, but it **absorbs heat energy from the outside air, ground or water and transfers it to the indoor**, by transforming it into useful heat. Heat pumps contain a fluid that quietly and efficiently harvests and extracts the heat from the air or ground surrounding your home. The heat pump then compresses the fluid and raises it to a suitable temperature. The heat from the fluid is then transferred to the water in your heat delivery system.

The lower the flow temperature into the heat distribution system, **the higher the efficiency of the heat pump**. Heat pumps are therefore ideal for well-insulated buildings. Additionally, for efficiency reasons, the use of heat pumps is recommended exclusively **in combination with low-temperature heat delivery systems** such as underfloor, wall or ceiling heating or low-temperature radiators with flow temperatures up



Did you know?

Despite its name, a heat pump can work as both a heater and an air conditioner.

In principle, heat pumps work like a refrigerator – only the other way round. A refrigerator works by removing the heat from the food and releasing it externally. With a heat pump, the aim is to harness the heat from the environment to use it for heating or for making hot water.

Heat pumps can also feature a cooling mode, where thanks to a reversing valve, they take coolness out of the air or ground and transfer the cool air into your home. So, you can actually replace both an air conditioner and a furnace with a single heat pump system.

And high-efficiency heat pumps are even better at removing humidity from your home than traditional air conditioners.

to 40°C, only. However, **if this is not the case**, heat pumps do not work as efficiently, which is reflected in **high electricity costs** at the end of the year. Un-refurbished houses also should not be equipped with heat pumps, especially if it is not possible to heat them with heating flow temperatures below 40°C to the desired room air temperature. Domestic hot water production, which because of legionella needs to deliver flow temperatures of up to 60°C, should therefore be preferably supplied by other systems, e.g. by solar thermal panels with a hot water buffer storage.

Where a heat pump fits to a building, an additional great advantage is that, in summer, the **heat pump can** also **be used for passive cooling,** i.e. without the compressor being in operation. The (winter) heating surfaces in the building are used as cooling surfaces.

Electricity is used in this process, but most of the energy needed by the heat pump is taken from the environment. As a basic rule, the higher the initial temperature of the heat source (air, ground or water), the less electricity is required and the more efficient the heat pump is. The efficiency is increased even further if the delivery temperature is not too high. Heat pumps are therefore particularly suitable for installation in well-insulated houses that can be heated at relatively low temperatures. This is the case if, for example, underfloor heating is installed that runs on a low flow temperature.

When purchasing a heat pump, it is also important to look at its **Coefficient of Performance (or COP).** The COP is used to gauge the efficiency of heat pumps. However, it should not be confused with the actual efficiency itself under changing, real operating conditions. The COP expresses the ratio of the heat pump's heat output to the electricity required to operate the compressor under defined, constant operating conditions. For example, a COP of 4.0 means that four times the amount of energy needed to run the compressor is available as potential heat output. The Seasonal Performance Factor (SPF) reflects the efficiency under real life conditions and is an individual figure. It is not possible to deduce the SPF from the COP, as the COP only applies to the heat pump alone and the SPF applies to the entire domestic heating

system, where the heating surfaces including the required temperatures, the hot water (if this is provided by the heat pump), the user behaviour and the weather are taken into account.

Air, water or ground source heat pump?

Heat pumps are classified based on the "free" or ambient heat source used for operating them.

Air source heat pump

Air source heat pumps use the ambient energy in outside-air or exhaust-air for heating, cooling and preparation of hot water. They can be installed as compact units entirely inside or outside the house (so called mono-bloc). Split systems consist of one unit inside the building and one outside. Heat is commonly distributed inside the house by a hydronic distribution system or by air using fan coils or a ducted ventilation system. Recent technical developments allow for efficient use in almost all climatic regions.

Water source heat pump

Water source heat pumps use energy stored in ground, surface or sea water. Where ground water is easily available it is accessed by two drillings. One is used as a water source, the second is used to reinject the water into the ground. The heat pump extracts heat from the water and makes it available for heating, cooling and preparation of hot water. Heat is commonly distributed inside the house by a hydronic distribution system or by air using fan coils or a ducted ventilation system. Water source heat pumps profit from particularly high efficiency due to excellent temperature characteristics of water as energy carrier.

Ground source heat pump

Ground source heat pumps use the energy naturally stored in the ground for heating, cooling and preparation of hot water. When considering installing a ground source heat pump one could choose between a network of horizontal collectors (shallow ground source heat pump) laid in the immediate proximity to the ground's upper layers at small depths, or opt for vertical (deep drilling) ground source heat pump boreholes instead, which is also known as vertical closed-loop geothermal heat exchangers. Selecting between these two systems, conceptually similar but structurally different, comes down to the available space for a geothermal pump installation, the square footage that requires heating and the budget allowance one can sanction for carrying the installation works. Vertical boreholes are good for small or limited areas, and although it bears high installation costs, borehole heat collectors produce a higher heat yield per metre, compared to horizontal collectors, which entails a better energy efficiency rate.

Why should I install a heat pump?

- **Energy efficient**: for each kW of electricity consumed by a heat pump, about 3kW of thermal energy is generated. This corresponds to a 300% efficiency.
- **Versatile**: thanks to a reversing valve, a heat pump can change the flow of refrigerant and either heat or cool a home.
- **Sustainable**: A heat pump can be up to 100% climate-neutral if the electricity needed to operate it is also generated from renewable energy, for example if green electricity is used or the heat pump is combined with a photovoltaic system on the roof of the house.
- **European**: the vast majority of the heat pumps installed in Europe are also manufactured in Europe. In fact, the EU heat pump companies play a leadership role in the technology development.

- **Provider of energy security**: the EU imports annually energy worth over 400 billion euro. Heat pumps reduce the use of primary and final energy. So, we would need less energy and by consequence less would need to be imported. This saves costs and secures the supply of energy at the same time: we become more energy independent.
- **Electricity System Transition facilitator**: Heat pumps potentially can help integrate large amounts of fluctuating electricity from wind power and photovoltaics. Combined units in conjunction with electricity or heat storage units can be controlled in such a way that they make optimal use of self-generated PV electricity or of renewable electricity from the grid. Energy suppliers already offer more favourable tariffs for this and heat pumps showcasing the "Smart Grid Ready" label are ready to meet these requirements.

Before installing a heat pump

Even though heat pumps can have many advantages, it does not necessarily mean that they are the best solution for your home.

In fact, heat pumps installed in poorly insulated building or not fitting the existing internal heating distribution system may result into poor efficiency and high operating costs.

- A **well-insulated house** is key prior to installing a heat pump: as heat pumps are a low temperature device, it is important that the buildings where they are installed are well insulated. Poorly insulated buildings require high flow temperatures (which entail a reduction in the efficiency of the heat pump, as the system must work harder to meet the production of higher temperatures), and the need of an additional heating system (i.e. a biomass boiler), bringing the costs up. Proper insulation, on the other hand, also reduces the size of the heat pump needed, the initial capital costs and, in the case of ground source, the amount of ground required.
- When it comes to the **heating distribution system**, most of existing houses have radiators installed as their heat emitting device. Radiators require the water to be heated to a high temperature, therefore the heat pump will run up to 25% less efficiently with radiators, compared to underfloor heating.
- **External space** is needed for the installation of a heat pump.
- In the case of **multi-apartments buildings**, normally a majority vote by all the tenants of the building is needed in order to install a heat pump for one of the flats.

Heat pumps match with…

In many cases, heat pump systems can be successfully combined with **solar thermal systems** so that solar thermal energy can be used to meet a large proportion of the hot water requirements in summer and part of the heating load during transitional periods. Alternatively, the efficiency of heat pumps increases significantly when the temperature of the heat source is increased with solar thermal energy.

Solar energy in combination with heat pumps is also used in the form of **PV panels**: heat pumps require electricity to run, and by installing solar PV to produce electricity, the solar PV will cover (part of) the heat pump electrical requirements.

Last but not least, a heat pump with **thermal storage** system is a system that operates a heat pump during nighttime using inexpensive electricity; during this time, the generated thermal energy is stored in a thermal storage tank.

Heat Pump Overview[22]

In the overview table, a 10 kW heat pump is considered.

Range	Air/water: 5 - 15 kW; average 10 kW Soil/water: 5 - 15 kW; average 10 kW Water: 5 - 15 kW; average 10 kW
Acquisition costs (purchase and installation)	23,000 to 33,000 €
Acquisition costs (with deduction of 45%, 35 up to 50% support possible)	12,650 to 18,150 €
Greenhouse gas emissions	175 g/kWh$_{th}$ to 189 g/kWh$_{th}$ (with fuel oil 327 g/kWh), no greenhouse gas emissions when using green electricity
Operating volume	Only outdoor air/water heat pumps may cause a problem - 35 - 75 dB
Building requirements	Well insulated house, surface heating, sufficient space in house or outdoor area

[22] To calculate the figures of the below table, a base case from the Bavaria Oberland region in Germany has been used as a best practice. Figures from other countries across Europe (Austria, Bosnia and Herzegovina, Bulgaria, Croatia, North Macedonia, Serbia, Slovenia and Spain) are available on the REPLACE project website at www.replace-project.eu.

FACTSHEET

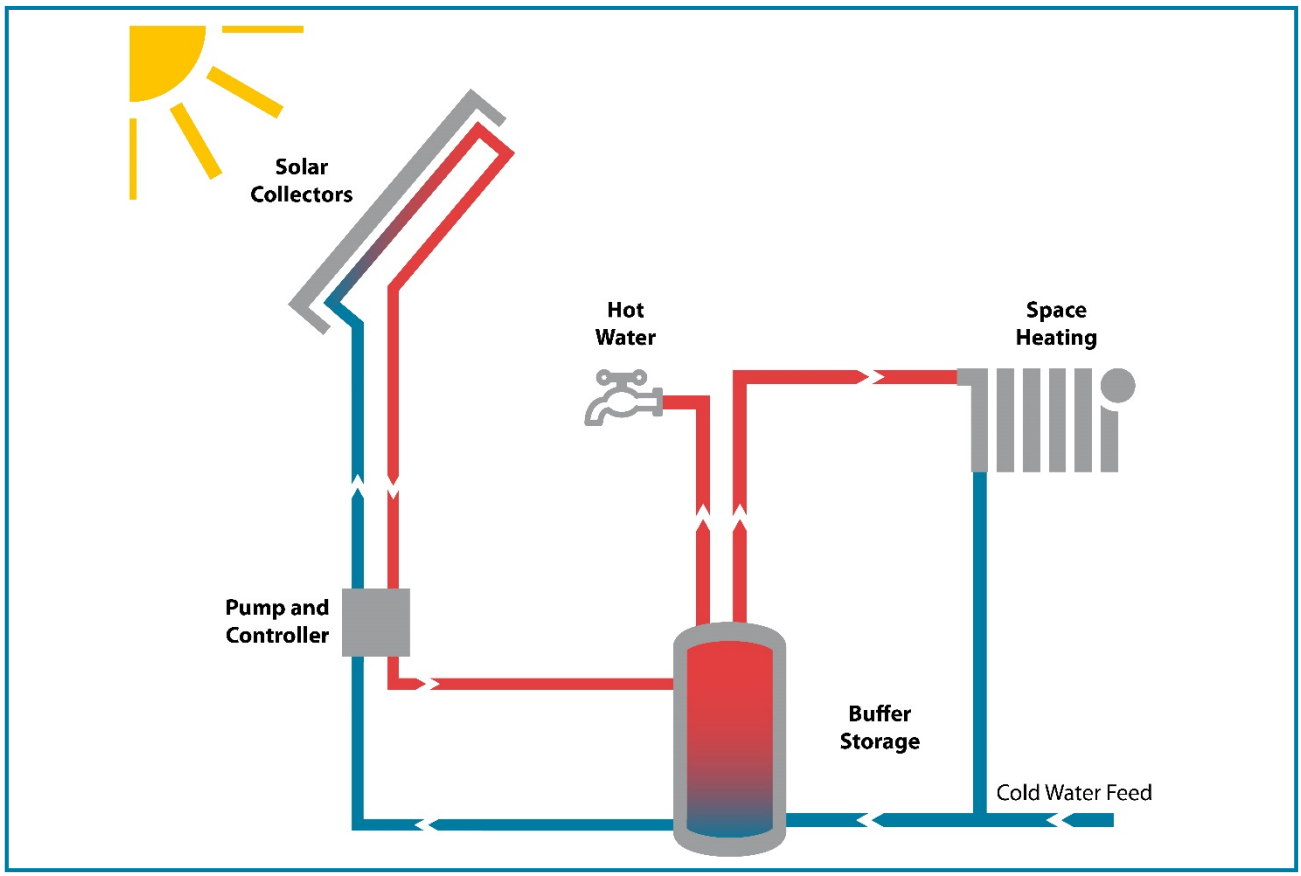
SOLAR THERMAL

Target group: Building owners of individual and small buildings

How it works

A solar thermal system works by harnessing the sun's energy and converting it into heat which is then transferred into your heating system for hot water or space heating.

Everyone knows what happens to the water inside a garden hose lying in the sun: after a while, the water gets hot. Solar collectors make use of this effect. **Absorbers** made of copper or aluminium capture the sun's rays and transfer the heat to the water that flows through them. The absorbers are covered with glass, insulated on the back and tightly sealed with a jacket so that as little as possible of the valuable solar heat can escape back to the outside. From around 1,000 kWh of solar radiation per square metre and year, solar collectors get 400 kWh of hot water. This is collected in a solar storage tank and fed into the sanitary and heating installations in the house.



Did you know?

While PV currently harnesses up to 20% of sun light, solar thermal plants harness about 40% per square meter.

Although both mechanisms rely on the energy of the sun, solar thermal collectors and solar panels (photovoltaics/PV) are used for different purposes. While PVs are (traditionally) used to generate electricity from solar energy, solar water heating converts sunlight into heat. Consequently, we can't use solar thermal for lighting, but we can use it to heat water or for space heating.

Typical solar collectors use the sun's rays to heat a transfer fluid which is a mixture of water and glycol, to prevent the water from freezing in the winter. The heated water from the collectors is pumped to storage tank or a **heat exchanger** inside a water cylinder.

The heat from the exchanger will then heat the water inside the **buffer tank**. The heat is then spread through the home via **radiant floors** or **radiators**. After the liquid releases its heat, the water will flow back to the collectors for reheating. A controller will ensure that the fluid will circulate to the collector when there is sufficient heat available.

There are two main types of solar water heating panels – **flat plate** and **evacuated tubes** (referring to the way the water interacts with the panel). Evacuated tubes look like a bank of glass tubes fitted to your roof. Glazed flat plate systems can either be fitted onto the roof or integrated into it.

Evacuated tube systems are more efficient than flat-plate versions, so they are often smaller but still generate the same amount of hot water. Unglazed flat-plate collectors are often used for swimming pool heating.

Solar thermal devices can also be differentiated between solar heaters for domestic hot water production and heaters that additionally contribute to space heating. A solar system for hot water in the kitchen and bathroom for a four-person household in Central Europe usually has 6 m² of solar collectors on the roof and a 300-litre water storage tank in the basement. In Central Europe, the sun provides about 50 to 60 per cent of the hot water needed over the year, the rest is provided by the heating system. A solar system for hot water and heating instead should have a collector area of at least 15 m² and a 1,000 litres water storage tank. The storage tank bridges short-term fluctuations in the transition months, i.e. it heats your house also when the sun is not shining. In well-insulated houses, you can replace 25 % or up to 50 % of the heating energy in this way.

But **is the surface of your roof suitable for a solar thermal system?** The orientation of the roof surface should not deviate more than 50° from the south. Roof surfaces with a pitch between 20° and 60° are optimally suited for solar installations. Flat roofs (inclinations between 20° and 30°) are an advantage in summer, steep ones (inclinations between 50° and 60°) in winter. A solar heating system makes sense if the heat generated can be consumed to the greatest possible extent by the people living in the house.

Why should I install a Solar Thermal system?

- Sunlight is free, so once you have paid for the initial purchase and installation of the system, **your hot water costs will be reduced**.
- Solar thermal systems can **reduce your electricity consumption**, for example by connecting the dishwasher and the washing machine to a hot water connection with the water heated by the sun.
- Solar hot water is a green, renewable heating system and can **reduce your carbon dioxide emissions**.
- Solar water heating can provide you with about **half to two-thirds of your annual hot water needs**.
- Solar thermal systems need **little maintenance** and the costs of it are very low.

Solar thermal system matches with…

Solar thermal systems are rarely stand-alone technologies. More often, solar thermal systems can be used to produce hot water and to top up a space heating system. They can work **in combination with biomass technologies, heat pumps and photovoltaics**.

Because of the unstable and intermittent nature of solar energy availability, a **thermal energy storage system** is required to store thermal energy and retrieve it whenever it is required. Thermal energy storage not only eliminates the discrepancy between energy supply and demand but also increases the performance and reliability of energy systems.

Solar Thermal Overview[23]

The overview table looks at a solar thermal situation for a 4-person household: once in the form of hot water supply (6 m^2 solar collectors on the roof and a 300-liter water storage in the basement), and once for hot water and heating (at least 15 m^2 and a 1,000-liter water tank).

Collector area	6 or 15 m^2
Acquisition costs (purchase and installation)	4.000 to 13.000 €[24]. (Cost vary depending on the type of collector selected (flat or tube collector). An indication from 300 € (flat) to 600 € (tubes) per square meter can only be given as a guide.)
Acquisition costs (with 30% deduction)	2. 800 to 9. 100 €
Greenhouse gas emission reduction (gg. oil heating, minus GHG emissions from the climate-friendly system under consideration)	25 g/kWh_{th} (with fuel oil 327 g/kWh)
Building requirements	Suitable surface (roof, wall, etc.), space for storage.

[23] To calculate the figures of the below table, a base case from the Bavaria Oberland region in Germany has been used as a best practice. Figures from other countries across Europe (Austria, Bosnia and Herzegovina, Bulgaria, Croatia, North Macedonia, Serbia, Slovenia and Spain) are available on the REPLACE project website at www.replace-project.eu.

[24] C.A.R.M.E.N., 2020, „Entscheidungskriterien für ein neues Heizsystem– mehr als ein Heizkostenvergleich“ (https://www.carmen-ev.de/wp-content/uploads/2020/12/Infoschrift_Heizkostenvergleich.pdf)

FACTSHEET

PHOTOVOLTAIC POWER FOR HEATING

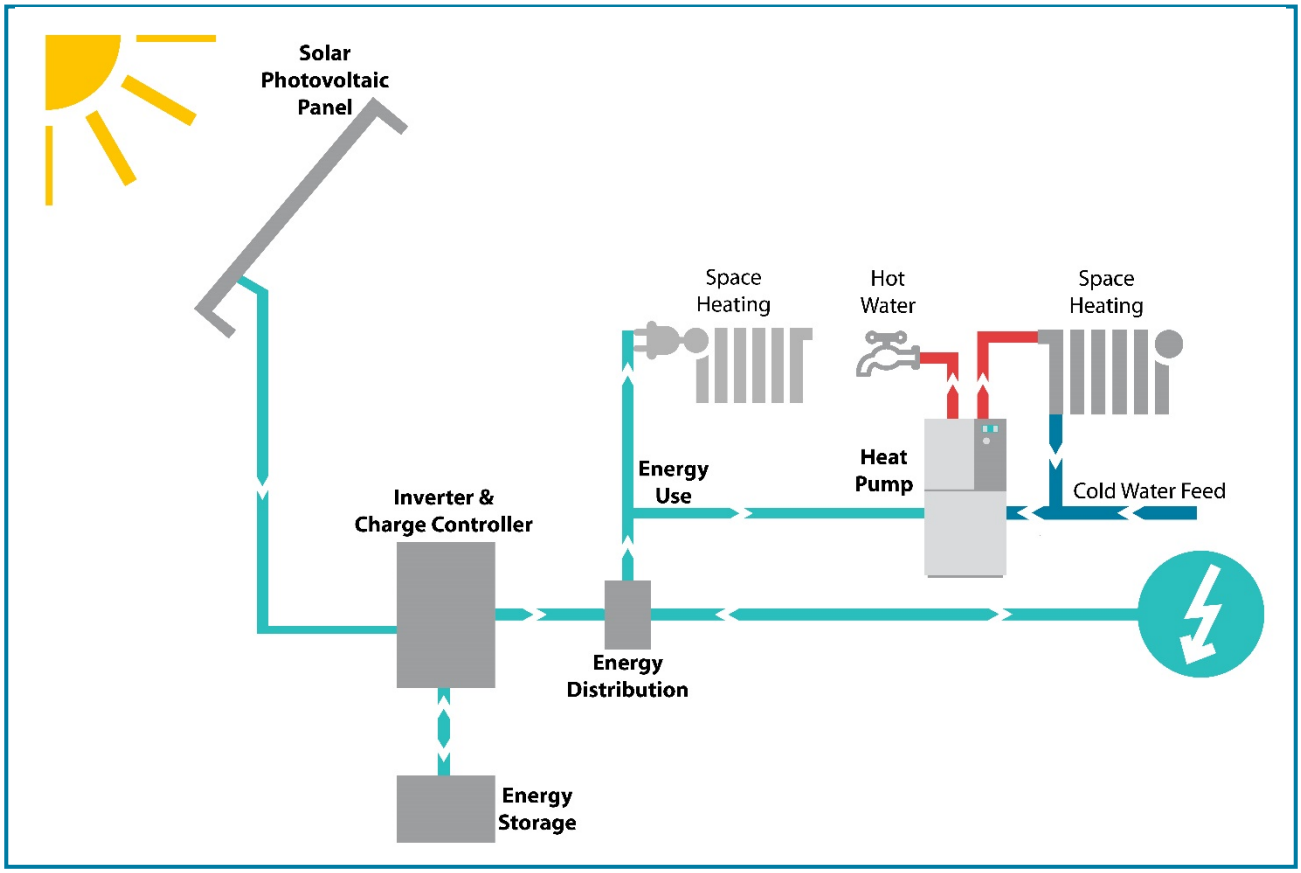
Building type: all building types

How it works

Most of the people probably know that a photovoltaic (PV) system allows you to independently produce electricity to power the electrical appliances of your house, to recharge your electric car or to feed the electricity into the power grid.

PV systems are becoming more and more efficient and therefore cheaper, because of increasing production volumes. While poly-crystalline cells currently have a system efficiency of 16.5%, mono-crystalline cells reach up to 20%. This means that at a place with a solar irradiation of 1,000 kWh/a (central Europe) about 200 kWh_{el}/a can be produced per square meter of solar modules. So, 5 m² would correspond to 1 kW peak (kWp) of installed PV capacity and about 1,000 kWh_{el} generated electricity per year.

But not everyone knows that in some cases heating with electricity produced by PV panels could also make sense. However, usually, this is only as an add-on to other main heating systems and not as a stand-alone technology.



Did you know?

With state-of-the-art PV technologies, you can now use PV panels not only to power your home and electric appliances, but also to heat your house and domestic water.

You can do so by complementing your heating system such as a heat pump with a PV system.

There are different options to use PV power for heating.

- **PV power to operate a heat pump**

Depending on the heat demand of the building, heat pumps can be already on their own very energy-efficient systems. They can be operated with own electricity from a PV system, and thus even increase the environmental and economic performance. This applies both to heat pumps for hot water supply only but also to heat pumps for space heating.
A challenge is that the heat demand is high in winter when the power generation from a PV system is generally lower. Therefore, it is recommended to install PV systems as large as possible, covering the whole roof.

- **PV/T: combined photovoltaic and solar thermal collectors/modules**

Some manufacturers provide special modules which combine PV and solar thermal collectors. The collector is usually behind the PV cells. It uses either liquids as heat transport medium or warm air. As light is absorbed in the PV cells, the collector is not as efficient as it would be without PV. However, the heat transport medium "cools" the PV cells which can increase the electricity generation. PV/T collectors are certainly niche products and might make sense at places with limited space, but high energy consumption.

- **PV power for an electric heating rod in the buffer tank**

Direct heating with PV power usually does not make sense from an economic perspective, since the cost of heat from the installed heating system is usually lower than the PV electricity costs. Furthermore, it does not work when the sun does not shine and it would be insufficient in times of high heat demand, especially during cold, dark winters. However, in some cases it makes sense to use PV electricity for direct heating, in addition to another heating system. This is the case when revenues for excess electricity fed into the public grid are lower than costs of heat supply (which is often the case, when feed-in tariffs do not apply). In these cases, an electric heating rod can be installed in the buffer tank, so to heat the buffer tank with electricity. This is used also in two other cases. In the case of manually fuelled logwood boilers, such an electric rod can be used as emergency device in case one is not able to fuel the logwood boiler, e.g. due to illness. The other case applies to those countries where there is a limit to the power output of PV inverters (e.g. 70% for some PV systems in Germany) and the electricity exceeding the limit would be taxed off (and would be lost). In this case, the unused power from PV can be used to operate the electric rod in the buffer tank.

Why should I use PV electricity for heating?

- **More independence from the grid**: the sun can provide you with energy which makes you more independent from the power grid.
- With a **central heat pump boiler**, instead of (an) electric boiler(s), you can save about two thirds of the electricity consumption of your electric boiler(s).
- **Decreased heating costs**: due to the stagnating or to the possibly increasing (in the future, due to climate protection measures) increasing energy costs of oil and gas and the sinking costs of PVs, today (and more and more so in the future) can be more profitable to use the self-generated solar power instead of burning fossil fuels.
- **Less CO_2 emissions**: from an environmental point of view, PVs reduce the consumption of fossil fuels, thus contributing to the energy transition.
- **Long, cheap lifetime**: solar modules keep working for a long time (between 30 and 40 years), they are mechanically wear-free and the maintenance effort is low. Manufacturers often still guarantee 80% of the output after 20 years.
- **Silence**: electric heating systems powered by PV do not make any noise as there are no moving mechanical components in the system, no water flows as in traditional boilers and no fans.

PV heating matches with…

PV is usually only an add-on technology for heating purposes. It can supplement any other technology, but especially heat pumps. As an economic viable or emergency system for log wood boilers, it can be used in the buffer tanks through the use of electric rods.

Heating with PV – Overview[25]

The application of a heating rod, which uses excess PV electricity in a buffer tank for hot water production, is considered below. The price of the PV system itself is disregarded.

Power of the heating rod	From 3 kW to 9 kW
Acquisition costs (purchase and installation)	Variable, prices start from ca. 100 € for a 3 kW solution
Greenhouse gas emissions of the PV system	50 g/kWh (with fuel oil 327 g/kWh)
Building requirements	Building types with sufficient roof space or other usable areas

[25] To calculate the figures of the below table, a base case from the Bavaria Oberland region in Germany has been used as a best practice. Figures from other countries across Europe (Austria, Bosnia and Herzegovina, Bulgaria, Croatia, North Macedonia, Serbia, Slovenia and Spain) are available on the REPLACE project website at www.replace-project.eu.

FACTSHEET

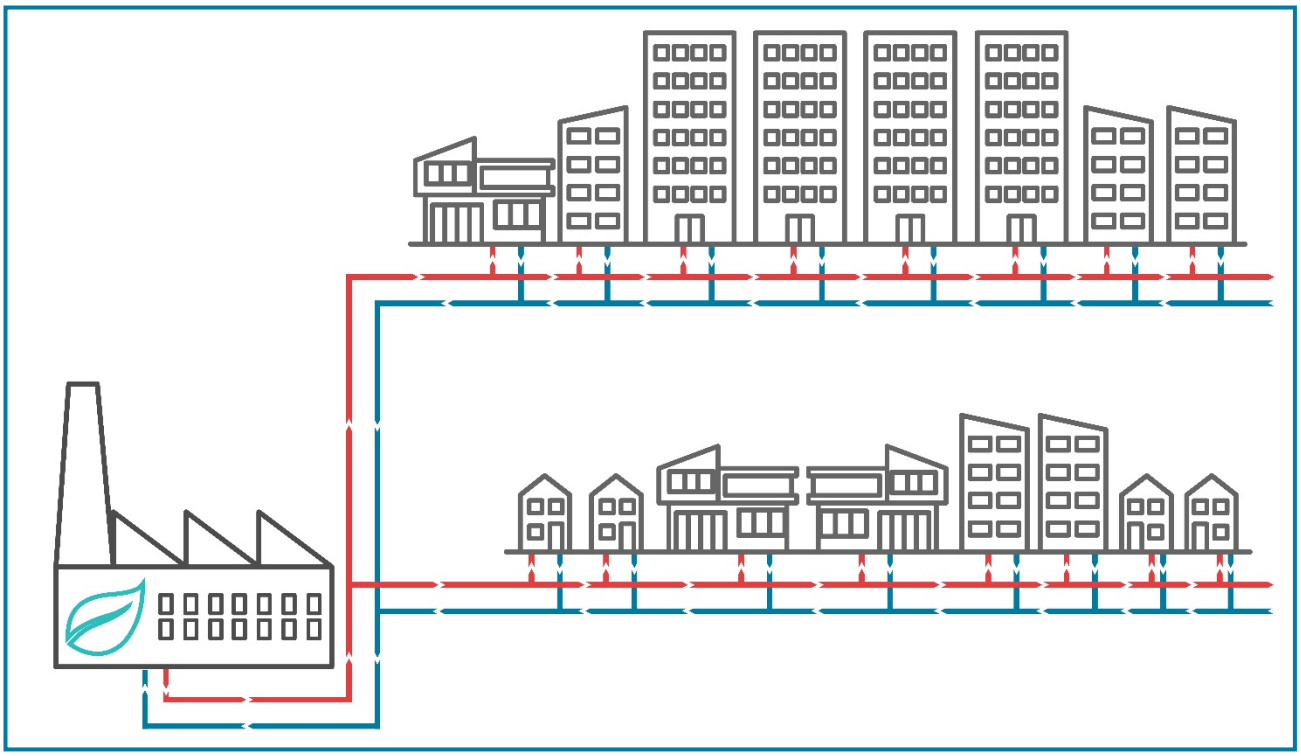
RENEWABLE-BASED DISTRICT HEATING

Building type: suitable for all buildings in areas where district heating networks are available, irrespective of size or type

How it works

The rationale of district heating (DH) lies within the concept of "economies of scale", which raises the following question: what is cheaper and less polluting?

- Two hundred small boilers in two hundred different homes, with two hundred chances of breaking down, two hundred small fuel deliveries required and two hundred separated services to be carried out?
- Or just one large boiler house for everyone? Admittedly, the large central boiler house will be expensive, but the cost can be split between two hundred households. In the end, the boiler house costs much less, based on investment per installed kW heat load and district heating systems are more comfortable for end consumers than (fossil fuelled) individual heating systems. In addition, DH systems are a good solution to decarbonize widespread natural gas heating systems utilized in densely populated areas.



Did you know?

The idea of district heating is as old as the Romans. The earliest examples of district heating were in fact the Roman hypocausts, a type of hot-air furnace often adapted to warm several buildings in close proximity. Although Roman engineers almost exclusively used hot air for heating, they extensively employed hot water in public baths.

Centrally produced district heating as we know it today, has been in existence for almost 150 years, with systems tested as far back as the late 19th century in the German city of Hamburg and in the USA.

In a district heating network, **heated supply water** is pumped from the heat generation plant to consumers, where it is used for space heating and domestic hot water. The cooled water returns to the boiler house, where it is heated up again, to the required supply temperature. A critical factor for the economic performance of a DH system is the spatial heat demand density of the district. The higher the heat density, which means a high heat demand per space, the better it is for the DH system.

Often, the investment for the heating grid is as high as that for the boiler house and its equipment. Therefore, compact DH grids with short grid lengths or a high amount of heat sold per year and meter grid length are beneficial for implementing such systems.

The heat consumers are usually connected to the DH piping system through a so-called substation. Therein, the heat from the DH piping is transferred through a heat exchanger to the water circulation system of the building. The heat can be normally used for space heating and for the hot water preparation.

Depending on the served area, different sizes of DH networks exist. Very small grids are also called **micro-grids.** An advantage of DH grids is that they can be usually extended to serve more consumers and to connect several heat sources.

The supply **temperature** of district heating water usually varies between 65°C and 115°C, depending on the end consumer with the highest heat demand temperature required. The lower the supply temperature of the DH system, the lower are the heat transport losses (which can range between 10 and 20%). The temperature is at its lowest in summer when heat is only needed for hot service water. Due to the problem of legionella, most systems operate with flow temperatures higher than 60°C. However, innovative DH system can also operate at lower temperatures, in this case they are called cold or low-temperature DH systems.

Traditionally, district heating systems were operated by using fossil fuels such as natural gas, coal, peat, or oil. Modern systems use renewable energy sources such as **wood chips, solar thermal energy, geothermal energy, or biogas**. District heating systems also often utilise **waste heat** from industrial processes. Some of this surplus heat has the desired temperature levels for direct use in the district heating systems, such as the heat produced from thermal power generation. But when the temperature levels are not high enough, add-on solutions are required in the shape of **large-scale heat pumps**, which move the heat from a low-

temperature input (the heat source) to a high temperature output (the district heating system) through a closed compression process.

Why should I connect to a renewable-based district heating network?

- **Local and renewable energy**: district heating can integrate combustible renewables that are difficult to manage in small boilers, for example wood waste, straw and agricultural residues as well as the biogenic fractions of municipal waste and sewage sludge. Additionally, renewable fuels including biofuels, geothermal, solar and wind energy are utilised more effectively when integrated into district heating networks.
- **Local pollution prevention and control:** district heating reduces local pollutants like particle emissions, sulphur dioxide and nitrogen oxides by relocating exhausts from individual boilers to centralised chimneys. Due to economies of scale, far more effective pollution prevention and control measures can be implemented in central production facilities.
- **High comfort:** district heating infrastructure is installed outside of people's homes. Storage, maintenance, replacement and system upgrades cause minimal disruption to citizens' lives. So, you don't have to care about anything, you just have to get connected and to pay for the heat supply bills.
- **Flexible and sustainable fuel mix**: district heating enables highly flexible energy mix. New fuels and energy sources can be integrated with minimal need for restructuring by the operator. For customers no adaptation measures at all are required when a switch of energy source is made.
- **Increased energy security:** past gas crises, notably in 2006-2007 and 2009, have made the vulnerability of the European energy supply system obvious. In several countries and cities district heating systems were able to considerably ease the situation by switching to alternative fuels.

Renewable-based district heating matches with…

Many district heating systems in densely populated areas in Europe use the **combined heat and power technology (CHP)**, allowing to produce heat and power simultaneously. Regardless of the "fuel" used in any energy conversion unit (i.e. natural gas, biomass, synthetic green gas or electricity), the utilisation of the by-product or "waste" heat increases the overall energy efficiency, lowers the greenhouse gas emissions of the energy system and makes those conversion units more resilient to "fuel" prices and revenues from electricity sales, due to heat sale revenues from co-generation.

Another significant advantage of DH is that it offers the option to utilise waste heat from industry, IT infrastructure, wastewater sewers (or treatment plants) etc., as well as renewable low temperature heat sources like geothermal, solar thermal or even ambient heat from lakes, rivers or costal stripes. Heat pumps can help exploit such energy sources by pumping heat from those sources to the required supply or return temperatures of DH systems and capturing it. With very low temperature DH heat can be stored even seasonally in underground storage or building component activation or water storage ponds for an exploitation during the heating season. A precondition here is that the houses of end consumers can handle low temperature supply heat (i.e. low energy demand and floor/wall surface heating systems).

Another match for DH systems is with solar **thermal energy.** In smaller DH grids, over summer it might be beneficial to bridge operation partly or completely by delivery of solar thermal energy via the grid. Often the boiler and/or the storage facilities have solar installations exactly for this purpose. If not completely shut down, the grid should be operated only for several hours per day by decentralised buffer storages. Otherwise, the heat losses might be too high in summer (as only domestic hot water is needed).

If you have already solar thermal collectors on your rooftop, usually this can be still used when you connect to a DH system. In this case you simply save money for each kWh that you do not need from the DH grid.

Renewable District Heating Overview[26]

Prerequisite for use of local/remote heat	- Heat consumers with a permanently required temperature level of 70 to 130°C are available (use) - An existing local/remote heating network is nearby (use) - Several companies with similar requirements can be found in proximity (heat grid new building) - Large unused waste heat quantities with temperatures > 70°C are generated (feed-in)
Benefits of local/remote heating networks	- Low operating and maintenance costs - No chimney cleaning, no ecotax burden and no emission test - Low space requirement due to compact transfer stations - High cleanliness during operation, as there is no direct use of fuel - High security of supply
Disadvantages of local/remote heating networks	- High initial investment - (If possible) Constant temperature spread between the feed and the return flow in the district heating/near-heat network is necessary[27]
Greenhouse gas emissions	79 g/kWh if operated with wood[28] (with fuel oil 327 g/kWh)

[26] To calculate the figures of the below table, a base case from the Bavaria Oberland region in Germany has been used as a best practice. Figures from other countries across Europe (Austria, Bosnia and Herzegovina, Bulgaria, Croatia, North Macedonia, Serbia, Slovenia and Spain) are available on the REPLACE project website at www.replace-project.eu.

[27] Franziska Biedermann, Michael Kolb, 2014, „Nah-/ Fernwärme“ (https://www.ffegmbh.de/download/informationen/528_ihk_hessen_waerme/fb_nah-fernwaerme.pdf)

[28] C.A.R.M.E.N., 2020, „Entscheidungskriterien für ein neues Heizsystem – mehr als ein Heizkostenvergleich“ (https://www.carmen-ev.de/wp-content/uploads/2020/12/Infoschrift_Heizkostenvergleich.pdf)

FACTSHEET

RENEWABLE MECHANICAL (ACTIVE) COOLING

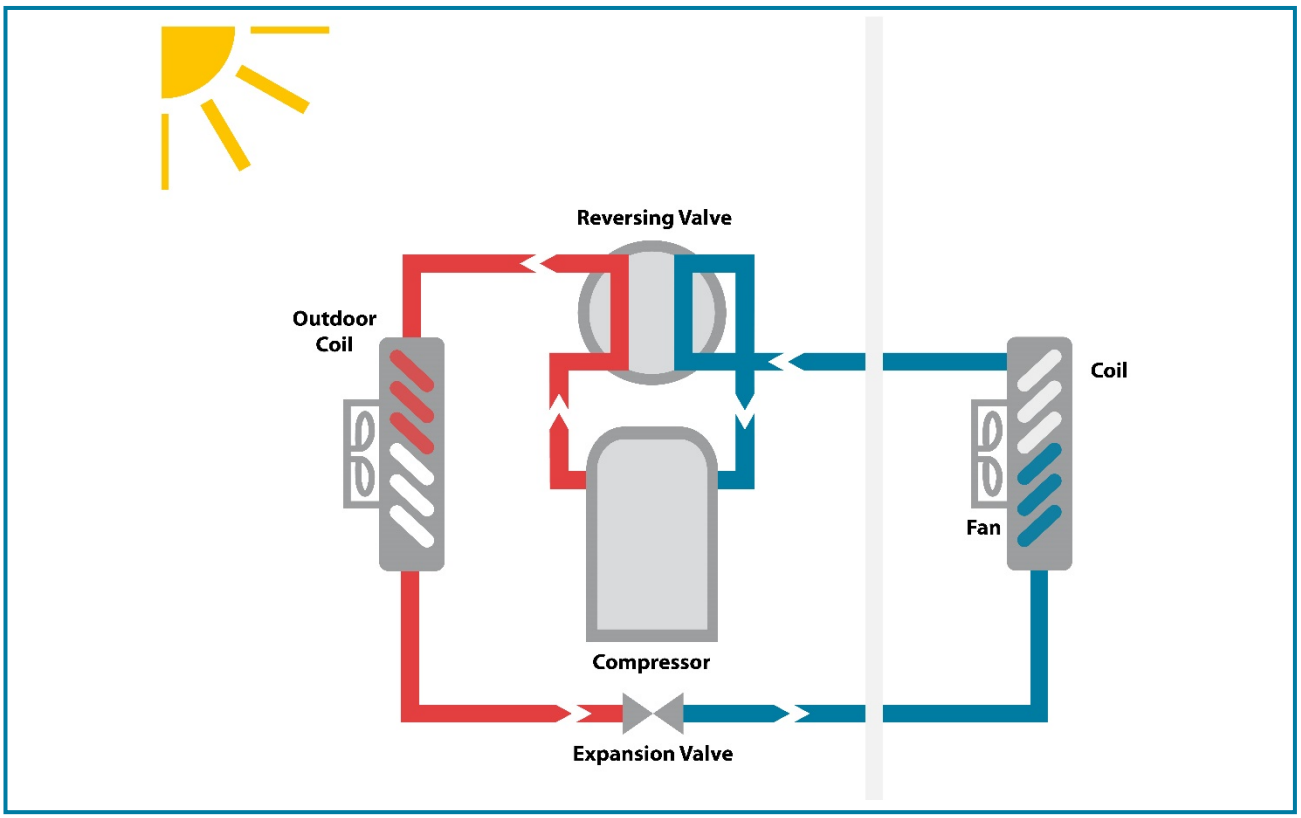
Building type: in buildings where shading of the façade is not possible or where houses overheat temporarily (e.g. if air ventilation during night has no cooling effect)

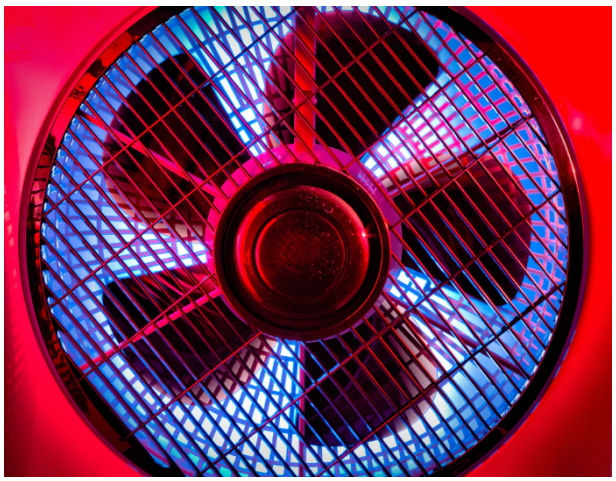
How it works

Cooling technologies are based on the transfer of heat from the space that is cooled to an external medium (e.g. the outside air, the earth or water). Renewable cooling services can be provided by thermally driven sorption chillers, by waste heat or renewable heat sources such as solar thermal systems, or by electrically driven compression systems using renewable electricity such as solar PV or "green electricity" from the grid.

Renewable cooling technologies include **reversible heat pumps** (which work in either direction to provide heating or air conditioning, by using a reversing valve to reverse the flow of refrigerant), **conventional air conditioning systems operated with photovoltaics, cooling systems using heat from solar thermal energy, from biomass or from geothermal.**

The need for cooling in Europe depends very much on the geographical location and on the duration and temperature levels of the hot season. **Before considering the installation of a cooling system**, even if it is





Did you know?

It may sounds crazy, but as climate change makes our planet hotter and demand for air conditioning climbs all around the world, one of the solutions to keep us all cool is to be found in the very thing that makes us sweat: the sun! Solar thermal chillers are in fact already on the market and use renewable electricity from the sun and are much more efficient than conventional air conditioners.

powered by renewable energy, other options to cool your home should be assessed. You should in fact try the following options first: protect your windows from the sun to avoid the penetration of heat; make sure that the heat is not coming from inside your home and turn off all electric appliances when not in use; open the windows early in the morning or during the night to allow air to circulate; buy a small and low-energy consumption table or ceiling fan.

Apart from **fans and ventilation**, there are other types of cooling systems.

Window and ductless mini-split air conditioners are based on electrically driven compression systems and deliver cool air without ductwork, which makes them quite efficient and the costs are rather low. They can be combined with a small PV system, which has its peak electricity generation when the demand for cooling and thus the power consumption of the air conditioner is highest. With still continuously shrinking prices of PV modules, this option can be very competitive. If you go with a window unit, you are making a smaller initial investment, but you are going to lose the usability of your windows. Mini-Split ACs don't require a window, making them more versatile and more aesthetically appealing, but more expensive. If you don't already have ductwork in your home, these cooling systems can be a wise investment.

Central air condition is another option of system for cooling. Nevertheless, depending on the condition of your ductwork, you could be losing significant energy as cool air moves through the ducts, thus making your central air conditioning system very inefficient.

Radiant and evaporating cooling systems operate differently than central AC, relying on dry air pulled from the environment. They tend to be more efficient and less expensive than central AC. Evaporative coolers literally evaporate water in the air to cool with incredible efficiency. Radiant cooling relies on panels at the ceiling or flooring to absorb heat in the room.

Like district heating networks, **district cooling systems** are becoming increasingly applied to provide the necessary cooling comfort in residential, industrial and commercial buildings because of their low cost and high energy efficiency. District cooling systems are centralised systems that produce and supply chilled water to buildings through an insulated piping network. The chilled water can be made from local natural resources such as from sea water and aquifers ("free cooling") or from renewable energy sources. The most suitable renewable energy technologies that can be integrated with district cooling systems are biomass energy, solar thermal energy, geothermal energy, surface water energy, solar photovoltaic energy, and waste heat energy.

Why should I install a renewable cooling system?

- Provides **predictable and often fixed energy price** over the life of the project (PV driven cooling systems)
- Offers a hedge **against financially volatile conventional energy sources** such as oil, gas, or electricity (PV driven cooling systems)
- **Reduces emissions and air pollutants**, if renewable energy is utilised, instead of fossil energy sources, without sacrificing comfort or performance
- **Provides comfort in the face of the rising temperatures**, due to climate change, especially in cities, and helps avoid collapses when it gets too hot, especially for elder and weaker people
- **Utilizes sustainable renewable resources** rather than finite fossil fuels
- **Increases our energy security** by developing domestic energy sources

Renewable Cooling matches with…

Renewable cooling matches with **renewable heating by a heat pump if the heat pump can operate in reverse mode**. In some cases, this can be beneficial for the smooth running of the technology itself. For example, if the heat source of a ground source heat pump is under-dimensioned, it could happen that the vegetation in the garden where the ground source is situated suffers from extreme cooling of the earth during the heating season. In such case, a reversible operation transferring excess heat from the building during summer back into the earth would replenish the ability to deliver heat during winter. In general, a regeneration of the winter heat source by feeding it with excess heat during summer is beneficial to the whole system.

Split cooling units and heat pumps match perfectly with **PV**, especially in Southern regions, where cooling is needed in summer when PV generation is at its peak. The heat pumps can then be also used in winters for heating, especially in Southern regions with mild winters where the heat demand is rather low.

FACTSHEET

MULTIFUNCTIONAL FAÇADE SYSTEMS

Building type: all building types, new and existing buildings

How it works

While renovation measures are of primary importance in order to ensure an efficient use of energy within the building, currently, most building renovations address isolated building components, such as roofs, façades or heating systems. This often results in inefficient and in the end expensive solutions, without an appropriate long -term energy reduction. Optimal results can not be achieved by single renovation measures and new problems could arise, including local condensation or overheating. Instead, the building envelope, both of new and existing buildings, must not be limited to weather protection, aesthetics and thermal insulation. The building envelope must combine energy conversion, energy storage and energy production.

A new multifunctional modular façade system, currently being developed, tested and demonstrated, is behind an innovative whole building renovation concept. The concept is based on largely standardised façade and roof systems that are suitable for prefabrication. It aims at contributing to quality control and standardization based on prefabricated modules and advanced retrofit strategies. The concept focuses on prefabricated and factory-assembled roofs, façades, and HVAC systems for diverse buildings.

There are two different approaches for retrofit module design: one is a fully prefabricated solution, the

Did you know?

Between the options to replace the heating system or to retrofit the building, the latter, allowing for reduction of energy losses and of heat demand, should take priority over the former.

For heat supply at home to be cost-efficient, it is in fact of primary importance to first realise the full potential of energy savings. This could be achieved i.e. by insulating the building envelope (top floor ceiling, basement ceiling and facade) and replacing the old windows, or also by getting a multifunctional façade system.

other concentrates on prefabrication at the window area as being the area with the highest density of details.

The modules are standardised in construction, layers, and joints; they are flexible in architecture, form, and cladding; and they can be combined with each other and with non-prefabricated (conventional) retrofit options.

Fundamentally, the module consists of:

- An equalizing layer mounted on the existing outer wall
- A load bearing construction with insulation layer and integrated ducts
- A second layer of insulation material
- A cladding layer that can be prefabricated and delivered with the module, or mounted on site.

The new multifunctional modular façade system, able to adapt to a variety of climatic conditions and of building types, aims at allowing real-time monitoring of the energy consumption of buildings through multiple sensors: a grid of sensors embedded into an innovative building insulation activates specific façade components to optimise energy savings while improving aesthetics. The system monitors relevant factors, including sun orientation for photovoltaic units and water feeding for organic green components. The advantage of this approach is that the monitoring operation is performed continuously, with no human supervision, except when the system detects a problematic situation.

The climate-modular multifunctional façade system for retrofitting applications has a parametric structure that allows tailoring the façade features depending on: (i) climate conditions (ii) building functions (iii) local building code (iv) and heritage constraints.

Some features of the technology include shading systems to control and exploit solar gain, thermal storage, integration of renewable energy sources, single and double skin systems with proper air gap integration and giving ventilation possibilities.

Even though the multifunctional façade system is still a niche solution, there are many different options being currently introduced by pilot projects and ranging from deep insulation plus solar (passive + active

activation of the shell up to net zero emission), to integration of micro heat pumps for space heating and domestic hot water into the prefabricated façade systems, to green facades, etc.

Why should I get a Multifunctional Façade system?

- **Energy savings**: thanks to the application of a Multifunctional Façade system, it is demonstrated that the heating demand in a building can be reduced by 62% and the cooling demand by 12.3%. Energy savings obviously translate into lower energy costs. Under certain conditions, they can make buildings net-zero or plus energy houses, thus achieving energy efficiency and comfort for existing apartment buildings comparable to new advanced low energy buildings.
- **Environmentally friendly**: in comparison with commonly used aluminum alloys, the light composite materials used in the façade system present much better insulation properties (electrical and thermal) and lower environmental footprint during the fabrication process. One kg of aluminium alloy manufacturing has an energy cost 70% higher than the energy cost needed for the manufacturing of one kg of the composite material.
- **Minimal invasive refurbishment of building shell** and of RHC equipment, without any displacement of residents.
- Very **quick** implementation, as well as optimised constructions, quality and cost efficiency due to prefabrication.
- **Adaptability**: the panels of a multifunctional modular façade system are developed using a modular system to fit any climate and housing situation. The anchorage system is developed with special trays that can easily be adjusted to allow for different building sizes.

Multifunctional Façade matches with…

Multifunctional façade system is a building retrofitting technique. It can go of course hand in hand with the replacement of an old heating system with a modern renewable one, but not necessarily.

Retrofitting measures shall in fact take priority over other actions (i.e. heating system replacement) in order to first realise the full potential of energy savings of the house.

In any case, if the installation of a multifunctional façade system is accompanied by heating system replacement, there are no specific requirements on the type of heating system to be installed, unless the heating system is integrated into the prefabricated façade (i.e. heat pumps and air ventilation systems).

5. OTHER HEATING OPTIONS

5.1. COLLECTIVE ACTIONS

Collective actions refer to actions taken together by a group of people whose goal is to enhance their condition and achieve a common objective. Collective actions can raise the awareness among the public for a certain investment e.g. into heating-related ones like thermal insulation of a building, low investment energy efficiency improvements, the renewal of the heating system or collective heat supply. The benefit is not only the higher awareness, leading to a higher impact, but often also a higher quality of the work. Furthermore, due to higher sales volume, prices are likely to decrease. Complexity for participating end consumers is reduced as the initiators of the collective action (mostly local project champions) normally offer a bundle of services simplifying participation and the implementation of the proposed measures for them.

There are three general types to community development efforts:

- **Top-down**: the government actively initiate community development activities, while the community and the general public remain passive.
- **Bottom-up**: the community plays the active role in initiating and managing development activities, while the government plays a more supportive role, enhancing the skills and knowledge of the local community actors.
- **Partnership**: a combined effort between the government and the community to carry out community development activities.

Social innovations are “bottom-up” innovations from civil society intended to address the failure of “top-down” private market and political approaches in solving complex modern societal problems.

Contributors of bottom-up processes can be civil society, self-organized groups, NPOs (non-profit organizations) and social enterprises as initiators and actors of civil society and municipal actors in community-based processes.

Collective actions are initiatives which can be embedded in local communities and implemented in cooperation with local networks (e.g. public municipal actors). Renewable Energy Communities (RECs) and Citizens' Energy Communities (CECs) are two forms of civil engagement whose role will increase in the near future. Ideally, an institutionalised caretaker (which is financed properly) would take over the process of establishing a collective action and of managing and steering its implementation.

Examples for collective actions in the field of heat supply and room air conditioning for the housing sector are:

- Wood pellet purchase
- Thermal insulation of the uppermost ceiling of single-family houses
- Purchase of boilers/equipment for renewable heating systems (by end consumers or installers)
- Implementation of low-cost measures recommended by public energy advisors or independent energy consultants at boiler inspections
- Purchase of PV systems with domestic hot water (boilers equipped/upgradable with) power-to-heat heating rods or together with efficient household mono- and multi-split room air conditioning systems
- Purchase and implementation of solar thermal systems
- Biomass micro grids supplying more than at least two buildings (e.g. based on farmers cooperatives, even operated as a kind of plant energy contracting completely for third parties)
- Compilation of lists for collective purchase and installation, with recommendations on who can implement the project

5.2. BOILERS AND COOLING UNITS CHECK MEASURES

5.2.1. Heating systems

Often boilers are highly efficient when measured in the lab; however, in real life the performance can be much poorer. The same applies to air-conditioning systems. The reason is to a large extent that the system is not well adapted to the building resp. on the users' needs or the maintenance is poor which leads by time to performance losses but also to a lower lifetime of the device.

The boiler room check measures should be organized together with installers or energy advisers, or with both. All heat distribution pipes in the cellar shall be insulated properly. The (integration of the) domestic hot water supply system should be checked and optimized. Old hot water circulation pumps should be replaced by energy efficient, variable-speed ones, ideally being able to support hydraulic balancing of the whole heat in-house distribution system (costing about 250-300 Euro), which includes the implementation of intelligent temperature controllers (thermostatic valves) on the radiators (price about 50 Euro per item). Hydraulic balancing can take from several hours up to a whole day, depending on the number of rooms and radiators installed. Additionally, it is required that an installer or a service technician ensures that the operating behaviour of the existing heating system and the newly purchased variable speed circulating pump have been adjusted to each other in such a way that, on the basis of the heating curve (the ratio of

required flow and outside temperature), the most efficient operation is ensured in the long-term and the customer receives appropriate training in the operation of the system.

With such measures, the investment would pay off within a couple of years, depending on cost of fuel prices.

A heating system check should include:

- The boiler itself:
  - Is the dimensioning appropriate?
  - measurement of the exhaust gas losses
  - measurement of the ventilation losses
  - Is the condensing of the exhaust gases working properly (mainly depending on the system temperatures)?
- The regulation:
  - Is the heating curve adjusted correctly?
  - Is the water circulation pump working in an efficient way and does it work with variable speed?
- The heat distribution system:
  - Are the pipes adequately insulated?
  - Is the hydraulic balancing correct?
  - Is there air in the heating circuit?
- The heat dissipation system:
  - Are the heat dissipation surfaces large enough?
  - Are there radiators covered by furniture, etc.?
  - Are the regulation valves working correctly?
- The domestic warm water system
- The usage of renewable energies: status and potential

The most often occurring problems are related to:

- The over-dimensioning of the boiler,
- Non-insulated distribution pipes,
- Problems in the regulation,
- The sub-optimal operation of water circuits with old, inefficient circulation pumps (without variable speed),
- The correct setting and limitation of heating times or room temperatures,
- Missing hydraulic balancing.

Experience from performed heating system checks show that savings of about 15% are feasible in most cases without any negative effect on the comfort. Such heating check measures are a low investment and low involvement action and pay off quickly. At colder climates for single-family houses monetarized energy savings of up to 2,000 Euro per year were observed. Therefore, it is highly recommended to make an assessment with a local installer to define the scope of the action and what benefits (pay-off times) you can expect.

5.2.2. Cooling systems

Room air conditioners ensure a pleasantly cool climate in summer, but also consume a lot of electricity. Anyone who uses these devices, unless if powered by a PV, must be prepared for a significantly higher electricity bill.

Cheap ducted mobile air conditioners with an exhaust air hose can normally be flexibly installed anywhere in the house. A socket for the power supply and a tilted open window are sufficient to discharge the heated exhaust air. Disadvantage: Warm ambient air flows into the room through the open window, which in turn needs to be cooled. For this reason, some mobile units are offered with a two-hose system in which the outside air is fed into the cooling circuit in a controlled manner via a second hose. Despite slightly opened windows, the two hoses largely prevent uncontrolled air from flowing into the room, thus saving energy.

In the case of split units, which are considerably more energy-efficient, an open window is avoided by permanently mounting an external unit. The outdoor unit supplies one or more indoor unit(s). The cooling energy is then released into the respective room. No disturbing noises are generated in the air-conditioning interiors as the compressor unit is situated externally. Additional information on cooling systems powered by renewable energy is available on the dedicated factsheet on the REPLACE website.

Hints for buying a device

- Look for the EU label (energy consumption, cooling capacity).
- Cooling capacity: the unit should be adapted to the conditions, such as room size.
- For single-hose systems the effective cooling capacity can be up to 40% less than specified; for two-hose systems up to 20%.
- Split-units guarantee the best energy efficiency (lowest energy consumption).
- Check the most energy efficient devices available on dedicated websites, like topten.eu.

For guaranteeing the efficiency of a split cooling system a system check should include:

- Refill or change of the refrigerant,
- Check of the system tightness,
- Check of the correct functioning,
- Cleaning and disinfection,
- Change of the air filter(s),
- Change of wear parts.

General hints for an efficient usage of cooling devices

- Only rooms that are used should be cooled.
- Place units in the room so that the air can circulate freely.
- Use sun protection outside – this reduces the operating time of air conditioning systems and thus energy consumption.
- Only ventilate at night or in the early morning.

5.3. SHADING AND INSULATION

In order to guarantee thermal comfort in summer – i.e. to avoid overheating of living spaces – a functional shading of the building is recommended. This is closely linked to the windows and partly to doors.

Due to the changing position of the sun during the day and the seasons, a reasonable shading system can only work outside. Depending on the angle of irradiation, glass allows a large part of the solar radiation energy to enter the interior. Interior blinds, even if they are reflective, are therefore very ineffective. In contrast to external shading, they cannot avoid heating up the interior29.

Options for external shading:

Eaves
Eaves or other fixed overhangs are the simplest way to provide protection against solar gain. They must be sized correctly to exclude summer sun but still admit winter sun.

Awnings
Awnings reduce sun when they are in position. They should be light in colour to deflect more heat. Retractable awnings will admit sunlight when in retracted position. Awnings may not be suitable in windy areas but motorised, retractable awnings are available that can monitor wind levels and retract when the wind strength gets too high.

Screens and shutters
Fixed and moveable screens and shutters are available in a range of sizes and methods of operation including sliding, hinged and bifolding. The louvre panels may be fixed blade or operable. They provide an excellent solution for low angle morning and evening sun as they can be moved away to admit light when not required.

Louvres
Horizontal, fixed louvres should be angled to the noon mid-winter sun angle and be spaced correctly to admit winter sun.

External (curved) blinds
With external blinds, it is possible to react precisely to the position of the sun while maintaining a good view to the outside. When the sun is high up, it is sufficient to place it horizontally due to the curvature of the slats. When the sun is low, a slight inclination is sufficient, so that a view is still possible. For higher wind speeds there are also options available, where blinds are guided within a fixed framework.

Verandahs
Deep verandahs are particularly good for shading east and west facing elevations although they will still admit very low angle sun. They can be used in combination with planting or screens to filter sun.

Pergolas
Pergolas covered with deciduous vines provide very good seasonal shading.

Trees

A very good shading option is to plant deciduous trees at the sunny fronts of buildings. In summer, the leaves shade the building, in winter when the leaves are fallen, they allow the sun to penetrate. It is a very low-cost investment and in addition it contributes to biodiversity and with the growth of the tree to bind

29 Source: http://www.level.org.nz/passive-design/shading

CO_2. However, the location to be planted must be suitable and it can take a while until they have the suitable size. A good selection of the tree species is required.

Options for internal shading

Internal shading is less effective at reducing solar heat gain than external shading because the solar radiation has already come through the glass. The shading absorbs the radiation, and while a small amount of heat is reradiated back to the outside, most remains within the interior space.

Internal shading can be a useful device when:

- The sun penetrates for only a short time,
- Heat build-up will not be a major problem,
- Windows can be left open adjacent to them,
- It is required to reduce glare.

Options:

- Curtains, when drawn, significantly reduce light but reduce heat gain by only a small amount. They also reduce ventilation and block views.
- Venetian blinds and vertical blinds can be used to adjust the amount of incoming light while retaining views but they reduce heat gain by only a small amount.
- Roller blinds and other types of window blinds reduce the light admitted but also reduce the heat gain by only a small amount. They may also reduce ventilation and block views but some types of blinds provide two adjustments: one setting provides partial darkening, the other setting provides full darkening. Blinds may be motorised for high level windows or roof lights. They can be made from a range of sun filter fabrics to suit the desired level of light, view and shading.

Regarding the **thermal insulation of the uppermost ceiling,** it is recommended to collectively organize the material demand survey and to buy the insulation materials (possibly renewable-based). Due to liabilities and different preferences of end consumers, the implementation of the action should be organized by the end consumers themselves, e.g. via engagement of professionals or via a joint organization of self-assembly groups. At mid-European conditions, the insulation of the uppermost ceiling as a collective action should not cost more than 2.000/3.000 euro, and it normally pays off in less than ten years.

Check and insulation measures can in fact reduce about 10/15% of the total heat demand, adding up to 20/30% energy savings, even before the heating system is replaced.

Similarly to boiler room check measures, also measures such as the thermal insulation of the uppermost ceiling brings with it a pay-off value that, even under the best conditions, is hardly achievable by a boiler replacement (payback times of renewable boilers may be between 12 and 20 years, even in the presence of subsidies).

5.4. INFRA-RED HEATING SYSTEMS

Infrared panel heating elements consist in their core of a heating conductor that converts electrical energy into infra-red radiation. In the process, the infrared panels are heated between 80 and 100° C. Only these

high temperatures enable an infrared heater to give off the main part of its heat to the room in the form of radiant heat to a large extent, but also convection.

Comfort

Infrared radiation is felt as more comfortable than convection e.g. from heater blowers. But also floor and wall heating as well as tiled stoves show similar radiation characteristics. However, the big temperature difference between panel and room air can be felt as uncomfortable, especially if installed improperly.

Economic aspects

Even if it is claimed that infrared heating systems consume less energy than other direct electric heating devices (which is doubtful), they are, despite low investment, a costly option in terms of overall costs, because of very high running costs. In the future, when time-dependent tariffs might gain importance, the price for electricity in times where infrared heating panels consume most energy, might even rise (winter, day-time). On the other hand, infrared heating shows low installation costs: about 100 € per m² are realistic, but the domestic hot water demand has to be covered by another system which causes further costs.

Environmental aspects

From an environmental point of view it is problematic that especially in winter the electricity mix is dominated by fossil fuels. Also a PV local production does not help as it will generate most of the energy when the infrared heating is not needed.

Fields of application

If at all, infrared heating panels can be installed in passive houses where the energy demand is extremely low and a system with high installation costs might not be an option. It might be useful to install an infrared heating as additional heating where heat is only needed very locally and in a limited timeframe (e.g. weekend house etc.). Infrared heating panels might be a good replacement for old electric heating systems as night storage heaters where no distribution system exists.

System choice and installation

Infrared heating systems show big differences in price and quality. A high percentage of radiation should be secured which depends on the materials. Therefore, the choice of the product should be done with care, if such a heating device is considered. The front side should show good emission characteristics (power-coated steel or ceramic) and the rear side should be insulated. Products with high quality have a minimum of 5 years warranty.

A dimensioning per room is necessary as well as a careful planning of the positioning of the heating device. It might make sense to install products that can be operated remotely and programmed per time or temperature.

Caution: As electric heating device they might be exempted as main heating system due to legal measures, depending on the location.

5.5. “DEMAND RESPONSE READY” MEASURES

Demand-response is a concept coming from the electricity market. Demand response is the intentional modification of normal consumption patterns by end-use customers in response to incentives facilitating stability of grids and avoidance of deviation of simultaneous consumption and production of power as well as of demand peaks that might cause costly upgrades of grid infrastructure and / or production capacities.

It shall lower electricity use at times of high electricity prices or when system reliability is threatened. Making use of automated solutions offered by service providers, not negatively affecting production processes or comfort at households, makes such services consumer-friendly. If electricity price is made time-dependent, especially industrial consumers can benefit, as many of them can shift significant consumption loads to off-peak hours. But also for households, this can be an interesting option.

Regarding the heating energy consumption, smart grid ready heat pumps and air conditioners are the most relevant use case, requiring an appropriately dimensioned heat storage, or exploiting the inertia (passive storage masses) of the heated or cooled system for a limited time. In newer (or frequently also comprehensive refurbished) buildings with activated building components (water pipes are situated in e.g. concrete building components, like walls or ceilings) storage masses can be utilized actively and can substantially reduce heating and cooling loads or investment in devices delivering the reduced loads.

Measures related to photovoltaics (PV) plants can also contribute to a load shift facilitating the operational capability of the electricity system, e.g. if they are connected to a heating rod in a warm water boiler or better a domestic hot water heat pump with a heat storage lowering the stress of local electricity grids in times with high PV electricity production but low overall consumption. Such systems are only effective in summertime as PV electricity production is substantially lower in winter and overall electricity consumption substantially increases.

In district heating systems peaks result from high request e.g. caused by households using hot water in the morning/afternoon at the same time e.g. for showering, or when the night-time heating temperature reduction is deactivated at the same time. Furthermore, the temperature in the whole distribution system is determined by that single consumer with the highest temperature need. Most DH systems have some peak-load boilers, working only for a few hours a year, but causing high costs and usually use fossil fuels for this short-term delivery (often fuel oil based to avoid connection and grid fees in case of natural gas). Therefore, also in DH grids, demand-response concepts can make sense. The turn-off time of the night-time heating reduction can be adjusted so that there is a lower peak in the morning hours.

Surplus electrical power from solar or wind energy can be used to (re)charge buffer storages in heating systems (DH or individual systems) by heating rods. By the means of large heat storages electricity and heat production can be decoupled. CHP plants can be operated rather in times of high electricity demand and do not have to follow the heat demand all the time anymore. Heating rods provide even more flexibility to CHP operation.

In general, it can be said that in the case of centralized heating and overall in electricity systems DR shall influence energy consumers' behaviour towards a more efficient and effective electricity and district heating network operation with regard to:

- The integration of large shares of fluctuating distributed generation from RES
- Reducing demand for grid extension or reinforcement
- Reducing storage demand and short-time fossil fuel based production..

ANNEX I: HEATING & COOLING IN THE EUROPEAN UNION

Heating & cooling in the EU

Buildings are responsible for approximately 36% of the greenhouse gas emissions in the European Union (EU) and 40% of energy consumption, which makes them the single largest energy consumer in Europe.

At present, about 35% of the EU's buildings are over 50 years old and almost 75% of the building stock is energy inefficient. At the same time, only about 1% of the building stock is renovated each year.

Renovation of existing buildings can lead to significant energy savings, as it could reduce the EU's total energy consumption by 5-6% and lower CO_2 emissions by about 5%[30].

The first step to reduce the environmental impact of the buildings sector is therefore the renovation of their envelopes (i.e. walls, roofs, windows). It is for this reason that the European Commission has recently put the stress on the key importance of renovation measures by announcing a "renovation wave"[31], which must be the catalyst for the decarbonisation of the building sector. This is an acknowledgment of the fact that our buildings infrastructure needs an urgent upgrade, not only to fight climate change but also to lift millions of Europeans out of energy poverty and to ensure that buildings provide a healthy and affordable living and working environment for everyone[32].

The second step in the decarbonisation of buildings is the use of renewable energy to provide the required energy services. Considering that in Europe there are approximately 120 million residential individual central heating boiler systems installed[33], the replacement of the ca. 80 million old and inefficient systems has in fact also a huge potential to decrease emissions from the buildings sector in the EU.

Nevertheless, even though the trends are encouraging, the era of renewable heating & cooling systems as the mainstream choice of European consumers is still far away: between 2004 and 2014, the stock of gas-fired individual central heating systems increased from 70% to 77.25%[34], as space heating in the residential sector still comes largely from natural gas (43%) and oil (14%), but biomass also accounts for a large share (20%)[35].

Cooling is a fairly small share of total final energy use and currently demand for heating in buildings outweighs demand for cooling. However, the latter is gradually catching up, and rising especially during the summer months – a trend which is clearly linked to the increase in temperature caused by climate change. It is expected that by 2030 the energy used to cool buildings across Europe is likely to increase by 72%, while the energy used for heating buildings will fall by 30%[36].

EU legislative framework on heating & cooling

With the objective to achieve a successful energy transition, over the past years the European Union has put in place several legislative measures addressing heating and cooling in the residential sector. The first acknowledgment at EU level of the need to prioritise heating and cooling was the **EU Strategy on Heating and Cooling**, proposed in 2016 by the European Commission with the objectives, among the others, of "stopping the energy leakage from buildings, maximising the efficiency and sustainability of heating and cooling systems, [...] and reaping the benefits of integrating heating and cooling into the electricity system"[37].

More recently, the European Commission has stressed the key role of building renovation measures, by announcing a "**renovation wave**" of public and private buildings, as part of the European Green Deal[38], aiming to take further action and create the necessary conditions to scale up renovations and reap the significant saving potential of the building sector.

Measures to improve the building stock are also included in the recently amended **European Performance of Buildings Directive (EPBD).** Based on the EPBD requirements, EU countries must establish strong long-term renovation strategies, set minimum energy performance requirements for new buildings and for existing buildings undergoing major renovation, ensure all new buildings are nearly zero-energy buildings, issue energy performance certificates when a building is sold or rented and establish inspection schemes for heating and air conditioning systems, introduce the optional Smart Readiness Indicator, etc.

Together with the EPBD, also the Energy Efficiency Directive and the **Renewable Energy Directive** incorporate some provisions which contribute to a highly energy efficient and decarbonised building stock

33 European Commission, Space and combination heaters – Ecodesign and Energy Labelling Review Study: Task 2 Market Analysis, July 2019 (https://www.ecoboiler-review.eu/Boilers2017-2019/downloads/Boilers%20Task%202%20final%20report%20July%202019.pdf)
34 Ibidem.
35 Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)
36 IRENA, Heating & Cooling (https://www.irena.org/heatingcooling)
37 European Commission, An EU Strategy on Heating and Cooling, 2016 (https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf)
38 European Commission, The European Green Deal, 2019 (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1588580774040&uri=CELEX:52019DC0640)

by 2050. These provisions include i.e. obligations for Member States to prepare comprehensive national heating and cooling assessment, to address the untapped potential of heating and cooling by increasing renewables in the sector by 1.3 percent point per year between 2020 and 2030, to ensure sustainability of bioenergy, to encourage the empowerment of energy consumers and define for the first time the concept of renewable energy communities, etc.

Another key piece of legislation for space heaters is **the Ecodesign**39 and **Energy Labelling Regulations**40, which address the energy efficiency of products. While eco-design requirements aim to gradually remove inefficient products from the market, the energy labelling promotes the best performing products in terms of energy efficiency by means of harmonised labelling throughout the EU.

Ban of fossil fuel heating technologies coming soon?

While the sale of very inefficient boilers had already been banned by the Ecodesign and Energy Labelling requirements for space and water heaters which came into application in 2015, some Member States are pushing these requirements further and are preparing legislations on a national carbon pricing scheme and to ban the use of fossil fuel for residential heating purposes.

I.e. the German Climate Action Programme 2030 includes a phased carbon pricing system for the buildings and transport sectors and a ban on oil-based heating in buildings from 2026. At the same time, incentives for retrofitting of buildings will increase[41].

Even more ambitiously, with a change to the Dutch law regulating the gas network operators ("The Gas Law"), the Dutch government now requires all new buildings to be almost energy neutral by the end of 2021, does not allow new buildings to connect to the gas grid, and targets to phase out gas in heating entirely by 2050, while many parties even recommend a government requirement that no gas-only boilers should be installed in any homes from 2021[42.]

In Austria, a federal law already regulates a gradual phaseout of oil and coal in the building sector, while the Austrian government is working to provide a legal basis for the replacement of gas heating systems. At the same time, the Austrian province of Salzburg plans a prohibition of like-for-like replacements of heating systems running on fossil fuels in case of a break down.

Even though there is no legislation at EU level going in this direction at the moment, other European Member States may autonomously decide to follow this trend as a measure to achieve the objectives agreed in Paris[43].

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39 Commission Regulation (EU) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R0813)

40 Commission Delegated Regulation (EU) No 811/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to the energy labelling of space heaters, combination heaters, packages of space heater, temperature control and solar device and packages of combination heater, temperature control and solar device (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013R0811)

41 International Energy Agency, Germany 2020 Energy Policy Review (https://www.bmwi.de/Redaktion/DE/Downloads/G/germany-2020-energy-policy-review.pdf?__blob=publicationFile&v=4)

42 Janene Pieters, "Call to ban gas heating boilers in Netherlands by 2021", 28/03/2018 (https://nltimes.nl/2018/03/28/call-ban-gas-heating-boilers-netherlands-2021).

43 "The Paris Agreement sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C. It also aims to strengthen countries' ability to deal with the impacts of climate change and support them in their efforts. The Paris Agreement is the first-ever universal, legally binding global climate change agreement, adopted at the Paris climate conference (COP21) in December 2015.The EU and its Member States are among the close to 190 Parties to the Paris Agreement" (European Commission, Paris Agreement, https://ec.europa.eu/clima/policies/international/negotiations/paris_en).

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