BEST PRACTICE EXAMPLES OF (R)HC REPLACEMENTS IN THE TARGET REGIONS

replace

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

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EXECUTIVE SUMMARY

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

In order to persuade consumers of the benefits of innovative low-carbon and renewable heating and cooling systems, the illustration of best practice examples is an excellent tool to show how replacements can be implemented under real local conditions, being at the same time technically and economically feasible.

This report shows real life testimonies of 38 end-users and building occupants who have recently replaced their old inefficient heating system with a greener solution, which provides both economic and environmental benefits. Three cases from each of the project's target regions, plus eight innovative best practice examples from more experienced countries (Austria, Germany and Spain), are presented and cover a variety of solutions and approaches, ranging from residential building refurbishment and (R)HC replacement to demand-response and collective consumers actions.

This report is part of the activities of Work Package 4 "Preparation of instruments for replacement campaigns" of the REPLACE project and is to be submitted to the European Commission by Month 15 of the project (January 2021), and will be also available on the REPLACE website.

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BEST PRACTICE EXAMPLES

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 have to 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 ten European pilot regions with a total population of 8 million. Specifically, the project targets consumers, investors/owners as well as intermediaries, like installers, chimney sweepers, energy advisors and consultants, and helps them to make well-informed decisions. Simple renovation measures that pay-off quickly as they reduce overall space heating consumption for a low investment and which are implemented as coordinated community actions are also part of the programme.

In order 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. Together, they will design comprehensive, locally adapted effective action packages, tackling the main barriers and challenges end consumers and installers face when boilers or ovens shall be replaced.

REPLACE’s primary objectives are to:

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

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

BEST PRACTICE EXAMPLES FROM AUSTRIA (FEDERAL STATE OF SALZBURG)

AIR HEAT PUMP HEATING SYSTEM + PV
FOR SINGLE FAMILY HOUSE

In a single-family house in the city of Salzburg with 143 m² floor space and 3 inhabitants, which was built in the 1960s, an old oil boiler was replaced recently by an air source heat pump (a 5 kWp PV plant is planned to be installed in 2021). A thermal insulation of the building envelope took place in 2003 and reduced the heat load of the building from 14,0 to 8,9 kW.

The old boiler had an adequate power for the heat load before the insulation of 16 kW, but was over-dimensioned for the status since then. The annual consumption was about 3,000 liters of heating oil.

The main reason for the replacement were the fact that the oil boiler was already over 25 years old and the energy costs were high as well as the maintenance effort. The regulation’s operation was not satisfactory anymore and there were concerns regarding the hygienic of the domestic warm water production. In addition, environmental concerns played an important role. The decision for an air source heat pump was done via broad internet research and via advice of experts (Energieberatung Salzburg and installers).

The intensive phase of installation lasted about one week, plus two weeks of smaller adaptations. The coordination of the construction works was quite demanding. The electric connection was too weak, so the power had to be increased. For 10 days a temporary domestic warm water supply system had to installed.

The heat pump supplies the heating as well as the domestic warm water system. In parallel, new radiators were installed which allowed a system temperature decrease from (inlet/outlet) 70°C/50°C to 55°C/45°C. A buffer storage was installed as well as a 180 liters domestic warm water storage tank. The regulation, the heating curve and the circulation pump were adapted to the system requirements. The total installation costs were € 38.000.- from which the electric installation cost € 12.000.- and construction works € 8.000. About 30% of the total costs were subsidized. The estimated annual heating cost savings amount to approximately € 1.500.- which means an amortization time of roughly 18 years (taking subsidies into account, but no price changes or interest rates).

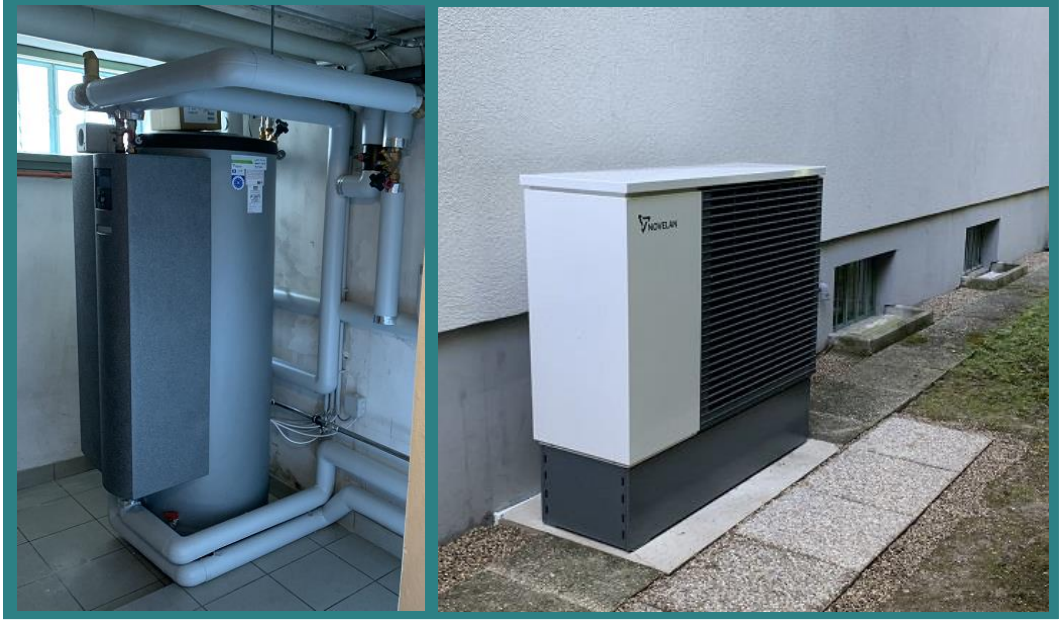
After the installation of the new system, especially the missing odor of heating oil, the additional space in the basement, the lower energy costs and the lower maintenance efforts are the main positive points. The costs occurred during installation were much higher than expected, as a lot of unforeseen work turned out to be necessary.

All information was obtained via the installer and the owner of the house.

New heating system in use	Air source heat pump
Previous replaced heating system	Oil heating
Building type	Single-family house
Useful energy demand (kWh/m^2a) – Before and after building shell renovation	Heat load 14.0 kW to 8.9 kW
Installed capacity (kWth) – Before and after	16 kW → 9 kW
Initial investment (purchase and installation)	€ 38,000.-
Yearly savings on the energy bill (compared to previous system)	1,500 € or 50%
Yearly energy savings (compared to previous system)	21 MWh or 70%
Yearly CO_2 emission reductions (only heating system replacement)	8.2* t CO_2

* Oil 33.000 kWh with 310 g/kWh → 9.000 kWh electricity with 227 g/kWh

New air source heat pump and buffer storage shortly after installation
source: installer



BEST PRACTICE EXAMPLES FROM AUSTRIA (FEDERAL STATE OF SALZBURG)

BIOMASS MICRO GRID IN A RURAL SETTLEMENT

The project “Sonnengarten Limberg” is situated in the outskirts of Zell am See, capital of the county of Pinzgau, which is in the southwest of the region of Salzburg.

Sonnengarten Limberg is a newly built quarter with 187 flats, offices and a kindergarten with a total useful area of 16,000 m². The construction started in 2018 and is planned to be finished in 2022.

A floor heating is implemented. The main energy generation plant is a pellets boiler with 350 kW nominal power. The estimated annual energy consumption is around 420,000 kWh. A buffer storage with a capacity of 18,000 liters is installed. The waste heat pump uses the waste from office cooling and ventilation of 22 flats as heat sources with a heating power of 22 kW and a planned energy output of 63 MWh/a, sufficient to supply 10 flats. The PV plants’ total power amounts to 140 kW_p (see the following figure). The inlet temperature is 55°C for heating and warm water all year, the return temperature between 28 and 35°C. The flue gas temperature of the pellet boiler is around 160°C and is cooled down to 45°C for heating purposes, which also reduces dust emissions. The pellet plant delivers around 92% of the thermal energy. For peak loads a gas boiler is installed. Only pellets from surrounding sources are used. A special funding was granted which allows lower energy prices.

A contractor, ENGIE, took over the whole responsibility for planning, installation as well as operation and maintenance of the heating system including warm water and also cooling. A fixed price per kWh delivered heat is contracted, which means that a high efficiency is in the interest of the system operator.

This kind of system configuration is said to be unique for domestic purposes.

There is only one central heating station (shown in the following figure), no disperse heating rooms. Heat exchangers in each flat allow a hygienic domestic warm water supply (temperature around 45 to 48°C).

Source:
https://www.hillebrand.at/fileadmin/Limberg/Content/WEB_Brosch_Sonneng_LIMBERG_final.pdf

New heating system in use	Pellets micro grid + waste heat pump, gas for load peaks
Previous replaced heating system	New buildings
Building type	Apartment building
Useful energy demand (kWh/m²a) – Before and after building shell renovation	22.5 → 30.1
Installed capacity (kWth) – Before and after	350 kW pellet boiler + 22 kW waste heat pump + 400 kW gas boiler
Input energy	Pellets (appr. 92%), waste heat, gas

New pellet heating central plant, which supplies a small district heating system

PV modules are installed at a part of the flat roofs, the other part is covered by terraces

BEST PRACTICE EXAMPLES FROM AUSTRIA (FEDERAL STATE OF SALZBURG)

PELLET BOILER REPLACES OLD OIL BOILERS IN A RESIDENTIAL BUILDING WITH THREE RESIDENTIAL UNITS

This residential house with a living area of 320 m² is located in St. Georgen, north of the city of Salzburg. It consists of 3 apartments and is inhabited by a total of 5 people. It was built in 1974 and was previously supplied with heat by an oil boiler (built in 1995). The boiler had an output of 20 kW and the annual oil consumption was about 3,000 liters. Because of the desire to save energy and to reduce the environmental impact, the owner conducted an internet research. After that, an energy consultant was contacted and a detailed discussion was also held with the installer. Finally, the owner decided to install a pellet boiler system for space heating. The investment costs were around € 30,000, which also included a chimney renovation (1,300) and the conversion of the existing tank room into a pellet storage room with a capacity of 8 tons (600). The existing radiators were kept in use. The plant was about 1/3 funded. A special bonus for replacement of old oil boilers was granted for this project. The installation took about 30 partie hours and ran to the complete satisfaction of the residents. The system has now been in operation for two months; so far it has been running without any problems, but it is too early at the moment for any meaningful operating experience. Hot water is now provided by a heat pump system with a heating element for cold days. The building owner was trained during commissioning.

New heating system in use	Pellet boiler
Previous replaced heating system	Oil boiler
Building type	3-family house
Installed heating capacity, old and new system	20 kW → ? kW
Annual energy consumption old system	30.000 kWh (3.000 liter oil)
Annual CO_2 savings	9.3 tons
Installation costs	€ 30.000.-
Subsidies	€ 10.000.-

Old oil boiler (left) and new pellet system (right)

BEST PRACTICE EXAMPLES FROM AUSTRIA (FEDERAL STATE OF SALZBURG)

COMBINED PELLET AND WOOD BOILER WITH SOLAR THERMAL COLLECTORS REPLACES COAL BOILER IN A SINGLE FAMILY HOUSE

This residential building with a usable living space of 180 m² is located in Übelbach near Graz. Its thermal quality can be described as average with an HWB of 126.5 kWh/m²a. It is occupied by 2 persons, was built in 1974 and was previously supplied with space heating by a hard coal boiler; the hot water was provided electrically. The boiler had an output of 13 kW.

The considerable amount of work associated with the coal heating system, especially with the increasing age of the residents, the desire to keep the house warm during a holiday in winter, as well as environmental concerns led to the decision to purchase a new heating system.

First, an in-house exhibition of a plumbing company was visited to gather information. After obtaining three cost estimates and intensive consultation with the suppliers, the contract was not awarded to the cheapest supplier, but to the company with the best expertise. The good cooperation of the plumbing company with the electrician and the tiler should be emphasised. The entire construction project went according to plan without any friction. The agreed deadlines were met exactly. It was a challenge to decide whether the future heating system should be based on a pure pellet stove or on hybrid technology.

In the end, a 15 kW pellet and log boiler was installed and combined with a 16 m² solar heat collector. In addition, a 1,000-litre heating buffer tank was integrated into the system. The solar heat is primarily used to supply hot water; however, surpluses are pumped into the heating buffer. A 9 kW heating rod is also installed in the buffer storage tank for backup. Furthermore, the hot water circulation pump was replaced and the heating curve and circulation pump were adjusted. The residents were also trained in the optimal operation of the new heating system when it was handed over. The flow temperature is about 60°C. Of the € 21,000 investment costs, about € 1,800 were subsidised. The 3 years of operating experience are very satisfactory. Instead of 20 tonnes of coal, 5 tonnes of pellets and 18 cubic metres of wood are now consumed.

New heating system	Combined pellet and wood boiler + solar thermal collectors and buffer storage
Old heating system	coal boiler
Building type	single family house
Installed heating capacity, old → new system	12,8 kW → 15 kW
Annual energy consumption new system	25.000 kWh + 36.000 kWh = 61.000 kWh (5 tons of pellets and 18 m³ logwood)
Annual energy consumption old system	160.000 kWh (20 tons of coal)
Annual CO2 savings	60 tons
Installation costs	€ 21.000.-
Subsidies	€ 1.800.-

REFURBISHMENT OF A CITY QUARTER IN SALZBURG: REPLACEMENT OF SINGLE OVENS AND GAS HEATERS

The City of Salzburg owns 26 residential buildings, which were all built in the years 1950 - 1965, in the Lehen district. Due to the small size of the apartments, location of the nearby highway and the deteriorating condition of the property, the apartments were unable to be easily rented and this section of the district became a rather undesirable place to live. The buildings had no central heating and about 50% of the apartments only had access to natural gas heaters. The other 50% had single ovens based on coal or wood. The local government had already tried to undertake a number of renovation measures, including changing the windows, insulting the facade and roofs in some buildings, which did not result in significant energy savings. Purely thermal renovation measures were considered sensible, but would not have been sufficient in this settlement.

Taking inspiration from other nearby projects, the City of Salzburg put forth a plan to create a sustainable, long-lasting residential complex with high functionality and ecological quality. The main goals of the renovation project (2008-2018) were to increase the overall quality of residents, build housing blocks in the best environmental standard possible, increase the quality of open areas, and ensure permanent rentability by improving the overall image. In 2012, the municipal council of the city of Salzburg decided to renovate 14 residential buildings and 12 apartment buildings to be demolished and rebuilt. The City of Salzburg took great care in ensuring that a number of stakeholders were involved in the project realization from the planning stage onwards:

- Main stakeholders: policymakers, investors, energy suppliers and decision makers, renovation experts, building owners and residents, research institutes and other intermediaries
- Early discussions with the Salzburg mayor to gain political acceptance and support
- Thorough survey of the current situation, including a survey with the existing residents
- In order to gain acceptance from the existing residents, a system for effective settlement management was established, including relocation assistance for residents of 300 households and satisfactory interim housing solutions (for 2011 to 2016), as well as ongoing direct communication and information on the project development.

A steering group was set up, moderated by the office of the responsible city council. This group proved its worth in steering the overall project and thus all the necessary official procedures could be appropriately coordinated and completed on time, optimum information was achieved for all those involved and the entire project was completed correctly on schedule.

In those 14 houses with 286 flats for which the Salzburg City Council had decided on a comprehensive refurbishment, the following measures were implemented between 2012 and 2013:

- Thermal refurbishment to the lowest energy standard: facade insulation, new windows, insulation of the basement and attic ceilings. The energy requirement for heating was reduced by 72 %.
- Balconies: Each flat was equipped with a balcony in the course of the renovation.
- District heating connection: In 2011, Salzburg's largest thermal solar plant with 2,000 m² collector surface and a 200 m³ buffer storage tank was installed in the Lehen municipal utility. This micro-grid of Salzburg

New heating system in use	District heating and solar thermal micro-grid; PV
Previous replaced heating system	Gas heaters and oil and wood ovens
Building type	Apartment building
Useful energy demand (kWh/m^2.a) – Before and after building shell renovation	Before 93-150 / After 27-35
Installed capacity (kWth) – Before and after	
Initial investment (purchase and installation)	
Yearly savings on the energy bill (compared to previous system)	
Yearly energy savings (compared to previous system)	72%
Yearly CO_2 emission reductions (only heating system replacement)	1,480 t CO_2

AG was extended into the Strubergasse housing estate so that the surplus heat from the solar plant (especially in summer) can be used. As the old flats were not yet connected to a modern central heating system, supply lines were laid to each flat.

- The CO_2 savings through these measures amount to approx. 757.6 t per year.

Overall, 286 apartments were renovated, 350 new subsidized apartments were erected from 2011 to 2018. In addition to the improvements to the apartment complexes and buildings, the City of Salzburg made sure to improve the overall quality of living in the area by creating welcome outdoor communal garden spaces, offering a better management of parking spaces for personal vehicles, and adding more bicycle paths. This renovation project took place under the EU program Concerto "Green Solar Cities" with the highest requirements and standards for sustainability and energy efficiency.

Sources:

- https://www.stadt-salzburg.at/fileadmin/landingpages/smart_city/smart_city_masterplan_2025_stadt_salzburg_2019.pdf
- https://www.salzburg-wohnbau.at/projekte/salzburg-strubergasse/
- https://www.stadt-salzburg.at/smartcity/smarte-gebaeude/quartierssanierung/strubergasse/
- http://annex75.iea-ebc.org/Data/publications/Annex75_STC_WPC1_Salzburg_Austria.pdf

Source: stadt-salzburg.at/smartcity/smarte-gebaeude/quartierssanierung/strubergasse

USE OF MOBILE HEATING DEVICES AND A CASE STUDY: HOTEL IN ANIF, NEAR SALZBURG

The boiler can also be replaced without any problems during the heating season in winter. The heating and hot water preparation are only interrupted for a few hours or days. The temperature in smaller buildings does not drastically drop down in just a few hours. The rental price for mobile devices to bridge the hot water supply is of little consequence in view of the often more favorable conditions for installers in winter. Such mobile devices can usually be used by installers, especially for larger properties, and can be rented directly from professional providers.

A mobile heating and hot water supply system can easily take over the supply without interruption in case of a planned replacement, renewal or maintenance of the heat supply system in a larger building, for example in a large residential complex, a hotel, a floor space extension or insulation of an existing district heating system.

An example of where such a mobile heating system has been successfully used can be seen in the State of Salzburg, namely in the boutique hotel “Am Essigmanngut” in Anif, near the city of Salzburg. The hotel was completely renovated in 2019 and was broadly expanded and modernized. A new hotel wing with an ecologically. and architecturally sophisticated wooden frame construction was added with a completion and fixed price guarantee. The hotel now has 1,937 m² of gross floor space. “Get out of oil” was the motto of the young hotelier family. On the basis of several profitability calculations, replacing the old oil heating system with a pellet heating system including a new boiler house and micro-heat distribution network as well as a new 17.6 kWp photovoltaic system, turned out to be the most interesting solution for the expanded, modernized, and environmentally friendly modernized hotel. Since 2020, the hotel has more than 50 modern and comfortable rooms.

A mobile heating system was required as a back-up system during the construction site to supply the hotel with hot water and heating energy. During this time, the old boiler house, including the oil heating, was completely demolished and subsequently disposed of. The transition to the new heating mode was very easy thanks to the mobile device, since the energy supply could be maintained trouble-free without major technical effort. In this example, a mobile heater with cloud-based sensor technology was used. The online sensor technology offers a double benefit: any faults are detected by the online monitoring system before they are noticed by the customer, the operating behaviour is controlled "remotely" via app in such a way that a high overall efficiency of the heating system is guaranteed even in the bridging phase.

Mobile devices also have another important function. For many years now, the decision for oil boiler replacements have often been taken spontaneously or unplanned as a result of an unsolvable problem. If this happens in the heating season, boiler replacement decisions are uninformed. The quickest solution is then a 1:1 renewal of the existing heat supplier with the same energy source (energy source lock-in).

Mobile devices can help ensure that no emergency replacements happen, but that instead unforeseen heating problems are temporarily bridged. End customers gain the time they need to obtain independent and product-neutral advice and are thus able to make more sustainable decisions.

New heating system in use	Pellet boiler
Previous replaced heating system	Oil boiler
Building type	Hotel, 137 m² gross floor area
Useful energy demand (kWh/m²a) – Before and after building shell renovation	Before n. a. After space heat demand: 28,2 kWh/m²a, domestic hot water demand: 12,8 kWh/m²a Cooling: 44,7 kWh/m²a
Installed capacity (kWth) – Before and after	Before 76 kW oil boiler, after 65 kW pellet boiler 1636 l hot water buffer storage DHW capacity heat exchanger 325 kW
Input energy – Before and after	Before about 10,.000 l/a fuel oil, after (including hotel extension) about 115 MWh/a or 24 t/a pellets

Depending on the system capacity, mobile devices are operated with electricity, pellets, gas or oil. Mobile devices are delivered on site on the agreed date, connected to the house installation via flexible and pressure-stable cables and put into operation. Depending on customer requirements, on-site support including tank management is also carried out.

A targeted use of mobile heating and hot water systems can also mitigate the problem of the skilled workers shortage that exists in many regions, because it makes it possible to replace boilers in the heating season. As a result, skilled workers can be better utilized seasonally (by-pass operation with bridging system in the heating season; flatten the curve). Such a solution would be of particular interest in larger buildings, where comprehensive thermal renovations tend to pay off.

Sources:

- boutiquehotel-anif.at/en
- energy4rent.at

Source: boutiquehotel-anif.at/de

PILOT PROJECT WITH (AIR/WATER) HEAT PUMP UTILIZING PROPANE AS A WORKING FLUID

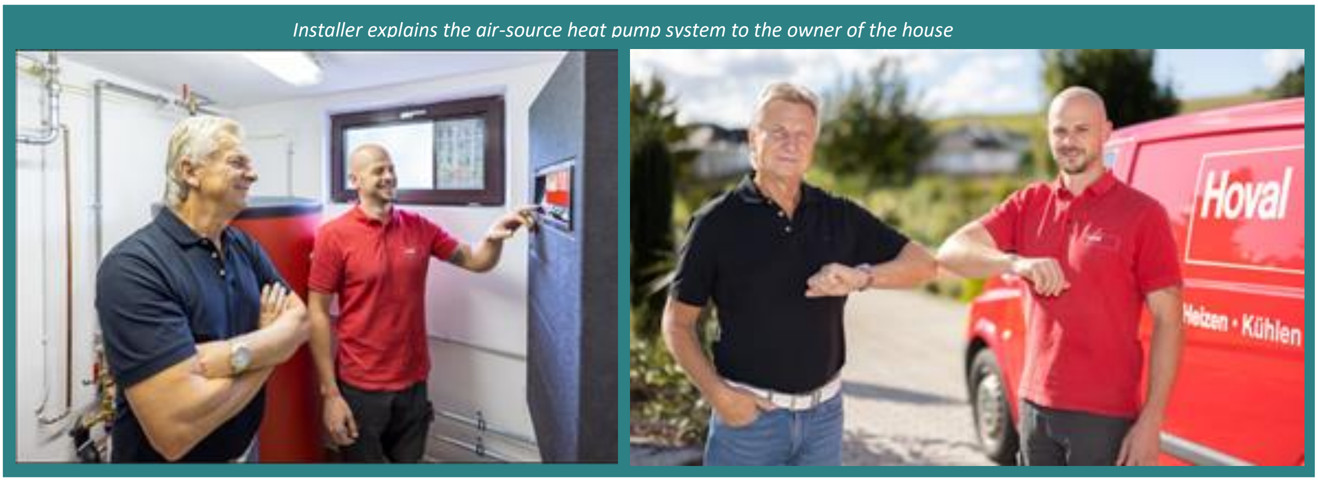
This single family house was built in 1982 and is located in Heugraben in the south of the region of Burgenland, AT. 4 persons are living there. In summer 2020 the old gas boiler (from app. 2000) was replaced by a air source heat pump with R290 (propane) as refrigerant. This refrigerant has a comparably low GWP of 3. The heat pump supplies the house with room heating as well as with domestic hot water. No heating element has been integrated into the system, which will always ensure efficient operation. The house was already heated partly by radiators and partly by underfloor heating - this has not been changed.

A new heating buffer tank with a volume of 100 liters can absorb short-term load fluctuations and helps the air-source heat pump to operate more evenly and thus more efficiently. The old hot water tank had a volume of only 150 liters, which was often insufficient for 4 people. In the course of the new installation of the air-source heat pump, a new 500-liter hot water tank was also integrated into the system. The system comes with an extremely generous 12-year warranty.

The owner was trained by the service technician on how to operate the system. Installation was unproblematic and to the client's utmost satisfaction (see photo). The operating experience so far is also very positive. In particular, this mode of operation is positively highlighted by the family - namely, the bedroom is located in the immediate vicinity of the outdoor unit (on the east side of the house) and does not cause any interference.

New heating system in use	Air-source heat pump with R290
Previous replaced heating system	Natural gas central heating
Building type	Single family house
Energy carrier	Outside air, electricity for the heat pump

Installer explains the air-source heat pump system to the owner of the house



BEST PRACTICE EXAMPLES FROM BOSNIA AND HERZEGOVINA (CANTON OF SARAJEVO)

HEAT PUMP AIR-TO-AIR

The heating system was replaced in a building located in the Sarajevo Canton, which is characterised by a moderately-continental climate, with average annual temperatures ranging between 9.6 and 11.4 ^{o}C.

The building is detached and was built in 1984, and is surrounded by family houses of similar size in the sloping part of the city. The total area of the building is 450 m^2 and is built of hollow brick blocks, while the area of an individual apartment is 110 m^2 and the building consists of four floors. Currently, the building is run as a family house, used by three families and each floor has a separate heating system.

In 2015, the building was reconstructed. Thermal insulation of external walls with EPS with a thickness of 10 and 27 cm was done (lower floors were made with 10 cm of insulation, and upper with 27 cm, because the insulation was used to 'straighten' the walls). Also, the external carpentry was replaced, the roof was reconstructed (insulated with stone wool) and a new heating system was installed. Space heating and hot water system are installed on the third and fourth floor. The system consists of a gas boiler with radiator installations. The owner decided to reconstruct the building from the third and fourth floor, and a two-level apartment of 115 m^2 was built, which is used by a family of three.

After being informed about the benefits of using an air-to-air heat pump, the family decided to replace the previous heating system with underfloor low-temperature heating (with a heat pump). The family got informed about the technology and benefits of heat pumps through online manuals and conversations with manufacturers and certain experts (engineers). By optimizing and installing the heating system more efficiently, the family aimed to achieve certain savings and benefits. Also, the objective was to use a more efficient heating system to contribute to the reduction of the negative impact on the environment and the improvement of air quality.

The total cost for the replacement of the heating system was 7,170.25 EUR, and the investment was through credit indebtedness because there were no incentives or subsidies to replace the heating system. The cost of the heat pump was 2,304.72 EUR (out of the total cost), and the rest of the money was used for the reconstruction of the building, during which a new system of low-temperature underfloor heating installations was installed.

Inside the two-storey apartment, the old system was completely replaced with a new low-temperature underfloor heating with an air-to-air heat pump. Previously, a central gas heating system was used, which consisted of radiator installations. The air-to-air heat pump operates by extracting heat from the outside air, which is transferred to the indoor compressor unit. After compression, there is a rapid increase in the temperature of the refrigerant and the creation of ideal conditions for the transfer of heat produced in certain rooms in the house.

Besides being used to heat the rooms in the apartment during the winter period, the produced thermal energy is used to prepare domestic hot water.

New heating system in use	Air-to-air heat pump
Previous replaced heating system	Gas boiler and radiator installations
Building type	Detached family house
Useful energy demand (kWh/m²a) – Before and after building shell renovation	
Installed capacity (kWth) – Before and after	Unknown → 5 or 7 kW
Primary energy - Before and after	Unknown → 5,460 kWh
Initial investment (purchase and installation)	7,170.25 EUR for the total system
Yearly CO_2 emission reductions (only heating system replacement)	t CO_2

The family did not express that they have had any problems or difficulties with the operation of the new system, such as noise due to the operation of the pump and other parts of the new system.

The family is satisfied with the new heating system that heats the whole apartment, as well as the domestic water, and which provides them temperature comfort in all rooms of the apartment. Energy costs are lower, so that certain economic savings have been achieved, as well as security and independence from frequent changes in the prices of imported energy product (gas).

Since the family previously had not lived in the apartment during the use of the old heating system, no data recorded on the previous consumption of energy product.

Generally, it is estimated that in the Canton, with such a replacement of the heating system, annual savings range between 45-55% for a family house of 150 m², while the payback period is between 9-11 years, depending on the location of the building and the actual installation costs.

The delivered annual energy of the new heating system, as stated by the owner, is about 5,460 kWh, while the useful annual heat is 5,460 kWh/year, so the heating efficiency system is 100%. The useful heat for heating is 5,078 kWh/year, so the energy consumption for heating is about 93%. During the heating period (seven months), about 780 kWh/month of electricity is consumed for heating and hot water preparation, which is a cost of about 71.70 EUR/month for heating.

Annual CO_2 emissions from heating energy consumption are 3.78 tCO_2/year.

It is estimated that the investment life cycle, which includes the installation of an air-to-air heat pump as part of low-temperature underfloor heating, is 15 years, with savings in life cycle ranging between 12,804.02 to about 20,486.44 EUR.

PELLETS INSTEAD OF ELECTRICITY

The heating system was replaced in a building located in the Sarajevo Canton, which is characterized by a moderately-continental climate.

The building is a detached family house built in 1933. The total area of the building is 130 m^2, and the building contains two floors and an attic. The floors are connected by an internal staircase and there is one apartment on each floor. The attic space is used as a storage space. The apartments on the first and ground floor are inhabited by a family of three and each apartment has an individual heating system. The building is built of double solid brick 25 cm thick with facade cement mortar and internal mortar. The roof is made of tiles without additional thermal insulation. Around the family house is a yard in which there is a smaller building made of boards that serves as a storage of pellets.

The family house is located in the urban part of the city near the city transversal and the railway track. Near the yard, there is a large shopping centre. The building is surrounded by residential and commercial buildings of various storeys.

Until 2013, two thermo-accumulation stoves were used in the apartment, which were located in the kitchen and living room. The other rooms (two rooms, hallway and a bathroom) were heated from the kitchen and living room. The main problem with this method of heating is the inability to achieve the desired temperature in all rooms. The rooms, in which the furnaces were located, overheated, and in other rooms, the desired temperature could not be achieved, especially during periods of low outdoor temperatures. The night heat accumulation was not always sufficient for day heating, so it was necessary to fill the furnace during the day as well, which increased heating costs.

To improve the heating system, the family (tenants) got informed about the technology of pellet stoves through manuals found on the Internet, and through conversations with experts in technologies for the use of energy from biomass. After that, the tenants decided to replace the then heating system with a pellet stove system. The investment was realized from the tenants' funds without subsidies and incentives for the use of renewable energy sources by local or state authorities or favourable loans for energy efficiency projects.

In 2013, two thermal storage furnaces with an installed capacity of 2 x 4.5 kW, were replaced with pellet stoves with an installed capacity of 20 kW. In this way, the use of electricity for space heating was replaced with the use of pellets (i.e., biomass). In the same year, wooden box windows were replaced with PVC windows with double glazing. A pellet stove was installed in the living room and a radiator installation was set throughout the apartment. The total heated area is 100 m^2.

Pellet stoves work on the principle of burning energy products (pellets), where the heat produced in the furnace is used to heat the rooms. In each furnace there is a fan at the flue gas outlet, thus preventing heat loss.

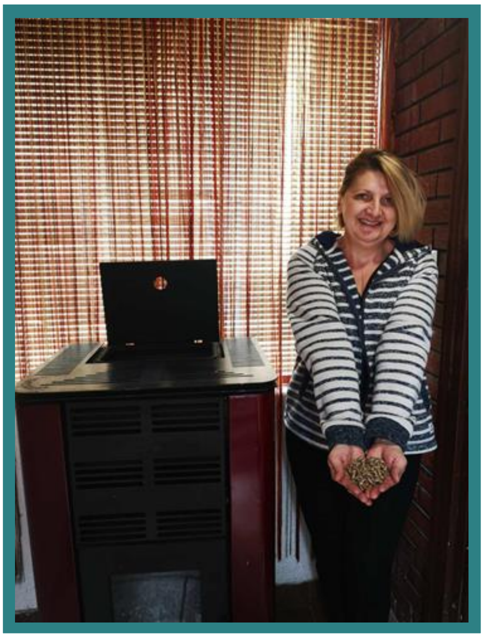
The total investment for the replacement of windows, heating installation, purchase of stoves, and installation of radiators with hot water installation amounted to 4,609.45 EUR. The new heating system is used during the heating

New heating system in use	Pellet stove with radiator installation
Previous replaced heating system	Two thermal storage furnaces
Building type	Detached family house
Useful energy demand (kWh/m²a) – Before and after building shell renovation	200 kWh/m² → 140 kWh/m²
Installed capacity (kWth) – Before and after	2 x 4.5 kW → 20 kW
Primary energy - Before and after	20,000 kWh → 18,400kWh
Annual savings in cash energy costs (compared to the previous system)	66.8%; 1,200 EUR
Annual energy savings (compared to the previous system)	27.5%; 5.5 MWh
Initial investment (purchase and installation)	4,609.45 EUR
Yearly CO_2 emission reductions (only heating system replacement)	14.5 t CO_2

period and for the preparation of hot water. In the summer (when heating is not used), the water is heated by the electric boilers.

By replacing the old heating system, the tenants got a new and more reliable heating system, and they have no objections regarding the use of the new system. The use of pellet stoves enabled the tenants to reach the desired temperature in all rooms and to bear lower heating costs. It is possible to automatically operate the heating system and automatically adjust the desired temperature in all rooms of the apartment. The beautifully designed pellet stove complemented the interior of the apartment and gave a special warmth to the ambience and comfort during the winter. The total annual delivered energy is 18,428 kWh/year, and the useful heat is 15,952 kWh/year, so the efficiency of the heating system is 87 %. The useful heat used for the heating is 14,357 kWh/year, so that 90% of the total useful heat is used for space heating.

The annual cost for electricity was 1,843.78 EUR/year, and for pellets it is 574.64 EUR/year, so that annual savings for energy in the amount of 1,269.13 EUR/year (66.8%) are achieved. Considering that the new heating system works more efficiently, savings in useful heat for heating have been achieved in the amount of 5,443 kWh/year, i.e., 27.5%, and savings in delivered energy amount to 1,600 kWh, i.e., 8%. It has been established that the payback period for the investment of heating system replacement and window replacement is four years. The replacement of heating system is also environmentally friendly because the CO_2 emission factor for electricity per energy unit of fuel is 0.7446 $kgCO_2/kWh$, and for pellets is 0.00 $kgCO_2/kWh$. By replacing the heating system and using pellets, a renewable energy source, as an energy product, CO_2 emissions were reduced by 14.5 tCO_2/year.



FROM BLACK COAL TO PURE PELLETS

The heating system was replaced in a building located in the Sarajevo Canton, which is characterized by a moderately-continental climate. The building is categorized as a detached family house, built in 1970. The building was built of a hollow brick block with internal and external facade cement mortar, which is characteristic for the construction during the 70s. The roof is covered with sheet metal with thermal insulation. In 2019, the building was insulated by installing an 8 cm thick EPS on the entire building.

The total area of the building is 240 m^2 and has two floors. On the ground floor, there is a living space of 80 m^2 and a garage, storage room and boiler room of 40 m^2. Upstairs is a living space of 120 m^2. Each floor consists of one residential unit. The floors are connected by an external covered staircase. A family of four lives on the ground floor, and one person lives on the first floor. The building is connected to the gas network and there is a gas boiler in the building. There is a yard around the building, and it is surrounded by other buildings of similar area, height and purpose.

The previous heating system consisted of a boiler on black coal and wood and a gas boiler. At the annual level, energy product consumption was 9 tons of coal and 2 m^3 of wood. Due to the temperature drop during the night, gas was used to reheat the space in the morning, before the boiler was started. The system was also used to prepare hot water during the heating period. The tenants were extremely dissatisfied with this heating system because it was necessary to invest a lot of work and time (lighting a fire, cleaning the stove, transferring energy...). The system was not automated, the room temperature could not be adjusted automatically and the desired temperature could not be reached 24 hours a day.

After the tenants got informed about the heating systems that work on the principle of burning pellets, the previous heating system was replaced. Tenants got informed through the Internet and conversations with experts for heating systems that use biomass as an energy source. The total value of the investment was 3,329.05 EUR. The investment was from the tenants' funds, as there were no subsidies and incentives to replace the heating system and switch to a renewable energy source.

In 2014, the boiler on black coal and wood with an installed capacity of 35 kW was replaced with a pellet boiler with an installed capacity of 40 kW. The pellet boiler was purchased and installed, and the radiator installation already existed in the building, so the boiler is connected to the existing radiator installation. All the necessary work lasted about three days. The boiler is located in the boiler room and is used to heat the entire building. The entire living space (80 m^2) is heated on the ground floor, while on the first floor, only one part of the living space (50 m^2) is heated. The total heated area is 130 m^2. Also, in the part of the apartment on the first floor, which is not used, radiator installation has been installed, but the thermostatic valves have been closed.

The pellet boiler works on the principle of generating heat when burning pellets, then the generated heat warms up the water circulating through the boiler and through the radiator installations. Unlike oil or gas heating systems, pellet heating systems require the integration of a hot water tank into the heating system in order to reduce heat losses.

New heating system in use	Pellet boiler with radiator installation
Previous replaced heating system	Coal boiler with radiator installation
Building type	Detached family house
Useful energy demand (kWh/m²a) – Before and after building shell renovation	230 kWh/m²
Installed capacity (kWth) – Before and after	35 kW → 40 kW
Primary energy - Before and after	51,282.40 kWh → 40,650 kWh
Annual energy savings (compared to the previous system)	1.2%; 0.4 MWh
Initial investment (purchase and installation)	3,300 EUR
Yearly CO_2 emission reductions (only heating system replacement)	9.93 t CO_2

The new system is used for heating and preparation of hot water during the heating period in the entire building.

The main benefit of the new heating system is automated operation and during the heating period (autumn-winter), the desired temperature is reached 24 hours a day. It is characteristic to adjust the temperature via a thermostat and manual operation is reduced to a minimum, which has led to a more comfortable way of life in the building.

Energy products savings are achieved because the previous heating system required an annual energy consumption of 9 t of coal and 2 m³ of wood, while the new system requires 7.5 t of pellets. However, since the price of pellets on the market is higher than the price for coal and wood, the annual monetary costs for energy have increased. The annual monetary cost for wood and coal was a total of 1,131.19 EUR/year. However, the tenants are very satisfied with the new heating system and have no objections to the operation of the system. Despite the increase in heating costs, the new system provides temperature comfort throughout the day. They pointed out that they invest less time and work in servicing the heating system and are no longer time-bound to maintain the fire in the boiler, which leaves them more time for joint activities. Tenants are also pleased that the replacement has contributed to the reduction in CO_2 emissions. By replacing the heating system, an annual reduction of emissions in the amount of 9.93 tCO_2/year was achieved. In order to reduce the annual costs for heating, i.e., energy product, in 2019, the thermal insulation of the building with Styrofoam (EPS) 8 cm thick was done. Given the rather mild winter of 2019/2020 and the stock of pellets, at this time it is not possible to accurately estimate the energy savings achieved by the insulation of the building. The tenants see the investment in the replacement of the heating system as an investment to improve the comfort of living and to increase the quality of life.

BEST PRACTICE EXAMPLES FROM BULGARIA (RHODOPE MOUNTAIN REGION)

MODERN PELLET HEATING SYSTEM

Dimitar Belinchev from the town of Velingrad replaced his wood boiler with a pellet boiler, and installed a remotely controlled substation in the basement of his two-storey house. In the rooms on the second floor, there is a thermometer with Wi-Fi connection to the Internet, and through installed software on the phone, his son regulates the temperatures in the rooms remotely from Stara Zagora, where he works.

The new modern system called Isotherm Pellet Bio is produced by the Bulgarian company Isotherm Style Ltd. The installed capacity is in the range 40-100 kW. The height of the boiler is 1650 mm. The substation is equipped with a buffer tank (1 m^2 water capacity). The water temperature in the installation is maintained automatically – by controlling the boiler. When temperature reaches 660 ^{0}C, the boiler automatically turns off. When temperature drops to 46 ^{0}C, the boiler starts warming up. Heat distribution system in the house was installed in 2001.

The old boiler was a Czech pyrolysis wood-burning Atmos. Its fueling required big quantities of oak or beech trees (not pine), which clogged the chimney. Access to firewood was difficult, a lot of wood had to be stored on site, burned, and the boiler had to be cleaned. Furthermore, there used to be a lot of smoke and the temperature could not be well regulated. The old boiler was so powerful that it was not possible to stop it suddenly, *"you want 22 ^{0}C, it can't go down."* With the current boiler, it is not necessary to go around the rooms to regulate the temperature. In addition, the previous boiler had to be cleaned every day and it was dirty, while the new one it is enough to clean once every 30 days. Now the owners of the house clean the boiler every week, during which time the collected ash is at the bottom of the bucket and there is no cinder, just plain ashes.

Mr. Katsarsky from the installation company in the town of Pazardhik can test the system and set the parameters of the remote control at any time via the phone. Since mounting, three years and three winters already, there has not been faults in the system.

The house is old, made of bricks, without external insulation, but it is warm and there are radiators installed everywhere. Both floors are heated, each of them with a floor area of 55 m^2. – 110 m^2 total, plus cellar of 25-30 m^2, entrance hall and the two rooms; 145 m^2 in total. The ceilings are insulated and all window frames are replaced with new ones. In 2019, the roof was also renovated. The owner does not see much point in insulating the external walls, for which he would need to invest approx. BGN 15000-20000 with no return on the investment. Radiators were mounted in 2001 by a person, who was not an expert, and so there is a possibility for further optimization of the system.

The investment in the new system amounted to BGN 6000 - 7000, incl. the substation. The system was a ready-made, the installation company only redesigned the boiler so that it could be connected in parallel. In the beginning, there was a problem with the noise from the installation up the floors, so it was redesigned and the noise was removed. The thermostatic heads of the radiators are no longer touched. *"Living in the house in winter is a pleasure, the bathroom doors are open."*

Heating is extremely economical and the savings are great. In order to heat one room with the old system were needed 7 m^3 of wood per year, or 20-25 m^3 for both floors. With the new system, 6 tons of pellets per season are enough. The money that the owners were spending on heating one room with wood now covers the price of pellets for the whole house. The investment pays off in 2-3 years. The boiler (for hot water) also runs on pellets.

New heating system in use	Pellets boiler (Isotherm Pellet Bio)
Previous replaced heating system	Wood boiler (Atmos)
Building type	Two-storey brick house, floor area of 145 m^2, no external insulation, new window frames
Useful energy demand (kWh/m^2a) – Before and after building shell renovation	182 kWh/m^2a
Installed capacity (kWth) – Before and after	100 kW
Input energy – Before and after	37.7 MWh/y → 29.4 MWh/y
Initial investment (purchase and installation)	BGN 6000-7000 including the substation, boiler and everything
Yearly savings on the energy bill (compared to previous system)	>33%
Yearly energy savings (compared to previous system)	22%
Yearly CO_2 emission reductions (only heating system replacement)	50%

“It is difficult to take wood from the forestry, there are problems with the delivered quantities and quality, and it also involves huge spadework. The consumption of wood is bigger because the quantity delivered is often less than paid and it is a humiliation to beg the supplier, who trades with the lack of reliable measuring of the quantity of delivery. The prices are also high - 120 BGN/m^3 of wood. Approximately BGN 3000 went for 25 cubic meters per season. The new system is used twenty-four hours. One ton of pellets costs BGN 320-340. The cost for the season is about BGN 2000 (3 tons per floor on average). At the same time, now the electric water heater does not work and so we save over BGN 1000 per year.” This expenditure covers the needs of two families - Mr. Belinchev and his wife, who live on the first floor, their son, daughter-in-law and grandson, who live on the second floor.

Mr. Belinchev often travels to Pazardzhik. When he decided to replace his heating system, he went to investigate what the various companies in the city were offering. He was looking for another company, but stopped in a parking lot near the Isotherm Style office that he knew made such systems. He went in to check what they were offering and chanced on Mr. Katsarsky, who gave him a thorough explanation of everything. Mr. Belinchev never went to another company; and does not think he made a mistake. His son had also examined the market - Italian boilers, Swedish boilers, which require special expensive pellets, and are looking as space stations; it is not known who will maintain them… Now the family feels secure with the Bulgarian company. The parameters of the system are regulated via the Internet. And Mr. Katsarsky is here. An acquaintance of theirs, who is an engineer, looked through the system and said he had never heard such a quiet system before.

PELLET BOILER AND MODERN FIREPLACE

Dimitar Ivanov from the town of Chepelare lives in a 5-storey single-family house, the ground floor of which is designed for and used as a restaurant. The house is made of bricks, the walls are well plastered and nearly 80% of the window frames are new.

Dimitar and his wife occupy the second floor, his mother lives on the first floor, and his brother, who comes to Chepelare several times per month for 1-2 days, resides a room on the last floor. During Christmas and winter season, the rest of the rooms are rented to groups, sometimes skiers or sports clubs, but this is for no more than 20 days a year. In winter mainly the restaurant and the upper two floors are heated, where there are 6 rooms with a total heated area of 180 m^2. Due to the increased stream of people during winter season, the restaurant is heated most of the time, hence the energy consumption goes up.

In the beginning, the house was heated with a wood and coal boiler, which has been subsequently replaced by a combined pellets and wood boiler. The restaurant was heated with an ordinary fireplace, which served also as a decoration. The owner however realized that it would be much more efficient to use the fireplace for heating and in this way to reduce the spadework and servicing of the stoves. Consequently, this fireplace has been replaced by one with a water jacket. Water is heated with electric water-heaters, not connected to the heating system.

Heat distribution system is typical for the houses in the town installed in the mid 1990-ies. The most commonly used rooms are equipped with two cast iron radiators each. When the house is used as a guesthouse, the rooms located on the middle two floors are heated twenty-four hours.

In the beginning of 2019, Dimitar equipped the existing boiler with a new 60 kW burner and bought a new 25 kW pellets boiler for the needs of the restaurant and the rooms on the upper two floors. He connected the fireplace with the new boiler in a common heating system.

The consumption of the new system with the two boilers is 6 tons of pellets per season, while in the past the wood boiler with the fireplace and stoves consumed 10-12 tons of wood. The price of the pellets, which Mr. Iavnov bought for the past 2019/2020 winter season, was 340 BGN/ton. Thus, the experience from the first season with the new heating system shows that the total cost for heating of 120 m^2 floor area and 60 m^2 restaurant area is 6*340=2000 BGN/season.

The replacement of the old and the installation of the new heating system was performed by the local company Belimars in 2-3 days. Belimars has been operating for years and has gained the trust of the customers in the region. It has installed about 80% of the new heating systems in the town of Chepelare, realized multiple projects in Smolyan, Pamporovo and the whole region. A relative of Mr. Ivanov, who works in the company, advised him to replace the heating with a more efficient one and helped him with the choice of the most proper equipment. In contrast to the previous system, there has not been need for servicing of the system from installation until now.

New heating system in use	Pellets boiler + modern fireplace
Previous replaced heating system	Wood and coal boiler + common fireplace
Building type	5-storey brick house, well plastered, changed window frames
Useful energy demand (kWh/m^2a) – Before and after building shell renovation	139
Installed capacity (kWth) – Before and after	85 kW
Initial investment (purchase and installation)	33.4 MWh → 28.8 MWh
Yearly savings on the energy bill (compared to previous system)	2 %
Yearly energy savings (compared to previous system)	14% (в MWh)
Yearly CO_2 emission reductions (only heating system replacement)	38%

Dimitar Ivanov is extremely satisfied with the pellets system as it is now. He does not have to carry wood, light fire, bring in and out ashes and wastes, clean. Mr. Ivanov's mother lives permanently in the house and with the new system, the daily cleaning and maintenance of her room is not necessary anymore. Furthermore, radiators are easy to be switched on for the visits of his brother. The heating of the house now is more efficient, clean and easy. The energy costs have decreased and the comfort has increased significantly.

PELLET BOILER AND SOLAR COLLECTORS

The house of Dr. Strinsky was built by his family in 1935. It is a typical two-storey Rhodope style house made of bricks and 50-55 cm thick stone masonry of the ground floor, with floor area of 90 m^2.

Before settling here, Dr. Strinsky, his wife and one of their children had lived in rented accommodation in the clinic, where they had grappled with heating on wood, coal and electricity.

Dr. Strinsky made major repairs to the house – built in walls and opened up doors in order to make rooms more comfortable. Then he came to the idea to install modern heating system and radiators.

Dr. Strinsky bought a 45 kW Bisolid system and separately connected two solar collectors.

Bisolid boiler operates on a combination of wood and pellets. The pellets burner was mounted in August at Dr. Strinsky's desire, in order to check the system's operation in very hot weather. From one of the pellets shops he bought 4 sacks of pellets and, seeing how convenient it is, on the second day he sold the 10 cubic meters of wood he disposed of.

The pellets burner is one of the biggest; its price was BGN 3800. Dr. Strinsky decided to wait until summer, when the company usually promotes its goods, and indeed – the price dropped by 400 BGN. Company's workers who have installed many such systems recommend them and say that people in the town also give a very high mark of them. The burner is produced in Turkey and Slovenia. Compared to the price of the similar burners, produced by Western companies, which is about BGN 8000, the price of this one is quite acceptable.

Now, during wintertime heat to the two floors is supplied by two water-heaters of 120 l each via 10 radiators and 2 bath radiators. They are connected to the heating system. One ton of pellets per month is used for heating. In the beginning, the price of the pellets was 280 BGN/ t. Then the prices in the city began to rise. *"The prices during the last two winters have raised immensely. It is not clear why. This should be a state policy, as a social activity to make environment cleaner, not to increase the cost of technologies that are environmentally friendly. Wood can be cheaper, but nobody gives an account of their transportation, use of vacuum cleaners, fuel for the cutting machines – who calculates the energy consumed for these activities?"*

The current system has been used for 6 years already without any troubles. The interior walls remain clean, there is no need of refreshing their paint or of plastering – *"Isn't this an expenditure? Saved!"* The other point - it's all electronics - there are factory-set programs, but one can do the programming by himself. A small appliance that measures the temperature is installed in the kitchen of the house. The electronics switch the burner on and off itself. There is an option to turn it on also via the phone via satellite, even from 300-400 kilometers and on the go. Solar collectors were not expensive in the long run. The whole installation including the 2 water-heaters, the collectors and mounting costed about BGN 1400. The output power is calculated by the surface area of the panel itself, which is 2,50 m x 1.2 m each. The temperature of water in summer is 67-72 degrees Celsius, the investment is wonderful and the owners are extremely satisfied.

"If you warm up the electric water-heater and set the thermostat at maximum capacity, water cannot become so hot as it is with solar energy. In the beginning when we started using the hot water, I used to say to my son-in-law – be careful because the temperature is so high that pure steam comes out. Now the temperature of water is about 72 degrees Celsius and it is used all year round. If the sun shines, temperature increases and helps the pellets. During summer, when weather is cloudy, we use electricity. In winter, water is warmed up with pellets. In the past, when we installed the system, it used to be the best system available on the market. During the (winter)

New heating system in use	Pellets boiler + solar collectors
Previous replaced heating system	Wood stoves + electricity
Building type	Single-family house, 2 floors, bricks and stone masonry
Useful energy demand (kWh/m²a) – Before and after building shell renovation	140 kWh/m².a
Installed capacity (kWth) – Before and after	45 kW
Input energy – Before and after	31.4 MWh/y (9 MWh electricity + 22.4 MWh/y wood) → 28.8 MWh/y
Initial investment (purchase and installation)	BGN 3400 + BGN 1400
Yearly savings on the energy bill (compared to previous system)	33% (in BGN)
Yearly energy savings (compared to previous system)	8% (in MWh)
Yearly CO_2 emission reductions (only heating system replacement)	85%

season, the water-heater is running twenty-four hours; it doesn't make sense to switch it on and off when needed."

While Dr. Strinsky and his family were living in the clinic, they were using three stoves altogether – 2 on wood and one on wood and coal. One of the rooms did not have a chimney, so it was heated with an electric convector. Electricity for the boiler, heater, TV and some smaller electric appliances costed them 300-310 BGN a month during the winter period. This was in addition to the expenses for the wood. The total heated floor area was about 60 m^2.

"When you pay in installments, money does not seem too much; wood however require cutting, chopping, putting them inside, engaging of people, using cutting machine for everything, providing of fuel, oil for the cutter. You are happy just to get rid of sawdust, dirt, ashes and waste of time".

Dr. Strinsky is laughing: "We unload the pellets on the sidewalk, 1 ton of pellets are 66 sacks, and in 15 minutes they are already put in the house. I'm joking with my neighbors (who use wood) – I brought the wood, chopped them and put them in the house. They are wondering – How did you manage to do it so quickly?!"

The company, Dr. Strinsky bought the system from, is well-known – it has installed systems all around the town and everybody praises them high. For all these years Dr. Strinsky also did not have to call them. Only once did the liquid for the collectors have to be topped up. There is something like antifreeze, you can also put antifreeze. Otherwise, if something happens, where to look for companies in other cities?

VACATION HOUSE WITH HEAT PUMP ON THE ISLAND OF KRK

Mr. Davor Bilobrk welcomed us in his beautiful five stars family house for rent in the little village Gornja Hlapa, on the Island of Krk, Primorsko-goranska county, where he installed heath pump (air-to-air) for heating and cooling, supported by solar panels for the preparation of domestic hot water. The house was built two years ago, it covers an area of 288 m^2 and additional 40 m^2 on the outside as an entertainment zone with sauna, exercise machines and hot tub. It can accommodate 8 people.

House itself was built in accordance with the highest standards, including three-layer insulated glass, window/door contact sensors, great quality of the house shell including 10 cm of black styrofoam etc.

Underfloor heating is conducted in every room of the house and cooling is provided through convector units. Heath pump with installed capacity of 15 kW$_{el}$/45 kW$_{th}$ is located in the garden and 5 m^2 solar panels are located on the rooftop, along with 500 l hot water boiler in a separate storage (boiler room) on the ground floor of the house.

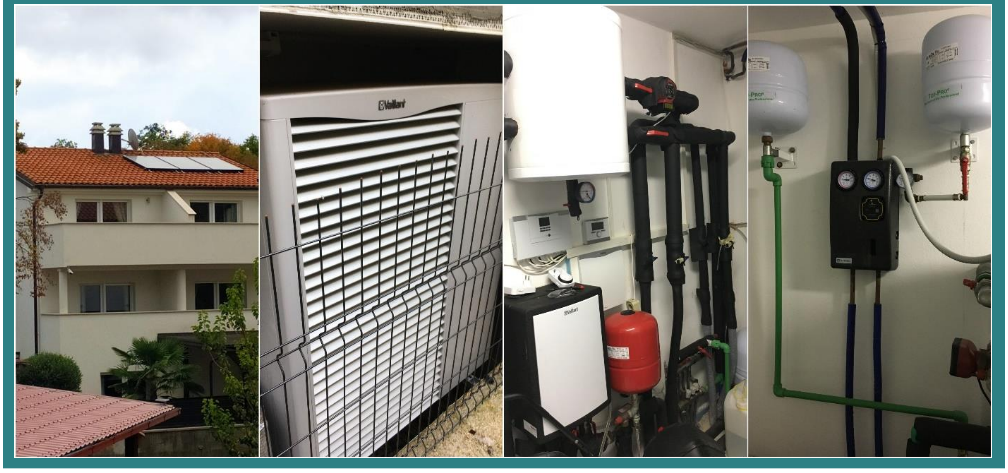
Investment in this system amounted around 15 000 EUR, and the decision was made at the suggestion of owner’s brother, who is a heating and cooling installer and has a great experience with this and similar systems. Also, he was unsatisfied with the existing system in the house they live in (combination of natural gas and electricity) because of the high energy bills. For them, this was the cleanest and environmentally friendly option, with great savings on the energy bill in comparison to the existing system in their family house.

The house was built in 9 months, including the installation of heat pump and solar panels and the owner didn’t experienced any difficulties, especially having in mind that his brother was the leader of the whole process and was in charge for the whole control and regulation technology aspects. Owner is more than satisfied with the result and does not have any complains on the system, he achieved what he expected - economic savings, contribution to climate change mitigation and system reliability. However, the installation process itself was not supported by any incentive schemes, it was completely financed by the owner.

New heating system in use	Heat Pump
Previous replaced heating system	None
Building type	House for rent
Useful energy demand (kWh/m^2a) – Before and after building shell renovation	182 kWh/ m^2a
Installed capacity (kWth) – Before and after	45 kW_{th}
Input energy – Before and after	10,000 kWh
Initial investment (purchase and installation)	15,000 EUR
Yearly savings on the energy bill (compared to previous system)	
Yearly energy savings (compared to previous system)	
Yearly CO_2 emission reductions (only heating system replacement)	

Mr. Bilobrk
in front of the hot water boiler in boiler room

A) Solar panels on the rooftop, B) External unit of heat pump C) Interior pipeline infrastructure D) Expansion



BEST PRACTICE EXAMPLES FROM CROATIA (PRIMORSKO GORANSKA COUNTY)

FAMILY HOUSE USING BIOMASS IN RIJEKA

Mr. Tomislav Bolić is an owner of the family house located in city of Rijeka, Primorsko-goranska county. For years he was using fuel oil for heating and electricity for cooling, but six years ago, in 2014 he decided to invest in modern and more environmentally friendly system for heating – pellets. His family house has two apartments with total area of 180 m^2, and the heated area amounts around 150 m^2.

Before he was encouraged to proceed to the new system, he spent a lot of time reading on the benefits that RHC systems provide. His neighbour is a heating and cooling installer, so he had all the information needed and decided to give it a go, even though at that time, there were no incentive schemes in his region.

New system with installed capacity of 30 kW_{th} (same as old) is located in the separate boiler room on the ground floor of the house. Since he already had boiler and indented central heating system, he just had to invest in new burner and a pellet storage. Heating is conducted through existing radiators. Investment amounted around 800 EUR, and the installation did not take more than 3 days.

He was unsatisfied with the existing system due to the high energy bills and pellets are much more environmentally friendly option. Since the system is located in a separate room on the ground floor, his family doesn’t experience any problems with noise or dust. In the first years, their economic savings were very large, up to 50% lower energy bills in comparison to the previous system. Moreover, plants in their garden became less diseased after the installation of the new system.

New heating system in use	Pellets
Previous replaced heating system	Fuel oil
Building type	Family house
Useful energy demand (kWh/m²a) – Before and after building shell renovation	170 kWh/m² – 170 kWh/m²
Installed capacity (kWth) – Before and after	30 kW/30 kW
Input energy – Before and after	2300 l of oil – 4.5 t of pellets
Initial investment (purchase and installation)	800 EUR
Yearly savings on the energy bill (compared to previous system)	50% in EUR
Yearly energy savings (compared to previous system)	0% in MWh
Yearly CO_2 emission reductions (only heating system replacement)	5,82 t CO_2

Mr. Bolić in front of the biomass boiler in the boiler room

A) Pellet supply, B) Expansion vessel, C) Pellet storage, D) Costs for pellets per year

BEST PRACTICE EXAMPLES FROM CROATIA (PRIMORSKO GORANSKA COUNTY)

FAMILY HOUSE WITH SOLAR PANELS IN RIJEKA

Mr. Mladen Pujić welcomed us in his family apartment located in a small residental building in city of Rijeka, Primorsko-goranska county. The heating and preparation of domestic hot water is provided by vacuum solar panels located on the rooftop of the building. The building has two floors and it accomodates three families. His apartment is located on the second floor including the attic of the building and it has 4 tenants at the moment. Ten years ago they had only smaller apartment on the second floor and they used wood for heating. It didn’t provide enough comfor since the heating system wasn’t indented and they had only wood stove in their livingroom. It was also very difficult to bring wood on the second floor in the building with no elevator.

When they bought an attic, they decided to make a complete reconstruction of the existing floor construction in order to accommodate underfloor and wall heating in their apartment. They also did a major upgrade on the roof (30 cm) and internal isolation (5 cm), and the outer building shell remained the same. The renovation, including the underfloor heating installation, lasted for two years. Even though it was a long process since included a lot of renovation and upgrades on the existing system, the owner did not experience any problems during the process.

Investment was around 4700 EUR, but it was co-funded through the tender “Green Energy in My Home”, financed by REA Kvarner and published in 2011. The subject of the tender was the installation of solar systems for heating and preparation of domestic hot water, as well as systems for heating and preparation of domestic hot water using biomass in households in Primorsko-goranska county. The owner received 1 600 EUR as a support for the RHC development.

They opted for Viessman technology and they are very satisfied with the efficiency, they receive same energy as they did before the installation of the new system, but they doubled the space they live in and where the heating system is provided, and the comfort of living is incomparable. Solar vacuum collectors are located on the rooftop, and 750 l hot water boiler in a separate storage in the attic of the house.

Main drivers of this long, but successful process was an energy efficiency, energy saving, innovation and comfort of living. Owner a lot of time reading and researching the new technologies and he is beyond satisfied with his decision.

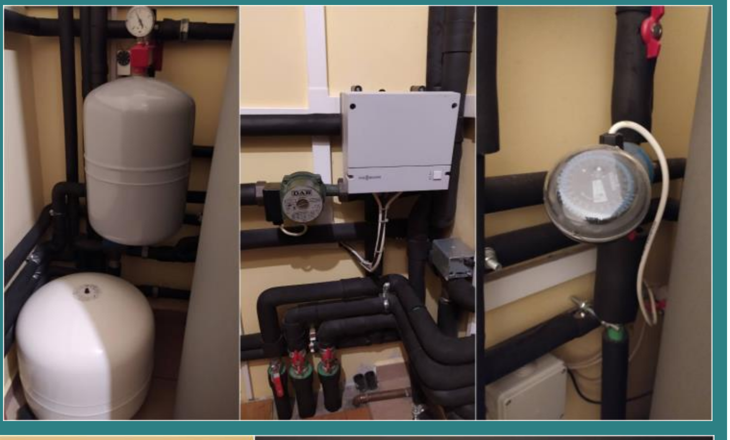
New heating system in use	Solar collectors
Previous replaced heating system	Wood
Building type	Residential building
Useful energy demand (kWh/m^2a) – Before and after building shell renovation	170 kWh/m^2a - 80 kWh/m^2a
Installed capacity (kWth) – Before and after	6m^3 of wood - 5 m^2 collectors and 750 l boiler
Input energy – Before and after	6 m^3 of wood + electricity – 100% of solar
Initial investment (purchase and installation)	4700 EUR
Yearly savings on the energy bill (compared to previous system)	50% in EUR
Yearly energy savings (compared to previous system)	47% in MWh
Yearly CO_2 emission reductions (only heating system replacement)	4,1 t CO_2

Mr. Pujić in front of the hot water boiler in a boiler room

A) Expansion vessels

B) Interior pipeline structure

C) Circulation pump



A) Heat manifold

B) Solar vacuum panels on the rooftop

BEST PRACTICE EXAMPLES FROM CROATIA (CITY OF ZAGREB)

REDUCED HEATING BILLS BY USING PELLETS

Until 2012, the family house of the Borovčak family was one of many in Hrvatsko Zagorje, which used natural gas as the main energy source for heating and preparation of domestic hot water.

That year, homeowners decided to install a new pellet boiler to reduce heating bills. Besides financial savings and using locally available energy source instead of natural gas, homeowners were also incentivised by subsidies granted by Krapina-Zagorje County within the public call for encouraging the use of renewable energy sources for homeowners. Subsidies covered more than 50% of the investment, which accelerated the investment payback period.

After submitting the necessary documentation and receiving the co-financing approval letter, the selected contractor installed a pellet boiler in the basement of the family house. After that, the family only had to wait for the new heating season to start, to notice the savings in the family budget. The pellet boiler was chosen for the convenience and ease of installation because besides the installation of the boiler, no additional changes were required to other parts of the heating system. The homeowners point out that during the entire installation process and the operations that preceded it, they did not have any problems or complaints about the installation and operation of the heating system.

As positive aspects of replacing the heating system, the homeowners mention greater comfort due to the increased feeling of warmth and the ease of procurement and delivery of pellets that come in 15 kg bags. In previous heating seasons, the price of pellets was slightly lower than it is now, but even with a higher price of pellets, this family has lower heating bills and recommends pellet boilers to others who are considering it.

New heating system in use	Pellet boiler
Previous replaced heating system	Natural gas
Building type	Family house
Useful energy demand (kWh/m^{2}a) – Before and after building shell renovation	
Installed capacity (kWth) – Before and after	Old system: 22 kw New system: 35 kW, due to expansion plans
Input energy – Before and after	New system: 6 t pellets per year Old system: unknown
Initial investment (purchase and installation)	HRK 32,000 (EUR 4,200)
Yearly savings on the energy bill (compared to previous system)	ca. HRK 5,000 (EUR 600)
Yearly energy savings (compared to previous system)	
Yearly CO_2 emission reductions (only heating system replacement)	

BEST PRACTICE EXAMPLES FROM CROATIA (CITY OF ZAGREB)

HEAT PUMP IN ZAGREB’S UPPER TOWN COURTYARD

Zagreb's Upper Town is known for its narrow streets, tourist attractions and hidden courtyards of buildings built in the 19th century. Right next to the world’s shortest funicular (66 m), in the Upper Town, is a residential building built in 1850 with an apartment on the first floor that uses an air-to-water heat pump.

The owner of the apartment, prof.dr.sc. Duić, after buying an apartment in the 1850’s building in the Zagreb’s city centre, started renovating it. The renovation included, amongst other measures, replacing the old gas stoves with a new and more efficient heating and cooling system. Given his profession and many years of experience in the field of efficient heating systems, he wanted to test the heat pump in his own home to examine in practice the advantages and disadvantages of such a system.

The air-to-water heat pump was installed in the prof.dr.sc. Duić’s home about ten years ago and is connected to three systems: underfloor heating in tiled rooms, ladder bathroom radiators and fan coil units in rooms where there is no underfloor heating due to parquet. Fan coil units are also used for cooling during the summer months, as well as controlling the room temperature.

In addition to installing a heat pump, old wooden windows were replaced with new ones, also made of wood, to match the style and period in which the building was built. The ceiling of the apartment was additionally insulated because it was previously tiled with wood boards. No other energy efficiency measures have been implemented, as the renovation of the façade is extremely expensive for a building within the cultural-historical zone. Regardless of that, the savings that resulted from the installation of the heat pump are very large, and according to the rough assessment of professor Duić, the investment has paid off in five years.

The outdoor unit of the heat pump is located on the facade of the building and is slightly larger than the outdoor air conditioning units. However, as the building is in the yard and not facing the street, no additional permits or permits from other co-owners of the building were required. Other tenants of the building initially complained about the noise, but after the noise measurements, it was determined that the noise level is within the legal limits and amounts to 30 dB. Apart from the initial disagreement of the building's co-owners, prof.dr.sc. Duić points out that he did not encounter any major obstacles during the installation, because the installation company did an impeccable job, especially since this was also their first installation of a heat pump in the 19th-century building.

Despite the fact that prof.dr.sc. Duić is extremely satisfied with this efficient heating and cooling system, due to lower bills and higher comfort, he believes this is not a desirable practice in densely populated urban areas and/or the city centre. For such areas, a better option would be the connection to the district heating system, and he hopes and advocates that the option of connecting to the district heating plant in the centre of Zagreb will be possible soon.

New heating system in use	Air-to-water heat pump
Previous replaced heating system	Natural gas stoves
Building type	Apartment building from 1850 in the Zagreb's city centre, within the cultural-historical zone
Installed capacity (kWth) – Before and after	Old system: ca. 24 kW New system: 11 kW, which he now considers to be oversized, but during installation they did not want to install a system of smaller capacity due to the age of the building and the lower energy class.
Used energy – before and after, kWh	Before: unknown Now: ca. 100 kWh per month electric energy
Initial investment (purchase and installation)	Before: unknown Now: ca. 100 kWh per month electric energy
Yearly savings on the energy bill (compared to previous system)	ca. HRK 4,000 (EUR 530)
Yearly energy savings (compared to previous system)	
Yearly CO_2 emission reductions (only heating system replacement)	

LOW-ENERGY FAMILY HOUSE IN ZAGORJE

The low-energy house of Brundula family in Hrvatsko Zagorje (Northern Croatia) was built in 2012 and uses renewable energy source systems - heat pumps and solar collectors for space heating and hot water preparation. The heat pump is installed on the lawn of the house and the installation was co-financed by the Krapina-Zagorje County, which covered slightly more than 50% of the investment.

Given that the family company of Brundula family has been operating in the construction sector for decades, the construction of a low-energy house marked a new phase in the company's business, but also opened the door to new, sustainable building opportunities.

During the installation of the heat pump, there were no significant difficulties, but since such an installation represented a novelty in 2012, the whole process took longer than usual. The owner of the house points out that the investment in a low-energy house met all expectations, due to the increased comfort, and also due to the use of solar and ground energy, which is aligned with the family lifestyle. Also, electricity bills for space heating and cooling and hot water preparation are low and for a house of 155 m^2, they average HRK 250 (ca. EUR 33) per month. As early as next year, homeowner plans to further upgrade the house and install a photovoltaic system, which will further increase the number of renewable energy systems in this low-energy house.

New heating system in use	Heat pump and solar collectors
Previous replaced heating system	
Building type	Family house
Useful energy demand (kWh/m^2.a) – Before and after building shell renovation	
Installed capacity (kWth) – Before and after	
Initial investment (purchase and installation)	HRK 50,000 (EUR 6,600)
Yearly savings on the energy bill (compared to previous system)	
Yearly energy savings (compared to previous system)	
Yearly CO$_2$ emission reductions (only heating system replacement)	

BEST PRACTICE EXAMPLES FROM GERMANY (BAVARIAN OBERLAND)

BIOMASS HEATING PLANT WEYARN – WITH LOCAL HEATING SUPPLY ON THE WAY TO ENERGY SELF-SUFFICIENCY

The municipality of Weyarn in the Bavarian Oberland has set itself ambitious climate protection goals: By the year 2025 it wants to be completely self-sufficient in energy. The 900-year-old, listed monastery, which belongs to the community and obtains its heat from fuel oil, posed a particular challenge. The path to a climate-friendly heat supply was finally paved by a planned new development area: Located on the neighboring monastery meadow, the community had the opportunity to build a common heating system for existing and new buildings.

The Weyarn biomass heating plant was built within less than two years in cooperation between the community, the private operating company MW Biomasse AG and a regional planning office. And the participation of citizens also played an important role. The heating plant, which has been operating successfully since 2015, now has a 440kW wood boiler with flat moving grate firing system connected to a 15,000 liters buffer storage tank. Under the cover flap, approx. 85 cubic meters of wood chips are stored, which are sufficient for a good week of continuous operation in winter.

With the heat supply the operator AG does not have influence on the energetic reorganization of the attached buildings, differentiates however with the feed of the 80 - 90 degrees hot water into the net between two systems: Buildings with higher energy requirements, such as older existing buildings and the monastery, are direct heat consumers. The new building area with lower demand receives its heat from the external buffer storage tank, which temporarily stores excess heat from the heating plant and thus simultaneously reduces performance losses. It is important for the operator to be able to measure consistently. The plant is equipped with modern technology and is connected by remote monitoring to all transfer stations in the respective building basements. The project was funded by the Bavarian Bioclimate Program and the KfW Program 27.

As the prices for oil and gas are low in 2020, the operation does not bring any financial added value, at least not at present. For the climatic protection the heating plant means however a genuine profit: Per year the enterprise with wood chips saves approximately 300,000 liters fuel oil and scarcely 800 tons CO_2. And also for the regional economy the biomass heating plant offers clear advantages according to Sebastian Henghuber, executive committee of the Biomass AG: Compared with the oil heating the operation with wood chips provides for the 10-fold creation of value in the region and the approximately 8-fold quantity of working hours. And the wood for the operation is abundantly sufficient: Alone from the own municipal area the plant can be operated four times from the annual forest remainder wood according to Henghuber and supplies thereby meanwhile 150 households as well as public bodies.

Videos:
Film-MW Biomasse AG (in German):
https://www.youtube.com/watch?v=H0X0NqDpEiI
MR, pro communo, MW Biomasse (in German): https://www.youtube.com/watch?v=kh1O6jCdE78

New heating system in use	Biomass heating plant with wood chips, buffer storage, gas peak boiler
Previous replaced heating system	Monastery: Oil Residents: gas, oil etc.
Building type	Existing buildings (residential buildings) and monastery, new development area
Useful energy demand (kWh/m^2a) – Before and after building shell renovation	Before: 3000 MWh After: 3000 MWh No uniform renovation of the various building envelopes
Installed capacity (kWth) – Before and after	Before: decentralised, i.e. no information possible After: 440 kW wood boiler Buffer tank: 15,000 liters Top gas boiler: 700kW
Energy used	Before: 300,000 liters of heating oil/year After: 4000 cubic meters of wood chips
Initial investment (purchase and installation)	About 800,000€ (gross)
Yearly savings on the energy bill (compared to previous system)	Little savings because oil and gas are cheap, but regional value added
Yearly energy savings (compared to previous system)	There is no reduction in the amount of heat. The saving of CO_2 amounts to 900 t per year.
Yearly CO_2 emission reductions (only heating system replacement)	t CO_2

Biomass heating plant

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HISTORICAL HOUSE WITH CLIMATE-FRIENDLY EQUIPMENT – WOOD PELLET HEATING, PHOTOVOLTAIC AND SOLID INSULATION

The house of the Achmüller family is old and new at the same time: Built around 1900 in Peißenberg in the Bavarian Oberland, Christian Achmüller wanted to preserve the residential building. It has always been in family ownership. At the same time, he sought the support of an energy consultant and invested in a modern renovation, supported by the KfW renovation and BAFA boiler exchange program.

The result is impressive: Where originally a gas floor heating system with very high consumption costs was installed, a wood pellet heating system now supplies the 400 square meters of living space with climate-friendly heat. The pellet heating system also generates the warm water via a heat exchanger. To keep the heat inside the house, the Achmüller family used extensive insulation measures. After the roof was replaced, an 18-centimeters thick insulation made of wood fibers was installed. The exterior walls were fitted with the same insulation and windows with triple glazing were installed. A photovoltaic system with a peak output of 9.9 kilowatts completed the renovation measures. From the roof, the system supplied approx. 20,000 kilowatt hours of electrical energy within two years, which is many times more than the family's own consumption.

In terms of heating, the home owners first had to familiarize themselves with the user level of the new control system. In the meantime, however, the instructions have been visualized in a helpful way so that the control system works well. "We are highly satisfied with the new heating system and the renovation measures," emphasizes Christian Achmüller. "Everything has gone extremely well. The full thermal insulation and the new windows not only reduce energy consumption, they also ensure a comfortable living climate". Achmüllers have made their family property fit for the future.

New heating system in use	Wood pellet heating with heat exchanger, PV system
Previous replaced heating system	Gas floor heating
Building type	Residential building
Useful energy demand (kWh/m² a) – Before and after building shell renovation	Before: approx. 150 kWh/m²a After: approx. 65 kWh/m²a
Installed capacity (kWth) – Before and after	Before: 10 kW After: 14 kW
Input energy - Before and after	Before: approx. 3000 m³ natural gas After: approx. 2.5 t wood pellets/year
Initial investment (purchase and installation)	
Yearly savings on the energy bill (compared to previous system)	Approx. 1,200 Euro
Yearly energy savings (compared to previous system)	Approx. 18 MWh
Yearly CO_2 emission reductions (only heating system replacement)	6,5 t CO_2

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HEATING WITH PIECE WOOD IN HAUNSHOFEN – PERSONAL CONTRIBUTION DURING RENOVATION AND OPERATION

The house of the Brennauer family has always been heated with wood: first mentioned in 1845, the farm originally consisted of a residential house, stable and barn. Before the renovation, only the house was heated - with a log boiler, in which approx. 25 Ster piece wood per year was needed for heat generation. For owner Florian Brennauer, who is a carpenter and at the same time ecologically orientated, it was then „a must“ that the house comes into shape.

Between 2013 and 2015, the Brennauer family thoroughly renovated the farm - and, apart from a few worm-eaten pieces of wood, encountered no further problems. In terms of heating, the family replaced the old log boiler with a new one. It now has a buffer storage tank with 3000 liters of water and heats the water for domestic use via a heat exchanger. And although the Brennauers with 380 square meters have meanwhile the triple surface available - also stable and barn were converted to the living and effective area -, they need further the same wood quantity as before the reorganization. This is due to the thermal insulation, which has been brought up to the current standard for the entire house. The exterior walls, which are made of tuff and solid bricks, were covered with 14-centimeter-thick mineral wool insulation, which was then plastered. Between the rafters, a 20-centimeter-thick thermal insulation made of wood fibers was installed and the new windows have triple glazing. Funding was available from BAFA and KfW Programme 151/152.

The fact that the renovation took relatively long, at two years, was due to the fact that part of the building always had to be habitable and the Brennauer family did a lot of the work themselves. Also, the topic ‚personal contribution’ plays a special role: Florian Brennauer brought the knowledge to reorganization and heating with him, and he heats the converted farm now with wastes from forest remainder wood and piece wood from his own carpentry enterprise.

New heating system in use	Log boiler with buffer tank (3000 liters of water)
Previous replaced heating system	Wood-fired boiler
Building type	Residential building
Useful energy demand (kWh/m²a) – Before and after building shell renovation	Previously approx. 170 kWh/m²a, afterwards 60 kWh/m²a
Installed capacity (kWth) – Before and after	Before: no information available After: 50 kW
Input energy - Before and after	Before: about 25 Ster wood (mostly spruce) Afterwards at triple surface: still only about 25 Ster wood (mostly spruce) per year
Initial investment (purchase and installation)	
Yearly savings on the energy bill (compared to previous system)	Approx. 2/3 of the energy costs
Yearly energy savings (compared to previous system)	Approx. 20MWh
Yearly CO_2 emission reductions (only heating system replacement)	t CO_2

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INNOVATIVE BEST PRACTICE EXAMPLES FROM GERMANY (BAVARIAN OBERLAND)

SMALL VILLAGE, BIG ACHIEVEMENT: ICE STORAGE AS HEAT SOURCE IN ELLBACH

In 2014 the extension of the fire station in the Bad Tölz district of Ellbach was scheduled. On the whole initiative of the city the reconstruction was also used for the renewal of the heating system. Gas, oil and wood were excluded as energy suppliers due to space and usage-related reasons, and air or geothermal heat pumps were also out of the question. The decision was finally made in favour of an alternative and ultra-modern system: a combination of ice storage heating with hybrid collectors and brine heat pump, together with a water-guided ceiling heating system in the old building and concrete core activation in the new one. "The fact that the choice fell on concrete core activation instead of a heat probe was due to the elimination of bureaucratic hurdles. Pellets were ruled out because they would otherwise have had to be taken care of," explains property manager Michael Wölk, who was instrumental in planning, programming and coordinating the new system.

The ice storage tank was embedded in the ground in a ten cubic meter concrete tub next to the building. Extraction heat exchangers extract energy from the water it contains, which is then used to heat the firehouse with the help of heat pumps. In the old building, the heat generated in this way is transferred via a water-guided ceiling heating system that is installed in the suspended hall ceiling. In the new building, the heat from the ice storage is used via concrete core activation. The entire floor slab is heated with energy from the ice storage, similar to a huge underfloor heating system. The floor slab is heated further when there is a surplus of energy from PV electricity and environmental heat. The concrete floor slab can store this heat over a long period of time and release it again when needed. In addition, two 900-liter buffer tanks absorb energy from the sun.

Since the water in the ice storage tank turns to ice during the heat extraction process, it must be thawed to repeat the heat extraction process. For this purpose - a rarity combined photovoltaic system with so-called hybrid collectors is used: With the help of solar energy, they supply heat to defrost the ice and electrical energy to operate the heat pump, among other things. A data logger is integrated for the entire system and enables fine tuning, especially at the beginning.

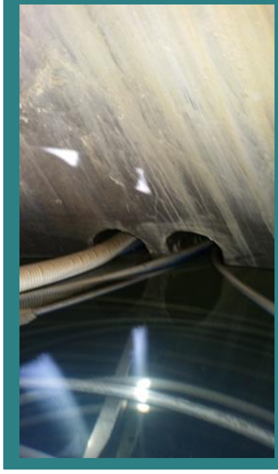
The fact that the system is suitably designed was demonstrated in the winter of 2016/2017, when the system was able to heat the fire department building even when temperatures were below zero for weeks on end. And the system has also proven itself economically: Before the conversion, the electricity costs were around 2500 euros per year. Including the feed-in of residual electricity, they have now fallen to zero euros for a floor space of 370 square meters. The Tölzer did not use any external planning aids but did everything themselves in the group of property manager Michael Wölk and his colleagues from the fire department. Financially, the city was able to use BAFA subsidies.

For a small village like Ellbach, the system is an enormous achievement and, thanks to positive experiences, it is already being used for a second time within Bad Toelz: The town hall has also been heated with the help of an ice storage tank since a conversion.

New heating system in use	Combination of ice storage heating with hybrid collectors and brine heat pump, a water-guided ceiling heating system in old buildings and concrete core activation in new buildings
Previous replaced heating system	Electric ceiling heating
Building type	Fire station
Useful energy demand (kWh/m²a) – Before and after building shell renovation	Before: approx. 300 kWh/m²a After: 80 kWh/m²a
Input energy - Before and after	Before: 12,000kWh electricity (see direct electricity heating) After: not specified
Initial investment (purchase and installation)	200,000€ and much personal contribution
Yearly savings on the energy bill (compared to previous system)	Before: electricity costs: 2,500€/year now: incl. residual current feed-in: 0€
Yearly energy savings (compared to previous system)	An energy saving in MWh cannot be quantified. The usable area has become considerably larger, PV electricity is used additionally

Fire station building with hybrid collectors
Copyright: Archiv der Stadt Bad Tölz/Wölk

Ice storage from inside
Copyright: Archiv der Stadt Bad Tölz/Wölk



Ice storage - still without water
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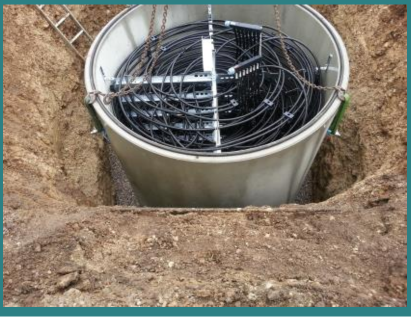


Heat pump
Copyright: Archiv der Stadt Bad Tölz/Wölk

HEATING CONTAINER IN PENZBERG – TEMPORARY SOLUTION AS A BRIDGE TO RENEWABLE HEAT SUPPLY

By becoming a member of the "Bürgerstiftung Energiewende Oberland", the city of Penzberg has committed itself to the energy turnaround goal of becoming self-sufficient in regionally generated energy by 2035. The newly planned swimming pool will also contribute to this goal. While the old wave pool was operated with a gas CHP and peak load boiler, a heating plant is being built for the new swimming pool that will be supplied with wood chips. In order to enable a change of energy source and to bridge the construction period of several years, the Penzberg municipal utilities rely on an elegant interim solution.

Until the new heating plant is completed, a mobile container system will supply the heat. Delivered, switched off and connected within one day, the temporary unit holds 55 cubic meters of wood chips. These are delivered two to three times a week on the basis of short-term supply contracts and last for two to three days during the intensive heating phase in winter. Due to the length of the operating life, the Penzberg municipal utilities bought the container and will resell it after completion - with special openings for the wood chips, chimney opening, large electrical connection and special noise protection for quiet operation. At the end of their use, the containers are to be sold again.

In combination with the heating container, the public utility company uses a CHP unit as well as a wood chip heating system with two boilers of 200 kW each - to supply the swimming pool and construction site with its own electricity and to provide heat. Both the CHP and the woodchip heating system will continue to be used after the temporary structure has been dismantled, e.g., for the summer base load. The Penzberg municipal utilities came up with the idea for the temporary solution in cooperation with a regional engineering office. The project was financially supported by the Bioclimate program of the Straubing Technology and Support Center.

To ensure the project's economic viability, the municipal utilities brought owners of neighboring buildings on board: the AWO's senior citizens' center and kindergarten, an elementary school, two sports halls, various apartment buildings and 180 new residential units are supplied with climate-friendly heat via the central heating system. That is about 1000 people. "A successful new business model for the municipal utilities - otherwise climate protection and the energy turnaround will not work", as municipal utilities’ manager André Behre emphasizes. Another positive effect: By switching to wood as a renewable energy source, the city can work with regional partners and leave the value creation in the Bavarian Oberland.

New heating system in use	Mobile container plant with wood chips
Previous replaced heating system	Gas CHP and peak load boiler
Supplied building type	Swimming pool, AWO children's house, 2 sports halls, primary school
Useful energy demand (kWh/m²*a) – Before and after building shell renovation	It grows dynamically; difficult to compare (swimming pool with CHP, wood chips, secondary school and gymnasium, swimming pool gone, old people's home, etc.). The value is only just being determined.
Installed capacity (kWth) – Before and after	Before: Not available After: 2 boilers of wood chips of 200 kW Cogeneration unit own power supply for swimming pool, kWh: not available
Initial investment (purchase and installation)	400.00€ for BHKW (it will continue to be used after the provisional arrangement) 500.000€ for woodchip heating: 2 boilers of 200kW
Yearly savings on the energy bill (compared to previous system)	Provisional: the situation changes constantly during construction, i.e., no information possible
Yearly energy savings (compared to previous system)	
Yearly CO_2 emission reductions (only heating system replacement)	t CO_2

Mobile container plant
Copyright: Energiewende Oberland/ Stadtwerke Penzberg

PROFITABLE VILLAGE HEATING IN WARNGAU – ENERGY WOOD POWER GENERATION PROVIDES HEAT AND ELECTRICITY

The development of a village heating system has been on the agenda of the municipality of Warngau in the Bavarian Oberland since 2010. After the heating systems of the town hall and surrounding buildings were technically outdated and prone to failure, the planning of a new day care center for children offered the opportunity to develop a solution for the entire area. The project was put under additional time pressure by a slump in the feed-in tariff, which was due in 2014/15, so that work had to be done at full speed to complete the village heating system on time.

In the search for a sustainable and at the same time economical model, Mayor Klaus Thurnhuber and his energy team designed a combination of wood chip heating for winter operation and a wood gasification engine for the base load. Since 2015, the heating plant has been supplying the connected buildings in an environmentally friendly way with heat from residual forest wood and covers their demand of around 500 MWh to 100%. At the same time, the wood gasifier engine produces around 320 MWh of electricity per year, which is fed into the public grid. From heat sales and EEG compensation for the electricity, income is thus generated for the entire plant and reduces the maintenance costs for the connected buildings. This includes all the community buildings, including the kindergarten and school, the gymnasium and teachers' residence, the town hall with the old innkeeper and the fire station. In addition, eleven private households are now supplied. The connection of further residential buildings and the Catholic Church is being planned.

The project was supported by a competent planner. At the time of planning and implementation, the funded project Bioenergy Region Upper Country for the expansion of bioenergy in rural areas was also active. With numerous excursions, technical information and events for potential heat customers as well as with the procurement of subsidies, Bioenergieregion Oberland was able to support the representatives of the Warngau town hall. The plant received financial support from the KfW program 271 - Renewable Energies - Premium. After the first gas engine was out-of-date according to plan in September 2018, the electrical and thermal output of the plant was increased (to 50 kW_{el}/100 kW_{th}). The costs have already been amortized.

New heating system in use	Village heating with wood chip heating
Previous replaced heating system	Natural gas
Building type	Community buildings, including the kindergarten and school, the gymnasium and teachers' residence, the town hall with the old innkeeper and the fire station, private households
Useful energy demand (kWh/m²a) – Before and after building shell renovation	Before: 1500 MWh After: 1000 MWh
Installed capacity (kWth) – Before and after	Before: not specified After: wood chips: 240 kW, wood gas engine: 30 kW
Input energy - Before and after	Before: 1500 MWH After: 1000 MWh
Initial investment (purchase and installation)	1,1 Mio. €
Yearly savings on the energy bill (compared to previous system)	70,000€ before, now 35,000€ but plus labour costs for operating the plant, i.e., costs about the same
Yearly energy savings (compared to previous system)	Approx. 500 MWh, CO_2 emissions saved due to change in energy carrier: an estimated 350 t per year
Yearly CO_2 emission reductions (only heating system replacement)	t CO_2

Wood carburettor

Copyright: Energiewende Oberland/Andreas Scharli

Wood chip boiler with flue gas cleaning

Copyright:Energiewende Oberland/Andreas Scharli

Heat distribution

Copyright: Energiewende Oberland/Andreas Scharli

BEST PRACTICE EXAMPLES FROM NORTH MACEDONIA (SKOPJE REGION)

REPLACING AN OLD WOODSTOVE WITH AN EFFICIENT PELLET STOVE IN THE MUNICIPALITY OF AERODROM

This best practice examples describes the replacement of an old fuelwood stove with a new pellet stove in a detached house located on Hadji Trajko Street, 19a, in the Municipality of Aerodrom. The old and inefficient stove had a capacity of 27 kW and was fairly inefficient (75%). Because of this, it was replaced with a new pellet stove with a greater heating capacity (30 kW) which is also much more efficient (92%).

The owner of the house initially got the idea about the replacement from hearing the positive examples in the neighborhood. After this, he contacted the Energy Efficiency Info Center in the City of Skopje and did additional online research in order to obtain better information about the procedures and requirements.

The new pellet heating stove is now installed in the kitchen, where it is connected to the central heating system of the house. No difficulties were found when installing the stove, or when connecting it to the central heating system and performing hydraulic balancing. The stove is automated and controls all the necessary parameters in order to optimally use the fuel while providing the best possible comfort. The only minor inconvenience noted by the owners is related to the suboptimal location of the pump. The owners have noted some low-frequency noise when the pump turns on to circulate the water in the central heating system, because it is located in the kitchen, along with the stove.

In the first year of operation, the new efficient pellet stove reduced the costs for heating due to fuel purchase by about 250 EUR (12,500.00 MKD). Moreover, it resulted in the reduction of local air pollution by reducing PM10 emission by 90%. The total investment in the system cost about 1,250.00 EUR. Due to the existing replacement campaigns in the City of Skopje, however, about 420 EUR (25,000.00 MKD) were covered by the municipal subsidies. The replacement of the inefficient woodstove boiler, despite not affecting the CO_2 emissions significantly, vastly reduces the emissions of particulate matter (PM) and contributes to the reduction of local air pollution.

New heating system in use	Pellet stove
Previous replaced heating system	Fuelwood stove
Building type	Detached house (157 m^2)
Useful energy demand (kWh/m^{2}a) – Before and after building shell renovation	Before: 100 kWh/m^{2}a After: 100 kWh/m^{2}a (no building shell renovation)
Installed capacity (kWth) – Before and after	Before: 27.0 kW After: 30.0 kW
Input energy – Before and after	Before: 10,500.0 kWh (15 m^3 fuelwood) After: 11,450.0 kWh (2.5 tonnes pellets)
Initial investment (purchase and installation)	77,000 MKD (1250 EUR)
Yearly savings on the energy bill (compared to previous system)	250 EUR
Yearly energy savings (compared to previous system)	% in MWh
Yearly CO$_2$ emission reductions (only heating system replacement)	

REPLACING AN OLD WOODSTOVE BOILER WITH A HEAT PUMP CENTRAL HEATING IN THE MUNICIPALITY OF GJORCE PETROV

This best practice examples describes the replacement of an old fuelwood stove with a new heat pump system. The house is located in the Municipality Gjorce Petrov and has a reinforced concrete construction with three levels. The floor area of the ground level is equal to 144 m^2, while the other levels have an area of 120 m^2 (1st floor) and 144 m^2 (2nd floor). The walls are built from a 12 cm thermal block with an additional ISOVER mineral wool layer of 5 cm. The walls of the building envelope have a 5 cm Styrofoam later (density 40 km/m^3) on top and, along with the windows and door, are energy efficient.

The old woodstove heating system had a capacity of 21 kW and 20m^3 annual wood consumption. Expenses per heating season with the old systems were estimated around 1000 EUR and reduced to 675 EUR with the new system. The radiators remained the same, only two additional fan-coilers to heat the ground floor were added. For cooling special inverter were used by need. The major difference is the heating time, with the old system around 12 hours and the new system is used non-stop (24h).

The newly installed system is used to heat and cool 59 m^2 on the 1st floor and 69 m^2 on the 2nd floor (128 m^2 in total). The installed system uses both radiators and fan-coilers to radiate the heat, and also uses a 100 liters hot water tank. The radiators have a capacity of 1x0.80 kW, 2x1.00 kW, 4x1.20 kW, while the fan-coilers have a capacity of 2x5.64 kW. The total installed capacity is equal to 18.9 kW. As the investment is partial, a combination of the old and new system, it is accounted for 5000 EUR from which 3000 EUR for the heat pump and 1500 EUR for the fan-coilers and an additional hot water system.

New heating system in use	Heat pumps
Previous replaced heating system	Fuelwood stove
Building type	Detached house
Useful energy demand (kWh/m²a) – Before and after building shell renovation	Before: 160 kWh/m²a After: 80 kWh/m²a
Installed capacity (kWth) – Before and after	Before: 21 kW After: 12.0 kW (heating)/ 10.0 kW (cooling); 18.9 kW (radiators and fan-coilers)
Input energy – Before and after	Before: 14,000 kWh (20 m³) After: 5,300 kWh
Initial investment (purchase and installation)	5,000 (EUR)
Yearly savings on the energy bill (compared to previous system)	325 EUR
Yearly energy savings (compared to previous system)	% in MWh
Yearly CO_2 emission reductions (only heating system replacement)	

SOLAR HEAT PUMP SYSTEM IN A FAMILY BUILDING IN THE MUNICIPALITY OF KARPOSH

The family building has 4 residential apartments. This is a new facility built according to the Rulebook of the municipality of Karposh from 2012 which subsidizes the construction of EE facilities using RES and received a refund of 20% of the utility tax as a subsidy. It has a basement, ground level, 2 floors, an attic and a pool. The apartments have a floor area of 130 m^2 (ground level), 150 m^2 (1s floor), 150 m^2 (2nd floor) and 145 m^2 (attic). The building is class B with combined heating and cooling system (solar collectors and air/water heat pumps). The installed heating system was used to cover the heating and cooling needs of the whole building, including the pool area.

The inside walls of the building are built from 10 cm plasterboard and are filled with mineral wool. The façade of the building has a Styrofoam with a thickness of 10-12 cm (depending on the location) with expanded polyester (density of 40 kg/m^3), reinforced grid, façade glues, anchors and a decorative textured mortar. The building envelope also has highly efficient windows with three-layered glass.

The heating system uses heat pumps connected to floor heating with fan coilers, for each apartment. The system also covers the hot water needs of each apartment by using 200-liter hot water tanks connected to solar thermal panels (12m^2) and the heat pumps. The pool area and the pool water are heating by two separate heat pumps. Hence, a total of 6 heat pumps are used (1 per each apartment (4 in total) and 2 additional heat pumps for the pool area). The heat pumps are of the model Mitsubishi PUHZ-SHW140YHA with a maximum current of 13 A on a 3-phase power supply of 400 V and a motor output of 2.5 kW. The heat pump has a 14 kW heating capacity and a 12 kW cooling capacity.

Comparison could not be calculated, as this facility is newly built, and there was no previous heating system in place.

New heating system in use	Heat pumps and solar thermal collectors
Previous replaced heating system	Fuelwood stove
Building type	Detached house
Useful energy demand (kWh/m^{2}a) – Before and after building shell renovation	
Installed capacity (kWth) – Before and after	Before: / After: 6x14.0 kW (heating)/ 6x12.0 kW (cooling);
Initial investment (purchase and installation)	17,000 (EUR)
Yearly savings on the energy bill (compared to previous system)	
Yearly energy savings (compared to previous system)	
Yearly CO$_2$ emission reductions (only heating system replacement)	t CO$_2$

BEST PRACTICE EXAMPLES FROM REPUBLIC OF SERBIA (CITY OF ŠABAC)

REPLACEMENT OF OLD COAL AND LOG-WOOD BOILER WITH A NEW PELLET BOILER

Wood pellet boilers have been selling on the Serbian market since 2010. In Serbia, log-wood boilers with a low degree of efficiency are traditionally used, particularly in rural and suburban settlements. Creativity came to the expression here as well, one of the first wood pellet boilers was handmade in a craft workshop in Šabac.

The owner of this boiler is Mr. Branko Jeremić from Šabac, who lives with his four family members in a single-family building in the wider city center. The heated area of the house is 180 m^2, with the intention of the owner to expand the building.

Mr. Branko Jeremić has been using the installation of central heating with cast iron radiators for a long time. The projected temperature regime is 90°C / 70°C, and the radiators are equipped with thermostatic valves that serve to regulate the temperature in the rooms. Fifteen years ago, a solid fuel boiler (coal or wood) was installed. The capacity of this boiler was 35 kW. In the design phase, night interruptions in heating were taking place, the degree of efficiency of the boiler, which amounted to 65%, as well as the quality of the thermal envelope of the building. The average annual consumption was 6 t of coal and 10 SCM (stacked cube meter) of logwood. Calculated at current fuel prices, which did not change significantly, the annual cost of fuel was about 1,400 EUR.

It should be noted that the house was already thermally insulated and a compact polystyrene facade 5 cm thick was installed. The windows were also replaced, new windows with a 3-chamber PVC frame, and a thermo-package of glass were installed.

However, ten years ago (2010), he replaced the old boiler with a pellet boiler. The boiler efficiency is 80% but the boiler capacity remained the same, 35 kW. Despite the higher degree of efficiency, the capacity of the boiler has not been reduced due to plans to expand the building. The technical reasons for the selection of the boiler capacity are that no buffer tank was installed as part of the heating installation, as well as the mode of operation with night interruption. However, a four-way valve was added to protect the "cold end" of the boiler. The comfort of the heated space is provided by the construction method of his house, a full brick that has large inertia due to the large mass, and the temperature difference between the walls and the indoor air is very small. Fuel consumption is 5 tons of wood pellets per year and heating costs are 1,000 EUR/a.

Mr. Jeremić made the decision to replace the boiler after analyzing the heating costs. According to him, the investment in the replacement of the boiler will be returned in a period of fewer than 5 years, which is very acceptable.

An important factor in decision-making was the attitude towards the environment. By burning coal and logwood in the old boiler, the emissions of soot particles and other harmful pollutants in the flue gases as well as the dust elimination or drastical reduction.

The decision to replace the old boiler was also influenced by media campaigns. In the media, more and more time are given reports on climate change, consequences, and measures that contribute to mitigating the negative effects. Mr. Jeremić says that he follows this kind of news and that he is really worried and that he himself was a witness and felt the consequences of the great floods that hit the region and the city of Šabac in the spring of 2014, which he is sure are the result of climate change.

New heating system in use	Wood pellet boiler
Previous replaced heating system	Coal or logwood fired boiler
Building type	one-family house
Useful energy demand (kWh/m^{2}a) – Before and after building shell renovation	140/100
Installed capacity (kWth) – Before and after	37/37
Input energy – Before and after the boiler replace MWh/a	33.74/23.05
Initial investment (purchase and installation)	1,525 (EUR)
Yearly savings on the energy bill (compared to previous system)	29 % in EUR
Yearly energy savings (compared to previous system)	32 % in MWh
Yearly CO_2 emission reductions (only heating system replacement)	8.96 t CO_2

In the activities related to the replacement of the boiler and the reconstruction of the heating installation, Mr. Jeremić himself participated. When dimensioning the boiler, he consulted with the design engineer. The boiler was installed in a multipurpose space in which there was no space to accommodate a buffer vessel. A buffer tank will be installed in the next step as well as an additional accumulator for heating the sanitary water. The installation of a four-way valve with auxiliary energy drive provides protection of the boiler from stresses caused by low return water temperature when starting the boiler, as well as protection against the occurrence of condensate in the flue gases.

The reconstruction of the heating installation did not include the installation of a variable speed pump (which will be done in the next step) and the heating installation was balanced by the use of manual control valves in control circuits and differential pressure regulators that compensate for changes in hydraulic load. The performed reconstruction was necessary even if there was no replacement of the boiler, so in that sense, it does not affect the total investment for the replacement of the heating system but is generally a measure of the improvement of the heating system.

BEST PRACTICE EXAMPLES FROM REPUBLIC OF SERBIA (CITY OF ŠABAC)

REPLACEMENT OF OLD ELECTRIC BOILER WITH A NEW PELLET BOILER

On the recommendation of a colleague from work, Mr. Branislav Marić has replaced his electric boiler with a new wood pellet boiler in 2017th. He sought the advice of an experienced designer of heating installations and on the basis of the received information and as well as consultations with members of his family, he made a decision to reconstruct the heating installation and replace the boiler. The heated area of the house and workshop, in which he performs simple repairs on electrical devices, is 250 m^2.

Mr. Branislav Marić uses a central heating installation with aluminum cast radiators. The projected temperature regime is 90°C / 70°C, and the radiators are equipped with thermostatic valves that serve to regulate the temperature in the rooms. Considering that he is an electrician by profession, he had the most confidence in the electric heating boiler due to its reliable operation, but he also considered that the installation of an electric boiler was the optimal choice from the aspect of maintenance.

He has been using the central heating installation for more than twenty years. In that time period, no major reconstruction was performed, except for the installation of thermostatic valves in 2012. The capacity of the electric boiler was 18 kW. Space is heated from the beginning of October to the end of April (next year) with night breaks or reduced boiler capacity during the night only if the outside temperature drops below -5°C. The average electricity consumption was 50,570 kWh_e/a. In the contract with the public electricity supplier, a clause was introduced, common for large consumers, which referred to the technical limitation of the capacity of the electrical installation and the calculation which included the measurement of the maximum load. Heating costs were 1,500 EUR /a.

Mr. Marić followed the media campaigns and initiatives initiated by the local administration, which were related to the thermal insulation of old buildings. After talking with the neighbors who performed the thermal insulation of their buildings, in 2015 he made the decision to install a compact thermal facade with 5 cm thick polystyrene on his house and workshop. In addition, new windows with a multi-chamber frame and thermal glass have been installed. Before the start of the heating season, he reconstructed the heating installation and installed a wood pellet boiler. The capacity of the new boiler is 35 kW. The reason for the installation of a higher capacity boiler Mr. Marić explained his desire to upgrade the house in which he lives, i.e., to build another floor. After the reconstruction of the heating installation and the installation of thermal insulation, the consumption of wood pellets was 5 t/a and the heating costs were 1,000 EUR/a. The complete investment was made partly with his own savings and partly with a loan taken from a bank under commercial conditions. Subsidies from the local administration were not received as well as any incentives and subsidies from the state administration. Reconstruction of the heating installation, in addition to the installation of a new pellet boiler with an efficiency of 80%, also included the replacement of the circulation pump, the installation of a four-way valve with motor drive, and the installation of manual control valves in the heating circuits. A buffer tank has not been installed but will be added after the building is upgraded. A sanitary water heating tank is also planned, which will also be installed during the next reconstruction of the heating installation. Boiler protection is provided by the installation of a

New heating system in use	Wood pellet boiler
Previous replaced heating system	Electric boiler
Building type	one-family house
Useful energy demand (kWh/m^{2}a) – Before and after building shell renovation	- /74
Installed capacity (kWth) – Before and after	18/35
Input energy – Before and after the boiler replace MWh/a	50.57/23.65
Initial investment (purchase and installation)	1,850
Yearly savings on the energy bill (compared to previous system)	33 % in EUR
Yearly energy savings (compared to previous system)	53 % in MWh
Yearly CO_2 emission reductions (only heating system replacement)	44.80

four-way valve. The heating installation works in a fully automated mode. The boiler servicer selected the temperature curve. The local boiler automation takes into account the outside air temperature read by an external sensor installed on the north facade of the building. Instead of the old circulation pump, a variable speed pump is installed, which is controlled via a sensor that monitors the pressure changes in the installation that occur due to the reaction of the thermostatic valves installed on the radiators. The electric boiler remained part of the heating installation as a reserve in case of wood pellet boiler failure.

The decision to replace the boiler was decisively influenced by heating costs as well as the announcement of electricity price increase. It should be noted that the price of electricity in Serbia is the lowest in Europe and is not sustainable at the current level. A significant increase in the price of electricity is expected, otherwise, supply disruptions could occur. The fact is that electricity is produced in thermal power plants that use very low-quality coal and that air pollution and general environmental pollution are very evident. Mr. Marić is a young man who is very well informed about environmental pollution. He is aware of the fact that individual furnaces that use fossil fuels, as well as thermal power plants, have the greatest impact on air pollution. The family of Mr. Marić lives in the southwestern part of the town of Šabac in the settlement of "Kasarske livade", where there is no district heating network. In this settlement, a large number of households use coal and wood boilers.

Wood pellets are a domestic products, therefore he knows that the price will be stable and that security of supply will be ensured.

BEST PRACTICE EXAMPLES FROM REPUBLIC OF SERBIA (CITY OF ŠABAC)

THERMAL INSULATION OF THE BUILDING AND THE USE OF RENEWABLE ENERGY

At the initiative of the city administration, the project of renovation of multi-family buildings was launched in Šabac in 2010. With a subsidy of 50% in relation to the investment costs, apartment owners in buildings connected to the district heating system are allowed to apply and participate in this collective action.

The family of Mrs. Branka Kostadinović was one of the first in Šabac who participated in the project. Mrs. Kostadinović is the owner of an apartment in the multi-family building which is located in the northwestern part of the city. The heated area of the apartment is 61 m^2. The building was built in 1982 at a time when there were no strict requirements regarding the thermal properties of buildings and when heating costs did not significantly burden the household budget. Since 2011, the billing of delivered thermal energy has been performed based on measurements in the heat substation. The average annual consumption was 130 kWh /m^2 a.

The heating installation in the apartment is designed with common vertical distribution lines and cast-iron radiators. The projected temperature regime is 90^{o}C / 70^{o}C. The heating system is indirect, with a heat substation located in the basement of the building and connected to the district heating network. The fuel used by the local energy company is natural gas and the heat distribution network is built of pre-insulated steel pipes. The heat substation contains an ultrasonic heat meter and the necessary equipment for automatic operation and control of operating parameters according to the outside temperature.

The introduction of billing based on consumption and the expectation that the thermal insulation of the building will improve comfort conditions motivated Mrs. Kostadinović family to apply together with other apartment owners in the building to participate in the project. Thermal insulation of the building was performed in 2010, and the following year, before the start of the heating season, thermostatic valves and cost allocators were installed on each radiator. Investment costs amounted to EUR 1,850 for thermal insulation (of which 50% was a city subsidy) and EUR 250 for the installation of thermostatic valves and cost allocators. Two split units were used for cooling the apartment. On the recommendation of energy efficiency engineer, in 2017 the existing split units were replaced by heat pumps, split constructions, capacity of 2.8 kW_{th} each.

The thermal insulation of the building is performed by a compact thermal facade made of polystyrene 10 cm thick. The old windows have been replaced and new windows with a multi-chamber frame and thermal glass have been installed. Windows replacement was not part of the project. The concept of heating after the application of energy efficiency measures and installation of split units is as follows:

- When the outside air temperature is 6^{o}C and more, the apartment is heated by a heat pump.
- In the autumn and early spring period, the thermostatic valves are set to 19^{o}C, and the internal units are set at temperature of 21^{o}C - 22^{o}C.
- When the outside temperature drops to 5^{o}C and lower, district heating is used for space heating and the thermostatic valves are set to keep a room temperature of 21^{o}C.
- When the owners leave the apartment, the thermostatic valves are positioned to room temperature at least 16^{o}C.

New heating system in use	DH system & Heat pumps air/air type
Previous replaced heating system	DH system
Building type	multi-family building
Useful energy demand (kWh/m^2a) – Before and after building shell renovation	130/64
Installed capacity (kWth) – Before and after	9/9 + 2 x 2.8*
Input energy – Before and after the boiler replace MWh/a	9.55 / 1.63 + 0.64**
Initial investment (purchase and installation)	1,175***
Yearly savings on the energy bill (compared to previous system)	42.40 % in EUR
Yearly energy savings (compared to previous system)	76.20 % in MWh
Yearly CO_2 emission reductions (only heating system replacement)	1.05

Remarks: * Heat pumps capacity
** COP of heat pump amounts to 4,0
*** Subsidy for thermal insulation is not taken into account

The total heat consumption, of course, depends on climatic conditions. However, according to data for 2019, the heat consumption (taken from the district heating system) amounted to 1,352 kWhth/a, and the electricity consumption for heating amounted 613 kWh/a. According to Mrs. Kostadinović, heating costs before the implementation of energy efficiency measures and installation of heat pumps amounted 608 EUR / a and after that (2019) amounted to 350 EUR / a.

Mrs. Kostadinović and her family are very well informed about the problems of environmental pollution, particularly on the problem of unsatisfactory air quality. They participate in public events where the protection of the environment is discussed, and it can be said that they are more informed than the average citizen of Šabac. From this perspective, the observed participation in renewable energy projects was expected and can serve as an example of good practice.

According to the data given in the table, the reduction of energy consumption is significantly higher than the reduction of CO_2 emissions due to the fact that Serbia has a very high national emission factor.

Heat pump air/air - split version

Cast iron radiator with TS valve and heat allocator

HOLISTIC ENERGY RENOVATION OF SINGLE-FAMILY HOUSE

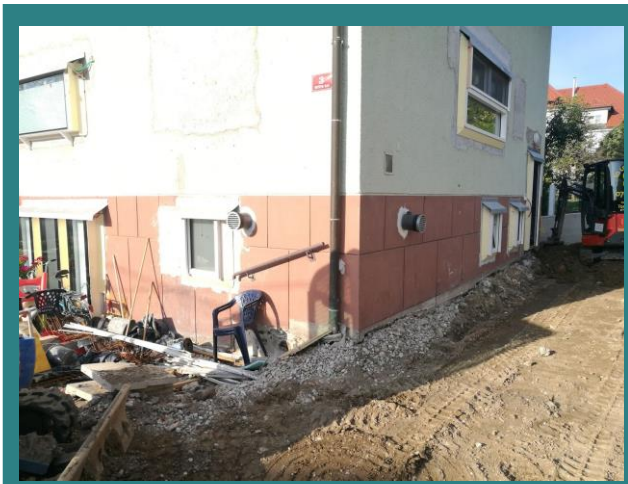
Energy renovation of the house covered large number of measures that included: energy renovation design based on PHPP calculations, renovation of thermal envelope (basement floor, exterior walls and roof), installation of energy efficient windows and entrance doors, installation of a central system for controlled ventilation with waste heat recovery and installation of air to water heat pump. Underfloor heating with low temperature distribution was installed for the new heating system (heat pump air - water). The new way of heating was replaced for an old natural gas boiler that used radiators with high temperature system distribution (design supply/return temperatures in use were 70/50 °C). Before the renovation, 11 different options of PHPP calculations were designed. The PHPP included financial and energy efficiency evaluation. The optimal solution out of 11 propositions was chosen, which had the highest economic and energy efficiency indicators. Important role of Eco Fund was recognized as they offer subsidies for holistic energy renovation of the house, where the installed technologies and used materials must meet their requirements in order to retrieve a subsidy.

The whole process of energy renovation consisted of initial architectural conditions review and the pre-investment calculations when the best option was chosen. Next steps that followed included preparation of the documentation (building permit, construction execution plan for different installations needed for the renovation) and informing the selected installers to initiate the renovation process of thermal envelope and system replacement. After this, application for Eco Fund subsidy was formalized and send to Eco Fund. The whole process was supervised and, in the meantime, measurements for airtightness were carried out (between and in the end of the process).

Building is located in a densely populated area in a municipality with Air quality decree. The later directs the investors to the use of RES technologies for heating and prevents installation of biomass boilers due to dust particles. Should the households install a biomass boiler, the investor would be ineligible to receive the subsidy due to Air quality decree. Thus, the investors decided to replace old gas boiler with air-based heat pump. The system efficiency was vastly improved, the temperature regime was switched to low temperature system distribution (new design supply/return temperatures are 45/35 °C).

Eco fund subsidy represented 40 % of eligible costs of the carried-out energy renovation. It was implied that when the investor cooperates nicely with the installers (and everybody involved) good results are almost guaranteed. Two critiques were proposed and the first one is that the engineers still like to construct excessive air changes for the houses which can result in dry air inside of the building. The second one was that there is an excessive amount of administration - regarding the building permits. After the renovation the benefits perceived were presented as modern comfort living with minimal heat loss, fresh air but no drafts. New architectural outline was functional (for inside and outside spaces) and it also offers lots of light for the inside areas. The renovation led to lower operating and maintenance costs. The Investment was economically viable and safe. After the renovation the perceived weaknesses were as stated before, issues with dry air (due to excessive construction of air changes) and on the south side of the building, some excessive sunlight was detected, due to no shading option.

New heating system in use	Heat pump (air-water)
Previous replaced heating system	Natural gas boiler
Building type	Single family house
Useful / heated floor area	248 m^2
Useful energy demand (kWh/m^{2}a) – Before and after building shell renovation	Before: 149 kWh/m^{2}a After: 19.4 kWh/m^{2}a
Installed capacity (kWth) – Before and after	Before: 15 kW After: 8 kW
Energy carrier – before and after	Before: Natural gas After: Electricity
Energy use for heating – before and after	Before: 39,430 kWh/a After 4,155 kWh/a
Initial investment (purchase and installation)	129,800 EUR
Yearly savings on the energy bill (compared to previous system)	87 % in EUR
Yearly energy savings (compared to previous system)	85.5 % in MWh
Yearly CO$_2$ emission reductions (only heating system replacement)	80 %



BEST PRACTICE EXAMPLES FROM SLOVENIA

OIL BOILER REPLACEMENT WITH HEAT PUMP

The second example in the study was the replacement of an old fuel oil boiler with a heat pump air-water. Backup for an old fuel oil boiler was biomass boiler and solar collectors. Expressed desire to replace fuel oil boiler originated from:

- the fact that the boiler was 30 years old,
- the desire to replace the old heating system with a more environmentally friendly and more cost-effective solution.

The house was renovated in 2006 and due to the promise of building a natural gas network in that area, the old boiler was not replaced at that time. The natural gas network has not been built yet, but given the climate policy, the transition to renewable energy was the only rational decision. The whole replacement process consisted of 3 steps:

- Selecting process: Selecting a quality heat pump with appropriate characteristics. The interviewee expressed that this was a time-consuming part as the comparison of different options among different suppliers can be quite demanding. The options were analysed in detail and all represented comparable purchase cost.
- Boiler room preparation: Prior to installation, it was necessary to remove the old boiler and prepare the room for necessary installation. The installation, plugin, and start-up of the new system, were carried out in one week.
- After installation: At start-up, a fault in heat pump electronics was detected, which was quickly fixed.

Due to the greater flexibility of the heat pump, additional storage for heated water (750 l) was implemented in combination with 300 l boiler from the solar collectors. The interviewee expressed that some additional joint effort from the supplier, installer, and investor was needed as the chosen additional installation was not (yet) a common practice. The whole process was rated as a positive experience that offered an environmentally friendly solution that is energy and cost-effective. Expressed positive experiences in the replacement process:

- fast execution of the system replacement,
- replacement was carried out without major construction intervention in the house,
- the market provided a wide range of products and suppliers to choose from.

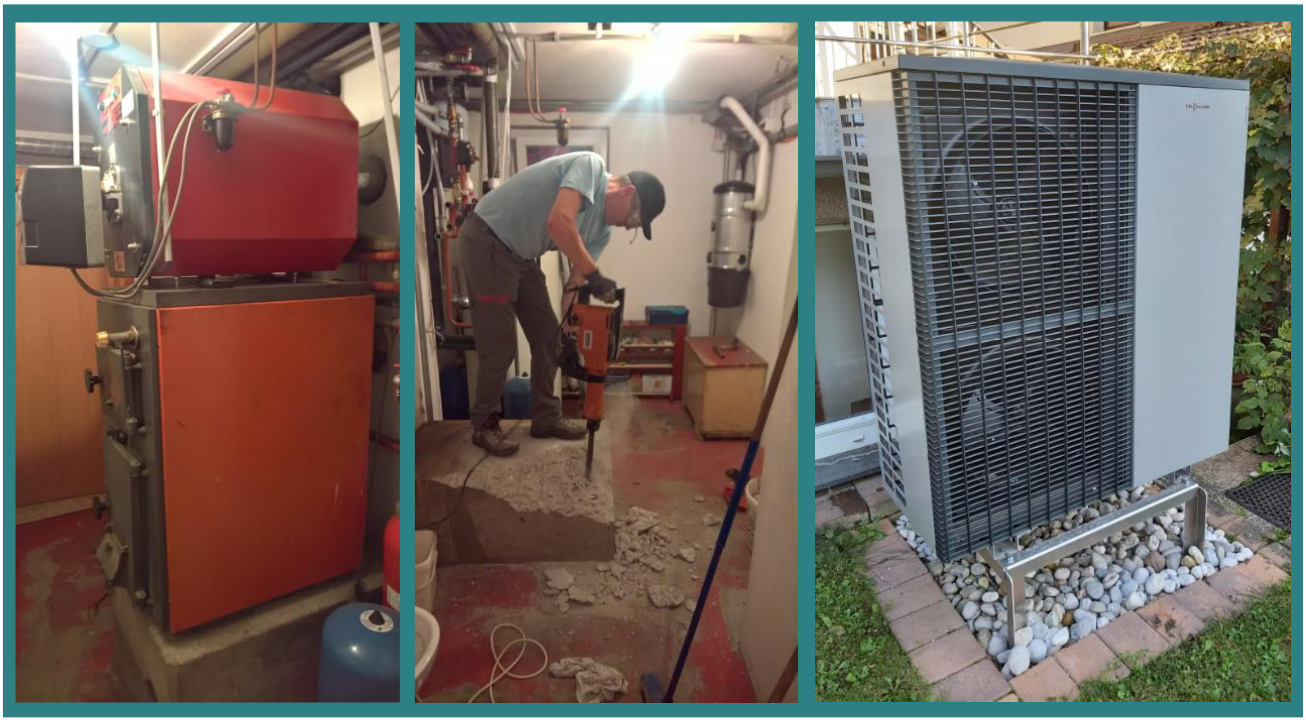
There were also some negative experiences in the replacement process:

- lack of expertise with customized systems,
- ineligibility to apply for Eco Fund subsidy, due to the fact, that location was considered to be included in the natural gas network,
- poor quality in execution for some of the installation (in terms of no pipe insulation, inadequate fastening of electrical wires …).

New heating system in use	Heat pump
Previous replaced heating system	Fuel oil boiler
Building type	Two-apartment house
Heated floor area	180 m^2
Installed capacity (kW) – Before and after	Before: 25 kW After: 10 kW
Energy carrier – Before and after	Before: Fuel oil After: Electricity
Energy use for heating – before and after	Before: 1.3 m^3 After:4,650 kWh
Initial investment (purchase and installation)	14,000 EUR
Yearly savings on the energy bill (compared to previous system)	60 % in EUR
Yearly energy savings (compared to previous system)	65 % in MWh (- 8.4 MWh)
Yearly CO_2 emission reductions (only heating system replacement)	73 %

Additional upgrade of the system enabled the use of lower temperature distribution in the house (below 50 °C). Due to the lower temperature regime of heating and adjusted temperatures at night, the investor states to have more stable temperature conditions and a higher quality of living. After the installation, some negative issues in terms of management of the heating system arose. Such as:

- limited possibilities for heat pump regulation,
- remote control of the new heating system provides only limited monitoring and no dynamic graphical representations,
- and to control electricity consumption additional electricity meter needed to be installed, which shows high electricity consumption in standby mode.



OIL BOILER REPLACEMENT WITH HEAT PUMP & SOLAR COLLECTORS

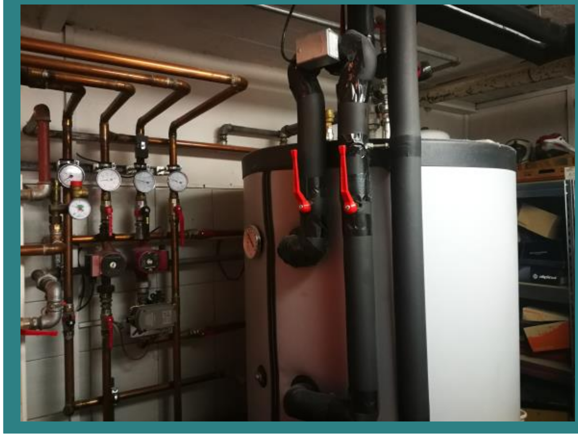
Third example of best practice is a fuel oil heating system replacement with heat pump air/water and solar collectors. The form of heat distribution throughout the house remained the same - with radiators, the temperature heating regime was switched to medium 50/35 °C. Other additional measures for energy efficiency were not implemented. Main reasons for the replacement of the old heating system, stated in the answers, were rising prices of petroleum products and rising greenhouse gas emissions caused by the fossil fuels. It was also pointed out that when replacing old heating system, the switch also brought additional benefit, which is lower heating costs compared to the old method of heating.

The whole replacement process consisted of four steps:

1. Getting advice from an expert
2. Choosing the appropriate installer
3. The actual replacement - where the new installed technology consisted of heat pump (air to water - 9 kW of power) and water storage.
4. After the replacement in investor applied for Eco Fund subsidy (that was granted).

Important role of Eco fund has again been proven to be important. The Eco Fund publishes a wide range of public tenders for households measures in efficient energy use and renewable energy sources. The whole process was rated as a good one. Cooperation with installers was assessed as good and the renovation was executed in time. Investor also stated that the instruction given by the installer, about the operation of the system, were sufficient and welcome in order to properly set the system at all times for different weather conditions. The new system also brought positive effects as the costs for heating were now lower, there was no need for a chimney sweeper and also the new system represents a more environmentally friendly option (low emissions). There were no negative side effects stated, not in terms of the whole process of the renovation or later on after the installation of the new heating system. When asked if they regret the investment (the new heat pump and solar collectors), the investor stated that he would do it again because of the financial and environmental benefits.

New heating system in use	Heat pump (air to water)
Previous replaced heating system	Fuel oil boiler
Building type	Single family house
Heated floor area	140 m^2
Installed capacity (kWth) – Before and after	Before: 30 kW After: 9 kW
Energy carrier – before and after	Before: Fuel oil After: Electricity
Energy use for heating – before and after	Before: 2.5 m^3 After: 6,500 kWh
Initial investment (purchase and installation)	12,000 EUR
Yearly savings on the energy bill (compared to previous system)	38 % in EUR
Yearly energy savings (compared to previous system)	37 % in MWh
Yearly CO_2 emission reductions (only heating system replacement)	45 %



REPLACING DIESEL BOILER WITH BIOMASS IN ARANDA DE DUERO

A Substation of Aranda de Duero´s DH network has been installed to replace the service provided previously by a 600-kW diesel boiler. The Aranda de Duero´s DH network substation uses biomass as fuel in addition to the recovered energy from the surplus of a cogeneration system installed at MICHELIN ARANDA´S factory. The building is made up of 48 flats for residential use. The substation has been installed in the existing boiler room, in the basement. This substation does not produce any noise, unlike the diesel boiler. In addition, since there is no combustion, there is no need for forced ventilation, so the noise made by the fan is reduced as well. Some of the reasons for installing this biomass system were the economic savings (minimum of 10 %), the environmental improvement (Emissions drop from 163 t to 8 t of CO_2) and because the initial investment was null.

Moreover, the owners wanted to make the switch to biomass because they were looking for renewable energy systems instead of continuing to use fossil fuels and they looked forward the money savings compared to diesel and gas. The substation was installed by REBI SL at the Aranda de Duero´s heat network and there were no costs were for the community living at the building. The installation lasted about 2 to 3 weeks. The community noticed the benefits early on since they get economic savings every month and the reliability of the heating system of the building has improved since old diesel boiler was removed. Also, the community did not benefit from any financial aid or grant, more than replacing the heating system for free.

New heating system in use	Biomass substation
Previous replaced heating system	Diesel boiler
Building type	Residential
Useful energy demand (kWh/m^2.a) – Before and after building shell renovation	465,125 kWh 61.93 kWh/m^2
Installed capacity (kWth) – Before and after	Before: 600 kW After: 700 kW
Input energy – Before and after	Before: 620,165 kWh After: 547,205 kWh
Initial investment (purchase and installation)	0 € for the client
Yearly savings on the energy bill (compared to previous system)	10 % in EUR
Yearly energy savings (compared to previous system)	25 % in MWh
Yearly CO_2 emission reductions (only heating system replacement)	155 t CO_2

BEST PRACTICE EXAMPLES FROM SPAIN (CASTILLA Y LEÓN REGION)

BIOMASS BOILER IN SALAMANCA

A coal boiler was replaced a year ago in Salamanca city (Castilla y Leon Region, Spain). The old one was a centralized coal boiler that was near the end of its lifetime. It was replaced by a biomass boiler, centralized as well, since it was installed on a residential building with many elders who did not want an individual boiler due to they were afraid that they would not be able to make it work.

The boiler is fully equipped, it has two buffer tanks of 1000 and 1500 l, 3 meters, ADSL connection, etc... The building located in downtown Salamanca has 2 apartments per floor with 150 m^2 each. There are 6 floors in the building and at street level you can find some small businesses. The boiler was installed in the same boiler room as the old one, in the basement. The building is oriented south, and the community was initially interested in installing solar collectors, but it was not be possible due to several barriers. Since they wanted to reduce space heating expenses and emissions, they finally opted for a biomass boiler installed by BIOENERGY BARBERO. Also, they wish to depend on an energy source that can be provided from their country and from a close provider. During the installation process there were some issues with the boiler room floor due to the age of the building which were finally fixed by the installer company, with some minor delays. In overall, householders are happy with the change since they are noticing economic and energetic savings considering they are paying the same amount of money annually for a new boiler, as they are still amortizing their initial investment, but with less maintenance needs (and costs) and without operating problems. By optimizing the boiler runs by better boiler control, they are starting to reach additional energy savings. Once the boiler operation is fully optimized they expect savings of around 7000 EUR annually compared to the previous situation, which will be a net benefit once they finalize paying for the investment. At the same time, they are looking for subsidies since they have not benefited from any. They expect to receive some once they complete the requirements for energy efficiency in the building´s envelope of about 15%.

New heating system in use	Biomass centralized boiler (pellets) 300 kW
Previous replaced heating system	Coal boiler 320 kW
Building type	Residential
Useful energy demand ($kWh/m^2.a$) – Before and after building shell renovation	Before: 365 kWh/m^2 After: 260 kWh/m^2
Installed capacity (kWth) – Before and after	Before: 320 kW After: 300 kW
Input energy – Before and after	Before: 1,179,230 kWh After: 728,000 kWh
Initial investment (purchase and installation)	72,600 € for the client
Yearly savings on the energy bill (compared to previous system)	27 % in EUR after the amortization in 10 years
Yearly energy savings (compared to previous system)	37 % in MWh
Yearly CO_2 emission reductions (only heating system replacement)	60% CO_2

DUPLEX WITH A HYDRO-STOVE HEATING SYSTEM

The heating system in this renovated duplex uses a small hydro-stove that works with pellets. The system provides the house with 14 kW of space heating power and it has a 200-l. storage double coil tank for domestic hot water that works combined with two solar thermal panels. Distribution is through aluminum radiators regulated by 3 thermostats, placed all around the house and connected with 3 solenoid valves that monitor the circuits. The surface area of the house is about 130 m^2 counting both floors. The home has 4 inhabitants, two parents and two kids. The hydro-stove is placed on the living room, so the living room´s radiators are never used. The boiler makes a little noise because of the 9 years of use, but it is tolerable, and the heat is comfortable. The family decided to invest in biomass for environmental reasons and heating comfort. They were indecisive between a wood biomass model or the hydro-stove with pellets, but the later was more economical. The users opted for this type of heating system because the wanted a boiler that did not pollute too much and it is automatic, so they can work away from home.

The installation process was initially frustrating because the machine was giving an error with the smoke exhaust and the installers could not figure out how to fix it. In the end it was just a cloth stuck in the exhaust, on top of the chimney that was forgotten after trying it out at the fabric. After that, they experienced no more issues. On the other side, the benefits are many, the system is comfortable, automatic, it heats up the house more than enough, the fuel is more environmentally friendly, they use pellets from areas close to them that helps the community keep their jobs and keep the pine groves cleaner. They think the fuel is definitely economical in every aspect, although they did not benefit from any subsidy or financial help.

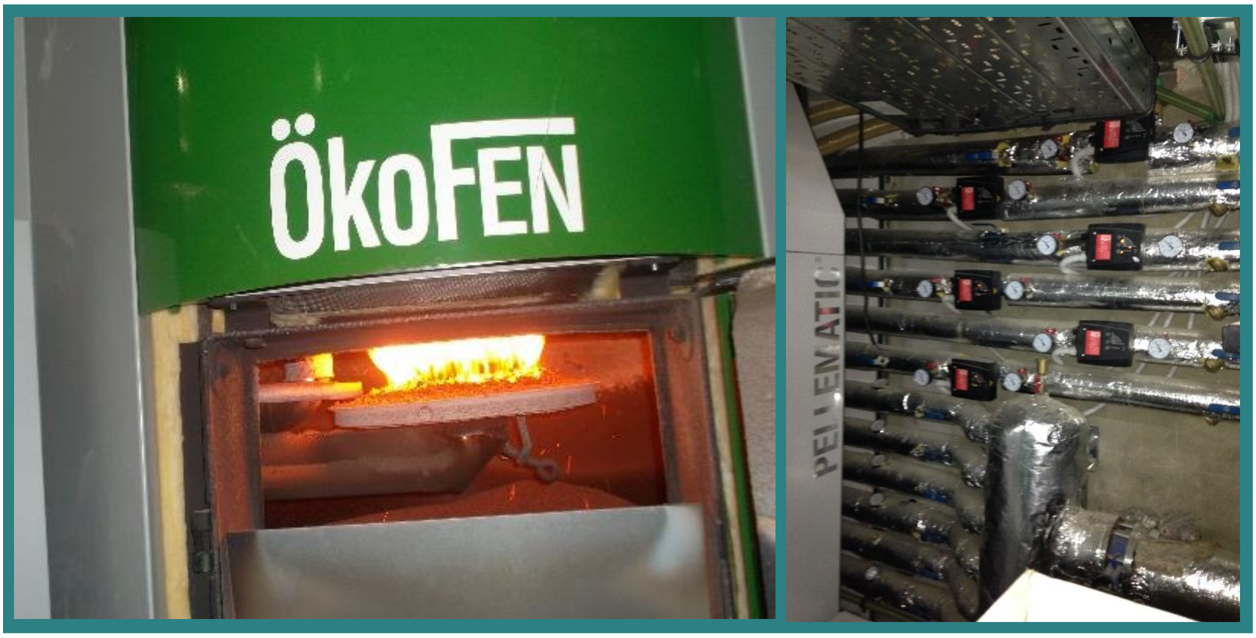
New heating system in use	Hydro-stove
Previous replaced heating system	Diesel boiler
Building type	Residential duplex
Useful energy demand (kWh/m^{2}a) – Before and after building shell renovation	Before: 100 kWh/m^2 (??) After: 88.51 kWh/m^{2}a
Installed capacity (kWth) – Before and after	Before: 20 kW After: 14 kW
Input energy – Before and after	Before: ?? kWh After: 11,506 kWh
Initial investment (purchase and installation)	4750 € with the solar panels
Yearly savings on the energy bill (compared to previous system)	335 €
Yearly energy savings (compared to previous system)	2300 kWh
Yearly CO_2 emission reductions (only heating system replacement)	2863 kg CO_2

OLD DIESEL BOILER ROOM REPLACEMENT IN RESIDENTIAL BUILDING, OVIEDO, ASTURIAS

A residential building located in the centre of Oviedo has gotten its boiler room replaced with a biomass heating system with pellets. The old system worked with diesel and was more than 30 years old, so the reasons to change the system were achieving a higher energy efficiency and emitting less CO_2. Each household were equipped with an individualized monitoring system that measures consumptions with remote viewing and thermostatic valves.

Initially the community that resides in the building wanted a natural gas boiler which was not possible to install due to the boiler room being located underground at a 2nd level. The total area of the building with 9 floors is about 5,254 m^2 and usually 192 people live there. The problems encountered during the installation were a few, such as the non-viability of installing natural gas or that the installation underground was complicated. The new boilers were installed in cascade configuration. In the end the community living in the building are enjoying the benefits, like saving quite a lot of money and at the same time that they use a more sustainable heating system. The replacement of the system benefitted from renewable energies subsidies from the “Consejería de Empleo, Industria y Turismo” of Asturias (2011-2020).

New heating system in use	Biomass pellet
Previous replaced heating system	Diesel
Building type	Residential
Useful energy demand (kWh/m^2a) – Before and after building shell renovation	Before: 83.26 kWh/m^2a After: 79.61 kWh/m^2a
Installed capacity (kWth) – Before and after	Before: 667 kW After: 336 kW
Input energy – Before and after	Before: 546,802 kWh After: 492,121 kWh
Initial investment (purchase and installation)	163,727.51 + IVA €
Yearly savings on the energy bill (compared to previous system)	25,543 + IVA €
Yearly energy savings (compared to previous system)	54,681 kWh
Yearly CO_2 emission reductions (only heating system replacement)	170 t CO_2



NEW SINGLE-FAMILY HOME, ASTURIAS

A new built single-family home has chosen for the heating system an ÖkoFEN pellet boiler which uses condensation technology with 14 kW of thermal power. The condensation system was chosen because the main use will be underground flooring heating and its most efficient when it works at low temperatures, reaching a performance of more than 107%. The household has a superficial area of 210 m^2 distributed over two floors and a garage. For the two floors, the heating system was divided so the owners can program different time schedules and temperatures in the bedroom zone and the rest of the house. The owners did not want to depend on electricity for heating and since it is located in a cold and humid zone, they chose to install a pellet boiler. The fuel can be obtained from local sources and friends had talked to them about how great the biomass boilers work. The installation was fast and there were no apparent problems. Another thing the users love is that they emit little CO_2, not even reaching 3 tons per year. Additionally, the installation of this system was financially aided by local subsidies from the region of Asturias.

New heating system in use	Biomass pellet
Previous replaced heating system	Nothing, new construction
Building type	Residential
Useful energy demand (kWh/m^{2}a) – Before and after building shell renovation	After: 65 kWh/m^{2}a
Installed capacity (kWth) – Before and after	After: 14 kW
Input energy – Before and after	13,975 kWh
Initial investment (purchase and installation)	15,000
Yearly savings on the energy bill (compared to previous system)	
Yearly energy savings (compared to previous system)	
Yearly CO$_2$ emission reductions (only heating system replacement)	12 t CO$_2$

INNOVATIVE HEATING REPLACEMENT IN GUISASOLA RESIDENTIAL, OVIEDO, ASTURIAS

An old coal heating system in Oviedo, Asturias, has been replaced with an innovative heating system that also includes DHW, an aerothermal system and photovoltaic panels. The building is made of 72 households, it was built on 1963 and has 7.440 m^2 with no surrounding buildings, so the thermal losses on the façade are important. Around 288 people live there, and it has been equipped with an individualized monitoring system that measures consumptions with remote viewing and thermostatic valves in each household. Due to the complex access to the boiler room and the desire of achieving maximum efficiency, it was installed as a cascade boiler system of the Okofen brand.

The reasons that lead to install a new heating system were the old system was outdated and very polluting because of the coal. Also, the building was looking to obtain the highest energy qualification possible. Anyhow, there were a few problems during the installation, like the need of dismantling all boilers to fit them into the boiler room. For now, the building enjoys the guarantee of an optimal operation by the energy service company and important economical and emissions savings. The replacement of the system benefitted from renewable energies subsidies from the “Consejería de Empleo, Industria y Turismo” of Asturias (2011-2020).

New heating system in use	Biomass pellet Aerothermal Photovoltaic
Previous replaced heating system	Coal
Building type	Residential
Useful energy demand (kWh/m^{2}a) – Before and after building shell renovation	Before: 108.48 kWh/m^{2}a After: 87.23 kWh/m^{2}a
Installed capacity (kWth) – Before and after	Before: 950 kW After: (624+16+5.4) kW
Input energy – Before and after	Before: 1,008,828 kWh After: 763,611 kWh
Initial investment (purchase and installation)	311,780 + IVA €
Yearly savings on the energy bill (compared to previous system)	36,714.53 €
Yearly energy savings (compared to previous system)	254,217 kWh
Yearly CO_2 emission reductions (only heating system replacement)	453.6 t CO_2

INNOVATIVE RENEWABLE ENERGY SYSTEM IN RESIDENTIAL HOUSEHOLD, OVIEDO, ASTURIAS

In a residential household of 160 m^2 with underfloor heating a biomass boiler was replaced with a new one of 16 kW because the old one did not reach the performance expected. The innovation consists of using a set of additional RES systems to be as independent as possible from the grid, and included 5 kW of photovoltaic panels, 1 kW of wind power and 4 panels for solar thermal energy, additionally to the biomass boiler. The house is occupied by 2 persons, but there are times when they are up to 6. The boiler feeds an inertia tank for domestic hot water, and the heating is divided in 2 zones, one for the underground heating and the other for conventional heating.

The household had installed a biomass pellet boiler beforehand, so the owner had his preferences clear. The old system gave him several problems and did not achieve the desired comfort. Since they wanted a biomass system, they bought a new boiler of higher quality. The installation process was quite easy since there was an old biomass boiler already, so the technicians just had to connect the new system. On the other hand, because of all the renewable systems installed in the household the electricity bill is almost null and as the resident comments, the environmental impact is really low. The system was financially helped with regional aid.

New heating system in use	Biomass pellet
Previous replaced heating system	Biomass
Building type	Residential
Useful energy demand (kWh/m²a) – Before and after building shell renovation	Before: 175 kWh/m^2 a After: 100 kWh/m^{2a}a
Installed capacity (kWth) – Before and after	Before: 28 kW After: 16 kW
Input energy – Before and after	Before: 28,000 kWh After: 16,000 kWh
Initial investment (purchase and installation)	500 €
Yearly savings on the energy bill (compared to previous system)	576 €
Yearly energy savings (compared to previous system)	12,000 kWh
Yearly CO_2 emission reductions (only heating system replacement)	13 t CO_2

AUSTRIAN ENERGY AGENCY

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