Market uptake of small modular renewable district heating and cooling grids for communities

Project No: 691679

Best Practice Examples of Renewable District Heating and Cooling

WP 2 – Task 2.1 / D 2.1

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CoolHeating website: www.coolheating.eu

Contents

Abbreviations

BA	Bosnia
CHP	Combined Heat and Power
CSP	Concentrated solar power
DBDH	Danish Board of District Heating
DH	District heating
DHC	District heating and cooling
EU	European Union
EUR	Euro
FCU	Fan coil unit
GHG	Greenhouse gas emissions
GW	Giga watt
GWh	Giga watt hours
HR	Croatia
HP	Heat pump
kW	Kilo watt
kWh	Kilo watt hours
MK	Macedonia
MW	Mega watt
MWh	Mega watt hours
ORC	Organic Rankine Cycle
RE	Renewable energy
RES	Renewable energy sources
RS	Serbia
SDH	Solar district heating
SI	Slovenia
WP	Work package

1 Introduction

This report on “Best practice and framework analyses” was elaborated in the framework of the CoolHeating project. The objective of the CoolHeating project, funded by the EU’s Horizon2020 programme, is to support the implementation of "small modular renewable heating and cooling grids" for communities in South-Eastern Europe. This is achieved through knowledge transfer and mutual activities of partners in countries where renewable district heating and cooling examples exist (Austria, Denmark, Germany) and in countries which have less development (Croatia, Slovenia, Macedonia, Serbia, Bosnia-Herzegovina). Core activities, besides techno-economical assessments, include measures to stimulate the interest of communities and citizens to set-up renewable district heating systems as well as the capacity building about financing and business models. The outcome is the initiation of new small renewable district heating and cooling grids in 5 target communities up to the investment stage. These lighthouse projects will have a long-term impact on the development of "small modular renewable heating and cooling grids" at the national levels in the target countries. A key objective of the project is to exchange information on best practices for small modular district heating and cooling systems.

This report presents best practice examples from Austria, Germany and Denmark, but also from the CoolHeating target countries (Croatia, Slovenia, Macedonia, Serbia, Bosnia-Herzegovina). The purpose of the report is to provide an overview of Best Practice examples for district heating (and cooling) plants. Each example provides details on the technical and economic facts as well as on ownership issues. Furthermore, each example is described in a short text and pictures or graphs are illustrated. An overview on the technical main components of each example is given in Table 1 in the conclusion of this report.

The report is closely related to other reports that will be prepared during the project period of CoolHeating. Some of the other reports that this report relates to, within the CoolHeating project, are:

- Report on study tours
- Report on framework conditions and policies
- Reports and national framework
- Report on dialogue with regulators and heating and cooling utilities
- Handbook on small modular renewable district heating and cooling grids

Each partner has supplied the description of the Best Practice examples for the partner’s country based on a template provided by PlanEnergi. In some cases it has not been possible to locate all data, asked for in the template. The template served to align the descriptions as much as possible.

2 Denmark – Best Practice Examples

Denmark has a long history of district heating, starting back in 1903, where the first district heating plant was built at Frederiksberg Hospital. The first major public heat installations were developed in Copenhagen in the 1930s and were based on surplus heat from local power production. The public heat supply expanded in the major cities in the 1950-1960s. And in the 1960s a shift from peat and coal to oil led to the establishment of a number of small and medium sized consumer owned district heating plants.

The later oil crisis led to an active political involvement and the first heat supply law entered into force in 1979 – around 700,000 house installations was at that time already in place. The purpose of the law was to improve energy efficiency and reduce the dependency of imported fuels, such as oil. The law was followed by an energy agreement in 1986 with the main purpose to ensure coproduction between heat and electricity. With this agreement, the authorities were also given the power to implement mandatory connection to natural gas grid or district heating networks to secure the investments in the pipe systems.

Further agreements and laws have followed and paved the way for both centralized and decentralized district heating in Denmark.

The development of district heating systems in Denmark has been an important measure to fulfil the national climate policy targets. The target, as of 2015, is to reach 100% renewable electricity and heat production by 2035. Statistics show that the share of non-fossil based energy production is already now substantial.

Denmark has 16 central combined heat and power production plants (CHP) which originally were only producing power and no heat. Besides the larger plants, Denmark has 380 decentralized plants, of which around 70 % are CHP, while some 30 % are heat-only plants. All decentralized plants were originally only producing heat, whereas the centralised plants were originally mainly for power production. Three out of four citizens of Denmark are supplied with this collective heat supply systems (district heating or natural gas). The systems are economically competitive and in many cases cheaper compared to individual solutions.

In Denmark district heating developed during the 1970s even without “appropriate framework conditions” or national political objectives, as described in the first sections. The development of district heating was at that time on private initiative. The establishment of district heating plants was organized by the consumers. The primary role of the municipalities was to provide guarantees for loans. Today this is still an important role. In the course of development, the role of the governments at different levels became more important in the planning process.

The district heating plants in Denmark try to diversify energy sources and to include solar thermal energy and electricity in terms of large heat pumps with various heat sources, see Figure 1, which shows the development of solar district heating in Denmark since 2006.

The market for solar heating systems in connection with district heating had a growth rate above 30 % per year since 2008. In 2015 about 280,000 m^2 of solar collectors are planned to be commissioned in addition to the existing 550,000 m^2.

The two largest of the upcoming systems combine large scale solar heating with a pit heat storage. In Denmark, as well as in other countries, increasing interest is on the combination of solar heating and seasonal storages to achieve large solar fractions. This also implies options for heat pumps, electric boilers and other technologies in combination with the large scale heat energy storage, providing flexibility to the electricity system and producing economically competitive and renewable district heating.

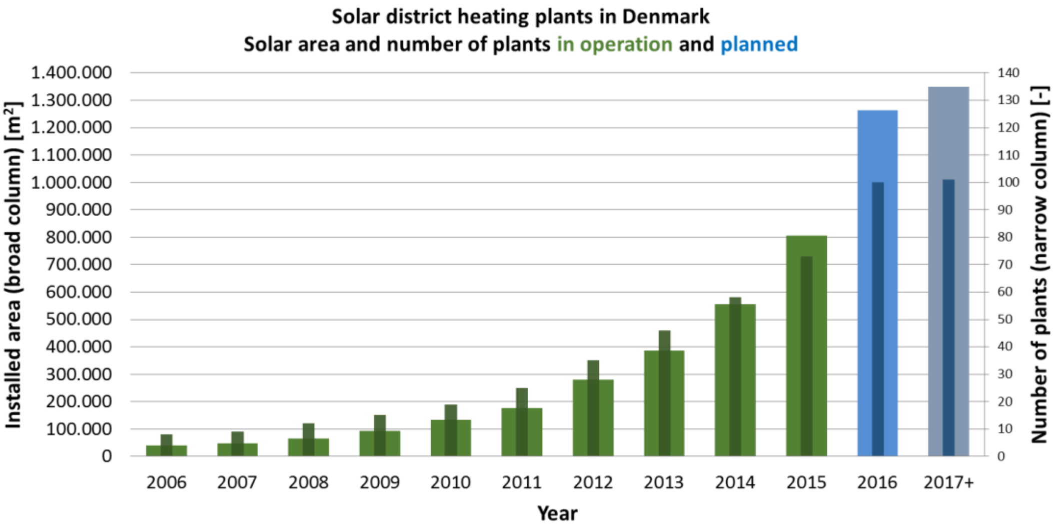


Figure 1: Development of solar district heating in Denmark since 2006

The Guiding Examples for Denmark are Bornholm and Brædstrup. These Guiding Examples are shortly described in this report, together with four other Danish examples.

Brædstrup District Heating is chosen as a Guiding Example since the plant during the last 10 years has been a frontrunner in Denmark on how to make district heating efficient, cheap for the consumers and environmentally friendly at the same time. This is done through activities in the electricity market, smart metering, and introduction of service visits and support to improvement of house installations. Increasing the efficiency and optimizing the production and distribution facilities in terms of technical economical and environmental aspects are central parts of the district heating company´s future policy.

Brædstrup is a consumer owned district heating company with almost 1,500 consumers. The district heating plant started as a traditional co-generation plant including CHP and boiler units. The first step towards increasing the plant's efficiency was taken in 2006 where one of the boiler units was replaced by a new unit with an efficiency of 104 %.

Bornholm is selected as another Guiding Example due to the island's energy strategy, where district heating is part of the 2025 Energy Strategy for Bornholm. The strategy envisions turning Bornholm into a carbon-neutral society based on sustainable and renewable energy by 2025.

The examples described for Denmark represents different technologies and sizes in terms of capacities and heat demand (number of consumers), ranging from small utilities in Bornholm to middle size district heating companies in Thisted, where waste heat incineration is used.

A major theme in the Danish district heating sector is at the moment heat pumps; today there are 15 electric heat pump installations in operation with an installed heat capacity of 20.3 MW. In 2016 nine more projects are under establishment with a planned heat capacity of 20.7 MW. An overview of the already installed heat pumps and the planned projects can be seen at: http://www.planenergi.dk/wp-content/uploads/2016/04/Oversigt-over-store-varmepumper.pdf

One of the major advantages of heat pumps is the balance between electricity and storage, that the technology can provide in connection with DH in energy systems with a high penetration of renewable energy, such as electricity produced by wind turbines. There is a large potential for heat pumps in the Danish DH system. In the report, http://www.ens.dk/sites/ens.dk/files/byggeri/udredning_vedroerende_varmelagringsteknologi er og store varmepumper til brug i fjernvarmesystemet.pdf, it is estimated that there will be established heat pumps with a heat capacity of 1,000 MW over the next five to ten years.

The description of the best practice examples in Denmark includes key data on the technical installation, the district heating network and key economic data. The Danish heat prices are all from the same source: Energitilsynets prisstatistik 2015 (Danish Energy Regulatory Agency, DERA price statistics), which can be found at: http://energitilsynet.dk/varme/statistik/prisstatistik/pr-15-marts-2015/. The statistics show a heat production price in EUR/MWh to cover the demand of a standard house in Denmark of 130 m^2 and an annually heat demand of 18.1 MWh[1].

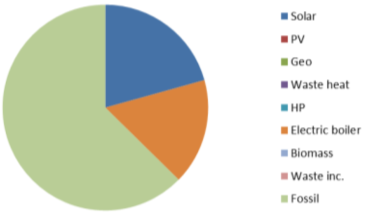
[1] The prices do not say anything about the actual price of heat for a given property in a given area. The actual price of a resident is based on the building's specific consumption (variable) and the actual basis for calculating the fixed contribution. The information to make specific calculations for a given resident is found in the heat supply tariffs of the utility, which often can be found at the utility’s website. The price list of the Danish examples is based on the pricing reviews that have effective date up to and including 15th of March 2015. The price list is published April 1, 2015 on the DERA website. The price includes VAT, but does not include capital costs of the installed consumer installation, nor connection cost to the utility.

2.1 Brædstrup District Heating

Location: Middle of Jutland
Google maps
http://www.braedstrup-fjernvarme.dk/

Video:
http://www.braedstrup-fjernvarme.dk/firmaprofil/billedegalleri/video

Technical data

Heat production technology // Fuel // heat capacity // year of installation 	18,600 m^2 solar collectors, 2007 (8,000 m^2) and 2012 (10,600 m^2) Electric boiler, 10 MW, 2012 Heat pump (high pressure screw compressor), 1.2 MW, 2012 Boiler 1, natural gas, 13.5 MW, 2006 Boiler 2, natural gas, 10 MW Engine 1, natural gas, 4.1 MW (8.7 MW fuel) Engine 2, natural gas, 4.1 MW (8.7 MW fuel)
Cooling	No
Efficiency of plants	Boiler 1: 104% Boiler 2: 100 % Engine 1: η(heat) 47%, η(el) 42% Engine 2: η(heat) 47%, η(el) 42%
DH network	27.9 km distribution and 21.1 km service pipes. Network age of 17 years.
Storage	Bore hole – seasonal storage: 48 bore holes Probes lowered to a depth of 45 meters 5 x 60 meters deep holes for temperature sensors 19,000 m^3 soil is heated Steel-tank, in total 7,500 m^3 2,500 m^3 in connection to CHP 5,500 m^3 in connection to solar collectors, electric boiler
Consumers // total annual heat sales	2015 numbers: 1,481 consumers 296,378 m^2 connected floor area 39,633 MWh heat produced 31,100 MWh heat sold
Heat price, fixed, variable, total (standard house)	63 EUR/MWh Total 1,721 EUR/year (standard house 18.1 MWh; 130 m^2 incl. tax, excl. capital costs)
Ownership	Private (consumer)

Brædstrup District Heating (DH) is a consumer owned district heating company with almost 1,500 consumers. The district heating plant started as a traditional co-generation plant including CHP and boiler units. The first step towards increasing the plants efficiency was taken in 2006 where one of the boiler units was replaced by a new unit with an efficiency of 104 %.

Brædstrup DH has over the last 10 years been a frontrunner in Denmark in how to make district heating efficient, cheap for the consumers and environmentally friendly at the same time. This is done through activities in the electricity market, smart metering and introduction of service visits and support to improvement of house installations. Increasing the efficiency and optimizing the production and distribution facilities in terms of technical economical and environmental aspects are central parts of the district heating company´s future policy.

In 2005 no Danish natural gas fired CHP had solar district heating. Brædstrup DH made design calculations showing that solar district heating combined with CHP in an open electricity market could be a feasible solution. The electricity prices are in periods so low, that the engine is stopped and the heat production takes place on natural gas boilers, making solar district heating a feasible solution.

Based on these calculations a total of 8,000 m² of solar collectors were commissioned in 2007. It was the world's first solar thermal plant in combination with natural gas fired CHP. In 2008 Brædstrup DH decided to take the second step towards 100 % renewable energy (RE). It was decided to implement another 10,600 m² of solar panels, 5,500 m^2 buffer tank, 19,000 m^3 pilot borehole storage, 1.2 MW_{th} heat pump and a 10 MW electric boiler. The solar collector installation was the biggest in Europe at that time, but there is still a need for natural gas boilers as peak load.

The consumers' benefit of the activities has been less pollution from reduction in natural gas consumption and low heat prices; Brædstrup DH is among the 25 % cheapest DH plants in Denmark. All house installations are checked every second year by the utility and all consumers can find key figures for their own consumption at Brædstrup DH´s homepage via a personal link. All large decisions are taken by the annual general assembly, where all consumers are invited and have a vote. Project preparation with local plan and landscaping has been carried out in co-operation with Horsens Municipality to integrate solar plants in the landscape and utilize them as recreation areas. A presentation of the plant can be seen in this link: http://dkfilm.jsmediatools.com/dk/200902/braedstrupfjernvarmeUK/.

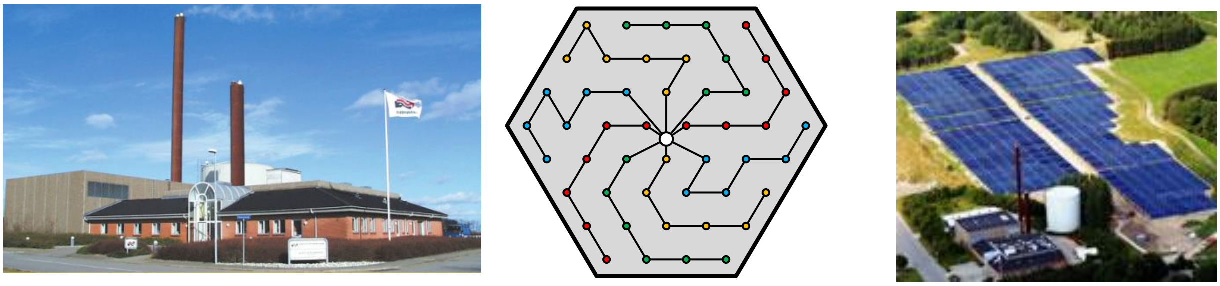
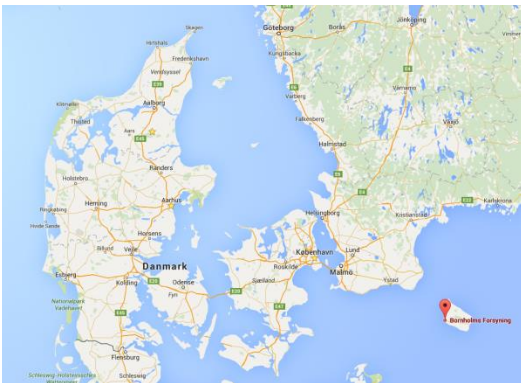


Figure 2: Facilities in Brædstrup: district heating facility building (left), design of the borehole storage (middle) and solar field (right) (Source: www.braedstrup-fjernvarme.dk)

The next step towards 100 % RE solutions is prepared in cooperation with six other district heating utilities in the municipalities Horsens and Hedensted. Brædstrup DH took initiative to this cooperation in 2011. Until now the cooperation has resulted in a common design study called FlexCities analysing how to convert to 100 % RE solutions using combinations of excess heat from industries, large solar thermal plants connected to the transmission pipes, large scale heat storages, large scale heat pumps, biogas CHP and conversion of individually heated houses to district heating. See more about the project at (only Danish version): http://www.danskfjernvarme.dk/groen-energi/projekter/flexcities

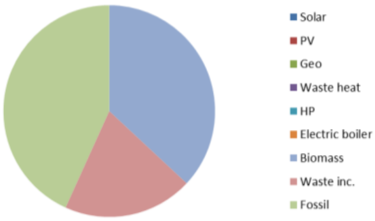
2.2 District Heating in Bornholm and Bornholms Forsyning

Location: Most eastern part of Denmark
Google maps
http://www.bornholmsforsyning.dk/varme



Nine town areas on the island of Bornholm are supplied by district heating, see map of DH areas in Figure 3 on the next page.

Technical data

Heat production technology // Fuel // heat capacity // year of installation 	District heating supplies: Rønne; waste CHP, coal/biomass CHP, 2000 Nexø; 2 x 5 MW straw boilers, oil peak load, 1989 Klemensker; 3.5 MW straw boiler, oil peak load, 1986 Aakirkeby; 8 MW wood chip boiler, oil and wood pellets peak load, 2010 Hasle / Vestbornholm; 4 MW straw boiler, 3 MW wood pellet boiler, oil peak load, 2008. Transmission Hasle – Allinge in 2016 and transmission between Hasle – Klemensker 2017. New biomass boiler Hasle in 2016, 14.5 MW wood chip boiler Østerlars; Straw boiler, wood pellet boiler and electric boiler as peak load, 2013 Gudhjem; Connected to Østerlars Svaneke; under establishment Allinge; under establishment; 8 MW wood chip boiler
Cooling	No
Efficiency of plants	Efficiencies depending on technology – not specified
DH network	No data
Storage	Steel tanks
Consumers // total annual heat sales	Numbers from Heat Plan Bornholm, 2011 numbers: 9,435 customers in total 255,531 MWh heat produced 206,700 MWh heat sold
Heat price, fixed, variable, total (standard house)	87 EUR/year (Bornholms Forsyning 2016) Fixed 3.83 EUR/m^2 plus 383 EUR/year Total 2,500 EUR/year (standard house 18.1 MWh; 130 m^2 incl. tax, excl. capital costs)
Ownership	Private (consumer) divided on three utilities

District heating is part of the 2025 Energy Strategy for Bornholm that envisions turning Bornholm into a carbon-neutral society based on sustainable and renewable energy by 2025.

Bornholm Municipality analyzed the potential of expanding district heating to more areas than the existing shown in the map in Figure 3 in Heat Plan Bornholm 2013. District heating will in the future be supplied in all town areas on the island of Bornholm, especially to the larger town areas on the northern shore of the island; Allinge, Gudhjem, Svaneke, among others.

There are two utility companies at Bornholm, where Bornholm Utility is the largest and operates the DH plants in seven out of the nine town areas. The other utility is Rønne Water and Heat.

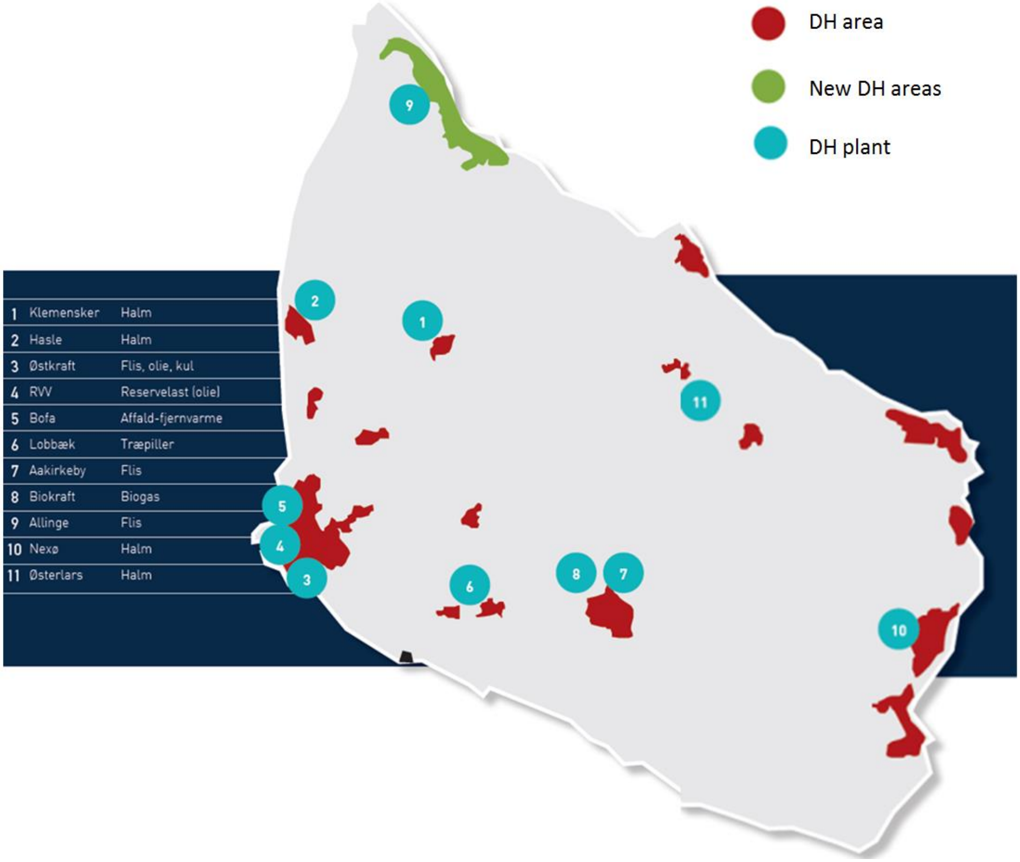


Figure 3: Existing and planned DH areas in Bornholm; 1, 2, 10 and 11: straw; 3: wood chips, oil, coal; 4: reserve load (oil); 5: waste incineration; 6: wood pellets; 2, 7 and 9: wood chips; 8: biogas, (Source: Bornholm Strategic Energy Plan)

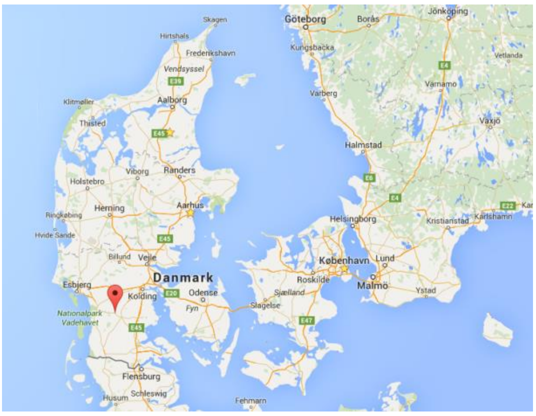
The production of heat is based on various types of technologies; In Rønne, the heat supply is primarily based on heat from waste incineration and excess heat from electricity production based on wood chips and coal (CHP). The peak load is from oil boilers. Nexø Heat Supply was established in 1989 and all heat is produced on a new 12.5 MW straw boiler. An oil boiler of 9 MW is used as back-up and the plant has an 825 m^3 steel tank. The heat production from the plant in Klemensker is also based on straw from a 3.5 MW boiler in connection to an 800 m^3 steel tank.

The plant in Aakirkeby is a newer plant from 2010. The heat is produced on an 8 MW wood chip boiler. The heat production in Vestbornholm / Hasle is based on biomass from a 4 MW straw boiler and 3 MW wood pellet boiler as peak load. This is also the case for the new plant in Østerlars from 2013, where heat is produced based on a straw boiler including wood chip pellet boiler and electric boiler as peak load units.

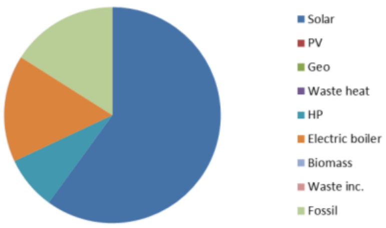
The strategic energy plan for Bornholm states goal of Bornholm being fossil free in 2025. The main actions to reach the goal is a new wood chip CHP plant in Rønne or utilizing geothermal heat in connection to the plant in Rønne. Other actions to reach the goal is a higher share of biomass and establishment of solar collector plants, e.g. a 10,000 m^2 solar area could be connected to the new wood chip boiler in Allinge. Transmission lines will also be part of the plans, where the heating supplies in Rønne, Hasle and Aakirkeby will be connected from 2017 (planned). See more in Bornholm Strategic Energy Plan: http://www.brightgreenisland.dk/media/4993/Strategisk%20Energiplan%20Bornholm%202050_210515.pdf and Heat Plan Bornholm from 2013: https://www.brk.dk/Borger/Bolig/Forsyning/Documents/Varmeplan%20Bornholm%202013.pdf

2.3 Gram Fjernvarme

Location: Southern part of Jutland, Denmark
Google maps
http://www.gram-fjernvarme.dk/



Technical data

Heat production technology // Fuel // heat capacity // year of installation 	10,073 m^2 solar collectors, 6.5 MW, 2009 34,727 m^2 solar collectors, 31 MW in total for all 44,800 m^2 solar collector field (3,556 panels), 2015 2 Boilers, natural gas, 10 MW Engine, natural gas, 6.5 MW (8.7 MW fuel) Electric boiler, 8 MW Electric driven heat pump, 900 kW, 2015
Cooling	No
Efficiency of plants	Boiler 1: 100 % Boiler 2: 100 % Engine: η(heat) 50 %, η(el) 41.2 %
DH network	21.1 km main network 13.3 km service pipes
Storage	Steel tank (in connection to CHP and first solar collectors) 2,300 m^3 Seasonal storage 122,000 m^3
Consumers // total annual heat sales	Around 1,200 consumers 25,000 - 30,000 MWh
Heat price, fixed, variable, total (standard house)	80 EUR/MWh 1,925 EUR/year (standard house 18.1 MWh; 130 m^2 incl. tax, excl. capital costs)
Ownership	Private/consumer owned

Gram District Heating Company was until 2009 based on natural gas with a CHP unit and two boilers. The heat capacity of the CHP unit is 6.5 MW and the heat capacity is 5.0 MW for each boiler. The annual heat demand is around 30,000 MWh.

The first phase of the solar field was established in 2009 and covers more than 10,000 m^2 with a maximal output capacity of 6.5 MW. The solar field could cover around 15 % of the heat demand and was connected to the existing storage, a steel tank of 2,300 m^3. The solar collector field is connected to the plant by a transmission line that is approximately 200 m and has a dimension DN200. The construction cost of the first solar field was around 2.4 million EUR. The solar collector field was expanded in 2015 to have an area of 44,800 m^2 in total. After the expansion the system is expected to be able to cover about 60 % of the heat production. The high penetration rate is only possible through the establishment of a seasonal pit storage, an absorption heat pump and an electric heat pump which allows the collectors to operate at a lower temperature, whereby the efficiency increases significantly.

The purpose of the electrically-powered heat pump is to cool the bottom of the seasonal heat store. By cooling the bottom of the heat store the operating hours of the solar plant is increased and thus will be achieved by increased utilization of the solar system. The CHP unit delivers the driving energy to the absorption heat pump. This is done by replacing the high temperature flue gas heat exchanger with an approved exchanger for heated water above 150 °C. To utilize energy from the CHP unit's exhaust gases an additional low-temperature flue gas exchanger is implemented to cool the exhaust gas down to about 20 °C. This results in an excess of cooling water that can be recovered for further optimization of gas boilers, solar heating and an electric driven heat pump. A performance of 450 – 500 kWh/m^2/year is expected from the total solar system.

Figure 4: The seasonal pit storage and the solar field under establishment. To the right is the existing 10,000 m^2 and at left and front is seen the area where the new solar panels installed together with the seasonal pit storage, picture by Gram Fjernvarme

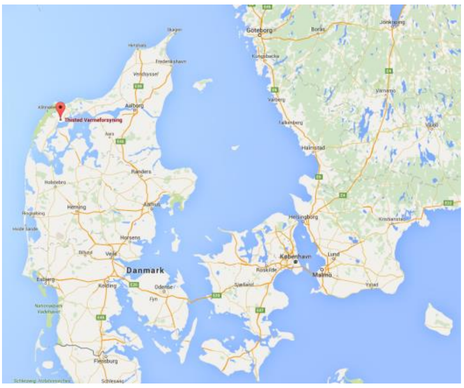
Gram District Heating is neighbor to a carpet factory. The carpet factory currently has two processes that have delivered surplus heat to Gram District Heating since June 2016. The surplus heat will be supplied at a temperature of 69 °C, so they only needed to establish a service line between the plant and the factory. To retrieve the excess heat 2 new heat exchangers was installed in the processes. It is expected that 2,000 MWh/year can be optained. To deliver excess heat from the factory is part of the factory´s commitment to the concept of cradle to cradle.

Figure 5: The new solar system established in 2015 including solar voltaic panels on the south side of the seasonal pit storage, picture by Gram Fjernvarme

2.4 Thisted District Heating and Cooling

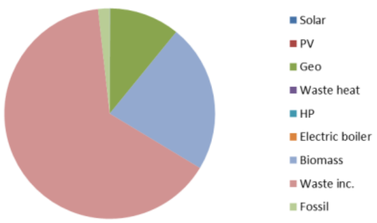
Location: North-western part of Jutland, Denmark
Google maps
http://www.thisted-varmeforsyning.dk/

Video: http://www.thisted-varmeforsyning.dk/firmaprofil/thisted-varmeforsyning-paa-film



Technical data

Heat production technology // Fuel // heat capacity // year of installation	Waste CHP, Waste incineration, 10.6 MW (2.9 MW_{el}), established 1979, renovated for waste incineration in 1991 Geothermal, 5 MW + 2.7 MW absorption HP, 10 MW boiler (high pressure hot water), 1984 Biomass boiler, straw, 11.5 MW, 2005 Peak load units: Boilers, natural gas (fuel oil), 46.5 MW, the first location was built in 1961 CHP units, natural gas,1.9 MW (1.3 MW_{el}), the oldest CHP unit is from 1967
Cooling	Groundwater, absorption heat pump
Efficiency of plants	Waste CHP Straw unit: 92 % Peak load boilers, minimum of 94 % Peak load CHP: η(heat) 57 %, η(el) 29 %
DH network	113.9 km distribution and 107.2 km service pipes.
Storage	Three steel tanks: 1,500 m^3, 2,500 m^3 and 360 m^3.
Consumers // total annual heat sales	2014 numbers: 5,057 consumers m^2 connected 195.400 MWh heat produced 157.500 MWh heat sold (15 % net loss) No data on cooling sales
Heat price, fixed, variable, total (standard house)	47 EUR/MWh, 1,230 EUR/year (standard house 18.1 MWh; 130 m^2 incl. tax, excl. capital costs)
Ownership	Private (consumer), see text below.



In 2014 Thisted District Heating had 5,057 consumers and 9 employees. The plant has since its establishment in 1961 supplied the consumers with district heating. The heat generation is based on renewable energy, supplemented with a smaller share of natural gas boilers for peak load. The system consists of CHP from waste incineration, natural gas boilers, geothermal energy, straw boiler and a smaller solar heating system (test facility). The majority of heat comes from the waste CHP and straw boiler, while approximately 11 % comes from geothermal energy; hot water delivered at 43 °C from the drilling.

Thisted District Heating A.m.b.a. and I/S Thyra each own 50 % of I/S CHP Thisted (waste incineration). I/S Thyra is owned by the municipalities: Morso, Jammerbugt and Thisted.

Thisted DH's vision includes prioritizing green operation, security of supply and stable low prices. The majority of the heat supplied from Thisted DH is based on heat produced at the waste incineration CHP plant. The incineration plant was established in 1979 and has been renovated and rebuilt in 1991 for waste incineration. The plant has a capacity of 10.6 MW of heat and 2.9 MW of electricity. The waste treatment capacity is about 55,000 tonnes of combustible waste on annual basis. The waste comes partly from local citizens and partly from imports from abroad.

At the site of Thisted DH are several heat production units: The biomass boiler fuelled by straw, a geothermal plant, a small demonstration solar thermal system (CSP, concentrated solar power) and gas boilers. The straw is delivered from local farmers. In addition, a number of gas boilers and engines (CHP units) are placed at two other locations in Thisted. Natural gas boilers serve as peak and reserve capacity. In Hillerslev is a plant, which can be used as peak and reserve load for Hillerslev if Thisted DH is unable to supply sufficient heat to the area via the transmission line.

An overview of the system is available on the DH Company's webpage at all times:

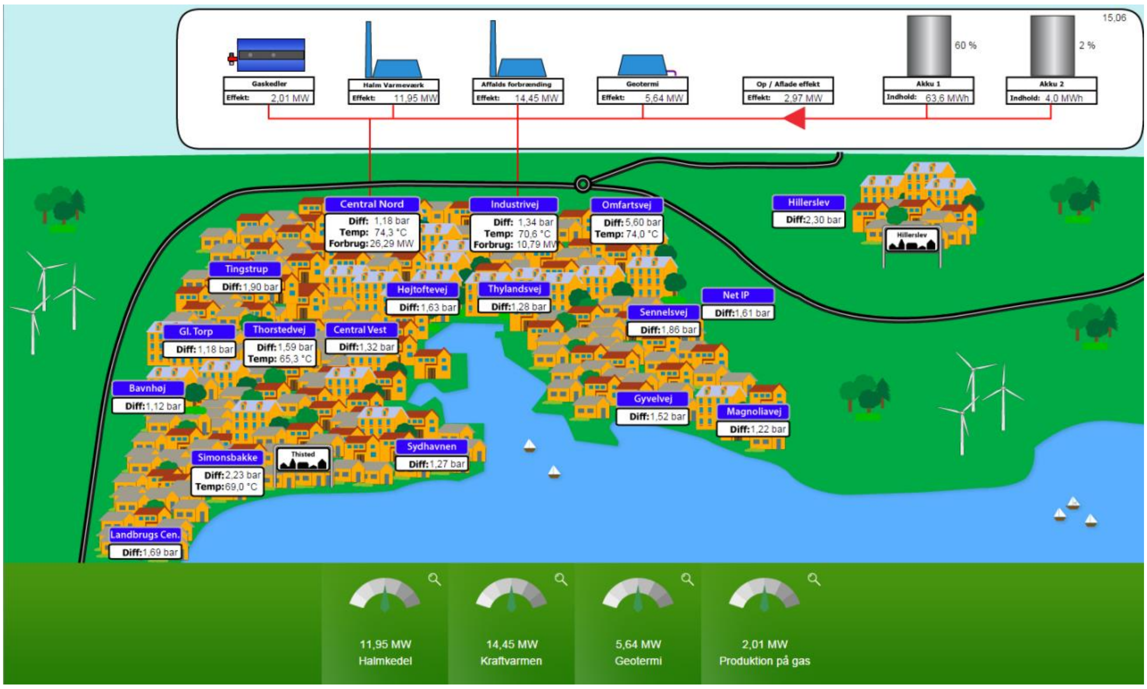


Figure 6: Overview of Thisted district heating (Source: http://www.dme-as.dk/component/dmeintranet/dmecustomer/2?popup=true%20)

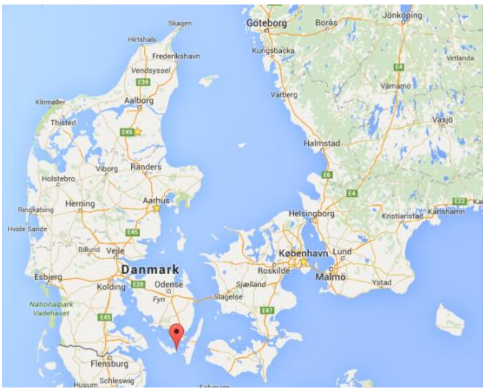
The existing geothermal plant has been operating since 1984. For many years the plant was partly owned by DONG Energy, while Thisted DH was responsible for the daily operations in all years. In 2011 Thisted DH took full ownership of the plant and the commitments as licensee and operator. The geothermal drilling is 1,243 m and has a flow capacity of 200 m^3/h.

The production of district cooling is done by pumping cold water from the soil under Thisted city. In summer, the excess heat from waste incineration is driving the absorption heat pump, and thus utilized in the cooling system.

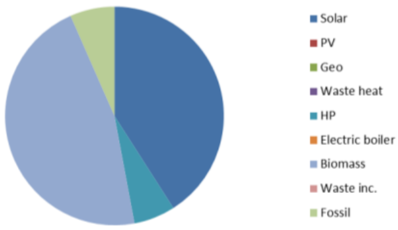
2.5 Marstal District Heating

Location: Southern part of Denmark – located at Ærø.
Google maps
http://www.solarmarstal.dk/

Video:
https://vimeo.com/user3541889/review/131825993/b0cd6f43cf



Technical data



Heat production technology // Fuel // heat capacity // year of installation	18,300 m^2 solar system + 15,000 m^2 solar system 8.3 MW bio-oil boilers; 10,340 m^3 pilot pit heat storage (not in use); 2,100 m^3 steel tank water storage; 75,000 m^3 pit heat storage; 4.0 MW wood chip boiler producing thermal oil for ORC. Heat output 3.25 MW 1.5 MW$_{th}$ heat pump using CO_2 as refrigerant; 750 kW$_{el}$ ORC (Organic Rankine Cycle)
Cooling	No cooling
Efficiency of plants	No data found
DH network	19.5 km distribution and 17.7 km service pipes.
Storage	2,100 m^3 storage tank 10,000 m^3 seasonal pit heat storage (pilot storage, not in use) 75,000 m^3 pit heat storage
Consumers // total annual heat sales	2015 numbers: 1,595 consumers (no. of meters) 35,000 MWh heat produced 27,850 MWh heat sold
Heat price, fixed, variable, total (standard house)	Variable 107 EUR/MWh, Total 2,525 EUR/year (standard house 18.1 MWh; 130 m^2 incl. tax, excl. capital costs)
Ownership	Private (consumer).

Marstal District was established in 1962 and currently supplies district heating to 1,500 – 1,600 consumers in Marstal.

District heating in Marstal today is based 100 % on renewable energy sources, from solar and bio-oil, where the sun's energy supplies 30 % of the annual district heating production.

The implementation of renewable energy started in 1994 where Marstal District Heating developed a project to install solar collectors on a swimming pool. The success of this installation formed the basis for a plan to install a large-scale solar heating plant 0f 8,000 m^2 connected to the district heating plant.

Marstal Fjernvarme (Marstal District Heating) has, through the EU's FP7, received funding for the SUNSTORE4 project. The project is, along with 10 other European projects selected to be a part of the so-called “EU flag projects”, see more on this webpage: http://sunstore4.eu/background/project-brief/.

The aim of the project is to demonstrate a large scale innovative, cost-effective and technically 100 % sustainable renewable energy system. Marstal District Heating’s nearly 1,600 consumers receive district heating based on 100 % RE sources with a solar fraction of 41 % and biomass to cover the remaining 60 % (2015 numbers). The project also includes a heat pump which is “moving” energy to the energy storage and a turbine, a so called ORC (Organic Rankine Cycle) which is an electricity-producing device that can use the energy from the flue gas produced in the biomass boiler.

With more than 18,000 m^2 of solar panels Marstal solar plant was in 2003 the largest solar installation in the world, and in the course of 2010-12 being expanded by another 15,000 m^2 and new pit heat storage of 75,000 m^3.

The solar panel plant in Marstal is built in several stages and consists of several different types of solar collectors (flat plate collector, vacuum solar collectors, and parabolic collectors). Likewise, different storage techniques has been implemented with a 2,100 m^3 steel tank, a 3,500 m^3 closed aquifer store (not in use any longer) and two seasonal pit heat storages of 10,340 m^3 (not in use any longer) and 75,000 m^3.

Marstal District has developed a management technique where the pumps from the solar collectors are controlled by the solar radiation. This has resulted in energy savings of 75 % of the pumping power and a possibility to produce solar heat at district heating flow temperatures most of the time.

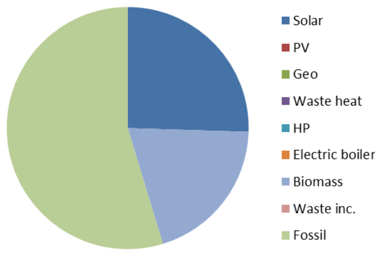
Figure 7: Marstal solar district heating and seasonal pit heat storage (Source: www.solarmarstal.dk)

2.6 Hjallerup District Heating

Location: Northern part of Jutland, Denmark
Google maps
http://www.hjallerupfjernvarme.dk/forside.aspx

Technical data

Heat production technology // Fuel // heat capacity // year of installation	21,500 m² solar collectors, 2015-16 4.4 MW heat CHP unit, 2012 4.4 MW heat CHP unit, 2012 9.3 MW naturgal gas boiler 6 MW electrical boiler 1.8 MW straw boiler, 2015-16 Old units in Klokkerholm are not specified; CHP unit and two natural gas boiler.



Cooling	No cooling
Efficiency of plants	Straw unit: 88 % Natural gas boiler 102 % CHP units: η(heat) 56 %, η(el) 43 %
DH network	No data
Storage	2 x 2,400 m³ storage tank (CHP) 3,500 m³ storage tank for solar and biomass
Consumers // total annual heat sales	2015 numbers: 1,622 consumers in Hjallerup and more than 360 in Klokkerholm
Heat price, fixed, variable, total (standard house)	93 EUR/MWh, 2,190 EUR/year (standard house 18.1 MWh; 130 m² incl. tax, excl. capital costs)
Ownership	Private (consumer).

Hjallerup District Heating was established on a General Assembly in May 1963 and the plant commenced operation shortly after. The plant was rebuilt in 1993, where two new engines (CHP units) were installed. At the same time, the entire plant switched to natural gas for fuel. Previously different types of oil incl. waste oil for a period had been used.

The plant was again in 2012 completely renovated where the old engines was replaced by two new Jenbacher Type JMS motors 620, each having a total thermal capacity 4.4 MW and new flue gas exchangers for cleaning flue gases.

The investments also comprised a new electrical boiler providing 6 MW with the purpose of exploiting low electricity prices for production of heat.

Besides the engines, the plant also consists of a natural gas boiler, providing 9.3 MW heat.

In 2015 Hjallerup District Heating merged with a smaller district heating plant a few kilometers to the north of the town; Klokkerholm District Heating. The merger took place on June 1, 2015. The two district heating grids are now connected via a transmission line. The equipment at the Klokkerholm site is worn down, meaning that the heat production takes place in Hjallerup and the heat is transported via the transmission pipe to Klokkerholm to cover the heat demand at that site.

The merger resulted in a lower heat sales price in Klokkerholm, which now has the same heat prices as Hjallerup.

Hjallerup District heating is now well advanced in the construction of new solar systems of 21,500 m^2 and storage tank of 3,500 m^3 together with a biomass boiler. The new production facilities are expected to be in operation before the end of 2016.

Figure 8: The solar district heating plant and the new tank storage under establishment in 2015, source: Hjallerup Sistrict Heating

3 Germany – Best Practice Examples

The main focus of the energy transition (in German "Energiewende") and the public debate is on the electricity sector. Large potentials still exist for energy efficiency of buildings and for the heating sector, which is much less debated in the public. The renewable energy share in the power sector is about 33 % in 2015, whereas the share of renewable energy in the heating sector is only 12 %, although about half of the energy demand in Germany is for heating.

In Germany a distinction is made between district heating (in German "Fernwärme"), which involves heating networks of larger systems (e.g. of cities), and smaller district heating systems (in German "Nahwärme") where the network is much smaller, decentralized and usually operated with renewable energy systems. Typical sizes of these small systems are in the range between 50 kW and a few MW.

The market share of large district heating in Germany is about 14 % in the residential buildings sector and includes about 1,400 heating grids and 19,000 km piping. However, there is no central statistic on this sector. The heat comes mainly from cogeneration plants (83 %). Heat-only boilers supply 16 % and 1% is surplus heat from industry. The cogeneration plants use natural gas (42 %), coal (39 %), lignite (12 %) and waste/others (7 %) as fuel.

There is a big difference between Western and Eastern Germany in terms of the district heating market share. The market share is around 9 % in Western Germany and around 32 % in Eastern Germany.

Most of the small district heating grids use biomass as a heating source, either through woodchips (single boilers or CHP units) or biogas. Several systems include solar thermal collectors.

Different scales of heat storage systems are demonstrated in several communities. A new trend is the application of ice storage systems in combination with heat pumps. Furthermore, there exist few district cooling grids, e.g. in the cities of Chemnitz and Munich. Since all the relevant technologies are available, and the market is characterized by various manufacturers supplying the demand, experiences with different systems, concepts and project implementation can easily be shared with other countries.

3.1 Low Temperature Heating Grid in Dollnstein

Location: Southern Germany; Central Bavaria
Google maps
www.dollnstein.de

Technical data

Heat production technology // Fuel // heat capacity // year of installation	- Ground water heat pump (440 KW_{th}) - 100 m² solar collectors - Photovoltaics (191 kW_p) - Combined heat and power unit (gas/LPG) (250 kW_{th} / 150 kW_{el}) - Peak load gas boiler (300 kW_{th}) - Installation year: 2014
Cooling	No cooling devices included
Efficiency	- 70 % reduction of heat demand - 70 % reduction of GHG - 40 % reduction of primary energy
DH network	1,800 m heat pipes and communication wires
Storage	- 27 m^3 stratified heat storage tank - 15 m^3 low temperature storage tank - In each connected household: heat exchanger, at least 0.3 m^3 buffer tank and heat pump
Consumers // total annual heat sales	- 47 connected households, at the moment 23 in use - Communal buildings (school, church, etc.)
Investment cost	1.6 million EURO
Heat price, fixed, variable, total (standard house)	0.11 EUR/kWh for heat consumption 0.10 EUR/kWh of injected heat from private solar collectors
Involved partners	- Operator: Municipal energy utility of Dollnstein (Kommunalunternehmen Energie Dollnstein AdÖR) - Planning: Ratiotherm GmbH & Co. KG - Heat pump supplier: Dürr thermea GmbH (Thermeco2)

Dollnstein[2] is a small community with about 2,700 inhabitants in the heart of Bavaria, Germany. Dollnstein is located in the Altmühltal Nature Park, one of the most popular

[2] The description and the graphs are based on several sources of information, including:
Personal communication
http://www.durr-thermeco2.com/en/projects/item/836-district-heating-network-marktgemeinde-dollnstein
https://www.energieatlas.bayern.de/kommunen/praxisbeispiele/details,583.html

touristic destinations in Bavaria. In 2011, the municipality has initiated and in 2013/14 installed an intelligent heating network for about 40 households and several communal buildings

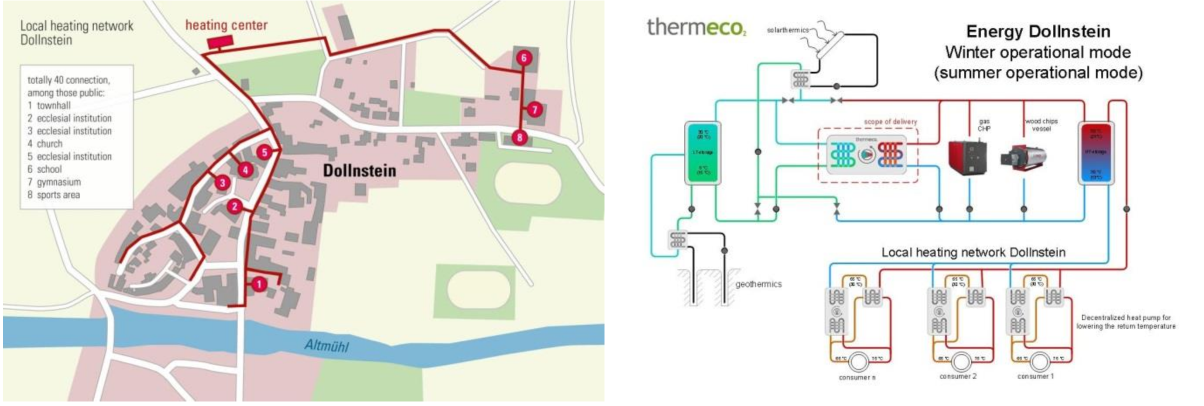


Figure 9: Overview map of the local heating network Dollnstein (Source: MinneMedia); Operating scheme local heating network Dollnstein (Source: Dürr thermea)

The concept of the Dollnstein local heating network is primarily based on two parts: utilisation of renewable energies and flexible temperatures adjusted to the consumption. In a typical network the heating utility permanently provides hot water of 80 °C. In summer, there is no appropriate demand for such a temperature in a small town like Dollnstein, which causes high heat losses. For reducing these losses, the network temperature from May till end of September is lowered in Dollnstein to 20-30 °C. This allows covering the heat demand in summer operation completely by renewable energy, as described below.

In winter, after all, half of the energy comes from renewable sources. One of that is groundwater, which is available at shallow depths. In the heating centre the thermeco2 high-temperature heat pump with a capacity of 440 kW is located. It extracts thermal energy from the low temperature storage tank (which uses the groundwater and the solar panels as energy source) and, thus, provides flow temperatures up to 80°C in the winter heating period. The feature of this technology: The system works with the environmentally friendly refrigerant CO_2.

In the summer months, there is enough solar energy to keep the network temperature at 20 °C to 25 °C. For the hot water demand of private households, for example for showering, this is, however, not sufficient. That is why the transfer stations in the houses are equipped with a small heat pump and buffer storage each. A combined heat and power plant (CHP) and photovoltaic power plants supply the electricity for the thermeco2 machine and the pumps in the households.

In an intelligent system, the heating centre, heating network and consumer are connected to each other – including power supply of the consumer stations. A control cable forwards information about temperature of buffer storages, consumption and other data to the heating center. By doing so, the buffer storages in the houses can be charged in line with the demand. Thus, the small heat pumps only run, if hot water is demanded. To take full advantage of the waste heat from the CHP and of the existing solar plants there is high-temperature buffer storage of 27 m^3 and a slightly smaller low-temperature storage.

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http://www.ratiotherm.de/fileadmin/daten/bilder/ratiotherm/Presse-Veroeffentlichungen/PM%20Er%F6ffnung%20Nahw%E4rme-Netz%20Dollnstein_ratiotherm.pdf

3.2 Seasonal Heat Storage "Am Ackermannbogen" in Munich

Location: Munich, Germany
Google maps
http://www.ackermannbogen-ev.de/quartier/solare-nahwaerme.html

Technical data

Heat production technology // Fuel // heat capacity // year of installation	- 2,761 m² flat plate solar collectors on the roof of multi-apartment houses - Capacity: 2,300 kWh_{th} - Connected to the district heating network of Munich in order to cover peak loads - Thermally operated absorption heat pump (560 kW) - Installation year: 2007
Cooling	No cooling devices included
Efficiency	- Solar fraction of about 45-50 % - 180 t/a reduction of GHG - 1,033 MWh/a energy savings
DH network	A mixture of water and glycol transports the energy through the solar network to the heating plant.
Storage	- Water thermal energy seasonal storage (concrete-steel; covered with soil) of 5,700 m³ (load size: 2.3 GWh / year)
Consumers // total annual heat sales	- Capacity: 30,400 m² space heating (320 apartments) - About 1,800 MWh/a heat supply About 200 MWh/a heat losses in the storage tank
Investment cost	5.1 million EURO
Heat price, fixed, variable, total (standard house)	No data
Involved partners	- Research: Bavarian Centre for Applied Energy Research (ZAE Bayern), www.zae-bayern.de - Technical Support: Solites, www.solites.de - System operator: energy utility of Munich (SWM Services GmbH), www.swm.de - Political support: City of Munich: Department for Health and the Environment, www.muenchen.de/rgu

The city of Munich[3] implements various policies to increase energy efficiency and to mitigate climate change. In 2007, the city of Munich realized the solar thermal heating project Am Ackermannbogen which includes a seasonal storage tank.

[3] The description is based on several sources of information, including:
http://www.bine.info/fileadmin/content/Publikationen/Englische_Infos/projekt_0211_engl_internetx.pdf
http://www.itw.uni-stuttgart.de/dokumente/Publikationen/publikationen_05-08.pdf
https://www.energieatlas.bayern.de/energieatlas/praxisbeispiele/details,197.html

The system supplies about 320 apartments with hot water and heat for space heating in winter. Heat is collected through solar collectors on the rooftop of the apartments. This heat is transported by a water/glycol mixture through pipelines to the seasonal underground hot water storage tank which heats up until autumn to about 90°C. The storage tank is well insulated. During winter, this heat is transported to the apartments (good thermal insulation standard buildings) for space heating and hot water supply.

Figure 10: Solar collectors on the rooftop of the apartment houses at "Am Ackermannbogen" (Source: D. Rutz, WIP)

Depending on the weather conditions of the winter, the stored heat is usually sufficient until January. After this period, a thermally operated lithium-bromide absorption heat pump (560 kW) uses the heat of the district heating network of Munich (80-120 °C) as well as the remaining heat of the storage tank (down to 10 °C) in order to supply the households with heat for the rest of the winter. The supply temperature to the households is about 60 °C. About 45-50 % of the overall energy demand is provided through solar thermal energy.

Figure 11: Seasonal storage tank covered with soil and well-integrated in the urban planning at "Am Ackermannbogen" (Source: D. Rutz, WIP)

3.3 Woodchip and Solar Heating: Bioenergy Village Büsingen

Location: Büsingen, south-west Germany
Google maps

Technical data

Heat production technology // Fuel // heat capacity // year of installation	- 1,090 m^2 vacuum tube solar collectors (1,000 m^2 ground-mounted; 90 m^2 facade collectors); 0.8 MW_{th} - Woodchip boilers (1 x 450 kW, 1 x 900 kW) - Installation year: 2013
Cooling	No cooling devices included
Efficiency of plants	- 1,200 t/a GHG savings - 800 m^3 woodchips saved due to the solar energy - about 13 % solar coverage
DH network	5,800 m heat pipes
Storage	- 100 m^3 buffer tank
Consumers // total annual heat sales	- 4.2 GWh/a heat supply - More than 100 households, a hotel, and a school
Investment cost	3.5 million EUR
Heat price, fixed, variable, total (standard house)	0.10 EUR/kWh (netto) basic fee: 300 EUR/a (netto) No connection costs as all technical installations are provided without a fee.
Involved partners	Operator: solarcomplex AG Planning of the solar system: Ritter XL Solar

Büsingen[4] is the only German town which is an exclave as it is entirely surrounded by the Swiss canton of Schaffhausen, Zürich and Thurgau. It has a population of about 1,450 inhabitants. Since the early 19th century, the town has been separated from the rest of Germany by a narrow strip of land. This and the fact, that Büsingen belongs to the Economic zone of Switzerland, creates a special legal status, one of the reasons why the heating grid was installed in Büsingen.

In 2013, Büsingen installed a small renewable heating grid with solar thermal and biomass boilers as core technologies. The heating grid is supplied with a 1,000 m^2 ground-mounted collector field, about 90 m^2 facade collectors as well as two biomass boilers with 450 and 900 kW thermal capacity. In the summer, the solar collectors supply most of the heat. In winter

[4] The description is based on several sources of information, including:
Personal communication
http://www.solarcomplex.de
http://www.bioenergiedorf-buesingen.de/pages/das-projekt/solarthermie.php
http://ritter-xl-solar.com/anwendungen/waermenetze/bioenergiedorf-buesingen/
http://solar-district-heating.eu/Portals/0/CasestudiesSDHplus/DE_D3.1_B%C3%BCsingen_DE.pdf

heat is supplied by the biomass boilers. This saves woodchips and increases the service life of the boilers, since they do not have to run continuously. The flow temperature of the heating grid is between 75 and 80°C and the return flow temperature is about 50°C. The share of solar thermal energy is about 13%.

Figure 12: Heating house of the bioenergy village Büsingen (Source: Solarcomplex)

Figure 13: 1,000 m² vacuum tube solar collectors of the bioenergy village Büsingen (Source: Solarcomplex)

3.4 Heat supply from a Biogas Plant in Vatersdorf

Location:
Vatersdorf, southern Germany
Google maps

Technical data

Heat production technology // Fuel // heat capacity // year of installation	- Biogas plant with 549 kW_{el} and 600 kW_{th} installed capacity - Input material for the biogas plant: manure (35%), corn silage, grass silage - One woodchip boiler of 220 kW_{th} - Peak load boiler (heating oil/biogas) (900 kW) - Total peak load: about 900 kW_{th} - Drying facility for woodchips and cereals - Installation year: 2006 (biogas plant), 2012 (heating grid)
Cooling	No cooling devices included
Efficiency of plants	- 100% utilized heat of the biogas plant - About 180,000 l/a heating oil saved
DH network	4,700 m heat pipes
Storage	- 20 m³ buffer tank hot water, - biogas storage of 1,900 m³ - Drying of wood chips
Consumers // total annual heat sales	- about 85 households connected - guaranteed heat supply (24h/365days)
Investment cost	- 1.45 million EUR (heating grid only)
Heat price, fixed, variable, total (standard house)	- about 0.078 EUR/kWh heat - basic fee: 15 EUR/kW/a - connection fee: 250-300 EUR/kW (during the first project phase); for new connections: 9,500 EUR/connection
Involved partners	Operator and owner: Ulrich Bader, engineer and farmer

The farmer and agricultural engineer Ulrich Bader installed in 2006 a biogas plant in Vatersdorf[5], a small village in southern Germany. In its initial phase, the main objective of the biogas plant was to only maximize power production due to the favourable conditions in Germany for renewable electricity generation (feed-in tariffs). Besides the heat supply for heating the digesters, for his farmer's house and for drying woodchips, the heat was released without use. This was typical for most biogas plants in Germany. Due to this inefficient overall energy use, Ulrich Bader decided to install a small district heating network in order to

[5] Some details are obtained from:
Personal communication
http://www.biogas-in-bayern.de/links/Infokampagne-Bayern/BGA-Buch-am-Erlbach/4113/

supply the households of Vatersdorf. In 2012, the heating grid was realized by Ulrich Bader, who did most of the planning and construction himself. He was supported by the heat pipe manufacturer Rehau.

Some biogas plant operators who have also a heat grid only sell as much heat as they have available. This means that the heat supply is not guaranteed, so that the consumers still have to maintain their own heating system in the house as back-up. Ulrich Bader, however, decided to be fully responsible for the heat supply and to guarantee it throughout the year and at any low ambient temperatures. Thus, the households practically do not need any other heating device in their household, except the connection point to the heating grid. In such a system, he needs further heat sources to complement the heat supply of the biogas plant. This is done by two woodchip boilers which are in use in the cold season. For peak load demand he furthermore has a fossil oil boiler, since other solutions would not have been economically feasible. Nevertheless, the operation of this peak load boiler is very limited.

The available heat from the biogas plant in summer is still too much for the hot water demand of the households. In order not to waste this heat, Ulrich Bader has invested in a feed-and-turn dryer, which can dry woodchips (for the small heating grid of Ulrich Bader as well as for external woodchip traders) and cereals. The woodchip drying can be considered as energy storage, since it increases the energy value of the wood chips. In doing so, all the heat of the biogas plant is used and the additional demand is covered by the woodchip and peak load boilers.

Figure 14: Digesters of the biogas plant and woodchip storage in Vatersdorf (Source: D. Rutz, WIP)

3.5 Biomass Heating Grid in Grassau

Location:
Grassau,
south-eastern Germany
Google maps

Technical data

Heat production technology // Fuel // heat capacity // year of installation	- Two woodchip boilers of 3 MW_{th} each (total 6 MW_{th}) - Peak load boiler (heating oil) (5 MW_{th}) - Drying facility for woodchips of the Biomass Trade Center Achental - approx. 28,000 m³/a regional woodchips used - 18,000 MWh/a heat production at temperatures of 75-95 °C (depending on the ambient temperature - Installation year: 2010 (boiler 1), 2014 (boiler 2)
Cooling	No cooling devices included
Efficiency of plants	- about 3,800 t/a GHG reduced
DH network	15,000 m heat pipes
Storage	- 100 m³ buffer tank
Consumers // total annual heat sales	- about 600 households, 60 SMEs, and public buildings connected - 15,000 MWh
Investment cost	- 9 million EUR (heating grid)
Heat price, fixed, variable, total (standard house)	- 0.081 EUR/kWh heat - no connection fee and no basic fee
Involved partners	Operator: communal heat supply utility (Wärmeversorgung Grassau KU; AöR) Owner: Municipalitiy of Grassau

[6]The Achental with its largest village Grassau is a mountainous valley just at the feet of the Alps in the southern Germany. In the north, it is located at the shore of Bavaria's largest Lake Chiemsee. It is a very touristic area with a high woody biomass potential as the surrounding mountains are covered by forest. In the framework of the EU-funded project (FP6) RES-Integration (www.res-integration.com), the Achental was selected in 2005 as target region for renewable energy actions. The ultimate objective of RES-Integration was to study the implementation of innovative renewable energy and energy saving technologies in selected poor regions of the participating countries (Greece, Germany/Austria, Italy, Serbia and Montenegro, FYROM, Albania). All regions of the RES-Integration project were located in

[6] The information is based on the following sources:
Personal communication
http://www.res-integration.com
http://www.bioenergie-region-achental.de/bioenergie-im-achental/
http://www.biomassehof-achental.de
https://www.energieatlas.bayern.de/kommunen/praxisbeispiele/details,605.html

rural, remote and underdeveloped areas of the partner countries. They were selected for their large development potentials concerning innovative and RE-actions. In the framework of this RES-Integration project, a detailed analysis in the Achental Valley was performed on its biomass potential. The analysis showed that the whole region could be 100 % energy self-sufficient by 2020. Based on these findings, the Biomass Trade Center Achental (www.biomassehof-achental.de) was founded in 2007 as a public-private partnership, operated and owned by several municipalities and private investors.

Figure 15: Woodchip storage and boiler house of the heating grid in Grassau (Source: D. Rutz, WIP)

As next step and in direct neighbourhood to the Biomass Trade Center Achental, the communal heating grid was initiated and installed in 2010 in order to supply more than 500 consumers with heat from locally produced woodchips. The heating grid is operated and owned by the communal heat supply utility (Wärmeversorgung Grassau KU; AöR). Involvement of the inhabitants and local actors was a core factor for the success of the project throughout the whole process.

The direct vicinity of the boiler house of the heating grid to the biomass trade center has various advantages for both organizations. The biomass trade center supplies the woodchips to the heating grid operator, and low-temperature of the exhaust gas condenser is used to dry woodchips of the trade center. In addition, the whole facility is in direct vicinity to the heat consumers – that is why a highly sophisticated exhaust gas cleaning device (electric and particulate filters) was needed.

Figure 16: Woodchip boiler (left) and heat transfer station (heat exchanger) used in the households (right) of the heating grid in Grassau (Source: D. Rutz, WIP)

3.6 Zero-emission Settlement in Bad Aibling

Location:
Bad Aibling
Southeastern Germany
Google maps

Technical data

Heat production technology // Fuel // heat capacity // year of installation	- Woodchip boiler (500 kW_{th}) - Flat solar collectors (716 m² further 600 m² in planning) - Peak load boiler with natural gas (1.1 MW_{th}) - Heat pumps (no data on capacity) - photovoltaic systems (2.3 MWp, 430 kWp, 34 kWp) - Realization: 2008-2013
Cooling	No cooling devices included
Efficiency of plants	- zero emission settlement (calculated)
DH network	- 1,800 m heat pipes
Storage	- central and decentral buffer tanks, 15 m³ and 60 m³
Consumers // total annual heat sales	- about 130 households and additional 1 hotel (6 buildings, 100 rooms, outdoor pool), 2 schools (3 buildings), offices + exhibition (2 buildings) // 2,560 MWh/a
Investment cost	Unknown
Heat price, fixed, variable, total (standard house)	fixed 590 EUR, variable 70 EUR/MWh about 0.129 EUR/kWh heat
Involved partners	- Owner and operator: B & O Parkgelände, Bad Aibling - Architect: Matteo Thun, Italy (only boiler house) - Project partners: B & O Saatinvest Heizhaus, Bad Aibling; HDG Bavaria (woodchip boiler); Ecolohe (woodchip supplier), Schräder (particulate filter); University of Applied Sciences Rosenheim

On the former US-army military complex in the Bavarian town of Mietraching/Bad Aibling[7], a zero-emission settlement is created. The settlement includes refurbished military buildings as well as new buildings in wood construction. In total of about 770 households, offices and public buildings are supplied with heat by the small district heating grid. Core technology of the installation is a woodchip boiler house, designed by the architect Matteo Thun from South Tyrol, Italy. The boiler house is designed in the style of the St.-Veit-chapel in South-Tyrol, so that it can be hardly recognized as technical facility and resembles more as a church or monument. The area of the whole settlement is about 70 ha and includes areas for living,

[7] The information is based on the following sources:
Personal communication
http://www.bo-wohnungswirtschaft.de
http://www.baunetzwissen.de/dl/1357083/Nahwaermenetz.pdf
http://www.baunetzwissen.de/objektartikel/Heizung-Heizhaus-in-Bad-Aibling_2564451.html

leisure and work. The settlement also includes a hotel, restaurants, schools and a kindergarten. Furthermore, the Solar-Decathlon-House of the University of Applied Sciences Rosenheim, as well as the first German 8-floor multi-apartment house in wood-construction with a height of 25 m.

Figure 17: Woodchip boiler house (left) and woodchip-container (right) in Bad Aibling (Source: D. Rutz, WIP)

The small district heating grid is supplied by decentral heat sources. The base-load is supplied by the woodchip boiler (500 kWth), especially in the cold season. Solar collectors of about 2,000 m² contribute to the heat supply on sunny days. This solar energy is stored in several small, decentralized buffer tanks and a central buffer tank. A gas-fired peak load boiler is used at peak demand in winter. The flow temperature of the heating grid depends on the operation of these three heating sources: woodchips, solar and gas. If the flow temperature in summer is low as the system is only supplied by solar thermal energy, heat pumps raise the temperature for the hot water supply to a higher level. The heat source for the heat pumps is used from the small district heating grid and increases the overall efficiency.

The locally produced wood chips are dry premium woodchips which were dried to 15 % water content with the waste heat of a nearby biogas plant. The woodchip logistics include a container system where the container acts as feeding-unit for the boiler. This minimizes noise and dust nuisances. During the change of the containers, the woodchip boilers are supplied by wood pellets in order to guarantee a continuous operation. In addition to the heat supply, photovoltaic systems, which feed electricity into the power grid, are installed. Thus, the overall calculated energy balance of the settlement is positive. The PV system produces more electricity than what the heat installations, including the heat pumps, need. Find more about the zero emission settlement on: http://www.bo-wohnungswirtschaft.de/cmswp/

Figure 18: Solar collectors (left) and 8-floor wood house in Bad Aibling (Source: D. Rutz, WIP)

4 Austria - Best Practice Examples

Austria is rather advanced in biomass district heating. A large number of villages and municipalities are already equipped with sustainable district heating systems. Large scale implementation started already more than 20 years ago, resulting in very valuable experience; long term statistics/data of market prices as well as a series of technical standards, details, quality assurance and problem mitigation structure have been developed during the past years, like heat mapping, impact of heat-connection densities (number of connections, amount of heat), standardization implementation costs, clear procurement procedures, and optimization of existing systems.

The largest district heating system in Austria is in Vienna (Wien Energie). Many smaller district heating systems are distributed throughout the country.

The new smaller district heating plants in the rest of Austria are constructed as biomass plants or as CHP-biomass plants, as also showed in the described examples in the Austrian Best Practice Examples.

In the 1990s district heating systems in Austria were characterized by a low technical standard. Thus, new standards, rules and recommendations have been prepared in cooperation with other European countries, here among Germany, to improve this. Today, Austria runs a quality assurance system within the national climate protection programme: klima:aktiv qm-heizwerke. GET was one of the first companies conducting quality assurance in this field. Five criteria need to be fulfilled in order to get the investment subsidies of 30 %. Nowadays, Austria has a strong network promoting renewable district heating. More information about qm-heizwerke here:
http://www.qmholzheizwerke.at/qm-holzheizwerke/die-qualitaetsanforderungen.html

In projects, where industrial excess heat is available, district cooling grids operated by thermal driven cooling devices have already been installed, like in Vienna. GET is cooperating with Wien Energie to share the experience of this district heating grid. In general, district cooling grids are an investment for the future; it is expected that centralized production of cooling energy will become cheaper than decentralized production (individual). At the moment most consumers have individual solutions, so using a cooling grid could be interesting for dense areas for industry and consumers with high cooling needs.

Since 2010, Austria has witnessed strong growth in district heating, with a 26 % increase in the pipeline network over the past five years (2015 numbers). This represents an annual growth of 5 % and district heating (including hot water generation) now accounts for a 21% share of the total heat demand in Austria. Furthermore, approximately one quarter of Austrian citizens are served by district heating and this is delivered in an environmental manner, as 85 % of district heating is generated from direct renewable energy and industrial waste heat recovery.

In 2013, district heating networks supplied the residential sector with a share of 37 %, the service sector with a share of 49 % and the manufacturing sector with a share of 14 %. On average, during the past five years, approximately two thirds of the heat supplied to the district heating networks was produced in highly-efficient combined heat and power (CHP) plants. However, this trend is decreasing due to difficult economic circumstances faced by CHP plants (low electric feed in tariff, end of duration of feed in tariff). Resulting in a movement where district heating generation is progressing from highly-efficient CHP plants to heating-only boilers.

As displayed in the graph in Figure 19, district heating currently satisfies 12 % of heating demand in Austria. The development of a new Austrian energy strategy up to 2030 is in progress and it is expected that district heating will occupy an important role in the national heat policy. This is supported through the 2008 law for expansion of district heating and cooling (WKLG), which provides state aid of up to 60 million EUR per year for the construction of new district heating and cooling infrastructure. It is unknown for how long the law will continue. The key reasons for investing into district heating are using wood biomass from the region, lowering the CO_2 emissions, lowering the air pollution, the creation of new jobs and the opportunity to build new infrastructure for a safe supply with a high comfort.

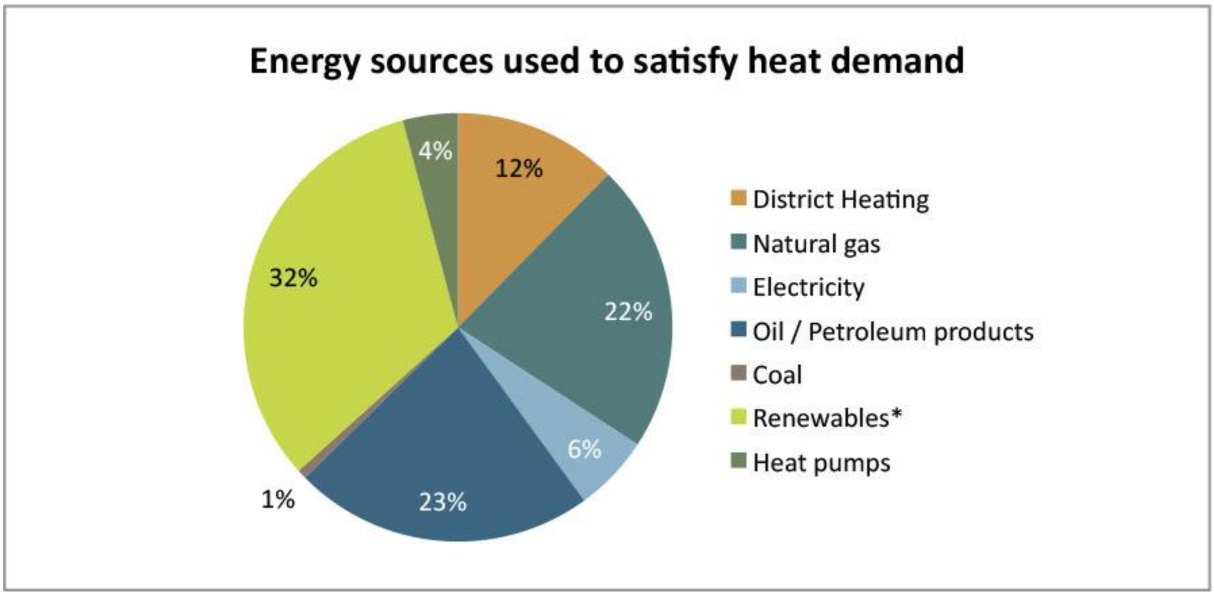
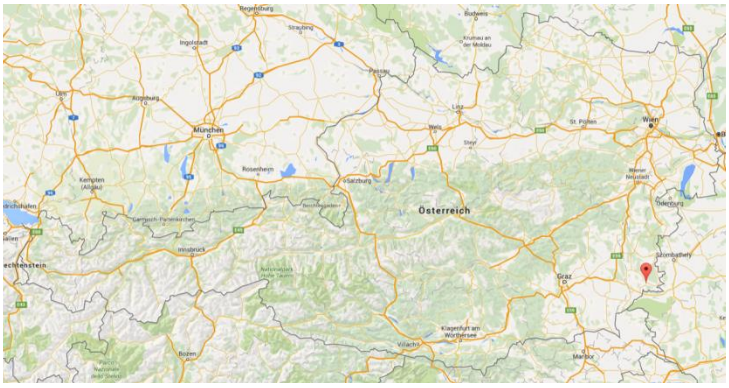


Figure 19: Energy sources to cover heat demand in Austria (Source: http://www.euroheat.org/knowledge-centre/country-profiles/district-energy-austria/)

4.1 Heating with woodchips in Güssing

Location: Güssing, Burgenland, Austria
Google maps
http://eee-info.net/index.php/de/energieerzeugungsanlagen/75-fernwaerme-guessing



Technical data

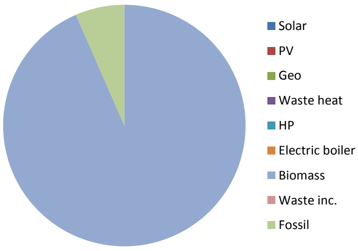
Heat production technology // Fuel // heat capacity // year of installation 	Biomass boiler 1: 5 MW thermal Biomass boiler 2: 3 MW thermal Fuel: wood chips and residual wood pieces from wood floor production Built: 1996 Oil peak load boiler: 6 MW thermal
Cooling	No
Efficiency of plants	Biomass boilers: ~85 % Oil boiler: ~90 %
DH network	37 km DH grid. Network age of 20 years.
Storage	There are no buffer storages installed at this heating plant. Drying of wood chips can be categorized as a storage
Consumers // total annual heat sales	There are about 550 consumers (heating of buildings, domestic hot water) and some industrial users
Heat price, fixed, variable, total (standard house)	Heating price 57.25 EUR/MWh Demand charge 33.73 EUR/kW per year Meter charge 24.50 EUR per year Total 1,373 EUR/year (standard house 18.1 MWh)
Ownership	Company mainly owned by the municipality

Figure 20: Güssing plant and wood shredder (Source: Güssinger Fernwärme GmbH)

In the Climate Alliance municipality Güssing in 1996 the biomass district heating plant was opened. Thus, Güssing was a flagship municipality. The controlled biomass firing is equipped with an emission control. So nowadays the emissions are much lower than using firing systems at each household.

Biomass for the district heating plant in Güssing comes in the form of small pieces of wood from the wood floor production companies in Güssing or as wood chips from local forests.

The heat output in the heating plant is 14 MW of 2 biomass boilers (3 and 5 MW) and one 6 MW oil-fired boiler for covering peak loads. In a total of 37 km long district heating network more than 550 households and almost all public facilities and industrial plants are supplied. The flow temperature of the district heating grid is 120 °C in the industrial zone to cover the needs for the industry. Most of the industries are wood floor production companies and drying chambers, as well as food production companies.

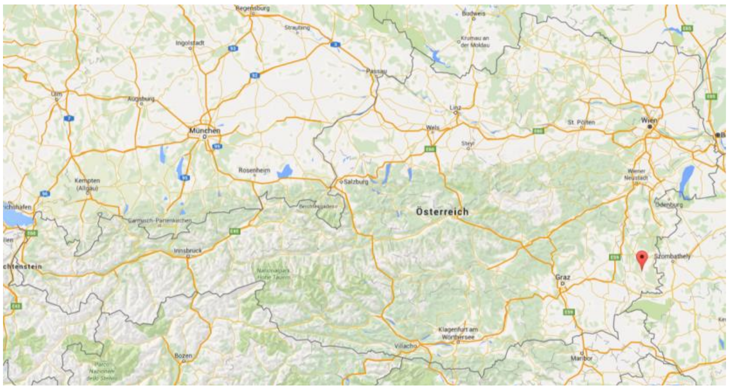
There are a lot of synergy effects, for example wood floor production sell their remaining small wood pieces to the heating plant and the heating plant is selling the heat to run the drying chambers of the companies.

Figure 21: Drying chambers for wood floor production are heated with the district heating in Güssing; Wood chips as input material for heat production in the boilers (Source: Güssinger Fernwärme GmbH)

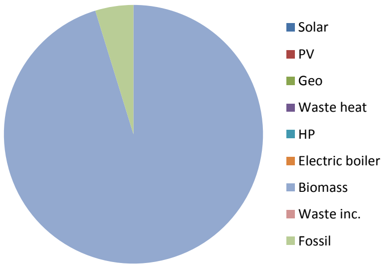
Figure 22: District heating pipes while installing the grid; Connection to the households (Source: Güssinger Fernwärme GmbH)

4.2 Heating with woodchips in Güttenbach

Location: Güttenbach, Burgenland, Austria
Google maps
http://eee-info.net/index.php/de/energieerzeugungsanlagen/87-fernwaerme-guettenbach



Technical data

Heat production technology // Fuel // heat capacity // year of installation 	Biomass boiler: 1 MW thermal Fuel: wood chips from the region Oil peak load boiler: 1.3 MW thermal Each year there are about 5,200 MWh heat sold Built: 1997
Cooling	No
Efficiency of plants	Biomass boilers: ~85 % Oil boiler: ~90 %
DH network	12 km DH grid. Network age of 19 years.
Storage	There are no buffer storages installed
Consumers // total annual heat sales	There are about 240 consumers (heating of buildings, domestic hot water)
Heat price, fixed, variable, total (standard house)	There is no data available
Ownership	Association

The biomass heating plant and district heating grid in Güttenbach (Austria) was built in 1997. The boilers are fired with wood chips from local forests. There are two boilers installed, one biomass boiler with 1 MW capacity and one oil boiler for peak load and backup with 1.3 MW capacity. The village of Güttenbach has about 900 inhabitants and an area of 16 km². The district heating grid has a length of 12 km with about 240 connected consumers. Each year there are 5,200 MWh heat sold to the consumers.

Concept for mobilizing unused resources from local forests:
In Güttenbach the district heating company developed a new concept for mobilizing unused resources from the local forests as energy wood. In this region there are a lot of private forest owners. Caused by the demographic change, there is an uncoordinated approach by the actors along the value chain from the forest to the energy consumption of wood. That's why wood is unused now and there is no gain for owners or other companies.

For these reasons, a concept for improved biomass logistics has been prepared by an economic incentive for forest owners to provide forest biomass for sale as energy wood and thus to achieve a mobilization of unused forest resources. On the one hand the burden on forest owners was reduced to a minimum and on the other hand a transparent and fair billing system was introduced.

With this concept the following targets should be reached:
- Development of a local energy wood market
- Transparent marketing- and purchasing structure
- Central contact persons for procurement logistics
- Reappraise economic incentive for forest owners to thinning residues
- Mobilizing unused energy wood resources of small sized woodland owners
- Compensation of annual supply and demand fluctuation
- Prevention of polluting the lumberyard outside the forest
- Regional added value

The key issue in this concept is to build smaller energy wood storage yards, where woodland owners can store and sell their wood. At the yard the energy wood is dried, chopped and stored. If there is a demand of wood chips at a power station, the wood chips are transported from the yard to the power station. In the following figure the concept is visualized. Route 1 is not adequate due to the fact that supply and demand varies significantly and the storage capacity of power plants is also limited. This fluctuation can be compensated with wood storage yards where the wood chips are stored till they are needed in the power plant.

All details about the concept (German version):
http://www.pemures.com/cms/images/downloads/Energieholzbereitstellung_Konzept.pdf

Slovenian version of concept:
http://www.pemures.com/cms/images/downloads/Energieholzbereitstellung-Konzept-SI.pdf

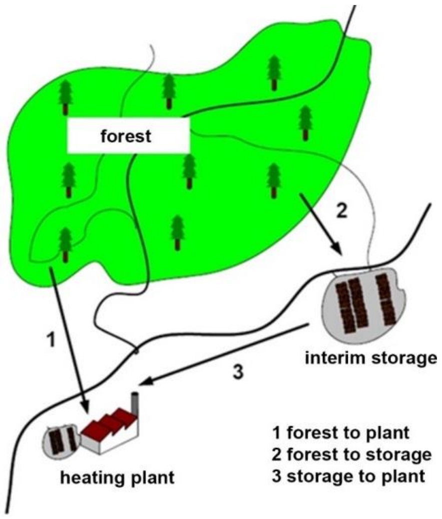
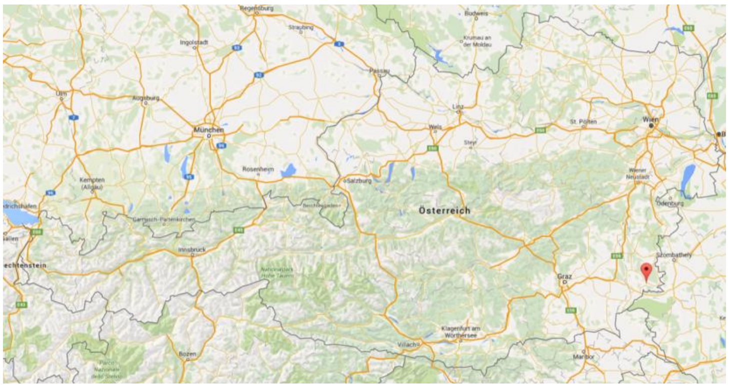


Figure 23: Biomass heating plant with 1MW biomass boiler and 1.3 MW oil peak load boiler (Source: EEE GmbH); Concept for mobilizing unused resources from local forests in Güttenbach with an interim storage

4.3 Güssing – Saw Dust Boiler

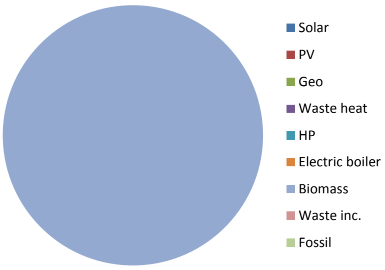
Biomass boiler for saw dust

Location: Güssing, Burgenland, Austria
Google maps
http://eee-info.net/index.php/de/energieerzeugungsanlagen/76-fernwaerme-guessing-2



Technical data

Heat production technology // Fuel // heat capacity // year of installation	Biomass boiler: 3 MW thermal Fuel: saw dust from wood floor companies Built: 2002



Cooling	No
Efficiency of plants	Biomass boiler: ~85 %
DH network	Connected to the existing 37 km DH grid. Network age of 20 years.
Storage	There are no buffer storages installed at this heating plant
Consumers // total annual heat sales	At the existing grid there are about 550 consumers (heating of buildings, domestic hot water) and some industrial users
Heat price, fixed, variable, total (standard house)	Heating price 57.25 EUR/MWh Demand charge 33.73 EUR/kW per year Meter charge 24.50 EUR per year Total 1,373 EUR/year (standard house 18.1 MWh)
Ownership	Company mainly owned by the municipality

Due to the fact of growing heat demand and the availability of saw dust as power source a second heating plant was planned in Güssing. In the year 2002 the Heating Plant II was built from the Güssinger Fernwärme GmbH in Güssing.

Another reason why a biomass heating plant was built in the industrial zone is that saw dust is not easy to transport, so a closed system with pressured air pipes is needed. With this heating plant the transport pipe from the production site to the biomass boiler was kept short and the heat losses were also reduced by having closer district heating pipes.

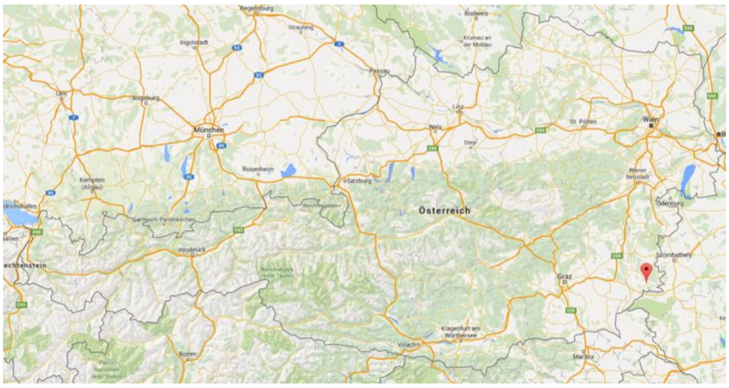
The saw dust is stored in a silo and burned in a special boiler where the saw dust is fired in flight. So there is no need for a grate firing. The boiler has a thermal output of 3 MW.

The synergy effect here is that the wood floor production companies sell their remaining saw dust to the heating plant and the heating plant is selling the heat to run the drying chambers and process heat of the companies.

Figure 24: Heating plant II in Güssing to fire saw dust for heat production (Source: EEE GmbH); The storage is provided with saw dust from 2 wood floor companies (Source: EEE GmbH)

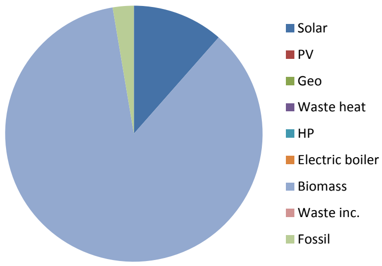
4.4 Biomass-Solar heating in Urbersdorf

Location: Urbersdorf, Burgenland, Austria
Google maps



Technical data

Heat production technology // Fuel // heat capacity // year of installation	Biomass boiler: 650 kW thermal Fuel: wood chips Built: 1996 Solar panels: 340 m² Peak oil boiler: 170 kW thermal



Cooling	No
Efficiency of plants	Biomass boiler: ~85 %
DH network	2.7 km DH grid. Network age of 20 years.
Storage	2 storage tanks of 30 m³ each
Consumers // total annual heat sales	There are about 47 consumers (heating of buildings, domestic hot water)
Heat price, fixed, variable, total (standard house)	There is no data available
Ownership	Association

The water is heated through the biomass fired stoker furnace or during summer with the solar system. The heated water is then transported through insulated pipes to the consumers. The water of the heating system is then heated up via heat exchangers and the cold water of the district heating system flows back to the power plant where it is heated up again.

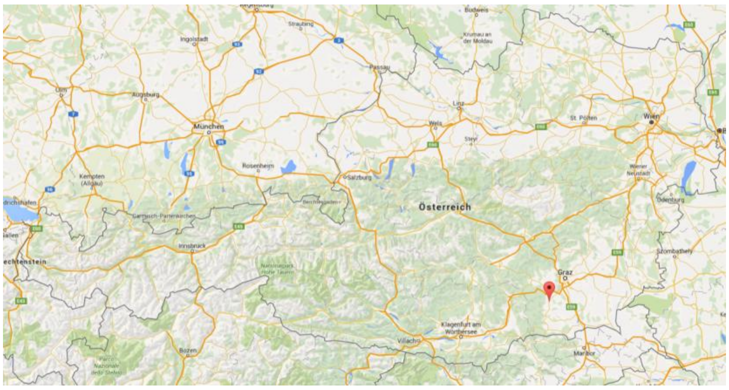
On a length of 2,700 meters 47 consumers are supplied with heat. To supply them with heat the biomass furnace has a thermal output of 650 kW. For peak loads there is an oil boiler with 170 kW. During summer the system is powered by the 340 m² solar collector and two 30 m^3 buffer storage tanks to store the heat. The district heating system operates throughout the year.

Figure 25: Plant at Ubersdorf (Source: EEE GmbH)

Operation of biomass boiler and solar heating:
During the summer months the solar collectors produce the heat for the system. The result is a competitive situation between the biomass boiler and the solar system. The biomass boiler is in attendance, and due to this the boiler is running in very low part load. This low part load leads to high standby losses and the danger of sootiness. This issues can be solved with an automatic ignition device or a small biomass boiler for the part load, especially in summer time.

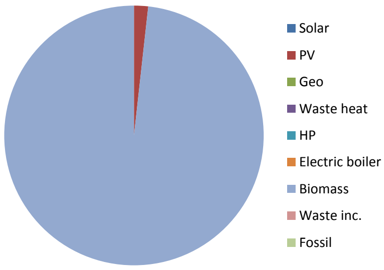
4.5 Biomass heating plant in Stainz

Location: Stainz, Styria, Austria
Google maps
http://www.nahwaerme.net/cms/index.php/de/12-projektbeschreibung-biomasse/167-stainz



Technical data

Heat production technology // Fuel // heat capacity // year of installation	Biomass boiler: 3,000 kW thermal Fuel: wood chips Built: 2010 Thermal output: 9,500 MWh per year



Cooling	No
Efficiency of plants	Biomass boiler: ~85 %
DH network	6.5 km DH grid. Network age of 6 years.
Storage	-
Consumers // total annual heat sales	There are about 98 consumers (heating of buildings, domestic hot water)
Heat price, fixed, variable, total (standard house)	There is no data available
Ownership	Company

In 2010, the Nahwaerme.st GmbH, a partner of the nahwaerme.at in west Styria, built a small district heating grid. The system grants heat supply throughoutthe year for the municipality of Stainz, Georgsberg and Stallhof.

The final plant has two biomass boilers. In the first step, the first boiler with 3,000 kW and the flue gas cleaning system was installed.

In 2015, the new wood logistic center was activated with a new hall with a storage area of 600 m². With this new hall the storage capacity was doubled. Due to this, the supply with high quality wood chips of the region can be granted. Another advantage of this new wood logistics center is that private and industrial biomass boilers can now also be delivered with wood chips of a high quality.

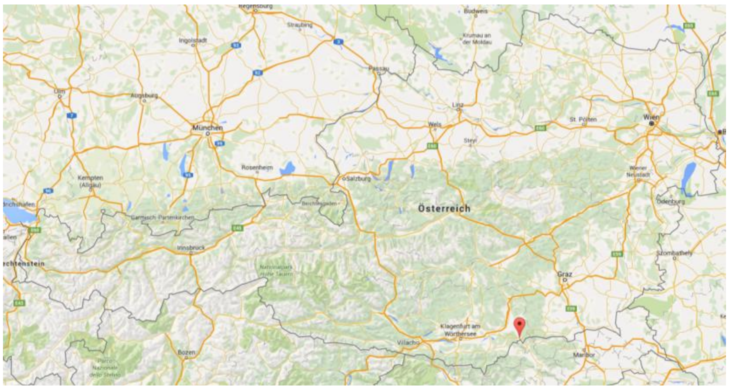
The existing photovoltaic with 67 kW$_P$ was upgraded with 1,200 m² collector surface which equals 190 kW$_P$. The modules which were produced in Austria were installed on the roof and on the facade of the building. With this module, 170,000 kWh of green energy can be produced. This corresponds to a power consumption of about 45 households.

The wood chips are 100 % from the region and this increases the added value of the region.

Figure 26: Exhaust gas cleaning at the biomass plant Stainz with an electrostatic filter; Photovoltaic modules with 257 kW_p on the roof of the biomass storage (Photos by: nahwaerme.at)

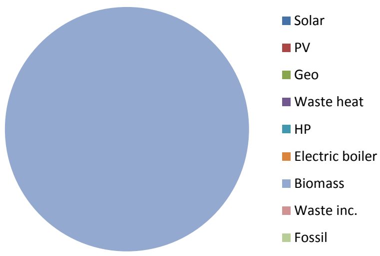
4.6 Lavamünd Biomass Boiler

Location: Lavamünd, Carinthia, Austria
Google maps
http://holzdiesonne.net/hsh-nahw%C3%A4rme/nahw%C3%A4rme-lavam%C3%BCnd



Technical data

Heat production technology // Fuel // heat capacity // year of installation	Biomass boiler: 800 kW thermal Fuel: wood chips Annual thermal output: ~1,859 MWh Annual biomass needs: ~ 2,500 m³ per year Built: 2015



Cooling	No
Efficiency of plants	Biomass boiler: ~85 %
DH network	2.1 km DH grid. Network age of 1 year.
Storage	-
Consumers // total annual heat sales	There are about 30 consumers (heating of buildings, domestic hot water)
Heat price, fixed, variable, total (standard house)	There is no data available
Ownership	Company

**Figure 27: Biomass plant in Lavamünd (Carinthia / Austria)
(Source: http://holzdiesonne.net/hsh-nahw%C3%A4rme/nahw%C3%A4rme-lavam%C3%BCnd)**

Figure 28: Grate of the biomass boiler; Biomass boiler with cleaning unit (Source: http://holzdiesonne.net/hsh-nahw%C3%A4rme/nahw%C3%A4rme-lavam%C3%BCnd)

It took almost 20 years from the first idea to the final decision of building a small district heating system for the center of Lavamünd. The project was finished within 6 months and the heating plant started in September 2015.

Consumers of the small district heating system are flats and buildings from the municipality, the storehouse, the road maintenance depot, apartments, some private households and two schools. These consumers had oil based heating systems before.

Think global – act local

The highest priority in this project was to involve local companies in the building process. With this aim all the investments would stay in the region, jobs were created and the added value was increased. The project in Lavamünd reached all the aims perfectly.

"HSH Nahwärme und Photovoltaik GmbH" did the planning of the whole project. The boiler was produced in the neighbour village St. Veit an der Glan and the building and construction work was done from the local construction company Steiner. The heat exchanger units for the consumers were installed by the company Zernig. The most important fact is that the wood chips are produced by local farmers in the region.

Many advantages for the consumers result:

- Comfort: the heat is delivered to the consumers
- 60 % funding of connection
- Independence: because the energy source is renewable and produced by local farmers
- Price stability: independent energy source which is not reliant on fossil fuels
- Positive image: environmentally friendly, added value to the region, new jobs and saving the climate

Sustainability and protection of the air

The plant consists of a biomass boiler, a large buffer tank and an oil-fired boiler as a backup. This district heating systems replaces many oil-fired boilers the household had before.

See more info at: http://www.holzdiesonne.net/hsh-nahw%C3%A4rme/

5 Target Countries – Best Practice Examples

This section gives an overview of the status for district heating in the five target countries of the CoolHeating project.

Croatia:
Croatia has the advantage of having already developed district heating systems. However, the use of renewable sources and waste heat is non-existent. District heating systems are usually big and without the possibility of modularity. The most promising renewable energy sources include low-cost biomass, solar energy, a particularly underused resource, geothermal energy and municipal waste. Important for small modular district heating systems in Croatia will be the inclusion of heat storages which would allow smaller communities to play a bigger role on the energy market. However, to really embrace the Croatian potential in terms of energy efficiency, planning issues need to be resolved.

In 2012, the share of heat (supplied through district heating systems) in the Croatian energy demand was around 8 %. Three main sectors using this heat are: industry, households and services. In the heat production, currently there are four main producers: public cogeneration plants, public heating plants, industrial cogeneration plants and industrial heating plants. The share of renewable energy sources in all those production plants is currently negligible.

Slovenia:
Slovenia has high RES-potentials, especially in terms of biomass, sun and geothermal resources. The current use of biomass for individual heating is high, especially in small cities and rural areas. Most district heating is based on large scale fossil driven district heating networks. Although there are only a few RES-driven small scale district heating networks in Slovenia today, the development of small scale district heating networks is a part of the Slovenian national energy plans and strategies. It is supported in a range of national tools like DOLB subsidies and supports schemes for small scale cogeneration plants. The main barriers are low awareness on positive impacts of centralized small scale DH (especially higher efficiency and less pollution with hard particles, smell) of the general population, problematic legislation for above 1 MW district heating networks, existing use of biomass or individual heating, low price of heating oil and natural gas.

The goal is that the RES-driven small scale DH in Slovenia would partially replace existing low efficiency biomass stoves for individual heating and it would replace fossil stoves for individual heating (mostly heating oil) and fossil stoves for micro DH of residential buildings.

In Slovenia, practically no small scale district cooling or district heating projects exist. There are only large scale district heating systems in larger cities. Slovenian cities and municipalities are scattered and relatively small. Only a hand full of small scale district heating systems in Slovenia is using RES.

Macedonia:
Macedonia has around 550,000 dwellings. The average energy intensity of the existing Macedonian building stock is roughly estimated at 220 kWh/m²/year. Electricity is the dominating heating source: In 2011, 52 % of households' total final consumption was made up by electricity. Biomass e.g. fuel wood has the second biggest share, 31 %, whereas heat provided by District Heating (DH) services only 6.7 % and oil products 8 %.

This is a reflection of the findings in a household survey[8], according to which 74 % of all households are heated by stoves using solid fuels and 14 % are heated by stoves using

[8] Household Consumption in the Republic of Macedonia, 2012 Statistical Review: Incomes, Expenditures and Prices (#4.4.13.01, 747, June 2013)

electricity, whereas only 6.2 % have central heating (based on DH), and 5.5 % have central heating (with private installations).

District heating only exists in three locations in Macedonia: Skopje, Bitola and Kamenica. The last two systems have been out of operation for several years. Only the DH network in Skopje is of important magnitude. Deliveries to the end users are measured at sub-stations or individual houses. Within apartment blocks the heating costs are divided according to heated area of the individual apartments. There is no individual metering per household. The system was expanded during 1990-2000 because many new apartment blocks were constructed and suitable for DH connections.

In recent years, the connections to the DH-system have slowed down and even decreased. The Skopje DH system is characterized by outdated boilers (for fuel oil and natural gas) and considerable technical losses in distribution. The new cogeneration plants are of a better quality. There are plans to convert two electricity production plants to cogeneration plants and utilize the heat for district heating in the City of Bitola.

To date, almost two decades after the introduction of natural gas, it has not been possible for Macedonia to achieve significant development and expansion in the use of gas, not even in the greater Skopje area, which – owing to its population density and large industrial base – would represent one of the most likely geographical candidates for increasing the use of gas. Nevertheless, according to the gasification plan, gas consumption in the households, tertiary and industry sectors combined is projected to increase substantially, as the new gas network is projected to expand into more than 50 municipalities.

Small renewable district heating grids, as well as district cooling systems, do not exist in the country and are not explicitly addressed in the relevant strategic and planning documents. There is a wide spectrum of barriers for deployment of these technologies - starting from lack of technical knowledge and capacities, through enabling legislative/regulatory frameworks and financing schemes for mobilizing investments, to lack of capacity of the local governments for planning and designing such projects.

Serbia:
Currently, there are no renewable district heating grids in Serbia. There were two energy licenses for the biomass cogeneration given in the municipalities Prijepolje and Cajetina. By the law, there is the interest for energy from renewable sources. Also, according to the National plan measures to develop district heating and cooling from renewable energy sources, should be taken. There are about 100 MW of biomass cogeneration with 640 GWh_{el}/year of electricity production envisaged with the National renewable energy action plan. According to this plan the envisaged share of biomass cogeneration in district heating and cooling amounts to 33 % of heat energy produced from additionally commissioned facilities (2009-2020), or around 570 GWh_{th}/year. According to the Law on privileged producer feed-in tariffs are available for the electricity production from biomass, but not for heat energy nor for cogeneration. The main barriers for development are the permitting procedures.

The licence permiting in heat production is issued by the municipalities. Also, support schemes such as feed-in tariff for the renewable district heating and cooling are in the hands of the municipalities. Futhermore, responsibility for the technical parts of the binding agreement for the heat producers lie with the municipal district heating companies, according to the National plan.

Currently, the district heating in Serbia is dominantly fuelled by fossil fuels: natural gas (61 %), lignite/coal (20 %) and fuel oil (18 %). They will be replaced with biomass for cooling and heating. Although highly needed, there are no experiences with district cooling in Serbia. There was an intention for the district cooling project development in the City of Subotica.

Bosnia-Herzegovina:
Large district heating systems exist in Bosnia and Herzegovina in larger cities. There are also a number of small district heating grids, built in smaller cities and towns for schools, buildings or blocks of buildings. However, these systems are often old (more than 30 years) and operate mainly on fossil fuels. Many consumers have individual solutions for heating as well, using fossil fuels or wood in their own household boilers, or electricity for heating.

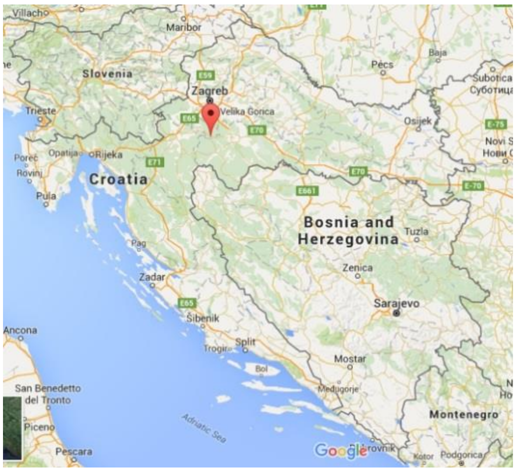
On the other side, there are several other examples of district heating systems as well, such as those based on waste woody biomass that have recently been constructed and put into operation, like in Livno, Gracanica, Gradiska and other cities. In addition, many cities and towns have plans for the construction of such heating systems, to eliminate pollution and improve the cost-effectiveness of the heating solutions (Visoko, Zivinice, Gorazde and many others). Some current examples of good practice are given in the following paragraphs.

It should be noted that there is no strong governmental support for the development of small heating/cooling systems in Bosnia-Herzegovina at the moment. There is the possibility to use some mechanisms of support through the feed-in tariff system for small co-generation plants. However, the present guaranteed price is not at a sufficient level to move and accelerate the construction of such plants. At the same time, Bosnia-Herzegovina is a member of the Energy Community with set targets on the integration of renewable energy sources into final energy consumption, as well as energy efficiency improvements. This project should hence form a good base for further steps in this regard.

CoolHeating will overall aim at helping facilitate cost efficient solutions and positively affect the environmental impact of existing heating solutions in many cities and towns in the country. Hence, it will help multiply the effects of other existing projects and examples, and the results will contribute to reducing harmful emissions, as well as offering opportunities for new job creation. At the end, all mentioned benefits should encourage the national government to fulfillthe requirements of increasing the share of renewable energy sources in final energy consumption and improving energy efficiency.

5.1 Croatia: Pokupsko Biomass Boiler

Location: Southern part of Zagreb County, Croatia
Google maps



Technical data

Heat production technology // Fuel // heat capacity // year of installation	Biomass fired boiler, forest biomass, 1 MW, 2015
Cooling	No
Efficiency of plants	Efficiency of biomass boiler = 94.7 %
DH network	2,8 km of distribution pipes, completely new district heating network
Storage	Steel-tank 24 m^3
Consumers // total annual heat sales	Currently 15 consumers, figures on annual heat sales are not yet available since the system started operating in the end of 2015
Heat price, fixed, variable, total (standard house)	Price for households (without tax) – 0.04 EUR/kWh Price for public buildings (without tax) – 0.05 EUR/kWh For a standard house of 18.1 MWh/year = 725 EUR/year excl. tax.
Ownership	Municipality owned

Pokupsko District Heating System is a new system, opened in the late 2015, which presents the first biomass powered district heating system in Croatia. It is located in the municipality of Pokupsko, in the southern part of Zagreb County which is a home to 2,224 inhabitants (2011 census). The heat capacity of the biomass boiler is 1 MW, which will supply around 30 consumers in the first stage of the project.

Currently, 15 consumers are connected to the district heating grid. The production facility also contains a heat storage in the form of a 24 m^3 steel tank. The production facility was completely funded by the EU IPARD-programme under measure 301 "Improvement and Development of Rural Infrastructure", while the district heating infrastructure was funded by municipality and regional funds. All the public buildings in the municipality have been connected to this system and a number of local businesses have shown interest in connecting to the system. It is expected that within the next 5 years, more than 60 consumers will be connected to the system. The production facility uses forest biomass, which also opens new jobs since the municipality has a lot of privately owned forests whose owners can deliver biomass for utilization.

Almost 70 % of the Pokupsko municipality is covered by forests, presenting locally available renewable source, which makes the area really attractive for biomass utilization.

Figure 29: Production facility of Pokupsko district heating system (Source: www.pokupsko.hr)

The amount of biomass available in municipality of Pokupsko is approximately 5.5 times higher than the municipality’s energy needs. Therefore, it is expected that users encounter significant economic benefits. In the second stage of the project, expansion of the district heating grid to other parts of the municipality is expected. One of the main benefits is, that the system can expand when and where it is needed. In other words, this system represents a modular district heating system, which can later add more consumers and more production facilities. The production facility, as well as the other infrastructure, is run by a utility company, which was founded for that purpose.

The project was developed by Croatian company Enerkon, while the consulting services were provided by North-West Croatia Regional Energy Agency. The preparation process for this project was lengthy – it took 6 years to prepare all the paperwork, and only 6 months to build the production facility and district heating infrastructure. The district heating network scheme is shown in the next figure.

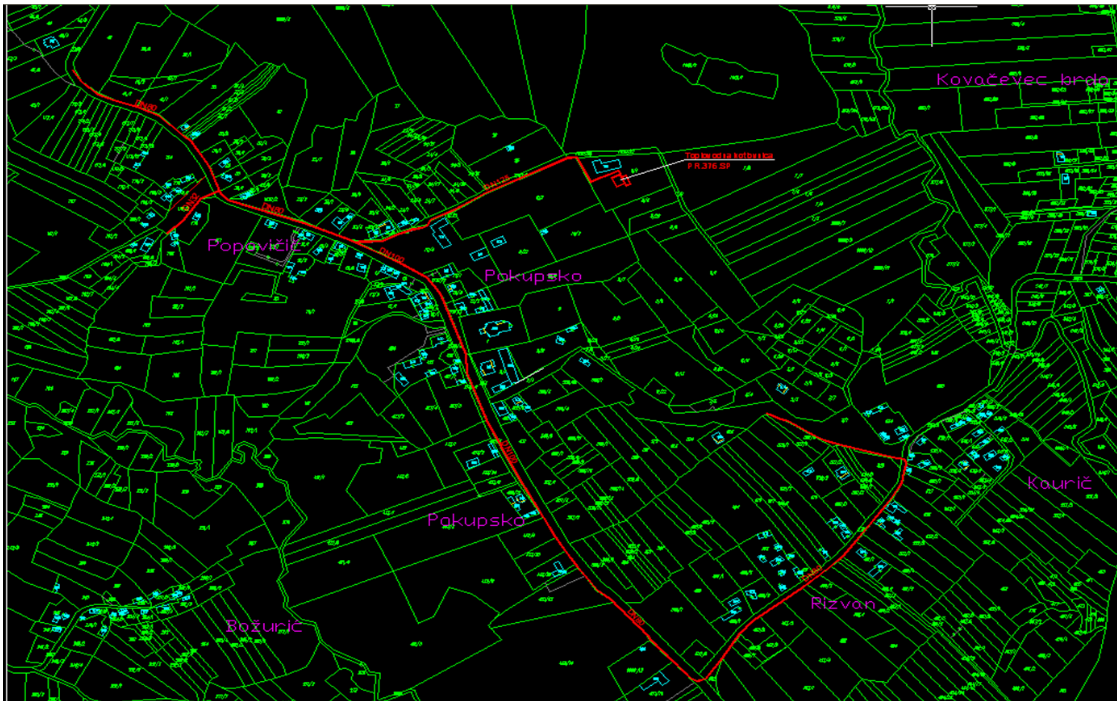
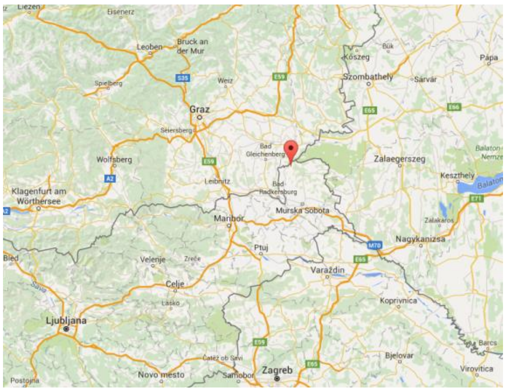


Figure 30: Pokupsko district heating network scheme (Source: www.enerkon.hr)

5.2 Slovenia: Kuzma small Biomass District Heating

Location: Northeastern Slovenia
Google maps

A small town of Kuzma is supplied by a biomass district heating.



Technical data

Heat production technology // Fuel // heat capacity // year of installation	District heating supplies: Wood chip boilers 500 kW + 220 kW (Fröling), built in 2012
Cooling	No
Efficiency of plants	not specified
DH network	1.5 km
Storage	Steel tank,10m^3
Consumers // total annual heat sales	Investment and connection of consumers in two phases: 23 houses + municipality building, elders peoples home, school, culture hall, two apartment blocks, church 35 houses
Heat price, fixed, variable, total (standard house)	Total 90 EUR/year (standard house 20 MWh, average price)
Ownership	Private BIOHICA, proizvodnja toplote in pare, d.o.o.

District heating in Kuzma is a private investment of a local company. The motivation was a poor local situation regarding individual heating: Extensive use of wood biomass in old inefficient stoves for individual heating resulted in high biomass demand and poor air quality in winter. In addition, much heating oil was needed for individual heating and heating of larger objects (municipality building, school), which was at the date of erecting of the plant in 2012 very expensive (around 1 EUR/l).

The private initiative had a positive nonfinancial support in the municipality and from the local community, providing help in administrative procedures and acquiring of required documentation. The local community has been very positive regarding the intention of the investor to purchase biomass from local suppliers. The project also received national financial support in terms of a grant within the national scheme for support of wood biomass DH. The project is a lighthouse project in north-eastern Slovenia where there are no small renewable district heating systems.

The production of heat is based on two biomass boilers of the producer Fröling, including a 10 m^3 heat storage which covers peak heat demand. No additional heat production using other resources is installed. Heat consumers are connected via a 1.5 km district heating network and Giaflex substations.

Figure 31: Kuzma district heating and district heating installations

The private investor is purchasing biomass from local wood owners. At present time the offer of biomass exceeds consumption of approximately 2.000 m^3 of wood chips, so the investor is also processing biomass and selling it to third parties – mainly to individual consumers within the radius of 40 km. The biomass is purchased in a radius of 40 km.

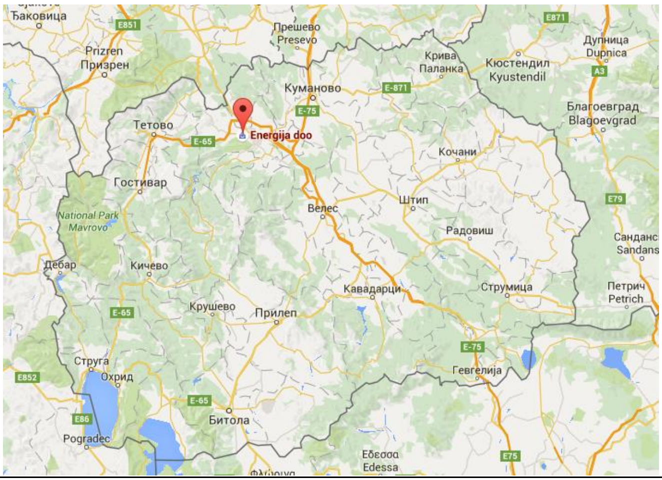
Figure 32: Kuzma town area

The overall investment amounts to 800,000 EUR. The investment was co-financed by a Slovenian national subvention fond for biomass DH-systems (Grant within the national DOLB programme, 50 % co-financing rate).

The project is annually saving 300 t of CO_2, and represents a positive example in Slovenia. The only problem encountered in the project was due to slow national administration and slow issuing of needed permits from the side of the Slovenian environment agency (especially water related permits for crossing a local creek).

5.3 Macedonia: Solar Heating and Cooling in an Energy Efficient Residential Building

Location: Skopje, Republic of Macedonia,
Google maps



Heat production technology // Fuel // heat capacity // year of installation	- Three air to water heat pump units (each with a cooling capacity of 6 kW and heating capacity of 8 kW) - VRF air to air heat pump (cooling capacity of 12 kW and heating capacity of 12 kW) - 12 m² solar collectors for solar hot water preparation - Three 150 l buffer storage tanks - Three 200 l sanitary hot water tanks, each with two heat exchangers (solar + heat pump) - Installation year: 2015
Cooling	- Air to water heat pump units (each with a cooling capacity of 6 kW and heating capacity of 8 kW) x 3pcs - VRF air to air heat pump (cooling capacity of 12 kW and heating capacity of 12 kW)
Efficiency	- Heat pumps with COP = 4.46
Under floor piping network	- 2,200 m heat pipes
Consumers	- 3 connected households and 1 office
Investment cost	50,000 EUR
Electricity price average	0.086 EUR/kWh for domestic household 0.166 EUR/kWh for commercial office
Involved partners	- Installation and End user: DPTU ENERGIJA doo - Macedonia - Planning: DPTU ENERGIJA doo - Macedonia - Heat pump supplier: TOSHIBA CARRIER

This heating and cooling system has been installed in a privately owned three story building - Energija. This is one of the 68 energy efficient buildings which have entered the Municipality of Karposh subsidizing program for 20 % communal tax return. The ground level of the building is a commercial space while the levels above are residential apartments. The system has variety of technologies among which are heat pumps solar panels, fan coil units, underfloor heating and heat storage. As a result of the proper insulation, the annual energy consumption of the building is 29.6 kWh/m^2. See U-factors in Figure 34 on the next page.

For the purpose of obtaining sanitary hot water, a solar-assisted air source heat pump is being used. The pump's outer unit is a Toshiba Super Digital Inverter technology with high energy efficiency. The compressors inside the inverter are equipped with a variable speed motor capable of adjusting the rotational speed of the outdoor fans. This keeps the air moving at the desired velocity. Moreover, as the rotational speed of the fans decreases, the electricity consumption decreases as well, making the heat pump less energy demanding.

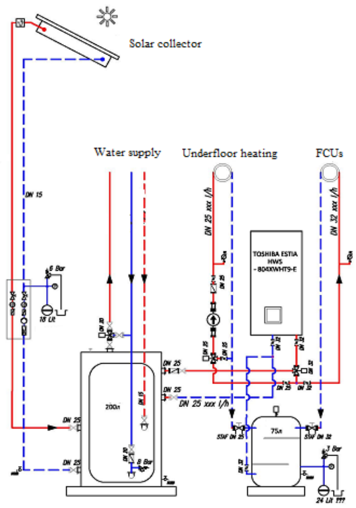
In order to increase the reliability of the system, buffers and boilers are installed. A boiler for the storage of sanitary hot water with a capacity of 200 litres is installed. This boiler is connected to the solar heating panel and the heat pump. Additionally, buffers for the heating and cooling needs are installed.

Figure 33: The building and the installation

The space heating and cooling is directly achieved through fan coil units (FCUs). Depending on whether the area is being heated or cooled, hot or cold water circulate inside these convectors, respectively. The heat conversion is achieved with the use of a heat exchanger. The FCUs are able to operate under five different speed settings. Moreover, a group of units can be connected and controlled from one central controller.

The underfloor heating is a closed water pipe system connected to the heat pump. The maximum temperature of the water in the underfloor system should be 35 ^{o}C, which happens to be the ideal working temperature of the heat pump. Consequently, the efficiency of the heat pump and the underfloor heating is high under these conditions.

The monitoring, control and supervision of space heating/cooling and/or heating of sanitary hot water, one control unit is being used. The control is achieved through valve control and temperature adjustment. A zone control system is applied as well, where separate areas of the building can be heated or cooled to different temperatures. Additionally, a working schedule can be set in the programmable thermostat. The U factors of the building are given in the table below. It can be concluded that the insulation plays an important role in the buildings' efficiency and enhances the benefits from the heating and cooling system.



Section	U (W/m²K)
Outer walls	0.181
Roof	0.103
Floor	0.256
Windows	1.1

Figure 34: Principle diagram of the installation and a table of U-factors of the building

5.4 Serbia: Sremska Mitrovica Biomass Boiler

Location: North-western part of Serbia, Serbia
Google maps

Technical data

Heat production technology // Fuel // heat capacity // year of installation	Biomass fired boiler, Sunflower shell (17,000 kJ/kg LHV), 18 MW, established in 1977, renovated for sunflower shell incineration in December 2012
Cooling	No
Efficiency of plants	87.5 %
DH network	45 km
Storage	No
Consumers // total annual heat sales	2014 numbers: 2,700 HOUSEHOLD sector consumers, 128,000 m^2 131 SERVICES sector consumers, 76,000 m^2 22,504.4 MWh heat produced 20,254 MWh heat sold (10 % net loss estimated)
Heat price, fixed, variable, total (standard house)	Total 1,167 EUR/year (2015), Fixed: 0.4 EUR/m^2*month, standard area 70 m^2 , 342.8 EUR/year Variable: 45.54 EUR/MWh, standard house 18.1 MWh/year), 824.3 EUR/year
Ownership	Electric utility JP EPS Beograd, see more in text.

The biomass fired boiler in Sremska Mitrovica uses sunflower shell with lover heating value of about 17,000 kJ/kg from the nearby city of Šid (around 40 km) oil refinery[9]. The heat is transported through a 45 km long distribution network owned by district heating utility "JKP Toplifikacija Sremska Mitrovica". The biomass fired boiler is owned by electric utility "JP EPS" Beograd, division "Panonske TE-TO" Novi Sad, subdivision "TE-TO Sremska Mitrovica"[10]. Finally, the heat is sold from "TE-TO Sremska Mitrovica" to "JKP Toplifikacija Sremska Mitrovica"[11].

The heating prices consist of a fixed and variable price, different from household and services sector. For the standard house the heating price has been calculated for the average household consumer heating area of 70 m^2. Total fixed price for the year has been obtained multiplying the 0.4 EUR/m^2 /month with average heating area and with 12 months over the year. For the yearly consumption of a standard house an amount of 18.1 MWh/year has been assumed. Total variable price has been obtained multiplying the 45.54 EUR/MWh with average annual consumption.

[9] http://www.victoriagroup.rs/clanice/victoriaoil-ad
[10] http://panonske.rs/lat/branches/tpp-hp-sremska-mitrovica/
[11] http://www.smtoplana.rs/

Figure 35: Biomass fired boiler Sremska Mitrovica, left: outside of plant, right: the boiler seen from inside

5.5 Bosnia and Herzegovina: Hybrid Heating - Livno

District heating systems exist in Bosnia and Herzegovina. These are, however, often old and operate mainly on fossil fuels. There is nonetheless a positive trend in introducing alternative district heating solutions, such as systems based on waste woody biomass, solar collectors and similar. Some current examples of good practice are listed in this and the following.

Location: Gračanica, Bosnia and Herzegovina
Google maps

Technical data

Heat production technology // Fuel // heat capacity // year of installation	Biomass boiler, 6.0 MW Fuel oil boiler, 11.0 MW (for peak operation)
Cooling	-
Efficiency of plants	-
DH network	14.5 km
Storage	-
Consumers // total annual heat sales	372 consumers 55,000 m^2 connected floor area
Heat price, fixed, variable, total (standard house)	-
Ownership	Private

Eko-Toplane Gracanica was put into operation in 2008. The plant is operated on biomass and is adjusted to meet the needs of local communities for the supply of heat, both to industrial plants and private residences. The heat is produced in a biomass boiler with a capacity of 6,000 kW. As an alternative for peak load operation a fuel oil boiler is installed as well. The network of the heating system has a length of about 14.5 km with a tendency of further expansion. The heated surface area currently amounts to approximately 55,000 m^2. More information about the project can be found at: http://www.eko-toplane.ba/

5.6 Bosnia and Herzegovina: Other Best Practice Examples

Biomass Heating - IEE Toplane, Gradiska
IEE Toplane Gradiska was put into operation in 2014. The plant is operated on biomass and provides heat both for private residences and office spaces. The heat is produced in two biomass boilers with a total capacity of 12,000 kW. The heated surface area currently amounts to approximately 120,000 m^2.
(http://www.ieegroup.net/projekti.html)

Hybrid Solar Collector/ Biomass Heating - Sports Hall "Dalibor Perkovic - Dali", Livno
The project of the reconstruction of the Sports Hall "Dalibor Perkovic - Dali" was selected as one of ten USAID 3E projects. The letter of intent for its implementation was signed in November 2011 and the project inaugurated in November 2013. The sports hall was connected to an existing district heating network based on biomass boilers. Solar thermal panels were installed on the roof for domestic hot water heating. To reduce heat loss, new windows and doors were installed, parts of roof covering replaced, and the facade additionally thermally insulated. The installation of a Monitoring and Verification System for heat consumption should additionally contribute to improving the energy efficiency of the building.
(http://www.sustainable-energybih.org/27-11-2013-sports-hall-inauguration-in-livno?lang=en
http://pdf.usaid.gov/pdf_docs/PA00K5JZ.pdf)

Hybrid Solar Collector/ Biomass Heating - Student Centre, Mostar
The Student Centre Mostar introduced the project of solar collector heating in 2012. Besides the solar collector, the Student Centre uses pellet stoves as well, activated at times when the solar collectors are not operated. Hence, the students are supplied with 24-hour hot water and heating. The overall aim of the project was to reduce power consumption and improve the student standard. Given the number of tenants (550 students during the academic year), the project provided substantial savings. Previous costs associated to average annual energy consumption amounted up to 500 KM[12] per person, while today they are reduced down to 185 KM per person, with the aim of further reduction.
(http://scm.pogled.ba/clanak/veliki-rezultati-projekata-ustede-elektricne-energije-u-studentskom-centru-mostar/38387)

[12] KM = Bosnia and Herzegovina convertible mark

6 Conclusion

The purpose of this report is to show best practice examples of small renewable modular cooling and heating grids in different European countries in order to show the feasibility and the different approaches of these projects. This shall inspire stakeholders from communities where no heating grid is yet installed, to develop their own ideas and concepts. The best practice examples shall help to learn more about different opportunities to set-up such projects. The presented examples comprise different technologies, as illustrated in Table 1.

Table 1: Overview of the technologies covered in this best practice report

BP #	City/area	Solar	PV	Geo	Waste heat	HP	Electric boiler	Biomass	Waste inc.	Fossil	Diurnal storage	Seasonal storage	Cooling
DK 1	Brædstrup	x				x	x			x	x	x	
DK 2	Bornholm							x	x	x	x		
DK 3	Gram	x			x	x	x			x	x	x	
DK 4	Thisted	x		x		x		x	x	x	x		x
DK 5	Marstal	x				x		x			x	x	
DK 6	Hjallerup	x					x	x		x	x		
DE 1	Dollstein	x	x			x				x	x		
DE 2	Munich	x				x						x	
DE 3	Büssingen	x						x			x		
DE 4	Vatersdorf							x		x	x		
DE 5	Grassau							x			x		
DE 6	Bad Aibling	x	x			x		x		x	x		
AT 1	Güssing							x		x			
AT 2	Güttenbach							x		x			
AT 3	Güssing							x					
AT 4	Ubersdorf	x						x		x	x		
AT 5	Stainz		x					x					
AT 6	Lavamünd							x					
HR 1	Pokupsko							x			x		
SI 1	Kuzma							x			x		
MK 1	Skopje	x				x					x		
RS 1	Sremska							x					
BA 1	Livno					x		x					
BA 2	3 examples					x		x					

The best practice examples were selected to cover a broad range of different sizes of the systems, technologies and ownerships. For instance, the examples from Germany and Austria represent rather small-scale systems whereas the examples from Denmark represent concepts of district heating utilities that supply whole towns.

The technologies used in the systems typically involve several components with several renewable energy types. It shows that most examples rely on more than one energy source. In several cases fossil energy is used, e.g. as natural gas or heating oil peak load boilers, to make the projects bankable. Biomass is an important energy carrier for many examples. There are generally many biomass heating projects available. The use of solar thermal energy for small heating grids is much less applied. Denmark is certainly the county with the best examples for solar thermal integration, whereas only few examples exist in other countries.

Even more difficult to identify are examples with small renewable cooling grids. Thus, only one example could be included in this report: Thisted. In Denmark, the need for cooling is rather small, and it is mostly in the service industry, offices and certain industries, where cooling is necessary. But there is seen a tendency towards combining the heating and cooling supply. This is for instance the case in the described example of Thisted DH. Another example of DHC in Denmark is Høje Taastrup DH, which is planning to build a large and advanced cooling system, integrating cooling and district heating in large scale. In practice this is done by distribution of the waste heat from the refrigeration compressors into the district heating network[13].

In regard to the type of ownership it should be noticed, that in Denmark all examples are consumer owned utilities, which is the case for the major part of DH utilities in Denmark. The DH utilizes are cooperatives with limited liability. This ensures the consumer's rights, as for instance the right to vote at the annual general assembly. In Germany and Austria, different types of ownership models are applied. In some cases it is private or commercial investors, public owned bodies, or cooperatives with the participation of citizens.

The development of small renewable district heating in Denmark, Germany and Austria is comprehensive, based on the description of the Best Practice examples. The selection shows that projects are commercially feasible and are able to supply customers with heat at competitive prices to fossil fuels systems. However, there is still room for further development in the use of renewable resources in order to make the concepts even more sustainable. In Denmark, the peak load is primarily covered by natural gas boilers, and in Germany and Austria the use of biomass could be reduced by using solar thermal or heat pumps.

The described examples from the CoolHeating target countries show the feasibility of such concepts in these countries. The objective of CoolHeating is to support the implementation of more "small modular renewable heating and cooling grids" for communities in South-Eastern Europe.

[13] http://www.htf.dk/#