RESIDENTIAL HEAT DECARBONISATION SOLUTIONS – A HANDBOOK FOR INSTALLERS, PLUMBERS, CHIMNEY SWEEPERS AND INVESTORS –

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.

For the replacement to be successful, the commitment of intermediaries and investors is as necessary as the involvement of end users.

This report aims therefore at providing professional intermediaries (such as installers, chimney sweepers, building developers, energy advisors, etc.) with in-depth knowledge of the renewable heating and cooling systems options available on the market today, with the objective of making them well-trained facilitators of replacements and of enabling them to measure and communicate expected energy and financial savings and wider societal benefits of heating and cooling replacements.

At the same time, the report informs investors (either financing institutions, public authorities, energy suppliers, or homeowners) about economic issues, best practices and innovative business models, as well as model contracts, for renewable heating and cooling solutions.

Today there is a myriad of heating solutions that consumers, professional intermediaries and investors 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.

TABLE OF CONTENTS

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
SG	Smart Grid
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. As a rule, 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 a change of energy source. In addition, the amount of information required for a switch is high: many questions must be clarified and different actors need to be consulted. Often people do not have enough money to be able to afford (currently still) more expensive low-CO_2 systems, even if the life cycle costs are already significantly lower and much less risky.

REPLACE wants to tackle those and other local challenges and barriers by developing and testing locally adapted, tailor-made replacement campaigns – for the first time, in parallel – across nine 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.

To develop efficient and strongly service-oriented campaigns as well as user-friendly information tools, REPLACE identifies requirements for implementation actions concerning infrastructure, regulations and law, it investigates stakeholders' mind-sets and their needs, refers to lessons learnt from previous projects, and develops action plans tailor-made for each pilot region. The replacement campaigns are to be launched and supported by the project partners on-site 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.

Project partners together with the local working groups 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 RENEWABLE HEATING & COOLING FOR INTERMEDIARIES AND INVESTORS?

The direct involvement and commitment of intermediaries and investors in replacing old and inefficient heating and cooling systems with renewable and environmentally friendly ones is key to achieve large scale replacement.

In this context, by the word "**intermediaries**" is meant all those key persons who, in the supply chain of heating technologies, are placed between the system manufacturer and the end-user. The category of intermediaries includes therefore professionals ranging from installers, plumbers, and chimney sweepers, to architects, building developers, energy agencies, engineering consultants and energy advisors.

Several analyses show that certain professional groups, such as architects and engineering consultants, still consider renewables as a potential risk to their clients[1]. This is due to the complexity of design/installation compared to fossil fuel alternatives available on the market. On the other hand, currently the installation of oil or gas boilers is often the simplest solution for the replacement of old or broken heating devices. Intermediaries often recommend the installation of oil or gas boilers as they are low risk technologies with low maintenance efforts and generally high consumers' satisfaction.

But as consumers' decisions are usually made based on recommendations of intermediaries such as installers, chimneysweepers, and architects, concerns from these categories of professionals must be considered and dealt with. Intermediaries must get the necessary support to be motivated enough to promote renewable solutions instead of fossil fuel-based systems. This support can – and should likely – be monetary (e.g. by tax reductions, subsidized training, etc.). The use of certifications and transparent platforms for providing and disseminating information on the design and performance data of installed systems would also constitute a trigger. Environmental and financial savings should therefore demonstrate to the professional groups the necessity of engagement[2].

The market uptake of renewable heating and cooling appliances also means that new skills will be required from energy planners, heating system providers, and installers as emerging automation, IT solutions, and

[1] ETIP RHC, 2019, "2050 Vision for 100% renewable heating and cooling in Europe" (https://www.rhc-platform.org/content/uploads/2019/10/RHC-VISION-2050-WEB.pdf)
[2] *Ibidem.*

This role will combine both energy planning and public policy skills. A shift is also needed in terms of business logic of traditional DH systems, moving from large production plants and distribution networks to decentralised, smaller-scale and efficient production and distribution of H&C[3].

At the same time, since the market of some renewable heating and cooling technologies is today still at its early stage, raising the awareness of investors on the benefits (for them and for the society as a whole) of such technologies is a prerequisite to ensure the thriving of the business.

Investors is not only meant in its most common sense of financing institutions, but also refers to public bodies, local energy planning authorities, energy agencies, Energy Service Companies (ESCOs), building developers, energy suppliers, district heating operators and energy cooperatives. And finally, it also refers to building owners and homeowners, who decide to invest in a renewable heating system for their house.

For a successful transition of the heating and cooling sector, public authorities should take over the pioneering role of first movers by considerably investing in public buildings and H&C network renovations[4]. Investments from the public sector will play a very important role.

One of the biggest challenges in this sense will be to engage businesses that are not energy related. In fact, for most of such businesses, taking concrete measures and securing investments to switch to renewables is a low priority. To enable a behavioural change in this context, the benefits of a clean energy transition (other than cost savings and contribution to climate protection) must be highlighted (e.g. increase in productivity, better working conditions, improved corporate image, and of course long-term financial returns). These are direct benefits, unlike the indirect benefit of contributing to the overall sustainability goals, which often is not the primary goal or business driver for profit-oriented organisations[5].

1.1. Why should intermediaries promote Renewable Heating & Cooling?

Renewable heating and cooling systems benefit not only those who buy them (and those around them), but also those who sell them and promote them! Renewable and efficient heating is a win-win option for the whole society. In fact, modern and efficient renewable heating systems offer the following advantages for consumers and for the society:

Environmental benefits:

Modern renewable heating and cooling technologies are efficient and save energy, thus reducing the carbon emissions and improving air quality.

Because of their efficiency they save energy, thus also cutting down energy bills of households. And finally, they are fuelled by free and infinite energy sources: renewable energy sources, such as sun, wood, air, water or geothermal.

[3] Ibidem.
[4] Ibidem.
[5] Ibidem.

Economic benefits:

Renewable heating and cooling systems decrease the households' dependency on the rising costs of energy nowadays and in the coming years. They are often incentivized by specific support schemes, which makes them more affordable and which reduce the payback time. They are future-proof, in the sense that they are not affected by legislations being prepared by some European countries, where soon the use of fossil fuels for residential heating will be banned.

They increase the value of a property, they empower territories, they are major job providers and support the European industry. And more generally, they support the local economy by reducing the dependency on energy imported from far away and by minimising money outflow to other regions.

Social benefits:

Renewable heating systems empower energy consumers to produce their own sustainable heat from renewable energy sources, thus making them 'prosumers' (a combination of the words 'producer' and 'consumer'), actively contributing to the challenge of decarbonising buildings and to the energy transition in Europe.

These are just some of the many reasons that will make you want to sell or promote a renewable heating or cooling system to your customers.

On top of that, the competition for the installation of a fossil fuel heating system is nowadays much higher than that for the installation of a renewable heating system. If you want to be a frontrunner and to set up a forward-looking business in your region, betting on renewable technologies is your best option. Because of all their advantages, renewable heating and cooling systems will act as a **marketing tool for your business**. The aim of all marketing strategies is in fact to offer the consumer optimal solutions and utility value, and to provide better services in comparison to the competitors.

Being a renewable energy system installer opens the doors to a wide range of attractive job opportunities in one of the most expanding and interesting economic sectors, fully supported by European and national legislations.

Looking at international and European plans to decarbonise the energy system and the world economy, renewable energies are in fact set to become the mainstream source of energy in just few decades from now, while the role of polluting fossil fuel technologies will progressively decrease. Some European countries are even preparing legislation to ban residential heating running on fossil fuels. No customer would be happy to find out soon after the purchase that the fossil fuel heating system is deemed to be banned by national legislation – right?

By becoming an installer of small-scale renewable energy systems you will enter **a market which is doomed to grow** favoured by factors such as the rise of fossil fuel prices, and with it the rise of heating costs; the increasing citizens' awareness related to the consequences of climate change; and European and national legislations.

Looking at the big picture, supporting small scale renewable heating systems will not only benefit your pockets, but would **boost the economy of your region** as well. Small-scale renewable installations are in fact major job providers and key drivers of the European energy transition.

The installation, maintenance and operation of renewable systems are important creators of highly skilled jobs that will make the green economy a local reality. Furthermore, local energy sources benefit local economies by delivering financial benefits to the community and to those who live in it. Local energy empowers 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.

In fact, sourcing energy locally, from a local company, means investing in a business that operates in your area. This means that it helps to improve the local economy and to increase its economic value.

Renewable energy sources and services *from* the region provide therefore benefits *for* the region.

1.2. Why should investors go for Renewable Heating & Cooling?

With the **regulatory framework** becoming stabler at both European and national level, it is no doubt that the market segment of renewable energy for heating & cooling will grow at unprecedented speed in the coming years.

With the recently passed European Union's Renewable Energy Directive in fact, the EU has set a target for Member States to increase the share of renewable heat by 1.3 percentage points per year from 2021 onwards[6]. Since the EU27 used circa 467 million tonnes of oil equivalent for heating and cooling in 2018, that could mean increasing the renewable element by 6 million tonnes of oil equivalent each year. The cost would depend on the type of technology, used to produce the renewable heat, and whether the new capacity included utility-scale plants or small-scale systems and stoves. The amount of investment required could be reduced if the EU continued to require less heat year-on-year, thanks to gains in energy efficiency[7].

To successfully and smoothly achieve the target set by the Renewable Energy Directive, Member States will be also required to create appropriate incentive schemes. According to estimates for the entire European Union, the additional volume of investment in renewable heating and cooling generation facilities will be approximately EUR 36 billion a year.

Investing in renewable heating and cooling technologies will pay off. Good reasons to invest in renewable energy projects include the following ones[8]:

1. **Clean energy investments yield an economic return 3 to 8 times higher than the initial investment during the whole project lifetime:** the International Renewable Energy Agency's (IRENA) new 2020 Global Renewables Outlook[9] assesses the socioeconomic impact of several energy transition scenarios. The "Transforming Energy Scenario" — an ambitious-yet-realistic energy transformation that would limit global temperature rise to well below 2°C — would cost globally $19 trillion more than a business-as-usual approach, but would bring benefits worth $50-142 trillion by 2050, growing the world's GDP by 2.4%. To go one step further, IRENA's "Deeper Decarbonization Perspective" — which outlines a net-zero-emissions world by 2050-2060 — would globally cost between $35-45

[6] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, Article 23 (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32018L2001).
[7] Frankfurt School-UNEP Centre/BloombergNEF, 2020, "Global Trends in Renewable Energy Investment 2020" (https://www.fs-unep-centre.org/wp-content/uploads/2020/06/GTR_2020.pdf)
[8] Renewable Energy World, 2020, "3 reasons to invest in renewable energy now" (https://www.renewableenergyworld.com/2020/05/06/3-reasons-to-invest-in-renewable-energy-now/)
[9] IRENA, Global Renewables Outlook: Energy Transformation 2050, 2020 (https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Apr/IRENA_Global_Renewables_Outlook_2020.pdf)

trillion, but yield $62-169 trillion in cumulative savings when considering avoided health and social costs from reduced air pollution.

2. **The instability of fossil fuel prices presents a global opportunity to accelerate the shift to clean energy:** while the COVID-19 crisis and the lockdown orders have certainly exacerbated the fossil fuel industry's challenges, this structural collapse was a long time coming. Over the past decade, the fossil fuel industry has spent more money on stock buybacks and dividends than it has brought in revenue, making energy one of the worst-performing sectors[10]. Additionally, some of the world's largest financial institutions continue to rapidly divest from fossil fuels, recognizing the growing financial risks of carbon-intensive investments. According to the Center for International Environmental Law, this means that "in the medium term, the prospect of a full recovery for many of these revenue streams is, at best, uncertain, and, in many cases, unlikely[11]".

3. **Ambitious investment in renewable energy and energy efficiency could lead to 63 million new jobs by 2050:** today, more than 11 million people work in the renewable energy sector globally, while 3.3 million people work in the energy efficiency industry across the United States and Europe alone. According to the International Energy Agency, most energy-efficiency jobs directly create local employment opportunities within small- and medium-sized businesses. Under IRENA's "Transforming Energy Scenario," the number of renewable energy jobs worldwide could more than triple, reaching 42 million jobs by 2050, while energy-efficiency jobs would grow six-fold, employing more than 21 million more people over the next 30 years. The job total rises to 100 million when considering the impact on the overall energy sector, including transition-related jobs such as infrastructure and grid flexibility, in addition to conventional technologies including fossil fuels and nuclear energy. By contrast, the fossil fuel industry is expected to lose more than 6 million jobs over the same time period, compared to today's employment levels.

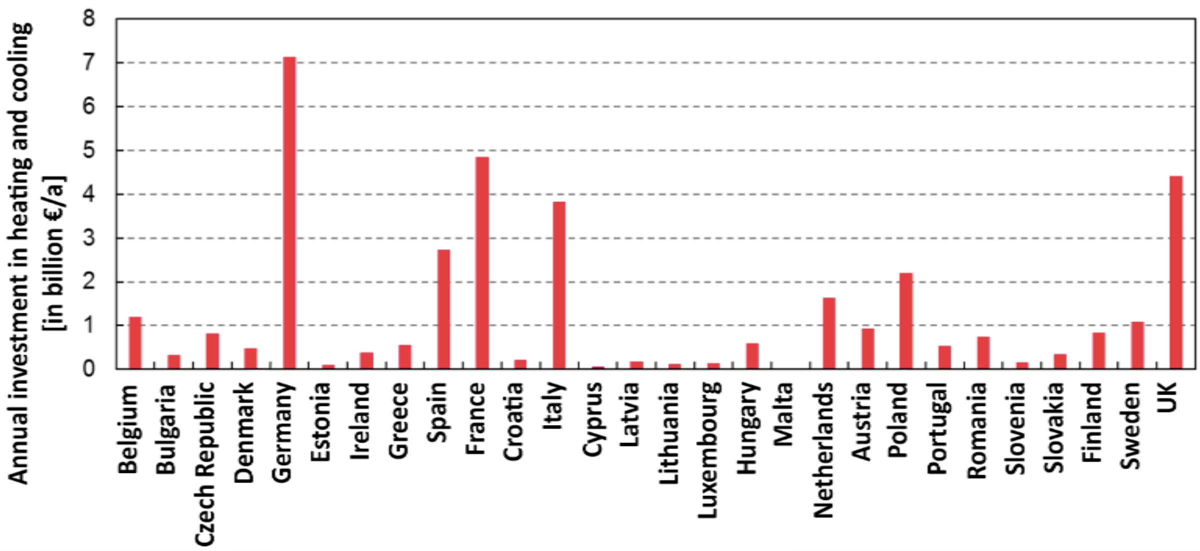

Figure 1 *Extrapolation of the additional annual investment volume in the European countries in the area of generation of heating and cooling from renewable sources based on the path of expansion at the rate of 1.3%*

Source: Rödl & Partner, "New EU Directive: A renewable energy (RE) investment offensive in heating/ cooling and in the generation of electricity for household self-consumption is on the horizon", 2018 (https://www.roedl.com/insights/renewable-energy/2018-08/new-eu-directive-renewable-energy-investment-heating-cooling)

[10] Center for International Environment Law, 2020, "Pandemic crisis, systemic decline – Why exploiting the COVID-19 crisis will not save the oil, gas and plastic industries" (https://www.ciel.org/wp-content/uploads/2020/04/Pandemic-Crisis-Systemic-Decline-April-2020.pdf)

[11] Ibidem.

There are often fundamentally different motivations for projects on renewable heating and cooling being initiated, developed and financed by the public or by the private sector. The public sector will generally pursue lower heat prices and better socio-environmental impacts, while the private sector will primarily pursue better economy[12].

Especially when it comes to **investments from the public sector**, i.e. in the form of a financial incentive scheme on renewable heating and cooling, the most important justifications include those listed below[13]:

- **Positive externalities:** society benefits from the reduction of emissions and from other environmental benefits linked to the use of renewable energies for heating or cooling purposes. A financial incentive scheme rewards the private investors for these positive externalities.
- **Security of energy supply:** by decreasing the dependency on imported and scarce energy sources, every renewable heating or cooling system reduces the need for public measures (such as strategic energy reserves), and for investment on infrastructure i.e. for transport of energy sources, or for diplomatic and military costs. By increasing indigenous energy supply, in the long-term a public financial incentive for renewable heating and cooling can be cheaper than alternative measures.
- **Gaps in market development within the EU:** for each renewable heating technology, there are huge gaps in market development between different European countries. It is possible – and necessary – to correct this unbalance by promoting renewable heating and cooling markets in the countries lagging behind.

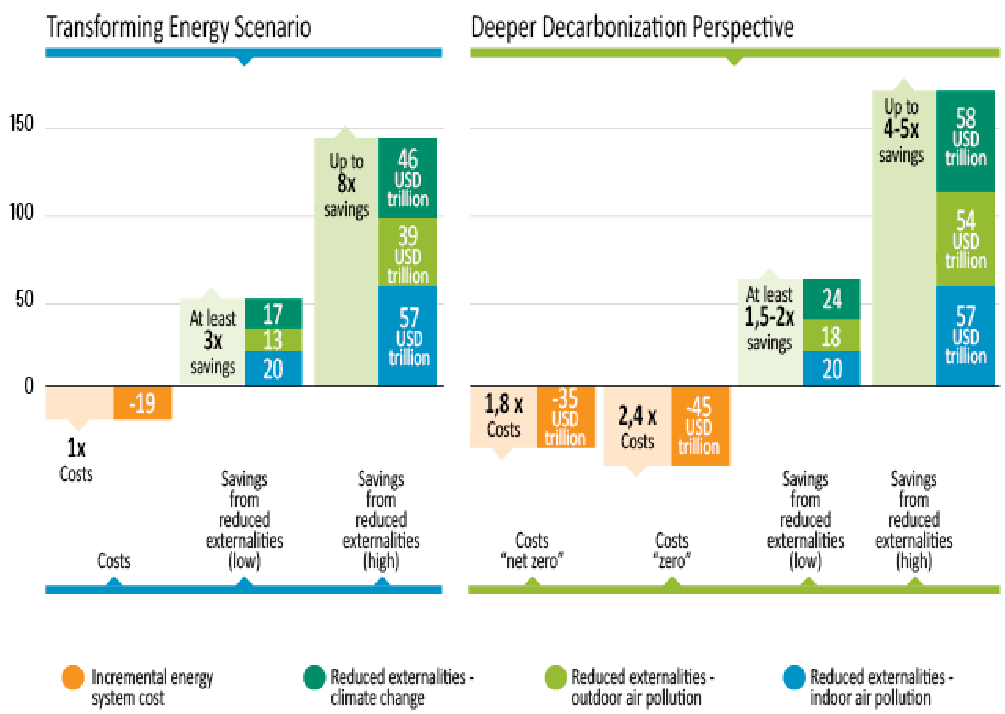

***Figure 2** Clean energy investments - Benefits vs. Costs: Cumulative system costs and savings from reduced externalities for Transforming Energy Scenario for the period to 2050, and Deeper Decarbonization Perspective for the period to 2060 (USD trillion)*

Source: Source: World Resources Institute, 2020 (https://www.renewableenergyworld.com/2020/05/06/3-reasons-to-invest-in-renewable-energy-now/)

[12] Sunko Rok et al., 2017, CoolHeating project, "Guidelines on improved business models and financing schemes of small renewable heating and cooling grids" (https://www.coolheating.eu/images/downloads/CoolHeating_D5.1_Guideline.pdf

[13] K4RES-H project, "Financial Incentives for Renewable Heating and Cooling" (https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/k4res-h_financial_incentives_for_renewable_hc.pdf)

- **Creating economies of scale:** the potential for economies of scale is substantial, not only in manufacturing but also for subsequent steps of the value chain, e.g. in areas like marketing and distribution, system design, installation, customer care, etc., usually delivered at a local and regional level. Financial investment schemes help creating economies of scale, thus reducing the price of renewable appliances in the medium term.
- **Support to meet the burden of upfront investment costs:** private investors can be discouraged by the high upfront costs as compared to a conventional heating or cooling system. Reducing this financial burden via public financial incentives encourages the purchase of a renewable heating appliance.
- **Technological leadership of the European renewable heating industry:** the largest part of the renewable heating and cooling devices installed in Europe are produced within the European Union. Moreover, the turnover linked to the installation of a renewable heating system is inherently local: design, installation, training, marketing and distribution. A financial incentive scheme for renewable heating creates therefore benefits for the regional and the European economy, while also reducing the need for imports of fossil fuels.
- **Positive signal from the public authority**: the fact that a public authority gives a financial incentive gives a positive signal to the citizens, concretely showing the public support for this kind of investment. This builds market confidence in the technology.
- **Financial incentive schemes as a marketing tool:** the existence of a FIS can be one of several methods for marketing renewable heating and cooling products. Financial incentive schemes should always be accompanied by a public awareness raising campaign. At the same time, private market operators will communicate the available incentive to their customers. In some cases, the financial incentive is not very high, but its existence motivates the public because of the "should not be missed" feeling operating in a similar manner to a discount campaign.

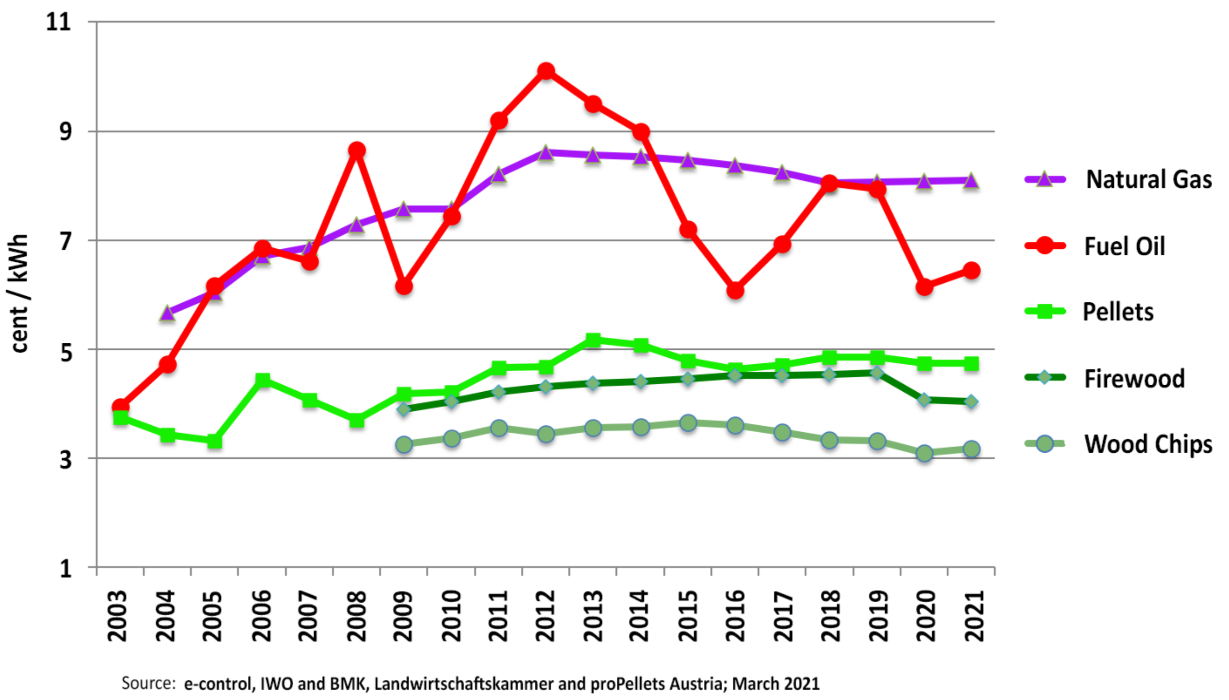

***Figure 3** Long-term comparison of costs of various fuels in Austria showing that ecological heating is economically attractive*

Source: proPellets Austria
https://www.propellets.at/en/wood-pellet-prices

Last but not least, it is worth mentioning that in the case of a private investment for a small-scale renewable heating system purchased by the building owner, one of the economic benefits deriving from such investment, beyond the lower running costs compared to heaters running on fossil fuels and the reduction in the energy bills, is the **increase the business value of the property** where they are installed.

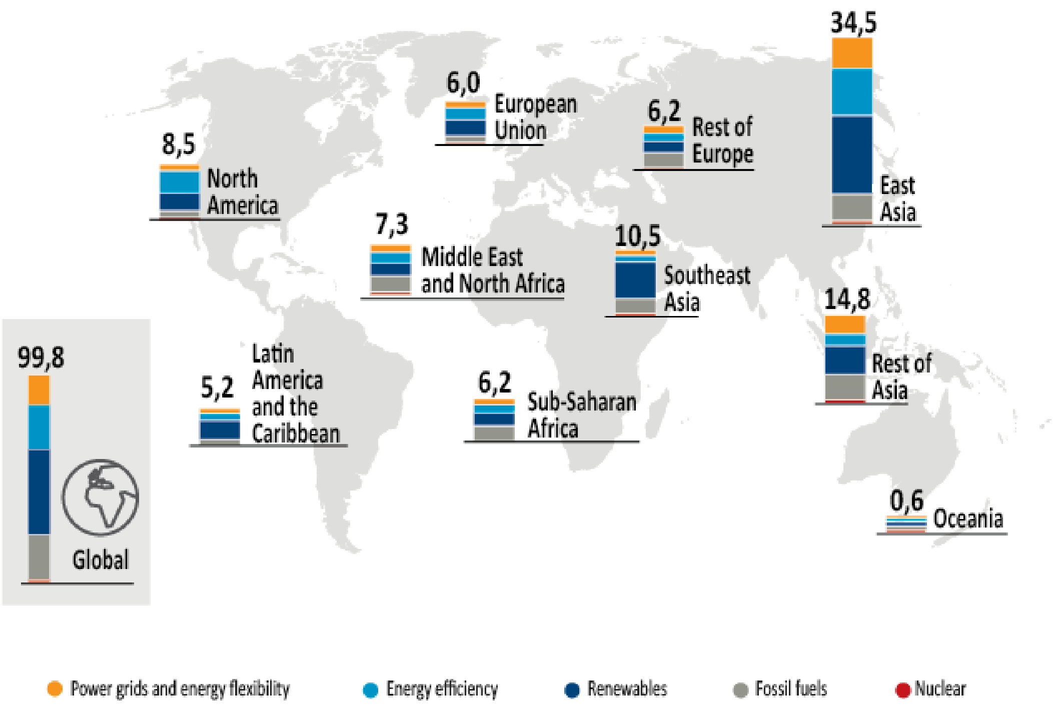

Figure 4

Job Impact of the Clean Energy Transition: 100 million jobs (energy sector jobs in 2050 under the Transforming Energy Scenario, by region)

Source: World Resources Institute, 2020

2 HOW TO PROMOTE AND MAKE THE MOST OUT OF RENEWABLE HEATING & COOLING?

2.1. How can intermediaries support the uptake of Renewable Heating & Cooling?

The realm of heating and cooling systems available on the market today is so vast that end-users are often disoriented and prefer to rely on the advice and expertise of professionals. As a professional intermediary you therefore have the trust of your inexperienced client. You are therefore the best placed person to recommend a renewable heating or cooling system over a fossil fuel one.

This chapter will present the different project phases to go through when recommending and finally installing a new heating system for a customer. It will then continue with a list of common installation mistakes and failures to avoid, and it will then provide an overview of national training and certification programs for intermediaries.

2.1.1. Replacement project phases

Normally, the process of the replacement of a domestic heating system is structured into different project phases, all equally important. All together, they make up the life cycle that most heating and cooling systems undergo. The sequence of the phases can vary depending on pre-existing conditions and several other factors (such as the type of building, size of heating system, technology chosen and customer's needs), but would follow a succession like the one outlined below.

1. **Conception and consultation**

   The process kicks-off with the conception phase. Ideally, the end-user or investor starts conceiving the replacement idea while the old heating system is still in operation. A timely conception phase allows to carefully assess all potential options, without taking rushed replacement decisions, which often happen in case of a sudden breakdown of the old device.

   In this phase, energy advisers, installers or other categories of professional intermediaries are contacted by the end-users to provide them with consulting services and preliminary recommendations.

During the consultation, the professional intermediary will try to understand the homeowner's needs in terms of heating or cooling, the preferences in terms of technology and of renewable energy source, and the building type where the homeowner lives. The intermediary will also inform the end-user whether district heat can be exploited on-site, locally, and regionally, considering the properties of the building and its surrounding.

Possibly, a home survey or in loco inspection at the premises of the customer should also be carried out by the professional tasked with the replacement, in order to assess the status of the building (i.e. whether it is well insulated or not, the existing duct system, the physical space available for the new heating system, etc.) and the energetic quality of the house itself (i.e. the energy consumption level per square meter, the level of flow temperature, the kind of heat distribution and dissipation), and whether there is any requirement in terms of chimney renovation or decommissioning of previous heating system.

2. Planning

The process continues with the planning phase. Following the preliminary steps of the conception phase, the professional can start planning the replacement itself: he/she will advise the customer on the best equipment options and system solutions for his/her property and needs, illustrate the process and its duration, provide a quote on the initial costs for the system and for the installation, and estimate the expected savings on the energy bill. The planning phase concluded with the choice of the new efficient and renewable system to be installed.

3. Design

The design phase of a heating and cooling system includes several subphases: the **determination of the heating and cooling capacity**, the **dimensioning**, and the **system configuration**.

It is imperative that the system can perform in accordance with occupants' comfort. And the design process, must in fact make it possible to secure the same performance even when the designers are different[14].

It is for this reason that the first international standard on design, dimensioning, installation and control of radiant heating and cooling systems has been published in 2012: it is **the ISO 11855 standard**. ISO 11855 includes the processes and conditions needed to determine the heating and cooling capacity of radiant heating and cooling systems in new construction and existing retrofitted buildings. In addition, the standard stipulates the design conditions regarding components such as the heat supply, hydronic distribution systems, panels, and control systems of radiant heating and cooling systems[15].

Once the configuration is finalised, the system is ready to be installed at the customer's premises.

4. Decommissioning and disposal of old system

In the case of refurbishment of an existing building and replacement of an old heating system, the professional intermediary shall normally also take care of the decommissioning and disposal of the previous existing heating system and of the remaining fuel. The person performing this work must be able to comply with the correct procedures and practices for decommissioning domestic heating systems. This work must be executed in accordance with the current versions of the appropriate industry standards and regulations, with industry recognised working practices, with the working environment and with the natural environment.

[14] LimJae-Han and Kim Wwang-Woo, 01/2016, REHVA Journal, "ISO 11855 - The international Standard on the Design, dimensioning, installation and control of embedded radiant heating and cooling systems", https://www.rehva.eu/rehva-journal/chapter/iso-11855-the-international-standard-on-the-design-dimensioning-installation-and-control-of-embedded-radiant-heating-and-cooling-systems

[15] Ibidem.

5. Realisation: installation and commissioning

In this phase, duct works are carried out, the selected system is installed and connected to the grid, and it is finally ready to work.

An important step of the realisation phase is the commissioning, consisting of the ability to set the systems to work properly. This step is key not only in terms of efficiency, but also customer safety. A variety of elements come into play for a heating system to run the way it iss supposed to – supply, pumps, ventilation, fluing, the boiler etc. During a commissioning job, professionals do not only look at the product itself, but rather at the system as a whole to see, if it is actually possible and safe for the customer to be turned on. A check to the quality of the water in the existing heat distribution system is also essential. Hydraulic balancing is an operation which is often underestimated, while of crucial importance: it can harvest energy efficiency gains, with energy savings of up to 5-15% per year, just with half or one day of installer's work.

Adjustment of steering and regulation of the operation of the boiler (taking into account tap water demand) should also not be forgotten. It is also important to keep in mind the regulation of the variable speed circulation pump according to the heating curve (required flow temperature related to outside measured temperature).

Commissioning and acceptance protocols should be the standard method to document professional service and to explain the legal consequences of ownership transfer to the owner/investor related to guarantee and warranty issues.

6. Operation: use and maintenance

Last but not least, once the system is installed and commissioned, it is ready to work, saving energy and reducing emissions. The system is expected to run reliably and efficiently and will be subject to regular revisions and professional maintenance measures in order to maintain a high standard of excellence. It is normally recommended that the installer checks the whole system and its optimal operation at least once per year after commissioning, and that he assesses whether there is any optimization potential.

In the most desired case, the customer should have the chance to rely not only on the installer for maintenance. Maintenance should be a service that can be taken over also by other companies for various reasons: the installing company may be too far away, may go bankrupt with the time, may not offer competitive prices for the maintenance service or the customers may not be satisfied with the customer support for various reasons. Thus, the installing company and the customer should make sure that all documentation such as executive designs, warranties, and specifications of the components and of the entire system are exchanged and that these files are available and kept by both sides.

The costs for the maintenance service should be kept at reasonable levels - e.g. the price for regular checks and routine works should preferably stay well below the costs of the annual energy savings from the system so that the system can be paid-back and the customer satisfaction be achieved.

The recently revised European Energy Performance of Buildings Directive also states the importance of inspections of heating, cooling and ventilation systems to ensure buildings and products deliver on their energy savings and maintain their optimal performance. Articles 14 and 15 require Member States to set up inspections of equipment for combined space heating/air conditioning and ventilation purposes over 70kW[16]. Inspections can help counteract the unavoidable ageing effects on

[16] 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)

products and systems, if they are followed by regular maintenance and servicing. Missing inspection and maintenance lead instead to significant system deterioration and unnecessary energy use.

2.1.2. Failures to avoid

Unfortunately, *errare humanum est* and mistakes do exist. When installing a new heating or cooling system (especially if it is not a widespread technology yet), some mistakes can occur. Such mistakes might cause failures of the system, as well as decrease its efficiency and performance, thus resulting in extra costs for the customer. The list below will help you avoid some of the most recurring replacement and installation mistakes.

1. **The wrong size:**
Installation errors can actually begin before you even sell the new heater or air conditioner. After all, if you sell the wrong size unit, you're just setting your customer up for failure. The system performance cannot be good when the wrong size of the equipment is involved. The idea that "bigger is better" is a trap. It may be wrong to install a system with the same nominal capacity as the previous one. It often happened that existing systems were over-dimensioned just to be on the safe side. Furthermore, new systems are more energy efficient and therefore system of smaller input (in terms of fuel or of power consumption) cover the same load as an output of useful energy. Installing a unit that is too large for the property will result in the unit turning on and off too frequently. Also, an operation at a much lower load than nominal system load means that the unit runs less efficiently and pollutes more. An over-dimensioned unit costs more in four dimensions: the investment is higher, the heating costs will be higher because of the lower energy efficiency, the service cost will be higher because of stop-and-go operation, and last but not least, the system is more polluting, thus harming the surrounding environment and the health of neighbors.
On the other hand, installing a system that is too small will result in the unit running constantly to work harder to meet the required temperature. Either way, it will use more energy than it should, and your customer will not achieve the manufacturer's promised energy efficiency[17].

2. **Disregarding the quality of the heat distribution water and the importance of the hydraulic balancing:**
It is key to make sure that the heat distribution water complies with the required standards (i.e. there is no decomposition due to rust or slagging due to rust particles). Such standards will not be met

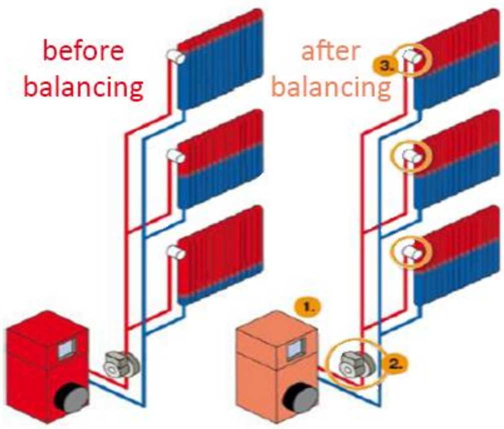

Figure 5 *The importance of the hydraulic balancing*

[17] General heating & Air Conditioning, "Avoid these top 3 HVAC installation errors", https://genhvac.com/avoid-top-3-hvac-installation-errors/

either if too many different metals and non-metals are mixed in the heat distribution and dissipation system.

At the same time, hydraulic balancing of the heat distribution system is necessary in order to supply all rooms with the same amount of heat, and it can help to save heating costs. For new systems, it is calculated exactly how much heating water should flow through each individual heating surface. In existing systems, the valves are set so that all heating surfaces are evenly supplied with heat. Without adjustment, the water would always seek the path of least resistance on its way through the numerous pipes and valves and would simply not arrive to some of the heating surfaces. Hydraulic balancing can therefore save up to 10% of the heating energy[18].

3. **Poor ductwork installation:**

Leaving duct leaks behind is a dominant fault in poor heating system installations. When ductwork is installed incorrectly, the efficiency of the heating or cooling system will likely be compromised. Not changing the ducts when installing a new equipment or using the cheapest materials can also be major mistakes. Cheap, poorly installed ductwork may quickly manifest gaps and cracks. Leaky air ducts will cost your customer money in terms of conditioned air that escapes via the cracks and gaps[19].

Additionally, the new technology must fit with the existing heat distribution and dissipation system. I.e. the installation of heat pumps should be avoided in the presence of radiators with flow temperatures above 45 °C, otherwise the heating costs will get so high that insulation of the building shell becomes unavoidable (especially in the case of an air heat pump). An alternative could be to refurbish the radiators (e.g. to install larger radiators, or radiators with an air fan to get down the flow temperature) or to switch from radiators to floor/wall panel heating.

Adjustment of steering and regulation of the operation of the boiler and of the circulation pump based on the heating curve is also very important. In fact, the flow temperature curve shall be related to the outside temperature: if the flow temperature is set even just 1 degree too high, there is an increase by 8% in the energy demand (i.e. 8% more energy per each excess degree), which could be easily avoided.

4. **Insufficient drainage:**

Air conditioners and today's high efficiency heating systems can create a significant amount of wastewater, which needs to be drained safely away from the system. If done wrong, water accumulation and water leaks can lead to damage in the building, mold growth, and air quality problems. In the cold weather, water backing up in pipes can freeze and cause the system to fail[20].

5. **Inadequate inspection and missed opportunities in home performance:**

Whether you are visiting a home to perform maintenance and repairs or a new installation, you should examine more than just one component. Heating and cooling equipment is in fact part of an entire system, and it must be treated as such. If you fail to inspect the various parts of the entire system, crucial details could easily be missed. This can result in costly repairs for your customer later[21].

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[18] Energie- und Umweltagentur Niederösterreich, „Optimierung der Heizanlage"

[19] Just In Time Furnace, "Common mistakes of HVAC service and installation", http://www.justintimefurnace.com/b/common-mistakes-of-hvac-service-and-installation

[20] Michael C. Rosone, 2014, "5 Common HVAC Installation Mistakes and How They Cost You", https://aristair.com/blog/5-common-hvac-installation-mistakes-and-how-they-cost-you/

[21] Ibidem.

Similarly, ignoring the opportunities in home performance by improving insulation and air sealing is a frequent mistake. It is in fact a great complementary service to advise the homeowners on the other work their home could undergo to improve its overall performance[22].

The following checks and tests are always recommended[23]:

- Check of the thermal insulation on pipes and fittings, buffer storage, hot water supply and circulation pipes;
- Check of the chemical properties of the heat transfer medium, and check if it necessary to add inhibitors (oxygen binding, corrosion protection) and venting the system;
- Check of the fill level of expansion vessels and if it is necessary to refill with treated heating water;
- Leak test and pressure test of the heat source and heat recovery system;
- Check of the safety devices (safety valves, automatic discharge safety devices, etc.);
- Check of the cleaning status of the heating surfaces of the fireplace and the trap.

Additional recommendations on checks to carry out include the following:

- Interview with the heating system's owner about the perceived heating temperature over the course of the year;
- Does the hydraulic balancing match with the heat distribution and dissipation system (do all rooms become warm at the same pace) or are adjustments needed?
- If the room temperature can be lowered by one degree, savings of 8% can be achieved on the heating costs per year, sustainably;
- Check of all the settings (time, temperatures, levels) on the heating system and circulation pump in order to optimize energy and adjust if necessary;
- Flow temperature shall be automatically adapted via the heating curve (i.e. relation to outside temperature);
- Charging times for hot water preparation (coordination of solar yields) set efficiently, also in connection with buffer storage;
- Pump control coupled and coordinated with boiler control, both interrelated with heating curve, setting value visible on pump;
- Control of the heating (daily, weekly and holiday program, summer / winter operation), setting of the reduced temperature;
- Input of time programs, fault messages, etc.;
- Carry out customer's training, especially if it was found that incorrect settings were made.

6. **Insufficient refrigerant charge:**

Beyond the above-mentioned too high flow temperature compared to the temperature of the energy source during the heating season, another very common service mistakes made with a heat pump or air conditioner might be using an inadequate level of refrigerant. By neglecting to check the refrigerant charge on a routine basis, an HVAC technician could reduce the energy efficiency of the home. The system might consequently require repairs or replacement that could have easily been prevented[24].

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[22] Allison Bailes, 2013, "The 7 biggest mistakes that HVAC contractors make", https://www.energyvanguard.com/blog/57031/The-7-Biggest-Mistakes-That-HVAC-Contractors-Make

[23] Source: www.klimaaktiv.it

[24] Just In Time Furnace, "Common mistakes of HVAC service and installation", http://www.justintimefurnace.com/b/common-mistakes-of-hvac-service-and-installation

Being a certified and trained professional or installer, together with smart commissioning and acceptance protocols, would definitely help avoid these common failures. The following paragraph provides additional information on how to get your certification on renewable heating and cooling appliances.

2.1.3. Offers for national training and certification programs for intermediaries

Even though the high renewable energy market growth rates experienced in recent years have resulted in an increasing demand for competent specialists able to install faultless and efficient renewable energy systems, today there is still a very limited number of professional intermediaries active in the renewables sector, especially compared to the number of professionals working with fossil fuel-based heating and cooling options.

But how to become a qualified installer of renewable heating and cooling systems? Even though actions have been taken at European level to ensure a concerted approach of Member States towards certification and accreditation of installers of small-scale building-integrated renewable energy systems[25], the schemes still change from country to country. They might be implemented by public authorities or by private entities, they might comply with an international norm or have been accredited by the national body, etc.

At the same time, trainings for installers may be provided by different training infrastructures depending on the country. Training institutions, manufacturers, federations, guilds may offer different types of training. It is always crucial though that the training structure, whatever it is, is accredited.

Across Europe, quality schemes aiming at giving assurance regarding the skills of installers even have different names: certification, qualification, label, etc.

As a plumber, electrician or technician for heating or climate systems you are strongly encouraged to undertake specialised training for the installation and maintenance of renewable energy systems. Whatever the name and the scheme, check the opportunities available in your region.

Sometimes, trainings for installers are offered by the manufacturers of the systems, some other times they are financed by your municipalities or by European Union funded projects, or organised universities and training facilities in your region. Check them out and get started, putting the basis for a thriving and successful business!

2.2. How can investors confidently invest in Renewable Heating & Cooling?

Even though over the past decade economies of scale have been reducing the high upfront costs of many renewable heating and cooling technologies and projects, initial costs are still often considered a barrier for those willing to invest on such technologies. For this reason, **reducing the risk (de-risking) of investment in renewable heating projects** is a critically important step for such technologies to thrive.

Most of the renewable heating technologies today have high initial costs but then cost very little to operate, because they do not require fuel. One consequence of this capital-intensive nature is that renewable heating is very sensitive to the cost of capital, that is, the interest rates or return rates demanded by those who lend

[25] I.e. via the EU-funded projects INSTALL+RES and QualiCert

or pay for renewable energy technology up front. Return rates and interest rates, in turn, are driven by risk. Investors properly demand higher returns when they face higher risks[26].

Risk comes in many forms and depending on the project phase: planning, installation (or construction in the case of a district heating and cooling network), and operation.

In terms of risk the most important phase is the initial phase of developing a heat project up to the first project development investment stage. In general, the project development process can be separated into the phases shown in the graph on figure 6.

Investors therefore should look out for professional project developers that are experienced in the initial phases of the project development after they have discovered / identified the project and before they conduct a full feasibility study (see red rectangle in the graph, PFS stands for pre-feasibility study). Generally, around 3/4 of the costs of a heat supply project arise during planning. Large savings are often possible through minor adjustments. The higher the project investment volume, e.g. a whole district heating compared to a single household system, the more time and money should be spent for that initial phase of project development. For smaller, household sized projects, the project development risk is much lower but professional advice is still needed.

Furthermore, administrative risks may occur in the planning phase by delaying the project because of lengthy bureaucracy procedures to connect to the grid or of permit problems. Technical and management risks can happen in the installation/construction and operation phases, if i.e. the technology fails because it is new and personnel might not be adequately trained yet to properly install it or make the settings run the system reliably, or in general due to the lack of experience of local installers and intermediaries. Finally, financing risks as well as sudden policy change risks can influence the project in all phases[27].

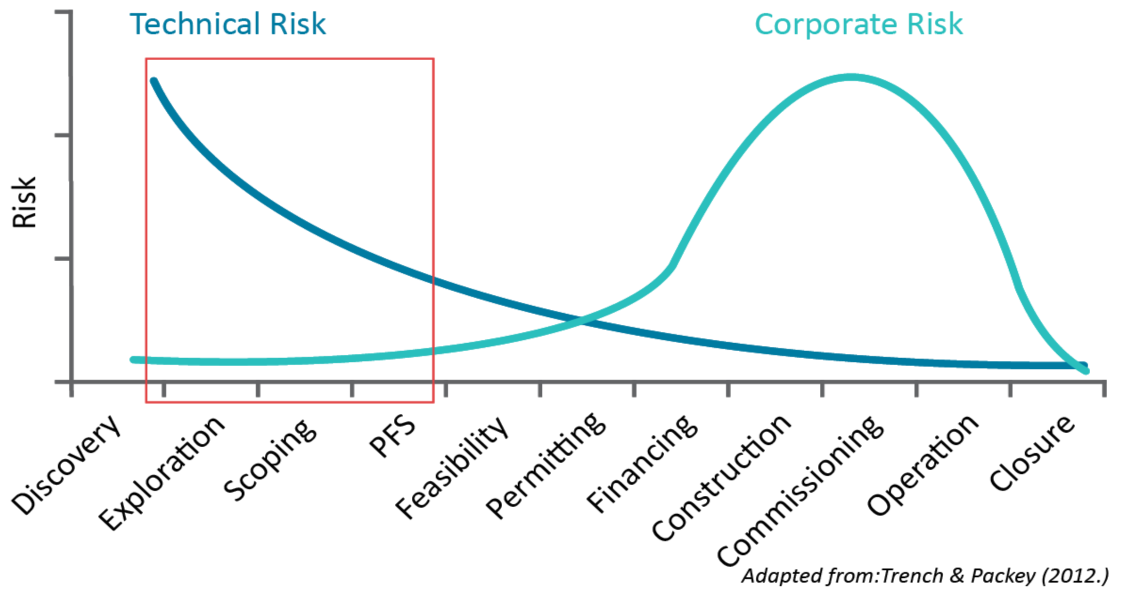

Figure 6 *The project development process*

Source: Trench & Packey, 2012.

[26] Mike O'Boyle, 2018, „Investment-Grade Policy: De-Risking Renewable Energy projects", Forbes (https://www.forbes.com/sites/energyinnovation/2018/11/12/investment-grade-policy-de-risking-renewable-energy-projects/#117f26084e77)

[27] DiaCore project, 2016, „ The impact of risks in renewable energy investments and the role of smart policies" (https://matressource.de/fileadmin/user_upload/Publikationen_Allgemein/zur_Ressourceneffizienz/diacore-2016-impact-of-risk-in-res-investments.pdf)

Smart and forward-looking public policies, as well as **a stable regulatory framework** and the **availability of well-trained professionals and intermediaries,** can mitigate risks, thus driving down costs and making renewable heating cheaper and more affordable and attractive to investors.

2.2.1. Economic and financing opportunities, best practices and innovative business models

When it comes to investments in the renewable heating and cooling sector, it is convenient to differentiate between public and private investors. Within the latter, an additional differentiation could be made between private investors on large-scale projects, and homeowners/investors on small-scale (i.e. residential scale for individual/multi-family use) projects.

An additional group could be included in this categorisation: energy cooperatives. They could be made of a mixed of private and public investors, or by purely private or purely public investors.

Because of their different size and nature, different financing opportunities will be available for the different categories of investors, different business models will apply, and different best practice examples could be followed.

This chapter will present examples of financing opportunities, best practices and innovative business models for the identified categories of investors.

It will finally provide examples on model contracts for heat supply and biomass procurement.

EU financing opportunities for large-scale public and private investors

Chapter 1.1 of this report has already outlined the economic benefits deriving from investments in renewable heating and cooling technologies, ranging from lower energy bills and decreased dependency on the rising costs of energy, to reasonable payback times (often made even shorter by the presence of favourable incentive schemes) and increased value of the building where they are installed. The economic benefits deriving from renewable heating and cooling projects are therefore clear.

Not only for their economic benefits, but also for their environmental and social benefits, the European Union and its Member States at both national and local level, are significantly supporting renewables energy systems since few decades already, through targeted investments and support schemes and dedicated EU or nationally funded projects[28].

For those investors willing to access European funding sources for projects aimed at deploying renewable energy in the heating and cooling sector, and at supporting innovation and job creation at regional level in the same sector, this paragraph presents the available EU funding sources suitable to develop projects in the heating and cooling domain[29].

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[28] The European Technology and Innovation Platform on Renewable Heating and Cooling (ETIP RHC) provides a database of 100 projects and counting in the area of renewable heating and cooling funded at EU level: https://www.rhc-platform.org/projects/

[29] For a better overview, please consult: R. van der Veen and E. Kooijman for the European Commission's Joint Research Centre, 2019, "Identification of EU funding sources for the regional heating and cooling sector" (https://op.europa.eu/en/publication-detail/-/publication/782b29a2-4159-11e9-8d04-01aa75ed71a1/language-en/format-PDF). The objective of the study is to inform regions on how they can better access European funding sources for projects aimed at improving energy efficiency and deploying renewable energy in the heating and cooling sector.

EU funding for heating and cooling projects is channelled both through (1) the five European Structural and Investment Funds (ESIF)[30] – which include i.e. the famous Cohesion Fund (CF)[31] and the European and Regional Development Fund (ERDF)[32] – and (2) through dedicated EU grants and financial instruments. The bulk of ESIF funding is concentrated on less developed European countries and regions, whereas the other EU funding sources are typically open to applicants in all Member States.

Many EU funding instruments require cross border cooperation, but there are also EU instruments that allow for a single applicant.

Some of the EU funding sources are well-known and established, others are less popular. Typically, the more popular programmes also have lower winning chances. They include, just to name a few, Horizon 2020[33] (to be followed by Horizon Europe[34] as of 2021) – which includes i.e. the European Innovation Council (EIC) Accelerator[35] for small and medium-size enterprises, the Fast Track to Innovation (FTI)[36], etc. – the LIFE programme[37], focusing on environment and climate action, the INTERREG: European Territorial Co-operation (ETC)[38], Connecting Europe Facility (CEF)[39], and many more.

EU funding sources cover different project activities, different phases in the technology development (Technology Readiness Levels/TRL) and increasingly also the different types of finance (e.g. equity, debt) that are required to fund a project – i.e. Smart Finance for Smart Building, European Energy Efficiency Fund, Green Bonds, etc. This offers opportunities to combine EU funding.

As part of the European Green Deal, the European Commission is also working on a new EU Renewable Energy Financing Mechanism[40], to apply from the start of 2021. This Mechanism will make it easier for Member States to work together to finance and deploy renewable energy projects[41].

Also the NextGenerationEU[42], a €750 billion temporary recovery instrument to help Europe repair the immediate economic and social damage brought about by the coronavirus pandemic, will provide new opportunities for projects and measures related to building renovation and to renewable energy systems in the residential sector.

Even though EU funding most often provides the basis for large-scale and long projects, it does not mean that individual end-users, intermediaries and small investors cannot benefit from EU-funded projects. Citizens are in fact always (at least indirectly, but often also directly) the ultimate target of EU funding, which aim to provide added value and to benefit the society as a whole, and this is also the case of this EU-funded REPLACE project.

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30 https://ec.europa.eu/info/funding-tenders/funding-opportunities/funding-programmes/overview-funding-programmes/european-structural-and-investment-funds_en
31 https://ec.europa.eu/regional_policy/en/funding/cohesion-fund/
32 https://ec.europa.eu/regional_policy/en/funding/erdf/
33 https://ec.europa.eu/programmes/horizon2020/en
34 https://ec.europa.eu/info/research-and-innovation/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
35 https://eic.ec.europa.eu/index_en
36 https://ec.europa.eu/programmes/horizon2020/en/h2020-section/fast-track-innovation-pilot
37 https://cinea.ec.europa.eu/life_en
38 https://ec.europa.eu/regional_policy/en/policy/cooperation/european-territorial/
39 https://ec.europa.eu/inea/en/connecting-europe-facility
40 https://ec.europa.eu/energy/topics/renewable-energy/eu-renewable-energy-financing-mechanism_en
41 European Commission, 2020, "European Green Deal: New financing mechanism to boost renewable energy" (https://ec.europa.eu/info/news/european-green-deal-new-financing-mechanism-boost-renewable-energy-2020-sep-17_en?pk_campaign=ENER%20Newsletter%20October%202020)
42 https://ec.europa.eu/info/strategy/recovery-plan-europe_en

Business models and best practice examples for residential private investors

Even though a renewable heating and cooling system for residential use brings many economic benefits, the upfront investment required to buy and install the device is often considered a barrier by many homeowners and investors. Nevertheless, it is nowadays possible to finance renewable systems with a **loan**, with conditions to be agreed together with the financing institution (most often, a bank).

In spite of the fact that the initial cost of a renewable system is higher than the cost of a fossil fuel one, the renewable system will eventually become cheaper, once the initial investment has been paid back by the energy savings you will get on your energy bills (it is important to remember that while renewable energy is free or mostly cheaper (e.g. biomass), fossil fuel prices are unstable and uncertain). The graph below provides a rough comparison between payback time of a system running on fossil fuels and of a system running on a renewable energy source.

If as a private consumer, you are planning to invest your savings on a modern renewable heating and cooling system for your home, we recommend you to read the REPLACE report on best practices[43], providing a long list of **best practice examples and innovative best practices** on heating and cooling systems replacements in Europe and in your region.

The report will provide you with real-life stories and suggestions on the technologies which might suit your home; it will give ideas on how to finance your investment; and it will present the monetary, environmental and social benefits you will get out of it.

The energy cooperative business model

An alternative way to finance the investment for a renewable heating or cooling system is to opt into an energy cooperative.

Energy cooperatives are groups of citizens who cooperate in the field of (renewable) energy and actively participate in the energy transition. They implement a bottom-up and collective dynamic based on the active participation of citizens and the involvement of multiple stakeholders (municipalities, local economic players, other cooperatives, etc.). In this way, energy cooperatives propose a distinct business model (compared with conventional energy companies) that promotes citizens' involvement in the decision-making processes and leaves room for multi-stakeholder engagement and dialogue[44].

For example, in the case of photovoltaic cooperative projects, often the PV plant is built in the vicinity of the cooperative members which have the opportunity to directly receive some of the PV power. The share of the power supply could depend on the share of the cooperative member[45]. The price of the power supply is transparent and does not include any profit margins. That is why there is a great opportunity to save money for consumers in such cooperative models. And in addition to that, the users do not have to bear the high upfront cost to purchase the renewable system on their own.

Another option to set up an energy cooperative is through citizens participation: in this business model, citizens finance i.e. the solar thermal project and get an interest rate for their investment.

[43] https://replace-project.eu/?page_id=256

[44] REScoop project, "Report on REScoop Business Models" (https://www.rescoop.eu/uploads/rescoop/downloads/REScoop-Business-Models.pdf)

[45] Going Solar, "The top 5 Ways to Finance Solar Panels for Your Home" (https://goingsolar.com/the-top-5-ways-to-finance-solar-panels-for-your-home/)

REScoop.eu, the European federation of citizen energy cooperatives, which represents a growing network of 1.900 cooperatives operating across Europe and over 1,25 million citizens, provides a long list of best practice examples and real-life stories of energy cooperatives[46].

One successful example of energy cooperative is BENÖ (Bioenergy Lower Austria) business model, applied in Austria, which refers to a farmers' cooperative which is specific to small scale DH, micro grids, in-house heat production and supply (e.g. residential buildings, commerce and service buildings, public buildings, agricultural-forestry facilities, industries). It is a "roof-cooperative" for rural cooperatives. It allows farmers to focus on the tasks they are familiar and capable of realizing (supply of boilers with biomass/woodchips, operation and simple maintenance of boilers, etc.), while the peak-cooperative which has this expertise, performs bookkeeping, detailed planning, etc. The cooperation of these entities allows cost reduction via common procurement of equipment, exchange of experience, etc[47]. Similarly, the concept of "**bioenergy village**" can be considered a form of energy cooperative.

A bioenergy village is a village, municipality, settlement, or community which produces and uses most of its energy from local biomass and other renewable energies. Biomass from forestry, agriculture and waste is used in a bioenergy village to generate electricity and heat. This is usually implemented by several technologies of different sizes, such as: woodchip boilers, pellet stoves, logwood boilers, biogas plants, combined heat and power plants using woodchips etc. They usually supply a small district heating grid of the village in order to distribute the heat to the consumers. The involvement and participation of a broad range of local stakeholders and consumers is crucial for the success of a bioenergy village. Ideally, biomass suppliers and energy consumers are shared owners of the necessary installations[48].

Business models for district heating and cooling networks based on renewable energy sources

The **upfront capital costs** involved in district heating and cooling (DHC) projects are significant, because of the much larger scale of the projects, compared to the replacement of an individual heating system for residential use. As an expensive heat distribution grid infrastructure (with a lifetime beyond 40 years) must be built, such projects usually pay off if the houses (heat consumers) are rather big or standing densely, close to each other. Nevertheless, due to economies of scale district heating projects can become cheaper per heat unit sold than individual in-house heating systems. Furthermore, flue gas cleaning systems ensuring clean air (e.g. in densely populated or touristic areas or in areas developed for health purposes) and fuel supply are also easier to realize and to control from a central point. In general, district heating networks should eventually pay for themselves (i.e. via heat sales, connection fees, operating grants and other and secondary services), but it can take 8-10 years (at good sites), or more, of **payback time** for the initial expenses for the design and construction to be recovered and for any profits to be generated. This means that district heating projects need investors who are looking for a relatively secure long-term revenue stream rather than a quick return on their capital[49]. Generally, larger district heating grids are infrastructure investments and are therefore frequently realized jointly by private and public investors. On a smaller scale, biomass micro grids – connecting only a few houses standing close to each other by a small grid – are often realized by a group of farmers (as community projects) as they get a special purpose vehicle to constantly sell wood chips from thinning operations in their own forests at a stable and predictable price. Here long-term financing of stable

[46] REScoop.eu: www.rescoop.eu

[47] Romanian Association of Biomass and Biogas (ARBIO), Bioenergy4Business project, "Report on bioenergy business models and financing conditions for selected countries".

[48] BioVill project, "What is a Bioenergy Village?" (http://biovill.eu/bioenergy-villages/)

[49] CoolHeating project, 2017, „ Guidelines on improved business models and financing schemes of small renewable heating and cooling grids" (https://www.coolheating.eu/images/downloads/CoolHeating_D5.1_Guideline.pdf)

forest management operations, ultimately increasing the value of the standing forest, is a motivation that allows for payback times beyond 10 years. Usually, local governments play a central role in addressing the risks (actual and perceived) and costs associated with investing in DHC systems. They stimulate private investment via financing and fiscal incentives (i.e. grants, low-cost financing/loans, subsidies, tax incentives, etc.), by making available city assets (such as lands or buildings) and demonstration projects on emerging technologies or new DHC policies.

Business models for DHC systems are project specific. A selected and defined business model needs to ensure that all stakeholders – including investors, owners, operators, utilities/suppliers, end-consumers and municipalities – can achieve financial returns, in addition to any wider economic and other (social, environmental) benefits that they seek.

The **involvement of the public or private sector** depends broadly on two factors: the return on investment for project investors, and the degree of control and risk appetite of the public sector.

Typically, while private sector investors will focus primarily on the financial aspect of a given project, the public sector, either as a local authority or a public utility, will also account for additional socio-economic and environmental costs and benefits that are external to standard project finance. The public sector may wish to steer a DHC project because of a variety of local objectives, including cheaper local energy for public, private and/or residential customers (e.g., the alleviation of fuel poverty); local job creation; local wealth retention; low-carbon power generation; and/or local air pollution reduction[50].

With the correct level of government regulation, and with a professional planning and dimensioning of all plant components (boiler sizes and load management, pipe dimensioning, grid length related to heat sales per meter, flow and return temperature spread etc.) in conjunction with a dedicated planning and with implementation quality assurance systems[51], district heating investment can offer attractive returns as the

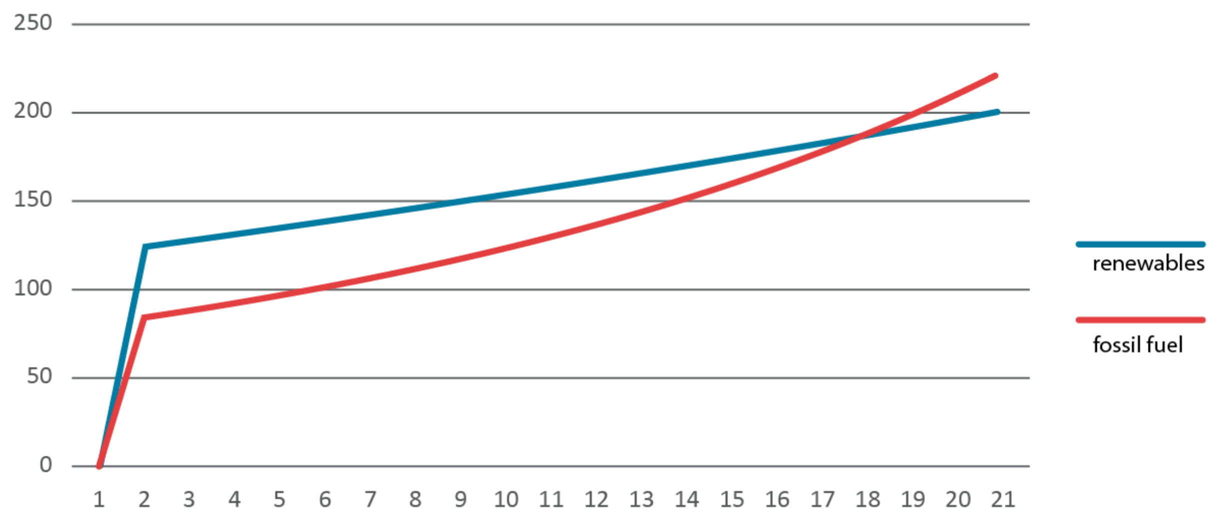

***Figure 7** Payback time fossil fuel vs. renewable system*

Source: REPLACE project

[50] Ibidem.

[51] For example in Austria, to receive a grant, plants would have to pass and fulfil the requirements of the quality management system "QM Holzheizwerke®", also applied in Germany and Switzerland on a voluntary basis. The requirements defined for the owners and planners of biomass heating plants under QM Holzheizwerke® are the following:

The heat demand data have to be plausibly determined according to the relevant valid rules and have to be documented by load characteristics and annual heat lines as well

- the DH network has to have a minimum density
- the combustion system has to be constructed according to a certain utilisation rate
- defined standard solutions have to be used for the hydraulic and pertinent measuring and the control system

technology becomes an attractive asset for long-term investors. Attracting private investment to significantly increase the network of district heating across the EU would contribute significantly to the decarbonisation of the heating sector[52].

In terms of **costs for homeowners**, connection to a small DHC system represents a comparable cost of a new and efficient individual heating system for a household. The investment costs of one typical household connection can be up to €4,000 -10,000 per connected household. Costs may vary as on-site conditions vary.

Usually, heat consumers can be classified in three basic categories: households, public buildings and industrial consumers. Especially when it comes to households, it is recommended to invest efforts to motivate them to connect to the DHC network. One option, besides marketing the substantial increase in comfort, is to decrease the connection fees and to cover the connection costs within the service price. It has been shown in some projects that at least some consumers prefer to get less energy-cost savings over having high connection costs. In some cases, the connection costs can be subsidized through national grant schemes. An innovative approach would be that a municipality would subsidize connection costs for households for the first (demonstration) projects in the municipality[53].

DHC often ends up being in a disadvantaged position compared to other heating solutions because most of the economic analyses available to end-users do not include all cost items when comparing DHC to other technologies, but only take into consideration operational costs (fuel, electricity, water). Instead, DHC can generate additional savings thanks to low operation, maintenance and revisions costs.

The ESCOs business model

An energy services company (ESCO) provides energy services to final energy users (such as households), including the supply and installation of energy-efficient equipment and/or building refurbishment.

As such, an ESCO is a recognised business model that drives the penetration of renewable heating and cooling solutions, but it has not yet reached its full potential throughout the EU. The core stakeholders of ESCOs are usually small and medium sized enterprises (SMEs). Increased adoption of the ESCO model throughout Europe would be key to drive performance expectations of the renewable heating and cooling sector, as it dictates that the earnings of the professional stakeholders when designing, installing and maintaining energy systems, are directly related to performance/energy revenue criteria of the systems installed[54].

In fact, the ESCO guarantees energy savings and/or provision of the same level of energy service at lower cost, and the return of the ESCO's investments is tied directly to the energy savings achieved. Therefore, the ESCO accepts some degree of risk for the achievement of improved energy efficiency and reduced energy costs, coming from the use of renewable energy sources.

In heat production, the business model often consists of the ESCO investing in heat production equipment while the customer pays the same price for the heat as before the investment. The heat produced with the

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- a high utilisation rate requires an optimised waste heat recovery and an optimal layout of the heating network
- the biomass storage has to be designed in accordance to the biomass demand of the plant and the regional biomass supply
- the used biomass has to be in line with the detailed classification of QM heating plants.

[52] Whitehelm Advisers, 2019, "The European Heat Sector – Challenges and Opportunities in a Hot Market" (https://www.whitehelmcapital.com/wp-content/uploads/2019/04/Thought-Leadership-April-2019-District-Heating-1.pdf=

[53] Ibidem

[54] ETIP RHC, 2019, "2050 Vision for 100% renewable heating and cooling in Europe" (https://www.rhc-platform.org/content/uploads/2019/10/RHC-VISION-2050-WEB.pdf)

new system (e.g. using renewable fuel) is cheaper than the older (i.e. using fossil fuel) system. After the ESCO has recouped its investment, the customers get ownership of the equipment and also benefit from lower heating costs[55].

For the customers, there are many benefits of the ESCO business model (also called plant contracting), which help to promote biomass heating among sectors where otherwise it would not be utilised without the possibilities of contracting:

- No own initial investments are necessary for the customer, so financial resources can be used for other purposes
- One contact person for the whole project
- Use of modern and efficient technology and special know-how by the contractor
- Use of renewable and clean energy
- Savings in fuel consumption due to efficient operation of the plant
- Assignment of duties to the contractor (organization, operation of the plant)
- Assignment of risks to the contractor (financial, technical)
- Guaranteed reliability: maintenance, repairs, operation, optimization, are done by the contractor
- Modern image of the real estate
- Quick realization is possible
- Security of supply.

Wood energy contracting – Hitzendorf

District Graz - Umgebung

Supplied buildings: four residental builings with 15 flats

Builder: ÖWGWS Gemeinnützige Wohnbau-gesellschaft mbH, Graz

Fact about the plant

Heat delivery 80 kW

Consumption per year 110 MWh

Fuel storage room 50 m³

Annual wood chip consumption: approx. 200 m³ – 100%% rutic wood chips

Facility system 80 kW retort firing system with 5 X 5 stirring feeder

Plant operator WLG Hitzendorf GesbR., 3 farmers

Costs (price excl. VAT)

Invetment costs	€	45.600,00
structural measure (bunker)	€	14.000,00
boiler	€	18.500,00
installation heting room	€	7.100,00
pipe for heat ditribution	€	4.000,00
planning and management	€	2.000,00
Connecting charge per kW	€	223,00
Standing charge per kW and year	€	16,00
Megawatt hourly rate per MWh	€	49,42
Metring charge per month	€	8,00

Wood energy contracting – Nestelbach

District Fürstenfeld

Supplied buildings: four residental builings with 19 flats

Builder: ÖWGWS Gemeinnützige Wohnbau-gesellschaft mbH, Graz

Fact about the plant

Heat delivery 100 kW

Consumption per year approx. 150 MWh

Fuel storage room 50 m³

Annual wood chip consumption: approx. 270 m³ – 100%% rutic wood chips

Facility system 1000 kW retort firing system with 5 X 5 stirring feeder

Plant operator WLG Nestelbach GesbR., 3 farmers

Costs (price excl. VAT)

Invetment costs	€	43.000,00
technical facility	€	17.500,00
structural measures	€	21.000,00
electrical and heating intallation	€	4.500,00
Connecting charge per kW	€	254,00
Standing charge per kW and year	€	15,00
Megawatt hourly rate per MWh	€	47,20
Metring charge per month	€	18,00

***Figure 8** ESCO examples*

Source: Regionalenergie, Styria (Austria)

[55] CoolHeating project, 2017, „ Guidelines on improved business models and financing schemes of small renewable heating and cooling grids" (https://www.coolheating.eu/images/downloads/CoolHeating_D5.1_Guideline.pdf)

For larger investments, on the other hand, financing of biomass heating plants has become more difficult due to bank-restrictions (Basel III) and reduced risks taken by banks. The contractor must bear the risks of insolvency by the customer.

The business model is preferred by project developers who want to be guaranteed the above services without being involved in construction and operation of plants. Such project developers are usually customers who concentrate their forces on their business apart from bioenergy (housing developers, hotel owners, industrial customers, etc.).

The ESCO's operations are often difficult to apply successfully on a small scale due to long payback periods of investments, and at present there is no simple method for an SME to raise the initial finance to initiate an ESCO contract. Therefore, there is an urgent need for suitable framework conditions allowing the further uptake of this business model.

Bioenergy business models

The most common business models for bioenergy in Europe include investor's own business initiatives and energy supply contracting, and to a lesser extent also energy performance contracting, cooperatives, partnerships and feed-in tariff schemes.

The Investor's own business initiative business model refers to the funding of the investment through own capital of the investor or through the combination of own capital, grant and bank loans, based on investor's planning. This business model is the most common and refers to in-house heat production in industrial facilities that either utilize their own biomass residues (in case the industry is a wood based) or are supplied the biomass from traders or other companies.

Under the **Energy Supply Contracting business model**, an ESCO (contractor) supplies useful energy, such as electricity, hot water or steam to a client and is remunerated on contract basis. Usually, the ESCO supervises the entire process from the purchasing of fuel (e.g. biomass) to the delivery and invoicing of energy to the client. Financing, engineering design, planning, constructing, operation and maintenance of biomass production plants as well as management of energy distribution are often included in the complete service package.

Under the **Energy Performance Contracting business model**, an ESCO (contractor) implements an energy saving project/intervention for a client guaranteeing energy cost savings in comparison to a historical (or calculated) energy cost baseline. For its energy costs savings services, the ESCO receives a performance-based remuneration from the client.

Co-operatives are legal/financial entities owned, controlled and operated by a group of people for their own benefit usually on a community/municipal level. Each member contributes equity capital and receives shares of the firm.

Feed-in tariff schemes are policy mechanisms offering long-term contracts reimbursing RES producers based on the cost of generation of each technology[56].

[56] Romanian Association of Biomass and Biogas (ARBIO), Bioenergy4Business project, "Report on bioenergy business models and financing conditions for selected countries".

2.2.2. Model contracts for heat supply and biomass procurement

The development and implementation of a district heating and cooling project involves a plethora of contracts: i.e. contracts with project developers/consultants/experts, contracts with manufacturers, contracts with fuel suppliers, contract related to financing and contracts on heat supply with end users (households, public buildings or industrial consumers).

A contract is a binding agreement between two or more parties, it is subject to relevant national legislation, including decisions made by judicial authorities, and it must comply with the existing regulatory framework. Even when it is possible to use an existing public contract for heat supply as a template, because of its complexity, it is anyways always recommended to involve the professional and expert advice of a lawyer when stipulating a contract.

Model contracts for heat supply

Because projects like the establishment of a district heating and cooling network represent a relatively large investment and a long-term commitment to a centralised heating solution, they are accompanied by a significant risk factor. Therefore, the elaboration of preliminary heat supply contracts, binding the heat utility and the heat consumers already in the development phase of the project can mitigate the risk because it provides a basis of guaranteed revenue for the project. Additionally, the contract as a legislative obligation ensures the quality of the district heating and cooling service and the protection of the consumers' rights.

The contracts on heat (and cold) supply are subject to national legislation and regulation, varying from country to country and defining the basic rules, conditions and criteria on distribution of heat, as well as the rights and responsibilities of the heat providers and consumers.

Heat supply contracts usually include general information on connection to the district heating network and on ownership of equipment, on heat supply specifications, on costs (installation costs, heat costs and metering costs), and on other specifications (i.e. metering and monitoring, maintenance, payment specifics, access rights, liabilities)[57].

Key features of a typical heat delivery contract, by the Austrian example

A **contract between a heat supplier and a heat consumer can be established freely**. Usually, however, the contract would follow the guidelines of a 16 page model contract which is available via a website[58] and which would only little differ from one of the Austrian federal states to the other. According to this reference, a **typical heat delivery contract between a heat supplier and a customer would comprise the following elements**:

- Maximum power connected (kW)
- Average annual heat delivery (MWh/a)
- The duty of the customer to allow the construction of the heat transfer station in his building – the heat transfer station would remain property of the heat-supplier
- The time of heat-delivery: only in the cold season or the whole year round, both options are possible

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[57] CoolHeating project, 2017, "Guideline on drafting heat/cold supply contracts for small DHC systems" (https://www.coolheating.eu/images/downloads/CoolHeating_D5.3_Guideline_on_drafting_heat_cold_supply_contracts_for_small_DHC_systems.pdf)

[58] See: https://www.noe.gv.at/noe/Energie/Mustervertrag1.html, in German only (link copied on 12.04.2021).

- An obligation for the customer not to use any additional heating systems (with the exception of tiled stoves, solar thermal plants and similar devices)
- Obligations for the customer to maintain and service his part of the heating system
- Composition of the price for the heat, which consists of three parts:
  - A heat-price (€/kWh) which would cover variable costs like fuel costs, ash disposal costs, and others
  - A basic price (€/month or per year), which would cover fixed costs on the side of the plant like investment, plant management, maintenance, all independently form energy consumption
  - A meter rent (€/kW), which covers fixed costs on the side of the customer
- Some regulations referring to the time of payment by the customer (4 times a year, monthly, etc.) and rights of the heat supplier in case of non-payment
- A reference to price-adjustment and
- Some technical details of the plant, the heat-delivery station etc.

For the **Plant Contracting business model**, the typical duration of a contract is **15 years**.

A key success factor for heating & cooling projects is the elaboration of sound heat/cold supply contracts which provide transparent and clear conditions and a solid long-term relationship between the heat-producers, -distributors and -consumers.

Model contracts for biomass procurement

Similarly to the realisation of district heating and cooling projects, contracts on biomass procurement can help the process.

For investor-sized projects mainly wood chips and wood pellets seem to be of relevance. Log wood is used by households rather, where it is of relevance too, also from a quantitative view of point.

Wood pellets are an industrial, standardized product with clearly defined properties and a narrow band of water content, particle size, impurities and calorific value per kg etc.

When buying wood pellets, consumers should primarily orientate themselves on the ENplus certificate – only the ENplus A1 quality is suitable for use in boilers or pellet stoves in households.

The ENplus quality seal for wood pellets controls the entire supply chain from production to delivery to the end customer and thus offers a high level of quality assurance and comprehensive transparency. The most important quality characteristics for pellets are a light colour, a shiny surface, low fines content (dust), high strength and low ash content. In addition, pellets should not be longer than 45 mm.

In general, wood pellets procurement of larger quantities (>1 ton) is no problem, e.g. when it is purchased and shipped via a pellet truck. Such a truck, loaded with 13 to 23 tons of pellets, can blow the pellets over a distance of 30 m with a hose and the finally delivered fuel amount is weighted automatically by the lorry itself on-site.

In the case of woodchips, biomass fuel procurement is more challenging. Wood chips, due to their nature can vary e.g. in particle size, water content, wood species and impurities. Therefore supply contracts must make clear what is purchased and under what conditions.

Key features of a typical raw material supply contract

Under the **Investor's own business initiative**, typical terms of a **biomass supply contract** are delivery **quantity**, delivery **date**, **quality of fuel** adapted to the combustion plant, **remuneration** and other rights and obligations of each party. **Price escalation clauses** bring the general market trend into account and facilitate the conclusion of long-term contracts.

The **cost escalation clauses** often involve a price fixing concerning the development of prices for fossil fuels and/or for wood. **Wood chip prices** depend on the **quality and quantity and the respective supplier**.

Within the delivery note, the supplier specifies the delivery volume and if procurable the composition of timber species. The customer randomly checks the plausibility of the particulars of the delivery only if it seems to be necessary. **In some cases, the billing is based on measurements using heat meters at the output of the boiler**.

There are several billing options:

- **Billing on volume**
  - most suitable for bulk material for homogeneous fuel ranges
  - least effort (quantity determination by the dimensions of the loading space)
- **Billing on mass and water content**
  - suitable for bulk material with inhomogeneous fuel ranges
  - quantity survey by using in-house scales
  - additional water content measurements increase the accuracy in determining the energy content
- **Billing on the amount of heat**
  - only makes sense when there is only one biomass supplier
  - reduced technical effort and high accuracy

For larger biomass plants running on woodchips (e.g. boilers with some 100 kW capacity, district heating plants etc.) it is highly recommended to bill on mass and water content, i.e. to weigh the fuel mass (that needs a weighbridge and a weighing before and after delivery) and to measure the water content (e.g. electronically or via a burning chamber).

That means that the woodchips should be purchased on a dry mass basis, preferably – depending on particle size and wood species purchased. Higher water contents may lead to a reduction of the fuel price as water has to be vapoured and lowers plant energy efficiency if the plant cannot run in water condensing mode.

A useful tool to convert biomass fuel costs easily and quickly into different units, like costs per mass, volume, lower calorific value can be found on the Klimaaktiv website[59]. The multilingual tool (see downloads) is able to treat different wood assortments (like woodchips of different wood species, wood pellets, log wood) and straw in terms of different particle size and water content (see English instruction manual).

The raw material (biomass) shall be reasonably free from incombustible foreign particles, such as stones. **If the quality of the delivered wood does not meet the agreed specifications, the purchaser may reject the delivery**. The supplier must substitute the delivery on his own expense. In some cases, the supplier is liable for damages that are proven to be held responsible for pollution in the fuel delivered.

[59]https://www.klimaaktiv.at/erneuerbare/energieholz/werkzeuge-und-hilfsmittel/kenndatenkalkulation.html

A comprehensive and exhaustive example of all the essential elements which should be included in a contract for biomass supply are provided by the EU-funded project Bioenergy4Business and are available at this link (English only).

3 WHICH REPLACEMENT OPTIONS ARE AVAILABLE ON THE MARKET

While in the past, the choice of the heating system to promote and to sell to your customers 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 a renewable heating system.

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 illustrations of their functioning, planning guidelines for installers and intermediaries, and the main benefits that the end-users should know.

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 each building type and to your customers' 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 the best renewable heating system for each situation.

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 a heating system or the improvement of the energy performance of a building, illustrated in chapter 4 of this REPLACE project report.

Before diving into the main features of the technologies, an introductory paragraph will explain which heating and cooling system fits best to the different building types and sizes.

Enjoy the reading!

3.1. Which system fits to which building?

This paragraph shows which type of heating system based on renewable energy sources, or also a connection to district heating and cooling, is most suitable for different types and sizes of buildings (i.e. to single or double family houses or to larger volume building). What kind of system is recommended depends not only on the size, but also on the thermal quality of the considered building, i.e. the useful heat demand in kWh per m² and year according to the Energy Performance Certificate[60].

But before focusing on replacement options, it is important to remind that replacing an old and inefficient heating systems with an efficient and renewable one is not always the best solution. In fact, it might happen that the building needs insulation measures first. In fact, 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 heat supply in a building to be cost-efficient, it might in fact happen to be of primary importance to first realize 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[61].

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

Passive house system – Comfort ventilation with air heating

The small amount of energy that is required in a passive house does not necessarily have to be supplied to the building via its own heating system with hot water distribution (such as underfloor heating or radiators). It can also be supplied by reheating the supply air in a comfort ventilation system that is already in place. As the heat is only supplied to the building via the supply air, the heating capacity of this system is very limited and only suitable for passive houses. Care should be taken to ensure that the passive house criteria are met, otherwise comfort may be compromised by too high supply air temperatures (above 52 °C) or too high air volumes (dry air, draughts), or too low room temperatures.

Combination devices

Combination devices save space and are very cost-effective thanks to the combination of a heat pump for space heating and hot water preparation, plus a comfort ventilation system in one device. In connection with a water-operated heat distribution system, its use in passive houses, as well as in almost zero-energy houses (up to energy class A) is highly recommended.

Heat pumps

For reasons of efficiency, heat pumps are particularly recommended in combination with low-temperature (up to 40°C) heat distribution systems, such as underfloor, wall or ceiling heating. Air heat pumps are particularly suitable for buildings with a low energy requirement and usually represent the best price-performance ratio. For buildings with a higher energy consumption, other heat pump designs may be more advantageous.

[60] Klimaaktiv, 2020, „Die richtige Heizung für mein Haus – Eine Entscheidungshilfe“ (https://www.klimaaktiv.at/service/publikationen/erneuerbare-energie/richtige-heizung.html)
[61] Klimaaktiv, „Renewable Heating“ https://www.klimaaktiv.at/english/renewable_energy/renewable_heating.html)

- **Ground source heat pumps**

Whether with geothermal probes or flat-plate collectors, ground heat pumps work very efficiently. Geothermal probes or geothermal collectors - if dimensioned correctly - work for several decades without problems.

- **Groundwater heat pumps**

Groundwater heat pumps work very efficiently due to the constant and high temperature of the water source (around 10 °C according to regional conditions). Both the feasibility and the investment costs depend heavily on the local conditions such as the groundwater level, water quality, approval procedures, etc.

- **Outside air heat pumps**

Outside air heat pumps are inexpensive to purchase and are particularly recommended for new buildings and for very good renovations. They are a little less efficient than groundwater or ground source systems, but clearly more environmentally friendly and less polluting than heating systems running on fossil fuels.

Biomass heating

Biomass heating shall be preferred when it comes to high heating flow temperatures and high energy consumption. It is recommended to well insulate the building before replacing the heating system, in order to significantly reduce energy consumption and heating costs.

- **Pellet central heating with buffer storage**

Pellet heating systems are fully automated and the logical successor technology to oil heating in buildings with radiators. However, the boilers available on the market are usually too large for passive or almost zero-energy buildings, thus resulting in higher investments costs. On the contrary, for buildings of energy efficiency class "A" or lower, they are an extremely recommendable solution from both an ecological and an economic perspective. A pellet heating system can in fact provide high flow temperatures without loss of efficiency, which is why it is not tied to a special heat delivery system.

- **Wood gasifier central heating with buffer storage**

Apart from the lower costs, the same conditions apply to the wood gasifier as central heating system. A wood-burning central heating system always includes a buffer tank. In this way, the heat generated can be stored temporarily and released to the building upon requirement. This increases the comfort because it makes the reheating necessary only once a day. However, the higher the energy demand of the building (i.e. the lower its efficiency class), the more frequently it needs to be reheated, which limits the comfort and the range of application of the wood gasifier as central heating system.

- **Local/district heating biomass-based**

The connection to a local or district heating network has many advantages: 100% availability, no longer investments in a boiler replacement, no additional costs for service and maintenance, free space in the boiler room and billing based on actual consumption are just a few of them. Nevertheless, in the case of a passive or low-energy house, the amount of heat consumed is so small that connection to a local/district heating network is usually not economically convenient for neither the heat user nor the heat supplier. On the other hand, buildings with higher heating requirements are perfectly suited for connection to a district or local heating network. Since the heat is also available with correspondingly high flow temperatures, practically any heat delivery system can be operated at the right temperature.

- **Fireplace stove (logwoods/pellets) or tiled stove for whole house heating with buffer storage**

The installation of a water-based wood-burning stove is a relatively inexpensive heating alternative, whereas the higher investment costs of a tiled stove are often consciously accepted for reasons of aesthetics or comfort. A fireplace or tiled stove that is operated as a water-fired central heating system has a limited heating capacity and therefore cannot supply with sufficient heat buildings of a low energy class and with a high energy demand. In addition, the more often heating is required or the fuel needs to be refilled, the less comfortable the system is.

- **Fireplace stove (logwoods/pellets) or tiled stove for whole house heating without buffer storage**

Especially in a passive house with an open floor plan, a fireplace or tiled stove, without water-guided heat distribution, can be a very good alternative as a whole house heating system and, in combination with comfort ventilation with heat recovery, it provides the ideal solution. However, as energy consumption increases, it becomes more and more difficult to guarantee an even distribution of heat throughout the building and it is therefore not recommended for buildings with bad energy classes.

Direct electrical heating (e.g. infrared heating) with photovoltaic system

An electric direct heating system generates heat directly in the rooms of heat demand. The most common devices are electric convectors, storage heaters and infrared panels. A problem with all electric heaters is the relatively high electricity consumption in the winter months. Since domestic electricity generation from renewable energy sources is significantly lower during the cold season, the CO_2 emissions of electric heaters are comparable to those from fossil fuels such as natural gas and heating oil. Even the combination with a photovoltaic system improves the balance only slightly because PVs can generate very little electricity in the winter months. As the heat demand of the buildings increases (in buildings with poor energy classes), the electricity costs significantly increase, and the advantage of initial low investment costs is thus cancelled out. On the contrary, electric heating can be very economically advantageous in buildings with a very low heating requirement (passive or almost zero-energy buildings).

This chapter has provided general recommendations on what heating system is normally more suitable to which building type and size, but conditions can vary on a case-by-case basis and it is therefore always important to talk directly to the end-user and to carry out an inspection of his/her home in order to personally assess what system fits best his/her building.

The REPLACE Heating Matrices[62] provide additional insight and detail to this short overview.

[62] https://replace-project.eu/?page_id=1582

FACT SHEET

BIOMASS BOILERS FOR WOOD PELLETS

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

Planning guidelines and recommendations for installers

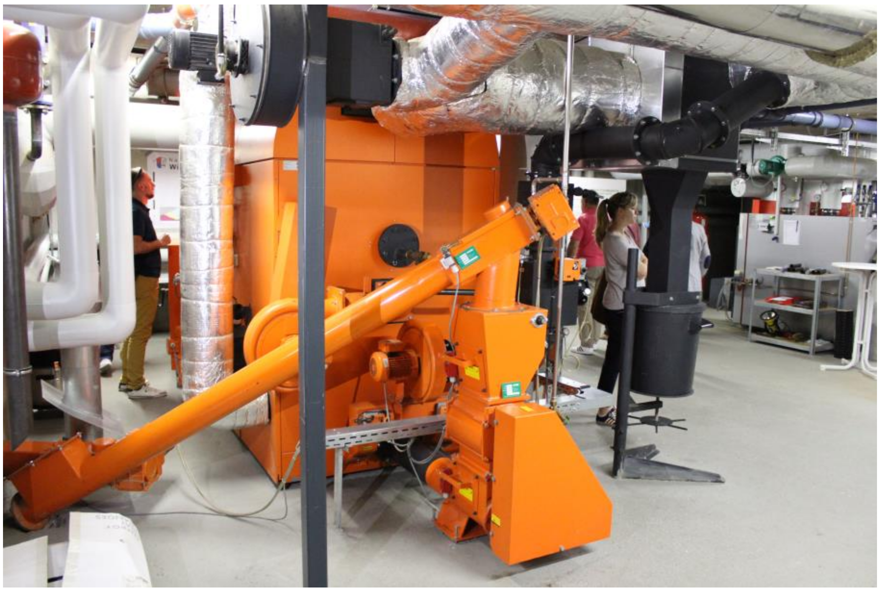
Boiler size

In the past, oversized systems were often installed for oil or gas boilers. For new installations, especially pellet boilers, it is key to suitably dimensioning the system and to not oversize it. However, a prerequisite for pellet boilers is the installation of sufficiently dimensioned buffer storage tanks.

For pellet boilers in residential buildings, a rough calculation of the previous heat demand is usually sufficient. A consumption of 3,000 liters of heating oil per year, for example, leads to an energy output of approx. 30,000 kWh. A heating system including hot water preparation is in operation for approx. 1,800 hours per year. If the amount of heat is divided by the full load hours, you get the approximate nominal output of the new system. For example: 30,000 kWh / 1,800 h = approx. 17 kW.

Buffer storage tank size

Pellet boilers usually require the installation of one or more buffer storage tanks. A sufficient size of buffer tank is required according to the boiler manufacturer's specifications and recommendations. In general, it is



advisable to plan for a larger buffer storage tank than a smaller one. However, excessively large storage capacities lead to higher heat losses and should also be avoided.

Exhaust gas emissions

In the member states of the EU there are different laws and regulations on the permissible emissions, especially fine dust from pellet boilers. The emissions largely depend on the regulation of the boiler. To minimise emissions, all eligible pellet boilers are equipped with a lambda probe. These values are processed by the control system and thus control the speed of the induced draught fan so that optimum combustion always takes place.

Noise protection

The operation of pellet boilers is usually quite. Only the cleaning of the flues is automatic, usually by means of a vibrating grate. Customers should be informed before the purchase that this process takes place once a day.

Limescale deposits in the freshwater system

The installer should know the water hardness of the fresh water supply in the customer's building. This can have an impact on the technical plans for the hot water supply. In recent years, so-called freshwater stations, which are equipped with a heat exchanger and connected to a buffer tank, have become increasingly popular. They defuse the problems of legionella. However, they are more sensitive to limescale deposits than a hot water storage tank. Therefore, the heat exchanger of the freshwater station should be rather large and vertically installed. There are several advantages and disadvantages to a freshwater station over a hot water cylinder, and the final choice will always be a case-by-case recommendation by the installer and a decision by the customer. For example, the use of a hot water supply circulation pump in a large building may destroy the temperature zones of a buffer tank if the freshwater station is installed, whereas the circulation pump will only destroy the temperature zones of the smaller hot water tank if it is installed.

Boiler life

The lifetime of a pellet boiler depends on the general quality of the boiler and its combustion chamber. After all, the longer the boiler is in operation, the shorter its service life. Therefore, the combination with e.g. solar collectors can be recommended, which allows the boiler to be switched off completely in summer. All these factors must be clearly communicated to the customer, who should be well-briefed before the system is put into operation.

Combined systems

The main disadvantage of log boilers is that they have to be fed manually. This requires that someone is always available to feed the boiler during the cold season. The frequency of charging depends on the outdoor temperature, system configuration, heating levels, etc. It can happen that no one in the household is available to feed the boiler due to special situations, e.g. illness or holidays. Therefore, log boilers are increasingly used in combination with pellet boilers. It is important that the system may be routed via a common chimney, as there is usually no additional chimney flue with a suitable diameter available. The connection of a solar thermal system is always recommended to cover the hot water heat demand at least in summer.

Pellet storage

For storage and automatic extraction of pellets, the existing space of the former oil tank can usually be used. Provided they are dry and sufficiently large, it makes sense to fit them with wooden slopes and an extraction screw. Boiler manufacturers usually offer practical components for erecting bag or fabric silos. This allows the available space to be used optimally.

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.**

What could you tell your customers?

→ **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.

FACT SHEET

BIOMASS BOILERS FOR LOGWOOD

Building type: single-family houses, multistore houses

Planning guidelines and recommendations for installers

Chimney

One of the first things an installer must check at the client is the suitability of the existing chimney for a logwood heating system. The diameter of the chimney pipe must fit with the requirements of the logwood boiler and thus it needs to be measured. If the chimney does not suit, a chimney refurbishment or the installation of a new one (e.g. stainless steel chimney outside the building) needs to be considered. This adds costs and may be a reason for the client that a logwood boiler is no option. Thus, the installer should clarify, before any other planning steps are made, the suitability of the existing chimney with the chimney sweeper and potentially also with the chimney manufacturer.

Boiler size

Historically, often oversized capacities for oil or gas boilers were installed. For new systems, especially for pellet and woodchip boilers, but also for heat pumps, a suitable boiler capacity should be determined which is not oversized. However, for logwood boilers, this is different. The larger the boiler capacity, usually also the larger is the combustion chamber. This allows to produce more heat per loading act with logwoods, and

thus increases the comfort for the client. Therefore, a slight oversizing of the logwood boiler can be useful. However, a precondition for logwood boilers is the installation of sufficiently sized buffer tanks.

Buffer tank size

Logwood boilers usually require the installation of one or more buffer tanks. A sufficient size of the storage capacity is required according to the specifications and recommendations of the boiler manufacturer. In general, it is recommended to plan a lager storage capacity than a smaller one. However, too big storage capacities lead to higher heat losses and should be avoided as well.

Electrostatic filters for flue gas emission treatment

The member states in the EU have different laws and acts on the allowed emissions, especially particulate matter, of logwood boilers. The emissions largely depend on the quality of the boiler and of the used wood. In order to minimize the emissions electrostatic filters can be used. In many cases, they are not yet legally required, but this may change with the introduction of stricter emission legislation. So, even if considerable additional costs for the installation of electrostatic filters need to be assumed, in the long-term it may be useful to recommend the filters to the clients. Thereby costs, legal aspects and environmental benefits should be transparently communicated to the client. Above all, the question of regular cleaning of the filter system should be clarified in advance.

Noise protection

Even if the operation of logwood boilers is usually quite silent, it may be recommendable to place the boiler on noise protection rubber feet. The cost for that is rather low and the risk of noise transmission is reduced.

Lime scale deposits in the freshwater system

The installer should know the water hardness of the fresh water supply at the client’s building. This may impact the technical plans for the hot water supply. In recent years, so called freshwater stations, that are equipped with a heat exchanger and which are attached to a buffer tank, are getting increasingly popular. They mitigate issues with legionella. However, they are more sensitive to lime scale deposits than a hot water tank. Therefore, the heat exchanger of the freshwater station should be rather large and vertically installed. There are various pros and cons for a freshwater station versus a hot water tank and it will be always a case-by case recommendation of the installer and decision of the client. For example, the use of a circulation pump of the hot water supply in a big building may destroy the temperature zones of a buffer tank if the freshwater station is installed, whereas the circulation pump only destroys the temperature zones of the smaller hot water tank if this is installed.

Boiler lifetime and logwood quality

The lifetime of a logwood boiler depends on the general quality of the boiler and its combustion chamber. Furthermore, an important factor is the quality of the used wood. Wet wood or the use of contaminated wood for example can dramatically reduce the lifetime of the logwood boiler due to corrosion. Furthermore, the manual feeding of the wood logs into the combustion chamber should be made with caution. Rough throwing the logwood into the boiler may cause breaks in the fireclays and thus may reduce the lifetime of the boiler. Finally, the more the boiler is in operation, the shorter is its lifetime. Therefore, the combination e.g. with solar thermal collectors can be recommended which allows the complete shutdown of the boiler during summer. All these factors need to be clearly communicated to the client. He should be well instructed once the installation is commissioned.

Emergency heating system

The main disadvantage of logwood boilers is that they must be fed manually. This requires that during the cold season there must be always someone available who feeds the boiler. The frequency of feeding depends on the outside temperature, the system configuration, heat levels, etc. It may happen that no one is available in the household to feed the boiler due to special situations, e.g. due to illness or vacation. For these cases, the installer should discuss the technical options with the client, such as the integration of a heating rod in the buffer tank or a heat pump. In any case, the combination of a logwood boiler with solar thermal collectors, a PV system or a heat pump is always advisable in order to cover the hot water heat demand, at least in summer.

Logwood handling

The installer should not only give recommendations on the installation of the logwood boiler, but also on the logwood handling. This handling should be as simple as possible which is sometimes challenging due to the design of the building and of the boiler room. Sufficient space for storing at least the daily amount of logwood in the boiler room should be available, better more space. If the access to the boiler room is difficult, the installation of doors, hatches or windows through which the logwood can be transported or thrown in the boiler room may be an option to simplify the logwood handling. It should be avoided that the logwood needs to be carried through the whole building.

Automation

Even if a logwood boiler is a manually fed, some automation devices could be installed that increase the overall comfort for the client. This includes for instance the automatic ignition and the installation of remote-control systems and IT applications. The automatic ignition would allow to fill the combustion chamber with logwood, but to let it automatically burn at a later time. IT applications would inform the client about the current system configurations and would inform the client about the time of next manual feeding. These technical opportunities should be well discussed with the client.

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**.

What could you tell your customers?

→ **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.

FACT SHEET

BIOMASS HEATING SYSTEMS WITH WOODCHIPS

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

Smaller woodchip boilers starting from about 25 kW heat capacity are suitable for homeowners that own their own forest or have easy access to forest thinning or forest management wood residues. Often farmers operate such heating systems as the fuel is cheap, storable and helps to make usage of wood wastes otherwise not so easy to market.

Another segment where wood chip boilers (starting from 80 kW to several 100 kW heat capacity) are applicable in the residential sector is multistore or large volume houses in case of single object heating. Many (especially mid-European) building developers have recognized this as a cheap and reliable option to sustainable heat their houses, also when refurbishing their houses.

A third option to utilize woodchip boilers in the residential sector is to heat a group of houses (also starting form 80 kW to several 100 kW nominal power) standing close to each other via a micro grid. Several hundreds

Figure 9 *The use of wood-chip boilers in the residential sector to heat a group of houses*

Source: Province Lower Austria, Franz Patzl of such biomass micro grids have been realized in Austria in the last decade, for example. As with single-object heating often a group of farmers invests in the woodchip heating plant and storage facility and delivers its own fuel to that storage. The farmers also run and maintain the plant. The homeowners deliver with heat pay for the heat like with district heat supply. This ESCO business model often is referred to as biomass heat contracting or farmers' bioheat communities. Recently also larger energy utilities entered this market, as boiler manufacturers offer plug and play ready wood chip (or pellets) heating containers that are fully equipped with fuel storage, all technical equipment needed, incl. hydraulics, steering and control systems (up to a SMS service with automatic messages to O&M personnel in case of failures or malfunctions). As an investor only need to build a concrete fundament and connect electricity and pipeworks. There is no other space demand in the houses supplied with hot water for space heating and domestic hot water.

A further option to utilize wood chip boilers in the residential sector is district heating. Here often two or more biomass boilers operate jointly (base load & middle load) or in summer only (tap water) and cover up to 60% of peak load. The remaining 40% of peak load normally are supplied by a fuel oil boiler (preferable fuelled with green oil) as it is running only a couple of days contributing less than 5% of annual heat supply. Such biomass district heating plants have a capacity of 0.5 to 20 MW or more. Boilers larger than 500 kW usually are firing systems specially designed for the biomass fuel that is burned, which can be of very poor quality like street cutting or wet wood waste like bark (allow a utilization of very cheap fuels, respectively). Boilers of lower capacity are mass production products with a narrower spectrum of biomass fuel assortments and qualities acceptable for long-term operation.

Planning guidelines

Chimney planning

When a biomass boiler shall be installed the dimensioning and positioning of the chimney should be clarified by a chimney sweeper, a boiler or chimney manufacturer. As a general rule, the distance to the boiler should be as short as possible, and a design that is not sensitive to moisture is recommended. Likewise, a water and a wastewater connection as well as necessary electrical installations should be taken into account already in the planning phase. If the existing chimney is offset or has to be renewed, as an alternative stainless steel chimney can be put outside the wall.

In case a stand-alone biomass heating container is placed next to a building, regarding positioning of the chimney or container facility, respectively the main wind direction should be taken into account, to avoid

Figure 10 *Example of a realized biomass micro grid heating container, heating blocks of flats*

Source: Bioenergie NÖ reg. GenmbH

harassment of tenants or neighbours. For fire protection and permission reasons a further acceptance attest of the new or refurbished chimney can be obligatory when the biomass plant is commissioned.

Woodchip storage (placing and dimensioning)[63]

When an existing heating system is replaced by a biomass heating system, the availability of a sufficiently large storage space – accessible for fuel delivery from outside via a delivery vehicle, especially within an existing building can be a challenge.

The easiest chase is when a fuel oil boiler is replaced, as a room formerly containing the oil tank is existing. Often building owners want to utilize such rooms, e.g. in the cellar for other purposes (tenants etc.), however. Biomass storages can be built outside, e.g. buried in the ground, if space is available. Modern stand-alone biomass container facilities often have a separate container (e.g. next to or on top of the container containing the heating plant. When storage space is limited, pellets can be an alternative to woodchips as pellets roughly have an energy density four times of woodchips (pellets have a water content of 8% and a mass density of 650 kg/m³, woodchips with a water content of 25% have a mass density of 250 kg/m³).

The dimensioning of the fuel storage room depends on many factors: available space, boiler output, fuel type, fuel delivery interval, capacity of the delivery vehicle, etc. The minimum fuel supply must be determined individually in each case. The decisive factor is the desired frequency of fuel delivery, which depends on the possibilities regarding storage type and size. In existing buildings, adapting the fuel delivery intervals to the existing storage space is usually more cost-effective than constructing a new storage space outside the building. A new storage room should have about 1.3 times the volume of the lorry load so that it can be unloaded quickly and at low cost. Furthermore, fuel is usually cheaper in spring or summer, so it is advisable to fill the storage rooms during this time.

When a load of woodchips is unloaded dust can arise. When situating a storage facility in the planning phase it advisable that no windows or open-space laundry drying etc. is nearby.

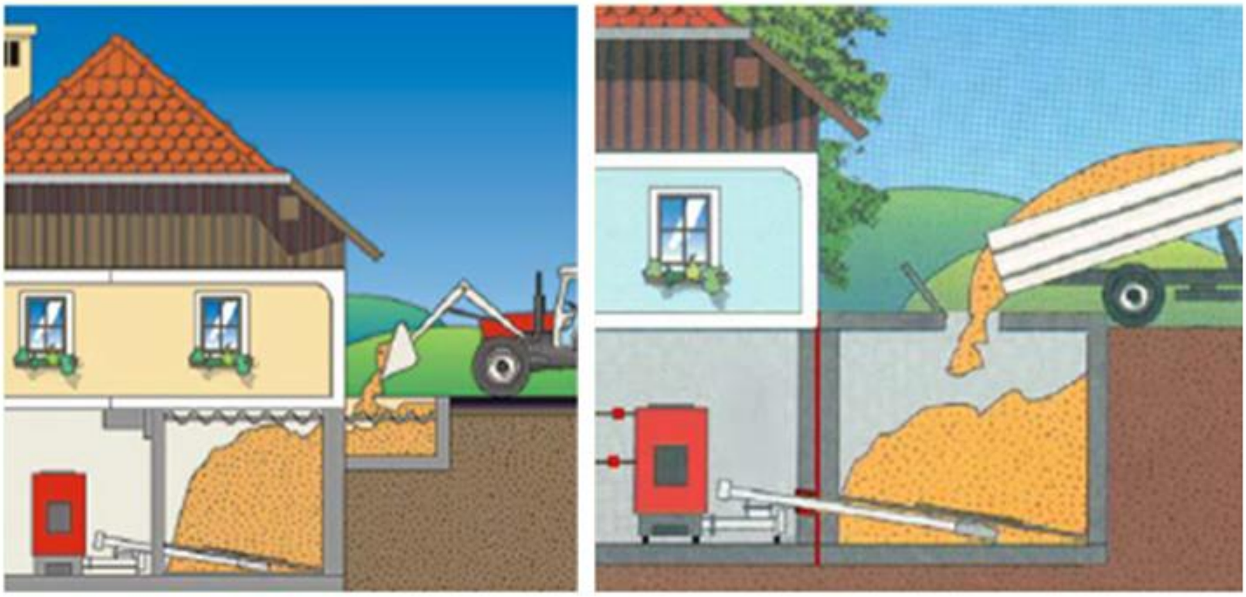


Figure 11 *a) Storage in existing cellar – storage filling screw b) Separate storage, easy to fill*

Source: Austrian office active in planning of biomass micro grid, called Regionalenergie, situated in Styria

[63] The pictures in this and the following sections are taken from an Austrian office active in planning of biomass micro grid, called Regionalenergie, situated in Styria.

A severe (e.g. architectural) planning failure that can turn out to become costly is, if within the wood storage room is a column supporting a ceiling. It has to be ensured that the automatic wood discharge system – especially in case of a leaf spring that rotates in a circle along the fuel bearing – can be installed, otherwise people have to shovel woodchips to the screw conveyor regularly, involving massive unplanned costs.

Other storage options are sloping bottom, funnel outlet systems or pull-push fuel retrieval floors; the latter for handling larger fuel amounts (up to 10 m height and 20 m³/h fuel delivery).

Woodchip boiler dimensioning

The correct dimensioning of the biomass heating system is an important prerequisite for economical and problem-free operation. Especially for larger buildings, the heating load should be calculated precisely. Existing buildings sometimes require five times the capacity to be installed compared to energy-efficient new buildings. If the boiler is chosen too large, a loss of efficiency and higher costs are the result. With correct dimensioning, investment costs can also be saved, as smaller boilers cost correspondingly less. When replacing a boiler, it is advisable to consider a thermal building renovation beforehand. This allows the heating load to be reduced and a smaller boiler to be used. Regarding least-cost measures at least the thermal insulation of the uppermost ceiling and hydraulic balancing should be considered when the boiler is dimensioned. Each of this two measures can save 5-15% of annual heating costs and peak heat load. So the boiler could become 10-30% smaller than without that two measures.

The rule of thumb for calculating the heating load is: heating load in kW = heating energy demand in kWh / full load hours. Under mid-European conditions, usual full load hours for space heating are 1,400 - 1,800 h (the latter including tap water provision). The following parameters, among others, are important for calculating the required boiler output: required/desired room temperature, coldest outside temperature for the location, heating demand of the building, tap water heat demand.

Here is an example of calculating the boiler capacity based on the existing energy consumption. Average energy consumption over the last few years: 30,000 l heating oil ~ 300,000 kWh heating energy demand (energy content of 10 kWh/l heating oil), heating load = 300,000 / 1,800 = 167 kW, without consideration of the efficiency of the previous and new heating system and any energy saving measures (as insulation of the uppermost ceiling or hydraulic balancing).

Balancing heat load fluctuations

Covering load peaks is always energy-intensive and expensive, so it makes sense to compensate for power fluctuations to a large extent. The speed and magnitude of the load fluctuation is the decisive factor. Slow

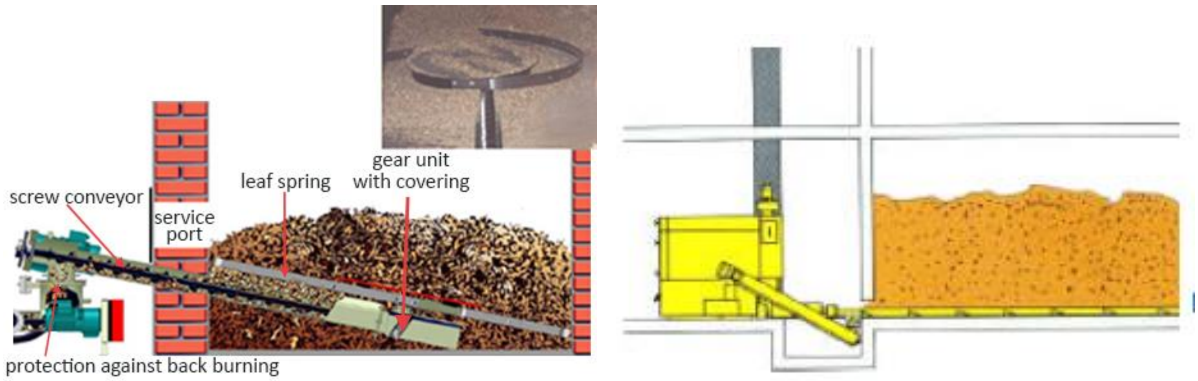


Figure 12 *Fuel retrieval for chips and pellets*

Source: Austrian office active in planning of biomass micro grid, called Regionalenergie, situated in Styria

fluctuations, such as regulating the flow temperature according to the outside temperature, can usually be controlled well. The boiler efficiency is relatively constant above 90% up to 30% of the nominal output.

The diagram (figure 3) shows that for mid-European climate conditions only on approximately 40 heating days the needed boiler capacity is below 30%. On these days, the operation of the boiler is very inefficient. Therefore, it makes sense to install a buffer storage tank to cover the heat demand during this time. For large systems, often two or more individual boilers are used to balance fluctuations and to increase the overall efficiency. This reduces the unfavourable partial load operation.

Buffer heat storage tank (application and dimensioning)

A buffer storage makes sense

- in the event of fluctuations in heat load, such as process heat demand or varying tap water consumption (see explanations above),
- when integrating different systems, e.g. parallel to a wood chip system, a solar system, a heat pump or a heat recovery,
- in conjunction with tap water production in summer (to avoid longer periods of part load operation),
- in general: to achieve higher boiler efficiencies. These are significantly improved, especially in partial load operation, compared to a system without buffer storage. In general biomass boilers should not be operated below 30% of nominal capacity for longer times. Longer standstill intervals, as the boiler runs on full capacity frequently, just to fully load the buffer storage, also extend the service life of the system.

When dimensioning the buffer storage volume, an orientation value of approx. 20 litres per kilowatt of nominal boiler heat output is recommended.

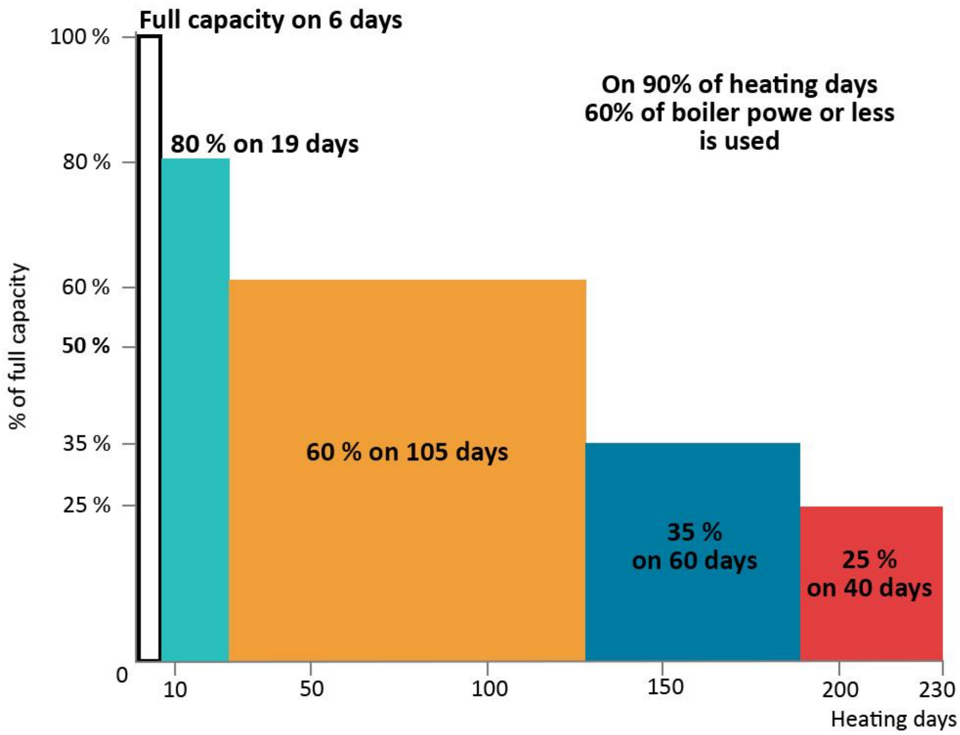


Figure 13 *Boiler load during the heating season*

Source: Austrian office active in planning of biomass micro grid, called Regionalenergie, situated in Styria

Boiler, recommended technical features

With the fully automatic boiler technology of new biomass heating systems, practically any heat load can be provided, even for larger output fluctuations. Almost all boiler manufacturers equip their products with fully automatic modes of operation. This means that the fuel is automatically transported by conveyor systems from the storage room into the boiler, where it is ignited without assistance. The water flow temperature is also regulated automatically, e.g. according to the outside temperature. Those are criteria for a high-quality boiler system:

- high annual utilisation rate (80-90%, due to high boiler efficiency, high plant utilisation, little maintenance of the ember bed and few start-up and shut-down processes)
- exhaust-gas-guided combustion air control (e.g. Lambda-probe)
- significant undercutting of the emission limit values in all operating conditions
- modulating mode of operation and sliding boiler temperature control for load-dependent operation of the boiler system
- reliable and low-maintenance operation
- low maintenance and servicing costs (through automation, use of high-quality system components, regular service; long-term service contracts shall be available)
- automatic ignition and shutdown
- automatic fuel supply and ash discharge
- automatic heat exchanger cleaning
- remote monitoring of boiler parameters
- optimum combinability with solar thermal systems (in conjunction with connection with buffer storage)
- highest operational and fire safety
- minimised power requirement
- buffer storage operation

***Figure 14** : Interior of a biomass micro grid heating container*

Source: EVN Wärme GmbH, Bernhard Baumgartner

Noise protection

For the wood discharge system in the woodchip storage room, for the whole screw conveyor system to the boiler room and for the boiler itself it is strongly recommended to put sound-absorbing plastics in-between the fixing points towards walls and the floor, otherwise sound spreads throughout the whole building (especially with concrete buildings) all the time the system operates. This is highly recommended, especially to avoid conflicts with homeowners and tenants, etc. It should not be forgotten to put the boiler itself on sound-absorbing plastics too, as modern boilers inherit automatic, mechanical self-cleaning of the boiler heat exchange surfaces and ash conveyor screws, which can squeak during temporary operation.

Heating water quality check

It is key to make sure that the heat distribution water complies with the required standards (i.e. there is no decomposition due to rust or slagging due to rust particles). A mixture of too many different metals and non-metals in the heat distribution and dissipation system should be avoided due to chemical decomposition reasons. Measures to prevent limescale deposits are described in the fact sheet for wood pellet boilers.

Boiler lifetime and maintenance

The client should be made aware that it is not allowed to burn household waste or biomass assortments that are not suitable for the boiler according to its specifications. This would not only harm the environment, but also reduce the boiler lifetime. Burning of straw for example can lower the ash melting point, which can cause slagging of silicates, i.e. glazing. Burning of wet or materials leaving behind acid substances can lead to rust or holes, up to a complete destruction of the whole boiler, respectively.

In general, the fuel may only be changed if this is expressly approved by the boiler manufacturer. However, there are boilers that allow you to switch between pellets, wood chips and log wood.

Woodchip procurement and quality aspects (fuel and storage issues)

Woodchips can be purchased directly from local farmers, some warehouses or also via biomass communities or exchanges. Wood chips are mechanically chopped wood of various sizes. In addition to the bulk density

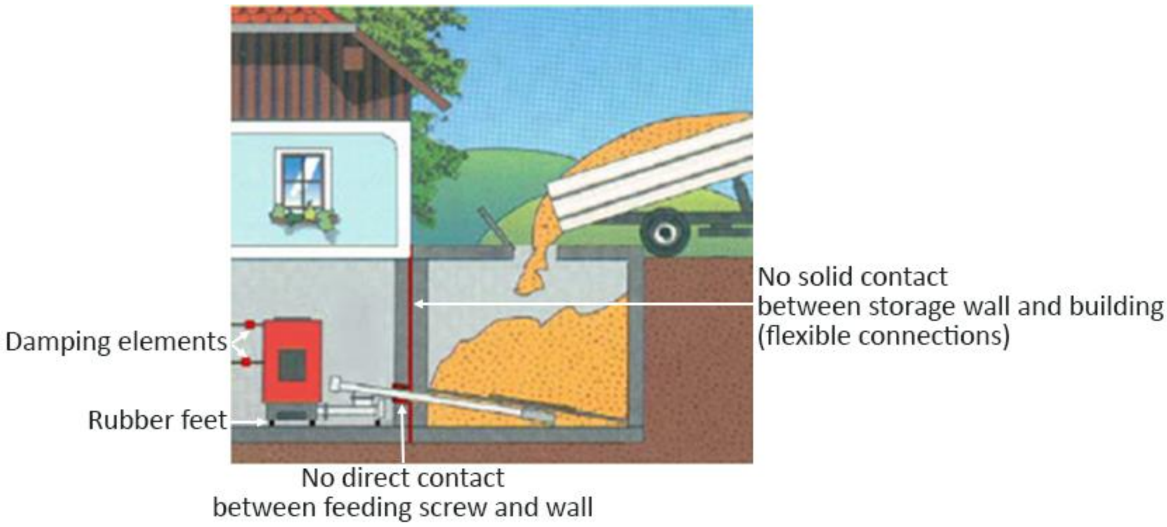


Figure 15 *Elements for noise protection*

Source: Austrian office active in planning of biomass micro grid, called Regionalenergie, situated in Styria

(weight), the main quality criteria are the size of the pieces and the water content. A distinction is made between the following classes:

	Fine wood chips	**Medium wood chips**	**Coarse wood chips**
Typical size of pieces	**P16** (formerly G30) – below 3 cm	**P24** (formerly G50) – below 5 cm	**P31** (formerly G100) – below 10 cm
Usage	Predominantly small plants	Industrial woodchips, rather larger plants, small plants possible	Large plants

The water content depends on the type of wood or the time of production. Along with the weight, the water content is the decisive quality characteristic. It determines the value and storability of the fuel. A distinction is made between the following quality classes:

W 20 air-dry	W 30 storage stable	W 35 limited storage stability	W 40 damp	W 50 freshly harvested
Water content less than 20	Water content at least 20 and less than 30	Water content at least 30 and less than 35	Water content at least 35 and less than 40	Water content at least 40 and less than 50

Woodchips must not be too wet. Otherwise, it biologically degrades and heats up, up to self-ignition, which can become very dangerous and in worst case criminal offence, not only for residential buildings. Woodchips from freshly harvested trees or from freshly processed sawmill operations with 45-55% water content can be used in district heating plants (just in time delivery) only, as boilers are specially equipped for that (e.g.

Figure 16 *Wood chipper with mechanized feeding*

Source: Austrian office active in planning of biomass micro grid, called Regionalenergie, situated in Styria

massive fire resistant cladding etc.). For long term storage of wood all kind of assortments shall not have more than 30% of water content. With more than 35% severe problems can occur already.

When operating a wood chipper, sharp blades and a metal screen (where branches are further shredded) in the ejector are crucial. It guarantees the sorting into the suitable particle size for the boiler. Oversized long particles like branches can lead to woodchip bridge formation, i.e. the automatic feeding does not work anymore despite the storage is full with woodchips. This means that the plant is in standby if this bridge is not destroyed manually, which can become costly too, in case the whole woodchip delivery contains such branches. Furthermore, stones (damage to screw and conveyors) or earth should not be in the woodchips also fine material like dust or green needles (visual check when woodchips are delivered, before unloading) can increase the ash amount and particulate emissions.

Ash manipulation and disposal

The ash accumulation is strongly dependent on the biomass fuel used. For sawdust and wood chips without bark, the ash content is around 0.5% of the dry fuel substance. The emptying intervals for ash containers depend on the system. The ash discharge works automatically with screws. For the ash collection often containers are used that can be transported directly by trucks. Depending on national and regional legislations, ash may be either be spread in the forest, used as fertiliser in agriculture, or dumped on landfills. Especially the fine fly ash, which is separated in electrostatic precipitators, is usually dumped on landfills, as it usually contains higher concentrations of heavy metals.

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.

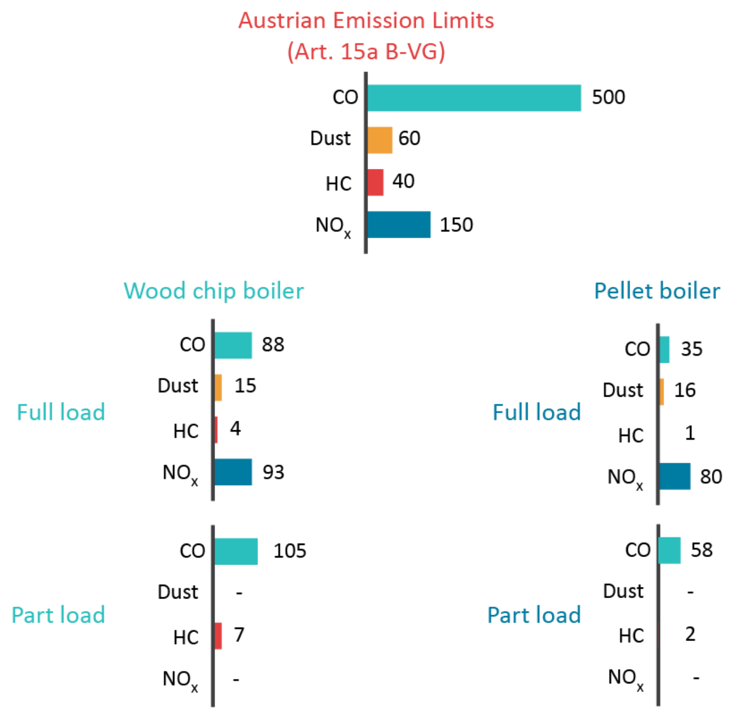


***Figure 17** Emission of state of the art wood boilers*

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.**

What could you tell your customers?

→ **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.

MODERN PELLET STOVES AND WOOD STOVES

Building type: small buildings often used as secondary heating source

Planning guidelines

Modern fireplaces and wood/pellet stoves made from cast iron, ceramic (tiled stoves) or steel (henceforth called “stoves” for simplification) are often only used as secondary heating source, in addition to a central heating system with another heat source as main system. 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 to provide the initial flame. The ventilation into the unit brings in fresh air to fan the flames to the desired heat.

Quality of the stove

The quality of the stove has a large impact on the efficiency as well as on the air pollutants. Usually, better performing stoves are more expensive and newer models are better than old ones. This should be always highlighted in sales communications with the clients.

Quality of the fuel

The combustion is largely influenced by the quality of the fuel. For wood stoves only clean, untreated and dry wood should be used. For pellet stoves, standardised high-quality pellets should be used. This should be well communicated to the client.

Air emissions

Air emissions largely depend not only on the fuel quality, but also on the quality of the stove. Electronic regulation of the inlet air improves emissions and efficiency. Furthermore, exhaust gas filters are available but are currently still only rarely installed due to additional costs. The main source of particulate matter emissions comes from the ignition of the combustion process. The installer should always instruct and train the client about this before commissioning the system.

For the ignition process, suitable ignitors and small firewood should be used. For wood stoves, it is possible to ignite the wood from the top or from the bottom and the instructions of the stove manufacturer should be followed. For pellet stoves, automatic ignition is standard.

Fresh and exhaust air

Stoves require a suitable chimney with an appropriate diameter for the exhaust air flow. This should be assessed by the installer before the stove is sold. In case the chimney is not suitable, then refurbishment of the existing chimney is needed or a new one must be built. In this latter case, an external stainless-steel chimney is often installed. This is also what happens in cases where no chimney at all exists.

Another important factor is to make sure that enough air can be sucked in order to ensure a safe and clean combustion process. Therefore, fresh air can be taken through the chimney from outside. However, in most cases, the air is taken from the heated room. Depending on the building insulation and sealing, this is usually no problem. Nevertheless, in modern buildings which are airtight, care needs to be taken if the stove is in operation and if the extractor in the kitchen is turned on. In this case, an exhaust air control can be installed that allows the operation of the extractor only if a window is open.

Safety issues

For the installation of stoves, national regulations on safety must be followed. This mainly concerns safety distances to walls or flammable material. If the wood stove is installed on a wooden floor, usually a glass plate is needed underneath the stove.

Maintenance of the stove

It is recommended to either offer a maintenance contract to the client or to train the client about required maintenance. The following maintenance may be required:

- Regular cleaning of the combustion chamber window may be required which can be best done with a wet tissue and some ash on it. Following this practice avoids the application of harmful and expensive chemical cleaners.

- Seals of the combustion chamber door should be checked regularly and if needed replaced.
- The connection pipe from the stove to the chimney is usually not cleaned by the chimney sweeper and needs to be cleaned regularly with a steel brush (usually once a year).

Connection to the central heating system

Wood or pellets stoves that are connected to the central heating system are usually equipped with well-documented guidelines for installation. Such guidelines need to be thoroughly followed, especially when it comes to safety issues. The connection and capacity of the buffer tank needs to be well planned. The route for the installation of new pipes must be well planned from the beginning of the planning process.

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.

What could you tell your customers?

→ A good quality of the stove is very important for minimizing emissions and improving efficiency. Higher initial investment costs can be paid-off by saving on the amount of fuel used.

→ Bioenergy is the oldest and by far the most used source of renewable heat, with very little CO_2 emissions. Therefore, the use of logwood or pellets highly contributes to climate change mitigation.

→ A good maintenance of the stove is very important.

→ Only high-quality logwood or pellets should be used.

FACT SHEET

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

Before installing a heat pump

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

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. In case the overall consumption of the house is adequate for a heat pump and only flow temperature is to be lowered, radiators with a higher surface (if there is enough space to install bigger radiators) or radiators equipped with a ventilator (if there is not enough space available) may help to reduce flow temperature to a level appropriate to install a heat pump.

- **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.

Additional planning guidelines[64]

Location

In addition to the technical requirements for the installation of a heat pump, also the electrical connection, the space requirements, and the possibilities of using heat sources must be clarified.

As a prerequisite for a favourable annual performance factor, the following must be ensured:

- Heating load design according to country's regulations;
- Low heating flow temperature at the design point: a temperature of 40°C should not be surpassed[65];
- For higher flow temperatures, additional clarifications are necessary in consultation with the client;
- Annual useful heat demand at the location: max. 45 kWh per m² gross floor area and year for systems with exhaust air heat source: max. 10 kWh per m² gross floor area and year
- For higher HWB, additional clarifications are necessary in consultation with the client. The hot water demand must be adapted to the equipment and, if necessary, to special user's needs (tapping profile). Orientation value: 2 kWh per person and day, target temperature of hot water 55°C;
- In the case of a combination with a solar thermal system, its yield must be determined. An appropriately designed thermal solar heating system largely takes over the hot water preparation in the summer half-year[66] The heat pump does not operate then, which extends its service life. The seasonal performance factor of the entire system improves significantly.
- Heat pump combined with an existing boiler: This combination, called bivalent operation, is a good solution in certain cases. Example: An existing biomass boiler replaces an air-water heat pump on cold days.

The installation of the system must be chosen in such a way that the noise protection requirements and the requirements for efficient operation are met (e.g. no generation of cold air pols in the case of air heat pumps).

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[64] The descriptions in this section follow correspondingly to the publication: Klimaaktiv, 2015, „WEGWEISER ZUR GUTEN HEIZUNGS- UND LÜFTUNGSINSTALLATION - Qualitätslinie 2: Wärmepumpe“, issued by the Austrian Ministry of Climate.

[65] 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 to 40°C, only.

[66] Since surpluses from the solar thermal system, unlike electricity, cannot usually be fed into a grid, the solar thermal system is dimensioned according to requirements (approx. 2 m² per person).

- The system must be planned in such a way that the requirements about regulation, acceptance protocol and system documentation are met.
- The necessary fittings and measuring connections must be planned so that hydraulic balancing of the system is possible. The balancing must be possible for each group and room.
- The heat source should be made accessible by a specialized undertaking ensuring high quality implementation.

Heat pump

The heat pump should meet the requirements of the European Heat Pumps Association (EHPA) test regulations or bear the EHPA Quality Label[67].

The coefficient of performance (COP) values shall be verified with a performance test according to standard EN 14511 of an accredited testing institute[68].

If the renovation check is used, a heat pump listed for this purpose must be selected and the entire system must be designed accordingly.

When dimensioning heat pumps, the surcharges to the standard heating load and the blocking times for reheating the heat pump must be taken into account. Over dimensioning of the heat pump must be avoided.

Seasonal performance factor

The annual performance factor must be calculated at the planning stage according to the BIN method and according to the conditions of the building for the selected system components and enclosed with the documentation.

The annual performance factor (APF) calculated in this way for the overall system must reach at least the value 4[69]. A distinction must be made between the SPF for heating and the SPF for heating and hot water. For buildings close to the Passive House standard, due to the large proportion of hot water with a comparatively high temperature level, it is difficult to achieve an annual performance factor for heating and hot water above 4 level, an SPF for heating and hot water above 4 is difficult to achieve unless a solar thermal system is combined.

Other procedures for the determination of the seasonal performance factor prescribed for the receipt of the subsidy must also be applied.

Heat meters and meters for electric drives

To check the annual performance factor, a heat meter and a separate electricity meter for the compressor and the auxiliary drives must be installed.

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[67] EHPA, „EHPA Quality Label": www.ehpa.org/ehpa-quality-label/about/

[68] 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.

[69] 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.

Modern heat circulation pumps are often able to meter the heat amount of flow and return streams by heat and volume meters. For larger plants it is recommended to monitor those figures online. With contracting project this normally is done anyway to allow an efficient operation and save money.

In addition to the control unit on the system, the heat pump has a control unit in the living area (this normally only applies to single-family houses, where owners directly can steer the heating system from there).

Control

The heating control has a timer with a daily and weekly programme (for single-family houses, additional holiday programme option).

The setting of the heating curve is optimized in consultation with the user, considering the specific technical and local conditions.

Single-family house: in addition to the control unit on the system, installation of an easy-to-adjust remote control unit in the living room with the following functions:

- Switch heating on and off,
- Change the temperature level in the whole house,
- Set timer programmes,
- Depth of setback during reduced operation.

Requirements for the optimization instruments:

- The system temperatures (temperature level and switching differential) must be adjusted by a specialist;
- For each heating group, the temperature of the flow and return can be read;
- The heating control system should enable optimization of operation in the high or low tariff range depending on the electricity supplier;
- If a PV system is present, a control system is required to optimize operation for own electricity use;
- Smart Grid (SG)-Ready-Label for the use of variable tariffs.

Pumps, accumulators

To avoid frequent switching on and off the unit (which shortens the service life of the unit) and to be able to bridge switch-off times of the power supply, a sufficiently dimensioned heat storage must be provided. In the case of underfloor heating, the storage effect of the floor structure must be considered. On very cold days it may make more sense to use electricity directly instead of overusing the heat pump.

Hot water should be provided by a separate hot water tank. A heating storage tank does not have the temperatures for fresh water. 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 separate hot water.

Noise

It is ensured that the heat pump, as a source of noise, does not cause any inadmissible noise emissions (see relevant rules about noise emissions in your country). A reduction of 6 dB per doubling of distance can be assumed as a guideline value. In quiet residential areas, these values may be too high.

Noise emission into the living space must be considered, especially with lightweight construction.

Design of earth probes / earth conductors

The design of borehole heat exchangers / ground collectors is carried out, based on a calculation in accordance with country's relevant regulation. The extraction rate for ground probes must not exceed max. 50 W/lfm, for ground probes and max./or 20 W/m^2 in the case of ground collectors. Higher values are only permissible if geology conditions allow it.

With regard to a documentation of the drilling, a site plan of the boreholes, the probe lines to the house, a protocol of the drilling foreman with drilling run sheet, grouting protocol and information on the grouting material as well as with a pressure test protocol of the probes are recommended.

Requirements for the thermal insulation of the pipework

All heating and hot water pipes in rooms must be insulated against heat loss at least in accordance to relevant regulation. Appliances and fittings must also be thermally insulated.

Indication of operating costs

The expected annual operating costs, including maintenance, are to be calculated on the basis of the annual performance factor for an agreed room temperature. A variant of operation costs with green electricity shall also be presented.

Installation of a heat pump system

The system is to be installed in such a way that the requirements regarding regulation, acceptance protocol and system documentation are met.

The necessary fittings and measuring connections must be planned so that hydraulic balancing of the system is possible. Hydraulic balancing must be possible for each group and room.

Certified heat pump planner or installer

In addition to national installers' trainings (hopefully available), evidence of additional qualifications can proof the commitment and specialist knowledge of the installer. Suitable proofs are reference installations and the certificate of a certified heat pump installer or planner, if available.

Operating instructions

For all essential functions, operating instructions including instructions for the determination of the annual performance factor should be made available by the installer or the manufacturer of the heat pump, respectively.

Adjustment, acceptance report, system documentation

After hydraulic balancing and adjustment of the operation heat pump and circulation pump to heating curve, an acceptance report should be drawn up and the system documentation should be handed over during commissioning.

Combination of a heat pump with photovoltaics

In principle, this combination offers the possibility of using self-generated electricity, but the yields from PV systems are low during the heating season. On an average December day, only about 1 kWh of electricity per kWp can be expected.[70]

In high winter, only part of the self-produced PV electricity can be used for heating and hot water. For the rest, electricity from the grid will be necessary. At the beginning or end of winter, however, the PV system can supply more electricity than is needed for household electricity. Then the heat pump can use energy from a photovoltaic (PV) system for its operation. The HP can make good use of the sun's supply, which fluctuates during the day:

a) In the case of underfloor heating, the screed acts as a buffer (rule of thumb: 1 square metre of floor corresponds to 100 litres of water storage)
b) A hot water tank the size of 300 litres can store approx. 15 kWh of heat, for which the heat pump uses about 5 kWh of electrical energy.

In the sunnier months, the heating of water with storage by means of a heat pump compared to battery storage is the more economical option. The self-consumption share of a PV system can be increased by about a fifth. It is recommended that the planner or installer calculates the daily electricity yield and demand on a characteristic winter day, e.g. 21 January, at a daily mean temperature of 0°C. Thereby, a realistic estimate of the own electricity use for the heat pump can be obtained.

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.

[70] Under mid-European conditions.

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.

Finally, a heat pump with **thermal storage** system is a system that operates a heat pump during night-time using inexpensive electricity; during this time, the generated thermal energy is stored in a thermal storage tank.

What could you tell your customers?

→ **Energy efficient:** for each kW of electricity consumed by a heat pump, about 4 kW 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.

FACT SHEET

SOLAR THERMAL

Target group: individual, small and large volume buildings

Planning guidelines

A large part of the heat requirement for hot water preparation can be covered by a thermal solar system. In addition, a solar system of the appropriate size can also support the heating. Basically, a solar system can be sensibly combined with any heating system. The demand for hot water depends heavily on the behaviour of the residents and is therefore subject to fluctuations. This is calculated using different methods (see the table 1).

A well-planned solar thermal system should achieve a degree of coverage of 60% or higher with the exclusive support of water heating. If the heating system is also to be supported by the solar system, a solar coverage ratio of at least 25% (old building) or 70% (new building) of the total heat requirement (hot water and heating) should be aimed for. In the case of unrenovated buildings, it can make sense to prefer insulation measures instead of installing solar collectors for supporting the heating system.

For a good acceptance of solar energy, it is also important to build the systems with a high aesthetic quality. This also shows that taking design requirements into account generally does not lead to any noteworthy losses in solar yield. In most cases, a nice integration even supports the overall profitability.

When dimensioning the sizes of the most important components of a solar thermal system (collector area and hot water storage tank), the following sequence should be followed:

1. Determine the daily hot water demand (temperature level 50°C),
2. Calculate the volume of the hot water tank,
3. Determine the collector area,
4. Correction of the collector area due to deviations from the optimal inclination and orientation

The daily hot water demand can be determined in two ways. Either a rough calculation method with 50 litres per day and person (at 50°C) is used or a detailed compilation based on the following table is made. The hot water demand, like the cold-water consumption, depends very much on the individual user behaviour.

Table 1: *Overview of various consumption quantities and temperature levels*[71]

	Hot water requirement (litres)	Temperature level (°C)
Dishwashing	12-15	50
Hands washing	2-4	50
Head washing	8-11	50
Shower	23-45	50
Bath in standard bathtub	90-135	50
Bath in large bathtub	188-300	50

Once the daily hot water demand has been determined, the storage volume can also be determined. The storage volume for a solar water heating system in detached and semi-detached houses should be about twice the daily demand, thus enabling bridging on days with little sunshine and covering peaks in consumption. Since the manufacturers do not offer storage tanks in every size, one must orient towards the usual market sizes. However, the storage tank should not deviate from the calculated volume by more than 10 percent at the bottom and by more than 20% at the top. The usual storage tanks on the market are 300, 400, 500, 750 and 1,000 litres.

The following step is to determine the collector area. Since the collector area depends on several factors, these must be taken into account when dimensioning. Possible influencing factors are:

- Domestic hot water consumption
- Collector type
- Desired degree of solar coverage of domestic hot water demand
- Climatic conditions at the location
- The inclination and orientation of the collector

For solar water heating, almost 100% solar coverage should be achieved over the summer months. Then the boiler for reheating (poor efficiency) does not need to be operated during these months. When dimensioning, a solar annual coverage of the domestic hot water of about 70% is therefore to be aimed for.

The table below applies to an optimal orientation (south) and a suitable collector inclination (45°). If the orientation and the collector area deviate from these optimal conditions, the resulting reduced yield can be compensated by increasing the collector area by 10-20%. In the case of systems integrated into the heating

[71] Source: Ausbildungsskriptum „Solarwärme“ (AIT und AEE INTEC)

system, the solar collectors should be aligned with a maximum deviation of 45° (south-east to south-west) and set up with an angle of 45° to 60°. In order to be able to handle the large number of parameters more precisely and more easily when calculating the degree of coverage, the calculation of the degree of coverage should be carried out using a simulation programme. The verification should be carried out by a calculation with a recognised calculation programme with local climate data.

Table 2: *Consumption and volume of the hot water tank and collector area*[72]

Daily demand (litres / day at 50 ° C)	Volume of the hot water tank (litres)	Gross collector area m^2 (flat plate collector)
Up to 100	200	4
Up to 200	400	6
Up to 300	500-700	8-12
Up to 400	750-1.000	12-16

Hot water / buffer storage

The solar storage unit stores the supplied solar energy while it is not or only partially required and makes it available again at times when there is no solar radiation. There are also different systems for the storage tanks: in addition to the classic solar storage tanks, in which drinking water is heated by means of a heat exchanger, there are also buffer storage tanks in which heating water is stored. There are also stratified storage concepts, especially with the above-mentioned buffer storage tanks, in which the heated water is "stratified" in the storage tank in such a way that no undesired mixing can occur. This facilitates a combination with other heating systems for partially solar heating of rooms.

A good insulation of the storage tank reduces heat losses. Even when installed in the heated area, losses can be high, therefore a good thermal insulation is necessary. If the storage tank is installed in the heated area, good insulation also reduces the risk of overheating due to unwanted heat emission. The storage tank is sufficiently good if its energy efficiency class is at least class B for storage tanks up to 500 litres or at least class C for larger storage tanks.

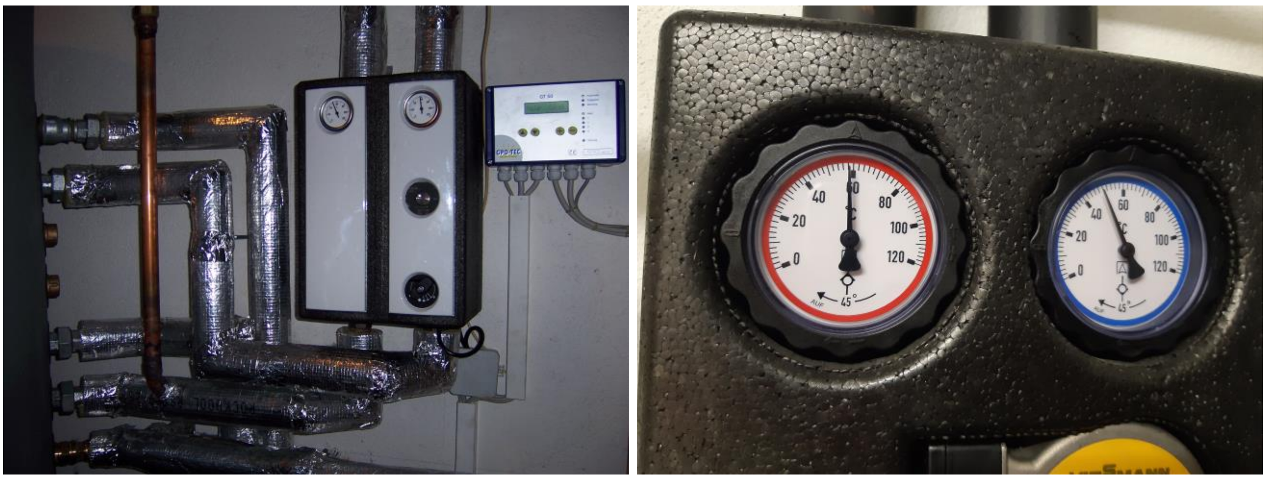

Figure 187 *Pumping system for solar collectors and solar thermal thermometers*

[72] Source: Ausbildungsskriptum „Solarwärme“ (AIT und AEE INTEC)

If a solar system is used for heating support, the buffer storage tank should be dimensioned with 50 to 70 litres per m² collector area. The technical data required for the calculation can be requested from the manufacturer.

Direct-electric hot water production

Since high conversion losses and emissions are associated with electricity generation, direct-electric hot water production is not recommended under primary energy and ecological criteria. It is therefore only acceptable as a reheating system in buildings with large-scale solar thermal systems (utilisation rate for domestic hot water preparation of over 80%) and as a reheating system in buildings with heat pumps with hot water preparation and with a heat pump compact unit to a limited extent. Customers benefit from the avoidance of direct electric water heating through lower energy costs, as electricity is far more expensive than other common energy sources. The climate policy benefit of solar thermal water heating lies in the significantly lower carbon dioxide and pollutant emissions compared to direct electric water heating.

Control / regulation

To be able to operate the solar system optimally and safely, a control is necessary. Their task is to control the pumps and valves depending on the collector and storage tank temperatures or, if the solar yield is too low, to heat the storage tank via the existing heating system[73].

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.

What could you tell your customers?

→ 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.

[73] klimaaktiv, 2017, „Wegweiser zur guten Installation von Solaranlagen Qualitätslinie Solarwärme“ (https://www.klimaaktiv.at/erneuerbare/erneuerbarewaerme/Heizungssysteme/solaranlagen/QL-Solarw-rme.html)

FACT SHEET

RENEWABLE-BASED DISTRICT HEATING

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

Planning guidelines

The district heating grid transports the warm heating medium to the consumers and the cooled medium back to the heating generators. To transfer the heat, the consumers need to be connected directly or indirectly (through heat exchangers) to the system. The connection point can be defined from a technical point of view, as well as from a legal point of view. Usually, the central heating system of the building belongs legally to the building owner, whereas the DH grid belongs to the grid operator. The heat transfer station can be owned either by the building owner or by the grid owner, depending on the business models and on the contracts.

Heat transfer stations

The heat transfer station is the equipment that transfers the heat from the DH grid to the consumers. Usually (i.e. in Austria and Germany), houses are connected to the district heating grid by using a heat exchanger (indirect system) to separate water from DH and installation of the house. This equipment is placed in a heat transfer station at the houses. In other countries (i.e. in Denmark), often a direct system without a heat exchanger is applied.

Heat transfer stations usually consist of a heat exchanger (indirect system), a control unit to regulate the flow temperature for the house, a motor valve and a heat meter. It is standard to use differential pressure balanced motor valves, in order to lower fluctuations and to set a maximum flow rate when the valve is completely open. With this adjustment, it is possible to limit the flow rate (heat power) of the heat transfer station to a contractually guaranteed value.

Depending on the legislation, it may be necessary to install an official calibrated heat meter. The heat meter needs to be calibrated periodical. Usually heating costs consist of costs for the used heat (€/kWh), needed heat peak load (€/kW per month) and metering costs (€/a).

A monitoring system (temperatures, opening of valve and quantity of heat consumption) that is connected to the heating plate is standard nowadays. This is achieved with a bus-system for all heating stations. This monitoring system can also be used to control the differential for all heating stations. This monitoring system can also be used to control the differential pressure of the main DH pump (valve management). Additionally, monitoring helps to identify customers with higher return temperature and to apply sanctions.

Advantage of an indirect system is that DH water and heating water of the customers are separated and no oxygenation from customers' plastic pipes could damage the DH grid.

The heating system of the building

The heating system of the building needs to be adjusted to increase the overall efficiency of the system.

The hydraulic installation in the building of the consumer should enable low return temperatures to the DH grid. If the return temperatures are too high, the consumer may be instructed to change some parts of the hydraulic installation. This should also be included in the contract.

Consumers usually use radiators, floor heating, wall heating, or radiant ceiling heating to distribute the heat to the rooms. Radiators need a higher temperature than the other panel heating systems (big surface). Hence, floor, wall, and ceiling heating results in lower return temperatures for the DH grid and lower the pumping costs of the grid.

If plastic pipes are used for heating, there should be an indirect connection of the consumer (heat exchanger) to prevent oxygenation and sludge accumulation at the DH grid.

Domestic hot water production

Besides space heating, the heat from the DH grid may be also used for domestic hot water (DHW) supply. In most heating grids in Germany or Denmark, the heat supply for preparing hot water is an integral part of the service. In some other countries, especially in southern Europe existing DH grids are only operated during winter and no service is provided for hot water supply. In this case, other equipment for the preparation of hot water is needed.

The preparation and provision of domestic hot water needs to ensure health safety. Pathogens, such as bacteria and Legionella, may cause health problems and need to be avoided. The occurrence of them is not a specific problem related to district heating, as they may occur in all warm water systems. The contamination with Legionella takes place in the domestic hot water production and distribution facilities, i.e. in the drinking water pipe system, the circulation and the storage tank. The owner of the domestic hot water facility is responsible for ensuring health safety.

Connection between district heating and consumer systems

The heating system of the consumers (households) needs to be connected to the district heating system in an efficient way. Thus, the hydraulic system at the consumer side needs to be well adapted. It is important to avoid shortcuts in circuit. The system of the consumer should not raise the return temperature of the district heating system; this means that the flow of the consumer heating should not be directly mixed with the return flow.

The figure 19 presents suitable and non-suitable hydraulic distribution systems used at the consumer's side. Practical experience shows that the third system is the most common system, which is easy to plan, and which operates without hydraulic problems. When connecting the hydraulic system of the consumer to the DH system, they should ensure the good practice schemes of the figure below. If the system is not suitable, it should be changed. Furthermore, it should be considered that the systems, including the heat exchanger, pipes, valves and motor valves are not oversized.

Often, consumers will have already installed solar heating systems on their buildings when the DH grid is planned. The integration of these solar collectors depends on various aspects, such as the type, size, and age of the solar system. If there are solar collectors existing at the consumer's building, they should be mainly used to produce domestic hot water. If it is also planned to include them into the heating system, a buffer storage tank should be used. The solar system could feed the buffer storage tank with heat and if the temperature is too low, heat of the DH grid could be used to maintain the desired temperature. Thereby, the heat could be transferred to the top of the buffer storage tank or the system could be heated externally with a heat exchanger[74].

Primary Energy Factor

If possible, heating and hot water should be provided by district heating from waste heat or CHP. The higher the share of renewable energy sources, the more positive the effect on the primary energy factor and thus on the primary energy demand or consumption.

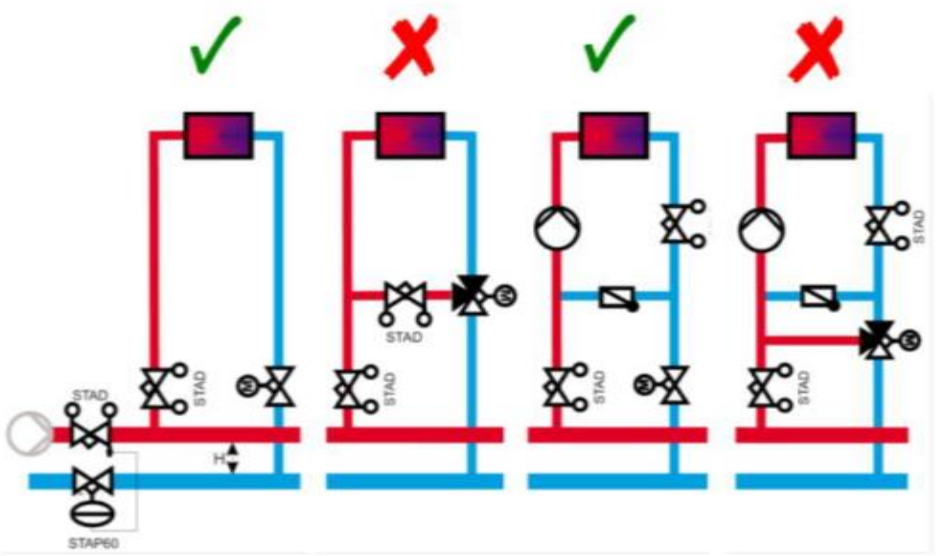

Figure 19 *Hydraulic distribution that can be used for DH systems at consumer side*

Source: Güssing Energy Technologies, based on Tour & Andersson Ges.m.b.H., 2005

[74] Dominik Rutz, Christian Doczekal, Richard Zweiler,Morten Hofmeister, Linn Laurberg Jensen, CoolHeating project, 2017, „ Small Modular Renewable Heating and Cooling Grids: A Handbook" (https://www.coolheating.eu/images/downloads/D4.1_Handbook_EN.pdf)

The main criterion for assessing whether the use of a district heating system is worthwhile from an energy and ecological point of view must always be the primary energy input (primary energy factor) of the respective district heating provider. District heating only makes sense from an energy point of view if the primary energy factor is significantly lower than the primary energy factor for direct use of a fuel (e.g. gas). This is due to the sometimes very high distribution losses of a district heating system.

Since every district heating system is structured differently, information about the primary energy factor should be provided by the district heating operator, in order to adequately assess the district heating system. However, this assessment should always consider the current power plant fleet, as the share of renewable energies and thus the primary energy used depends on this.

It should also be clarified with the operator of the district heating connection whether there is an obligation to purchase certain amounts of energy over a certain period.

In addition, many district heating suppliers limit the maximum return temperature after the heat exchanger. This enables them to better utilise the district heating networks and the heat generators but has a direct impact on the operation of the building's heating network, as it affects the return temperature of the district heating connection.

Since the primary energy consumption of a district heating system depends not only on the generation but also to a large extent on the losses, it is important to minimise these. In addition to an absolute reduction of losses through thermal insulation, other measures can also be implemented to reduce losses. On the one hand, the district heating network should be as short as possible in order to reduce the total losses. On the other hand, the ratio of the amount of heat purchased to the length of the pipe network should be as large as possible. The more buildings are connected per metre or kilometre of pipe (i.e. the more heat is tapped per metre), the lower the losses of the distribution system.

The target value to achieve a good benefit-loss ratio should be at least 1.2 MWh per metre of pipe (incl. house connection pipes)[75].

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).

[75] Klimaaktiv, 2011, "Merkblatt Fernwärme" (https://www.klimaaktiv.at/dam/jcr:d99f71a7-a24a-4563-9dbf-edbb20dd6066/Merkblatt_Fernwaerme.pdf)

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 the client has already solar thermal collectors on the rooftop, they can be usually still be used when the building is connected to a DH system. In this case the client simply saves money for each kWh that is not needed from the DH grid.

What could you tell your customers?

→ **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.

4 WHICH OTHER MEASUREMENTS CAN BE IMPLEMENTED?

4.1. PVs for heating

With state-of-the-art PV technologies, PV panels can now be used not only to power homes and electric appliances, but also to heat houses and domestic water.

This can be done by complementing the main 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

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 lost. In this case, the unused power from PV can be used to operate the electric rod in the buffer tank.

4.2. Multifunctional façade systems

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. Due to the consideration of only individual components, this often results in inefficient and in the end expensive solutions, with only limited long-term energy reduction.

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 other concentrates on prefabrication of only the window part, as this is the most complicated part.

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.

Principally, the module consists of:

- An equalizing layer mounted on the existing outer wall

Figure 20 *PVs for heating - cell and installation*

- 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.

4.3. Micro CHP

With the ability to attain overall efficiencies above 90%, micro-CHP units meet the demand for heating, space heating and/or hot water (and potentially cooling) in buildings, while providing electricity to replace or supplement the grid supply. Depending on the regulatory arrangements in place the electricity produced by micro-CHPs could be sold to the local supply network, partnering with intermittent renewables to balance supply and demand and provide further services to the grid.

Figure 21 *PVs for heating - cell and installation*

The heat generated could be used on-site (maybe in combination with gas fired boilers) and/or supplied to other homes nearby through district heating infrastructure. Micro-CHP systems can also provide cooling through the use of absorption chillers that utilize heat as their energy source (i.e., Combined Cooling, Heat and Power (CCHP)). In this way, end-users from different sectors (including multi-family buildings, commercial, and industrial applications) become partners sharing responsibility for a greener and more sustainable energy supply.

A micro-CHP system is also a controllable Distributed Generation solution that can empower consumers by enabling them to produce their own electricity and heat, taking control of their energy bills (i.e. becoming active participants in the energy market). Also, as viability of carbon capture and storage (CCS) solution for decarbonisation targets remains in doubt, micro-CHPs can play a leading role in this regard at the domestic level.

A micro-CHP system can be based on several types of technologies, including engines (both Stirling and Internal Combustion Engine), gas and steam turbines and fuel cells. Micro-CHP systems deliver important benefits to energy consumers as well as the wider energy system, in line with EU reaching its energy and climate objectives:

- Savings on total energy costs for the end-user (as a function of electricity and heat savings),
- Improved efficiency of fuel use – better fuel utilization factor (at least 25% compared to importing electricity from the grid and using boilers to generate heat),
- High level of fuel flexibility, reduced emissions (up to 33%),
- Independence and security of power supply,
- Improving the energy performance of buildings

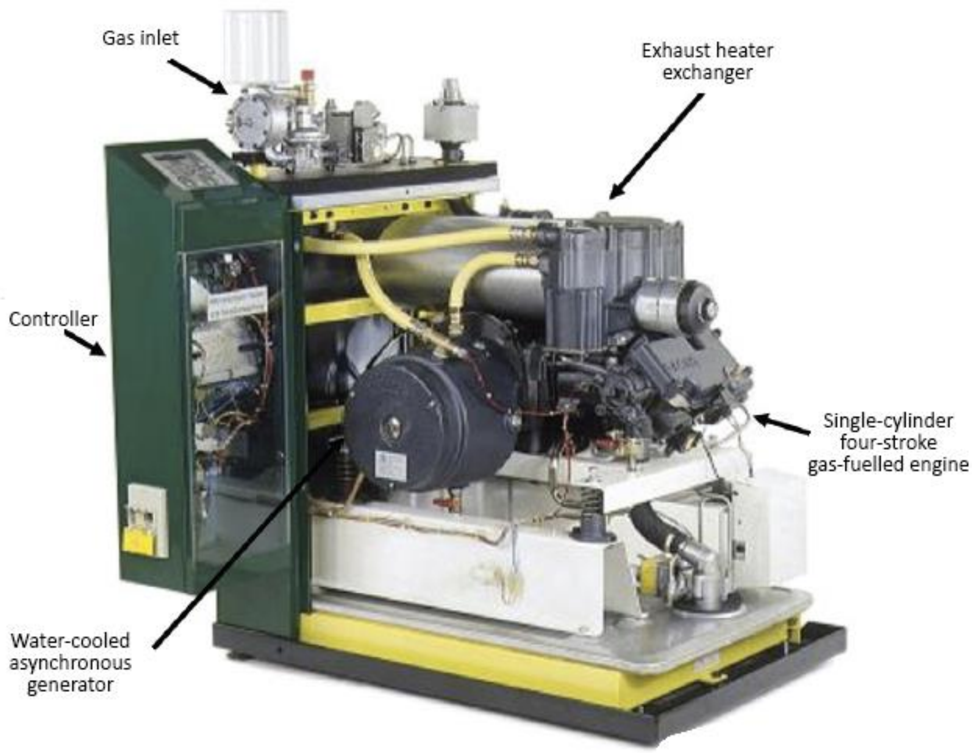

***Figure 22** The components of a typical 'off-the-shelf' CHP unit – 5 kWe, 12,5 kWt*

Source: Senertec
https://www.cibsejournal.com/cpd/modules/2016-04-chp/

- Supporting the electricity grid and helping the integration of intermittent renewables[76]

4.4. 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

[76] European Turbine Network and COGEN Europe, "The role of micro-CHP in future energy sector: A focus on energy efficiency and emission reduction (https://setis.ec.europa.eu/system/files/integrated_set-plan/etncogen_input_action5.pdf)

- 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

4.5. Checks of boilers and cooling units

4.5.1. 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

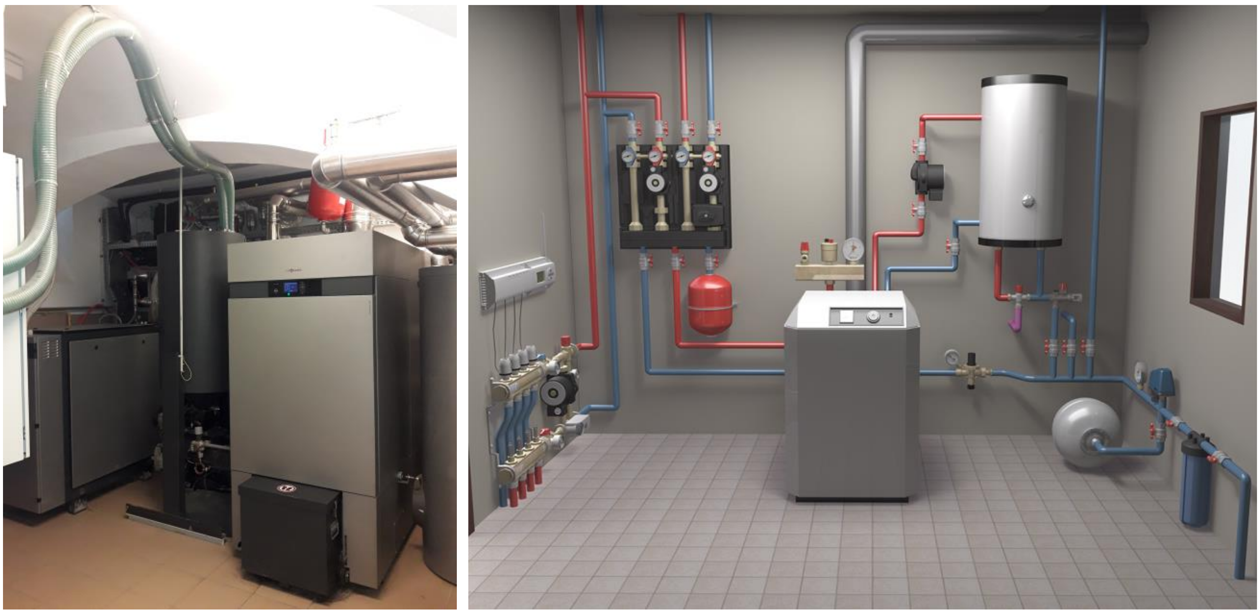

Figure 23 *Heating system – pellet boiler and house heating system*

adjusted to each other in such a way that, based on 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.

4.5.2. 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 can normally be flexibly installed anywhere in the house. A socket for the power supply and a tilted open window is sufficient to discharge the heated exhaust air. The disadvantage is that 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. The two hoses largely prevent uncontrolled air from flowing into the room, thus saving energy.

In the case of split air conditioning 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[77].

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.

[77] https://replace-project.eu/?page_id=785

4.6. Shading

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 interior[78].

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 color to deflect more heat. Retractable awnings will admit sunlight when in retracted position. Awnings may not be suitable in windy areas but motorized, 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.

Figure 24 External shading: eaves, awnings, screens and shutters

[78] Level, "Shading" (http://www.level.org.nz/passive-design/shading)

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.

Verandas

Deep verandas 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 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.

Figure 25 External shading: louvres, external (curved) blinds, verandahs, pergolas and plant shading

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 motorized 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.

4.7. Insulation of the uppermost ceiling

Insulation measures can considerably reduce the total heat demand and thus contribute to mitigate climate change. Insulation measures can be done on the walls, on the basement ceiling, on the roof and on the uppermost ceiling. It very much depends on the building, which measures do make sense. However, very often, single-household buildings have an unheated loft. In these cases, much heat is lost, if the uppermost ceiling is not well insulated. Then, the insulation of this uppermost ceiling is a very good measure, as it can be usually implemented easily with rather low cost and with a high impact. The measure usually pays well off in a short time.

Figure 26 Internal shading: curtains, venetian blinds and roller blinds

The thermal insulation of the uppermost ceiling can be also organized as a collective action in which the material can be purchased together. It is beneficial of course, if the insulation material is renewable-based. Due to liability issues and different preferences of end consumers, the implementation of the action should be organized by the end consumers themselves, e.g. via consultation 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 could cost for a standard house about 2.000/3.000 Euro, depending on the size of the building. It normally pays off in less than ten years.

4.8. 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.

4.9. Demand response 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.

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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%[79].

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"[80] 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[81].

[79] European Commission, "Energy Performance of Buildings Directive" (https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/energy-performance-buildings-directive_en)

[80] "To address the twin challenge of energy efficiency and affordability, the EU and the Member States should engage in a 'renovation wave' of public and private buildings. While increasing renovation rates is a challenge, renovation lowers energy bills, and can reduce energy poverty. It can also boost the construction sector and is an opportunity to support SMEs and local jobs", European Commission Communication, "The European Green Deal", 11/12/2019 (https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf)

[81] Buildings Performance Institute Europe (BPIE), "An Action Plan for the Renovation Wave: Collectively Achieving Sustainable Buildings in Europe", 2020 (http://bpie.eu/wp-content/uploads/2020/04/An-action-plan-for-the-renovation-wave_DIGITAL_final.pdf)

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[82] 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%[83], 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%)[84].

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%[85].

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"[86].

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[87], 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.

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[82] 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)
[83] Ibidem.
[84] Heat Roadmap Europe, 2017, "A low carbon heating and cooling strategy 2050"
[85] IRENA, "Heating & Cooling" (https://www.irena.org/heatingcooling)
[86] 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)
[87] European Commission, "The European Green Deal", 2019 (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1588580774040&uri=CELEX:52019DC0640)

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 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**[88] and **Energy Labelling Regulations**[89], 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[90].

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[91].

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.

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[88] 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)

[89] 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)

[90] 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)

[91] 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).

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[92].

[92] "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).

ANNEX II: TOPTEN.EU – ONLINE SEARCH TOOL PRESENTING MOST ENERGY EFFICIENT HEATING AND COOLING PRODUCTS

Topten is an online search tool for end consumers and professionals, which presents the most energy efficient products available in 15 European countries in various product categories, in the fields of

- white goods and electronics for households and undertakings
- as well as technology for heating and cooling (HAC) living spaces or buildings.

Each participating country has its national website. Among the Replace projects' target countries the following "topten" websites listing energy efficient HC products are available:

- topprodukte.at in Austria,
- topeffizient.de in Germany,
- eurotopten.es in Spain.

Countries not having national websites with HAC products available domestically, can find general information on energy efficient products on the website **topten.eu**.

The products listed in the various topten websites are selected and updated continuously. They are ranked according to their energy efficiency or consumption and environmental performances, independently from the manufacturers.

THE HORIZON 2020 PROJECT HACKS

The **objective** of the Heating and Cooling Knowhow and Solutions (HACKS) project is to achieve market transformation for heating and cooling (HAC) appliances and improve comfort and health of European citizens. Across the EU almost half of all buildings have individual boilers that were installed before 1992 with efficiency of 60% or less. The expected energy savings from a speedy replacement are immense. To achieve this goal, 17 **HACKS partners in 15 countries** (among them are the Replace target countries Austria, Germany and Spain) are working together, thanks to the financial support of the European Horizon 2020 programme.

After **scanning market actors**, current policies and most commonly used products in each country, starting from April 2020 the HACKS partners will implement **involvement campaigns** to raise awareness of the economic and environmental benefits brought by good HAC products and solutions:

- HACKS will **motivate households** equipped with old and inefficient devices –boilers, water heaters, air conditioners, certain types of boilers and stoves, etc. –**to replace** them with new super-efficient equipment.
- In each country, partners will **set-up dedicated on-line platforms** to **assist consumers in their purchasing process**. The platforms will propose: tools to assess households' needs and provide customized information; best product lists with technical specifications; direct links to suppliers of most efficient products; and advice on how to use and maintain equipment.
- For those **households who** need to improve their situation because they **feel too hot, too cold, or too humid** but who cannot invest in new equipment or can avoid getting equipped, HACKS will propose **simple and low costs solutions**. It is possible to reduce energy consumption and energy bills while improving winter and summer comfort, air quality and health conditions through the installation of shading devices, thermostats, water saving taps and showerheads, etc.

Beyond households, **HACKS will target** all relevant stakeholders ("**multipliers**") that participate in the decision-making process of consumers by **setting up strategic partnerships** to facilitate the purchase of energy efficient appliances. HACKS places a **strong emphasis on installers** but also **retailers** and **consumer organizations'** because of their proximity to consumers, their capacity to involve them and bring them guidance on energy efficient equipment.

More information on the **HACKS project** can be found at www.topten.eu/hacks

Countries not participating in HACKS can find information on energy efficient HAC products on **topten.eu**. Currently (May 2021) for the following product categories is information provided:

Air Conditioning Units

Single split
Multi split

Comfort Fans

To the product list

Electric Water Heaters

To the product list

Circulation Pumps

To the product list

Solid Fuel Boilers

To the product list

Local Space Heaters

To the product list

Heat Pumps

To the product list

Taps & Shower Heads

Taps
Shower Heads

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