UNLOCKING THE COMMUNITY BIOENERGY POTENTIAL

Technical catalogue on biomass district heating

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About

Over the last years, the EU has witnessed some remarkable steps in Renewable Energy (RE) deployment. However, at the same time, we see an increasingly uneven penetration of RE across the different energy sectors, with the heating and cooling sector lagging behind. Community bioenergy schemes can play a catalytic role in the market uptake of bioenergy heating technologies and can strongly support the increase of renewables penetration in the heating and cooling sector, contributing to the EU target for increasing renewable heat within this next decade. However, compared to other RES, bioenergy has a remarkably slower development pace in the decentralised energy production which is a model that is set to play a crucial role in the future of the energy transition in the EU.

The ambition of the EU-funded BECoop project is **to provide the necessary conditions and technical as well as business support tools for unlocking the underlying market potential of community bioenergy.** The project's goal is to make community bioenergy projects more appealing to potential interested actors and to foster new links and partnerships among the international bioenergy community.

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Project partners

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1. Introduction

A biomass district heating, basically it is a heating power plant that generates heat and through a piping network supply this thermal energy to different consumers that belongs to different buildings. Taking into account the BECoop audience (residential sector), these consumers could be municipalities, community of neighbours, individual houses, swimming pools, local business, nursing home, hospitals, etc.

This technical catalogue about biomass district heating has the aim of facilitating the steps that a stakeholder, that want to promote this technology, needs to do in order to analyse the feasibility of developing a DH. In order to assess this goal, the information that can be found in this report it is the following.

- A general overview of what a district heating is in order to guarantee that this is the project that you want to promote.
- Technical considerations that should be known before contacting with stakeholders that can help you to develop your initiative. It should be known the main elements of the district heating, the information necessary to assess the power of the DH, and the operational and maintenance requirements for this type of installations.
- Although, the best option (if you don´t have technical experience) it is than an expert carried out a feasibility study, the point 4 explains how to assess a first estimation of the economic profitability of a DH, but as indicated, this is just a starting point and then needs to be studied in more detail by an expert. Also, environmental and social benefits are mentioned in this point.
- The point 5 indicate the group of stakeholders that can help you in the development of your initiative, and what kind of activities can be expected for each group of stakeholders. Not all of the stakeholders should be involved to develop a biomass DH, it will depend of each particular case according to your necessities.
- The point 6 gives the general steps that should be carried out from the idea to the final implementations, with suggested stakeholders that can provide support if needed.
- Finally, some success cases are mentioned in order to provide some real examples of biomass district heating that are properly working.

Important: This technical catalogue is based on general recommendations to be taking into account and facilitate the conversation at the time of establishing the first contact with the energy services /engineering companies that will carry out the project, being them finally, the ones that will decide how the installation should be distributed and the type of equipment and technologies they will count on.

2. District Heating concept

A "district heating" or centralized systems for heat production based on district networks, is understood as a centralized system of production and distribution of thermal energy to an entire neighbourhood, district or municipality, which allows connecting multiple energy sources to multiple points of energy consumption and distributing it to the buildings through a piping system that transports a thermal fluid (hot water, cold water, thermal oil...) to the exchange points in the buildings [1].

Figure 1. Scheme of a District Heating [2].

In particular, district networks allow the efficient use of thermal energy generated by waste heat from industrial processes, natural geothermal sources, energy recovery from solid urban waste and the use of renewable sources that are easier to integrate into centralized systems, such as biomass or solar energy. In particular, this specific catalogue will be focused on biomass district heating networks.

The use of biomass enables the use of autochthonous and renewable energy resources while contributing to create local employment in the municipalities where the valorisation initiative is implemented. From the economic perspective, biomass usually has a lower price than conventional fuels and, additionally, environmental benefit derive in terms of forest cleaning which contributes to reduce forest fire risk, prevention of open-fires (as for instance of agricultural pruning) and the reduction of CO_2 emissions due to the substitution of conventional fuels by biomass.

From the point of view of the users, modern district networks could offer economic and technical benefits. It could contribute to reduce operation and maintenance costs related to the boilers placed in each building, and the district network producer can offer more efficient energy services to the consumer.

District networks also facilitate competition between different heat sources and fuels. For this reason, it can become an important element in a liberalized energy market.

There are other factors to consider, for instance, district networks facilitate the provision of a range of efficient energy services throughout the community. They provide fuel flexibility for the future, boosting the use of new renewable sources, and due to the low CO_2 emissions achieved they can be integrated more easily than individual installations, whether they are detached houses or buildings, where the grid quickly provides an easy route for supply to a large number of consumers.

Finally, it should be remarked that there is another catalogue addressing direct heating (chapter 3 and Annex I) that should not be confused with district heating. The district heating catalogue, as previously mentioned, focus on a central installation covering the energy demands of different buildings (physically separated) while in the direct heating the central installation covers the energy of a single building.

3. Technical considerations

3.1 Main elements of a district heating installation

The main goal of this chapter is to provide a general overview of the main technical elements of a district heating in order to facilitate the conversation and the agreements with the energy service/engineering company in charge of the design and development of the district heating installation. The main elements to consider are:

- Generation plant: heat production in these systems is carried out centrally to meet the demand of the several consumers. This way, individual equipment that should be placed otherwise at the points of consumption (houses or buildings) can be avoided, while it is possible to have more energy-efficient technologies installed at the generation plant (more efficient equipment and operation & maintenance are carried out by professional staff in order to avoid operational problems).
- Distribution piping network: the piping network allows the distribution of fluids (normally water) through insulated pipes to minimize thermal losses. By means of a thermal fluid, the energy is transported to the users, where the heat is transferred to the consumption points by cooling the fluid. The network also has a return circuit to the plant. The pipes are usually distributed in subway trenches that follow the layout of streets in urban areas.
- Substations: the heat transfer between the distribution network and the consumers (buildings or houses) is carried out through a substation consisting of a heat exchanger and the elements that regulate, measure and control the correct operation of the installation.
- Control and management of district heating networks

3.1.1 Generation plant

When establishing the technical requirements to be met by the installation to be able to use biomass, it is important to focus not only on the boiler, but also on the entire feeding and storage system, since many times it is where the greatest source of clogging occur.

3.1.1.1 Storage area

Next to the generation plant, it is essential to have enough space to store at least the amount of material necessary to supply the boiler for a minimum period of time (a minimum period of at least 2 weeks is recommended). This storage must be located adjacent to the room where the boiler is located but cannot be located together according to the regulations.

The volume of the storage area will be defined considering the following aspects:

- Amount of biomass to be stored, where it has to be considered the self-sufficient target of the plant for a certain period of time.
- Bulk density of the biomass to be stored, it will depend on the biomass selected and the size distribution of this biomass. In order to have an estimative value of the bulk density of different biomass, the BECoop Factsheet "Solid Biomass for Small-Scale Heating Applications" (Annex IV) can be consulted.
- Average consumption of biomass per day.

Taking into account the previous considerations, the approximate storage area can be calculated by means of the following formula:

$$\text{Usable volume needed} = \frac{\text{consumption of biomass per day}\left(\frac{\text{kg}}{\text{day}}\right) \times \text{ number of days to be self} - \text{sufficient (days)}}{\text{bulk density of the biomass }(\frac{\text{kg}}{m^3})}$$

Even though, the final surface needed will depend upon the equipment selected for biomass storage. It is possible to choose between a vertical silo, a feeding chamber or pit, a top loader or even a mobile floor. This final decision must be made by the energy services company that carries out the installation, taking into account the final location of the generation plant, the biomass selected and the available space. More information about storage systems, according to the size distribution of the biomass selected, can be found in the section 3.1.2 of the BECoop technical catalogue "Direct Heating" (Annex I).

3.1.1.2 Feeding systems

The feeding system is also usually a critical point for three reasons:

- Biomass is sometimes heterogeneous (which makes its flow very difficult in certain systems) and can cause clogging, therefore it is necessary to ensure a homogeneous particle size.
- Possibility that the shredded material contains exogenous materials of non-negligible size (stones, wires, ...), it is not very common in the case of forestry woody biomasses, although in the case of agricultural resources it can occur.
- High inorganic content in the fines (soil, sand, dust) that can affect the accelerated wear of the feeding systems, this will be influenced by the collection system used on the field and the pre-treatments carried out to obtain the final biomass product.

Generally, the most common feeding system (in small installations) used is by means of screws conveyors (in this sense, it should be noted that normally the lower the angle of inclination, the lower the probability of clogging). Even though, the standard screws conveyors are not compatible with the presence of exogenous material, that is why this external contamination should be avoided. If this is not possible, or if you want to opt for a more robust system, some alternatives that should be required in the installation would be:

- There are other screw conveyors capable of handling the transfer of heterogeneous material. Reference and evidence of operation of the system in other installations should be requested. Some key points are:
  a) use of screw conveyors oversized and robust.
  b) screw conveyors with sharp cutting edge.
  c) control system that avoids blockage; motor with variable pitch.
  d) Screws with thread angle changeability
  e) rotary shearing valves (in case of a long woody sticks, it does not jam the valve, but it cuts the stick).
- There are other feeding systems such as redlers and pneumatic conveying systems, but normally this imply higher costs and space that are possibly not compatible with medium/small thermal power installations (eve though, each case should be independently analysed).

3.1.1.3 Thermal power plant

The generation plant is the core element of a district heating network and where the thermal energy is generated and distributed to the buildings through the distribution network.

The generation plant is located inside a building built for this purpose, exclusively for the production and pumping of hot and cold water. The power generating elements (boiler room), as well as the main pumping units, which drive the heat transfer fluid to the different consumption points, are located inside this building.

The thermal power plant operates automatically, depending on demand, regulating its operation with a control system that takes data from the consumption points and from the plant itself. The operating time of the generation equipment depends on the installed power compared to the thermal demand and the capacity of the existing accumulation systems (water accumulators, buffer tanks, etc.).

The connection of the water supply network supplied to the boiler room will consist of valves, pipes and manholes that allow the cutting or isolation of sections in case of failure of any of them.

The boiler room site (but also the storage area) should be equipped with:

- Low voltage electrical network and its corresponding protections.
- Interior and exterior lighting.
- Fire protection installations.
- Rainwater drainage, especially important in the storage area.

The main thermal generation equipment used are listed below:

- The boilers used in urban heat networks are water-tube or pyrotube boilers (with efficiencies around 85-90%) that use local energy resources such as biomass as fuel.
- Cleaning system, as for instance cyclones and/or bag filters, sometimes are needed in order to fulfil with the emissions directive. In this sense, two directive should be taking into account, the Ecodesign regulation 2015/1189 for boilers lower than 500 kW and the directive 2015/2193 for biomass boilers lower than 50 MW.
- The accumulation systems of the heat networks allow to dimension the plants in a way more adjusted to the needs, achieving that they work during more time at full load and improving, in this way, the energetic performance of the installation. The main drawback is the necessity of space for the storage tanks and the auxiliary systems.
- As safety measure, the installation should account with a the tank or expansion vessel that absorbs the increase in pressure of the fluid when its temperature rises.
- The pumping system (pumping groups) that drive the heat transfer fluid from the power plant, through the distribution network, are used to regulate the flow.
- Other auxiliary equipment can be used in an installation such as compressors for the air supply of pneumatic drives, shut-off valves, hydraulic distributors, regulating valves, etc.
- A first number to be considered for the space needed for this generation plant, could be the ratio 30-200 m^2 per MW_{th} heat output [3].

Focusing on the "heart" of the thermal generation plant, the boiler, there are different technologies, but for small-medium heating capacities, the most frequently used are:

Underfeed biomass boiler

The fuel is fed through a vertical duct, by means of a screw conveyor, and it is burnt in a fixed grate. This is an appropriate technology when a small-medium power installation is required, with power in the range from 20 kW to about 2 MW. Regarding the fuels to be consumed, it is appropriate when they have a medium size (up to 100 mm), a low percentage of ash (<1 %) and a medium moisture content (up to 30 %).

Biomass boiler with fixed grate

In these boilers, the material descends/advances through a grate as the new fed material enters in the boiler and causes the inner material to advance. It is usually set in small power as an inclined grate in steps or in a grate. Even though they may be more robust than underfeed biomass boiler, it is difficult to guarantee good combustion with some fuels given the limited regulation over the material and the bed. This can cause low efficiency, and thus loss of economics, and visible smoke in the stack.

It is an appropriate technology when a small-medium power installation is required, with power outputs in the range from 20 kW to about 2 MW. Regarding the fuels to be consumed, it is appropriate when they have a medium size (up to 100 mm), a low percentage of ash (1-3 %) and a medium moisture content (up to 30 %).

Biomass boilers with mobile grate:

Regarding to mobile grates, these can be used for a wide variety of biomass resources. This is due to the high flexibility of the system to handle heterogeneous fuels in terms of particle size, moisture and ash content.

In general, existing mobile grate systems can operate with chips up to 55% moisture and particle sizes up to G100 (although such moisture contents and particle sizes are generally not recommended). Depending on the ash content and the melting temperature of the ash, it is also possible to install water-cooled mobile grates, which prevent the possible sintering of the solid residues (ashes) in the grate.

It is a robust, reliable technology suitable for processes where higher plant availability it is required. Normally it is recommended from power ratings from 200 kW to 200 MW. The main disadvantage it is the higher price of this technology compared with the other previously mentioned.

Also, according to the size distribution of the biomass to be used some modifications should be considered in these technologies, in the point 3.1.1 of the BECoop technical catalogue “Direct heating” some considerations are mentioned according to the size distribution (pellet, woodchips, briquettes and log) of the biomass fuel to be consumed.

Additionally, since it is necessary to cover the needs of a certain number of buildings, whose demands may vary from one building to another at different times and days, it is possible to opt for an installation that allows modularity in the production of energy. For example, the installation of two boilers of less power, instead of one that covers all the power, would allow a more efficient work of the installation.

3.1.2 Distribution piping network

The distribution network is a network of insulated pipes that distributes the thermal energy (thermal fluid) from the generation plant to the different buildings.

The heat transport line consists of two pipelines (with their corresponding collectors), one for the supply and one for the return. In the case of centralized heating and cooling networks, the line consists of four pipes.

There are three main factors to be considered to design the distribution piping network:

- Where the pipes should be located? The current trend is to install underground installations for visual and safety reasons, even though the investment cost is lower in surface installations.
- Type of material to be used. Larger pipes are usually made of carbon steel and for smaller diameter pipes plastic materials are being used, such as cross-linked polyethylene.
- The selection of the type of insulation is quite relevant since it has an influence on the overall efficiency of the system. It should be taken into account that in the distribution networks is where the greatest performance losses occur in this type of installations, which can range between 5 and 10 % (taking the latter as a very conservative value).

In addition to the pipes, the distribution network incorporates other elements necessary for its proper and optimum operation: fixed points for expansion control, pre-insulated sectioning valves, air trap located at high points, discharge or emptying points (valves) located at low points, expansion elements, branches for service connections, manholes, junctions with existing services, filters, pressure and temperature gauges, etc.

3.1.3 Substations

The thermal energy produced in the generation plant is transported through the distribution network and finally reaches the consumer through substations located near the consumption points. At the substations, the pressure and temperature of the network are adapted to the conditions of consumption.

In each building there is a heat transfer substation, consisting of a heat exchange system, without fluid or pressure exchange, through which heat is transferred to the terminal elements for heating, cooling and domestic hot water service.

In the substations, in addition to the heat exchanger, there are regulation and control elements and metering equipment for billing the thermal energy supplied from the network to each end user.

A list of the minimum components would be as follows:

- Shut-off valves at the inlet and outlet of each individual installation.
- Approved energy meters.
- Differential pressure regulation valves.
- Power regulation valves.
- Water treatment system for internal circuits.
- Sieve filter.
- Electrical and control panel including regulation and communication devices with the control panel.

In the buildings/houses, where currently are being heated with other fuel, normally they account with the majority of these equipment and can be reutilised for the new district heating network with minor investment in most cases.

3.1.4 Control and management of district heating networks

The main aim of the control of the district heating networks entails the regulation between the generation of energy and the real demand in the network in each moment. Another important variable to regulate is the control of the supply and return operating temperatures, which is usually based on the outside temperature.

In order to adjust the supply of the thermal energy, the most common solution is to regulate the supply temperature and the flow of the thermal fluid.

This control is usually managed through a "supervisory control and data acquisition" (SCADA), this supervision will allow the optimization of the operation of the network and will increase the safety of its operation. The control and monitoring of the installations include the elements of the power plant and, in some cases, the regulation and measurement substations of the consumption points.

3.2 Power of the District heating

The real power of the installation should be calculated by an expert company in this field, as for instance an energy service company with expertise in biomass district heating, even though in order to assess this profitability the user should provide some input information.

3.2.1 Buildings

It is necessary to identify the buildings to be covered by the district heating network, here two stages can be differentiated:

- 1st stage: This step refers to the buildings, which the current energy demands should be covered at the moment of the implementation of the district heating.
- 2nd stage: Additionally, it is often the case, where there is a possibility that other buildings will join in the future. If possible, an estimation of these building should be also done at the initial stage, since this could be also considered at the moment of the design of the district heating, but without making the mistake of greatly oversizing or downsizing the installation from the beginning.

The location of the buildings should be indicated along with their distance to the plant. If possible, a map considering the roads, buildings, and so forth will facilitate this information and the future steps regarding the design of the piping network.

3.2.2 Energy demand

From the buildings previously identified, the energy demand of each of them should be known in order to determine the power of the installation. To obtain this data, the invoices can be checked and reported. It is recommended to provide the data from, at least the last three years, in order to have a representative energy demand of each building.

Additionally, if possible, the power of each individual installation should be provided along with a consumption curve of each building. This will allow to know when the power consumption is carried out in each building throughout the day.

Sometimes, the previous data cannot be obtained. In that case, it could be useful to provide information about the building to be heated, as for instance:

- What type of building is it? Residential? Office? Sports centre? Swimming pool?
- Year of construction of this building? What type of insulation?
- Useful surface to be heated in each building?

- Are people living/working all the time?
- Number of hours that it is heated along the day.

The same information should be provided about the domestic hot water (DOC) and cooling (if cooling wants to be covered in the DH), if possible.

Summarizing, an example of the data to be provided are indicated in the following Table 1:

Table 1. Necessary data to be fulfil by the user to know the energy demand of each building

Stage 1 or 2	Name of the Building	Heating/ Cooling/ DOC	Useful surface to be covered (m^2)	Final energy consumption (kWh/year)	Number of hours of operation (h)	Additional information
1	City Council	Heating	1.000	100.000	1.500	-
2	Nursing home	Heating	1.500	200.000	2.000	-

In case, that cannot be provided the energy demand of each building, there are different tools that allow have a first number regarding the energy density of the area selected, some of them are: Hotmap (https://www.hotmaps.eu/map), S-EEnerrgies Dataset (https://s-eenergies-open-data-euf.hub.arcgis.com/apps/417665ed989a4319acfbec2b92a08332/explore), and THERMOS (https://www.thermos-project.eu/thermos-tool/tool-access/). All these tools can be found in the BECoop toolkit (https://becoop.fcirce.es/toolkit/), where at least a summary can be found, and in some cases a guideline about how to use it.

Also, other option about how to do a first estimation of the final energy consumption from a simple way (but less accurate), can be found in the point 3.2 of the BECoop catalogue “Direct Heating”, based on the energy class of the building to be heated and the useful surface area to be heated.

3.2.3 Power of the installation

Taking into account the buildings to be covered, where they are located, and the energy consumption of each building, a first estimation about the power needed of the installation can be done. In order to do so, these main considerations should be taken into account:

- Final energy consumption: it means the sum of all the useful energy of each building, this will imply the average thermal demand to be consumed and therefore the minimum amount to be generated each year.
- Maximum power to be supplied: since there are moments where the heating demand will be higher than the average, this should be assessed to calculate the power of the installation, normally through the consumption curve. In this sense, the accumulation systems can mitigate these punctual moments, and therefore an appropriate design of the volume of this equipment and the power of the installation should be properly established.

- Heating losses in the network: as mentioned, there will be energy losses in the distribution of the thermal fluid to the different substations. These energy losses will depend on the parameters indicated in the section 3.1.2 of the Annex II. As starting point, 5 and 10% of energy losses could be considered (taking the latter as a very conservative value). This mean, that 5-10 % more of energy should be generated in the output of the biomass boiler.
- Yield of the biomass boiler: biomass boiler doesn´t have a yield of 100 % (although in the case of condensation biomass boiler this can happen), normally the yield ranges between 85-90 %. This fact should be considered in order to assess the real power of the installation.
- Additionally, more specific aspects should be considered as for instance the climate conditions of the area where the district heating is going to be located.

Figure 2 provides a basic estimation of the energy that should be provided in the different elements of the district heating network, even though this calculation is more complex, and therefore should be carried by an expert in this field.

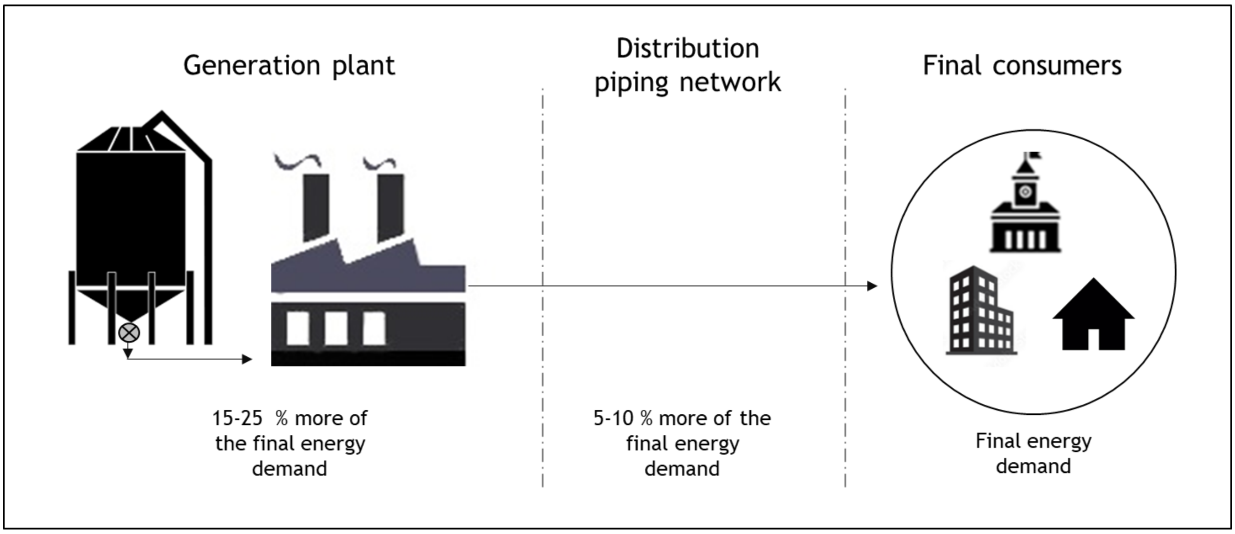


Figure 2. Basic scheme of the energy to be supplied in each part of the district heating system.

3.2.4 Amount of biomass needed

At the same time, once the amount of energy to be produced in the generation plant is obtained, an estimate number of the amount of biomass required can be assessed. In order to do so, the low calorific value and the moisture content of the biomass selected should be obtained. If these parameters are unknown the BECoop factsheet “Solid biomass for small-scale heating applications” can be consulted where average values are provided.

$$Energy\ to\ be\ produced\ in\ the\ generation\ plant\left(\frac{MWh}{year}\right) = \frac{Final\ energy\ demand\ of\ the\ consumers\ (\frac{MWh}{year})}{Efficiency\ of\ the\ piping\ network\ (\%)}$$

$$Energy\ to\ be\ covered\ by\ biomass\ (\frac{MWh}{year}) = \frac{Energy\ to\ be\ produced\ in\ the\ generation\ plant(\frac{MWh}{year})}{Efficiency\ of\ the\ generation\ plant\ (\%)}$$

$$Amount\ of\ biomass\ needed\ (\frac{t}{year}) = \frac{Energy\ to\ be\ coverd\ by\ biomass\ (\frac{MWh}{year})}{Low\ heating\ value\ of\ the\ biomass\ (\frac{MWh}{t})}$$

3.3 Operational and maintenance of the installation

Although biomass is a cheaper fuel than fossil fuels (natural gas, heating oil, propane, etc.), its operation and maintenance cost are slightly higher, considering that more frequent maintenance operations should be carried out due to the significant amount of ash generated during the combustion of the biomass in order to guarantee the correct operation (and therefore do not decrease the yield of the installation) and to guarantee the service life of the installation:

- The frequency of the bottom ash accumulated removal will depend upon the installation characteristics and the biomass to be consumed, but it is recommended to perform it at least once each two weeks.
- Removing the fly ash, that can be located in the heat exchangers tubes and other auxiliary/cleaning emissions systems, can be done automatically by means of a pneumatic system (or other technologies). It is also recommended to be performed at least once per year, (normally after the winter season) and invest additional time to deeply clean all the installation.

Normally these operations are carried out by the company in charge of the operation of the installation.

If these maintenance operations are being done and the design of the installations is based on the energy to cover and the biomass resource to be fed, no malfunctions should arise.

Sometimes the bad experiences associated to the use of biomass, it is because:

- The district heating has been oversized and therefore the installation usually operates at very low capacity.
- The biomass fed it is very different for which the installation has been designed, as for instance: (i) different moisture content, (ii) size distribution (this can cause problems in the combustion but also in the feeding system), (iii) chemical composition (be careful with that since it cannot be visually identified, high alkali and chlorine content, if the boiler it is not designed properly, can considerable decrease the service life of the installation), (iv) low heating value, (v) ash content, etc. There are different quality schemes in order to guarantee the quality of the biomass (ENPlus, DINPlus, BIOmasud, etc), so this should be taking into account when the biomass it is purchased.

4. Profitability of a biomass direct heating

Profitability should be measured in economic, social, and environmental terms, since all of them are important, even though, it is well known that economical aspects are one of the main considerations in order to carry out the final decision. So let´s focus on how to assess the economical profitability of a biomass district heating.

The first aspect that should be addressed is related to the information previously mentioned in section 4.2, regarding the energy demand to be covered annually. Additionally, information should be retrieved regarding the current fuel used in these installations/buildings and the annual price that is paid. With this input data, the annual cost to cover the heating demands for all the buildings will be calculated, without taking into account the amortization of the installations, since it is understood that the installations are currently amortized.

At this point, it could be considered not just the current annual price, but also the tendency in the future years, since the stability of the prices will not be the same for all the fuels. Also, if the current fuels used are fossil fuels, it should be considered that in the coming years fossil fuels are expected to have an extra tax according to the specific emission factor of the fuels used. The same is currently happening in the industry sector (Figure 3), which can lead to a significant increase of the final price of the fossil fuels used.

Figure 3. Evolution of the price of CO_2 emission in the last 5 years [4].

Complementarily, in order to have a good overview of the current and future scenarios with the current fuels, a sensitive analysis (final price and emission prices of the current fuel) can be done in order to have more information to take the final decision.

Once the current situation is well analysed, it should be compared with the future installation, and thus, two main aspect should be considered:

- Investment (CAPEX) of the new biomass district heating installation: it includes the investment cost, the assembly and the transportation of all of the equipment required, together with the civil engineering costs (installations necessary for the operation of the DH, as for instance the building of the generation plant, and the civil engineering of the piping network). This number is very sensitive to the specificities of each case (location where the initiative will be implemented, expertise of the company in charge of the operations, the equipment selected, the biomass fed, the linear meters of the piping network, etc.). An initial estimation with uncertainty ranges for heat biomass plants based on DH is provided by the Danish Energy Agency [5] for a power of 6 MW fed with different biomasses, Table 2.

Table 2. Investment costs according to the Danish Energy Agency for a DH of 6 MW fed with different biomasses [5].

CAPEX (€/kWth – heat output)	Woodchips	Pellets	Straw
Equipment	410 (350-470)	440 (380-510)	460 (370-550)
Installation	300 (250-340)	290 (240-330)	460 (390-530)
Nominal investment	710 (600-810)	730 (620-840)	920 (760-1,080)

- Operational and maintenance cost (OPEX): considers the actions mentioned in the section 4.2.3, and it can be divided in two groups: fixed cost (biomass cost, periodic maintenance, etc) and variable cost (electricity, etc.). According to the Danish Energy Agency Table 3 depicts some reference figures.

Table 3. Operational and maintenance cost according to the Danish Energy Agency for a DH of 6 MW fed with different biomasses [5].

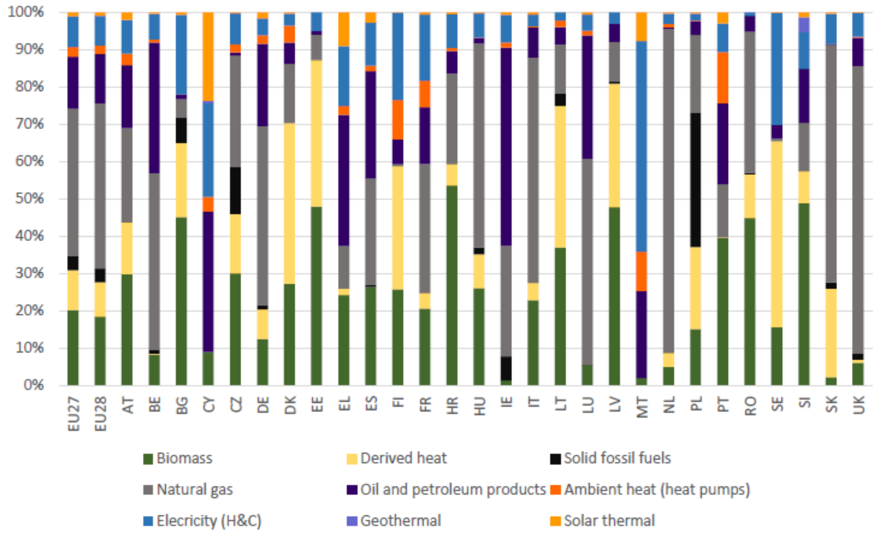
OPEX (referred to heat output)	Woodchips	Pellets	Straw
Fixed O&M (€/MW_{th}/year)	27,800-37,700	28,000-37,900	43,900-59,600
Variable O&M (€/MWh)	2,34-3,71	1,81-2,30	1.92-2.59
- of which is electricity costs (€/MWh-heat)	1,51-1,99	1,40-1,61	1.43-1.71
- of which is other O&M costs (€/MWh-heat)	0,83-1,72	0,41-0,69	0.49-0.88

Once, the CAPEX and OPEX of the new installation are estimated, in order to assess the economic profitability, the annual savings regarding the OPEX of the new installation should be calculated. After having estimated all the investment and operating costs along with the potential savings/ revenues, a simple way to calculate the payback period (this parameter indicates the necessary years to obtain the return of the investment carried out), is obtained through the division of the CAPEX and the annual savings associated with the new installation. The lower the payback, the lower the risk associated with the new installation. It should always be lower than the service life of the new DH installation (an average service life is between 20-30 years) for being economically profitable.

$$Payback = \frac{CAPEX\ (€)}{Annual\ savings\ (\frac{€}{year})}$$

As mentioned, this is a simple way of doing a first estimation, but to be more accurate other parameters should be considered as the inflation or the tax rate. If the CAPEX is covered by own or external resources, loans, etc., in order to obtain more information about business and financial considerations, the BECoop Catalogue for the provision of business and financial support services can be consulted.

Nowadays, due to the high percentage of the fossil fuels used to cover the energy demands of the residential sector (Figure 4), supporting financial mechanisms are available to accelerate and mitigate the risk of new investments in renewable energies, as in this particular case of biomass district heating. If this happens, the payback period will be lower than the one initially calculated (without financial support), since the CAPEX will be lower.



Note: Ambient heat is the energy in form of heat captured by heat pumps, the electricity used to fuel the heat pumps is included under "Electricity (for H&C)".
Source: Eurostat

Figure 4. Shares of energy used for heating and cooling in the residential sector by Member States in 2018 (%) [6].

Table 4 summarises the information mentioned in this section, through an example of investing on a new biomass DH and replacing the current consumption of a total of 250,000 litters of heating oil in all the buildings. In this example an inflation rate of 2 % has been considered for the case of heating oil and 1 % for the case of the biomass (since the price it is more stable, as previously mentioned), as a result a 10 year payback period is obtained.

Table 4. An example of a breakdown of savings, expenses and investment obtained for a DH.

Items	Unit	Data year 1
Savings (current situation)		
Consumption of heating oil	Litter/year	250,000
Price considered of heating oil	€/l	0.8
Annual heating cost	€/year	200,000
LHV heating oil	kWh/l	9.98
Yield of the oil boiler	%	85
Useful heating consumption	MWh/year	2,120
Expenses (future situation)		
LHV woodchips (at 30-35 moisture content)	kWh/kg	3.1
Yield of the district heating	%	75
Amount of the biomass needed	t/year	911
Nº of hour of operation	h/years	1,400
Power of the installation	MW	2
CAPEX cost (taking into account the average value of the Table 2)	€	1,443,887
• OPEX cost (taking into account the average value of the Operational and maintenance cost (OPEX): considers the actions mentioned in the section 4.2.3, and it can be divided in two groups: fixed cost (biomass cost, periodic maintenance, etc) and variable cost (electricity, etc.). According to the Danish Energy Agency Table 3 depicts some reference figures. Table 3)	€/year	70,488

Financial considerations		
Inflation of heating oil	% of inflation per year	2
Inflation of biomass	% of inflation per year	1
Grant	%	0
Loans	%	0
Payback		
Payback	Years	10

Environmental and social aspects, that sometimes are forgotten, should be also considered. In the case of biomass, these aspects are very relevant, since in order to develop new initiatives, these resources should be collected and consumed in the nearby areas in order to be economically profitable. This implies that employment is generated locally and normally in rural areas since it is where the biomass is located. Also, the use of biomass, can contribute to a good forest management that can prevent forest fires, avoid uncontrolled pruning burning on the fields, contribute to pest control, etc. And, of course, the mitigation of the dependence of fossil fuels, keeping in mind that the EU has a clear commitment to achieve carbon neutrality in 2050, and to contribute to the development of rural areas. Both goals are properly addressed with the promotion of district heating based on local biomass resources.

5. Stakeholders needed

In order to develop a district heating unit, the users, in the majority of the cases, would most likely need the support from other stakeholders, that sometimes can be integrated inside the community/RESCoop or in other cases they will provide external support by subcontracting. Some of the stakeholders that could be necessary are listed below:

Biomass producers/suppliers

It is very important to guaranty the supply of the raw material (biomass) that should feed the district heating installation. There are a huge range of biomass with different composition and size distribution, therefore the biomass purchased should guarantee the same range of properties since the installation it is designed for a specific biomass. It is recommended to consume local biomass, because it is more sustainable, and the transportation cost it is lower. These biomasses can be purchased from the biomass producers or from biomass suppliers, in any case it is important to carry out supply contract specifying who is in charge of transportation, the frequency of supply, and the quality of the biomass supplied.

Energy Services/Engineering Company (ESCO)

A district heating installation, it is an industrial plant, so therefore it is important to account with an expert company that will be in charge of the proper design of the installation. This step it is critical, since a bad design of the installation can jeopardise the viability of the project. It is recommended that these companies have a general overview of all the project, as for instance the energy demand to be covered at the initial stage, and the future stakeholders that can join in the future, also to have a clear idea of the biomass to be consumed, since the installation should be designed accordingly. Sometimes this lack of information entail problems in the future, so dedicating efforts to making the project fully understood is highly recommended.

Normally, this stakeholder can be in charge of the operation of the installation selling the energy to the final consumers, this fact it will depend on the business model selected by the community. In any case, which is not usually recommended, it is that one company it is in charge of the design, and other of the operation, since if problems happen, they can blame each other, this does not always have to be the case, but unfortunately it sometimes happens. Also, it is also frequently, that this stakeholder could be in charge of the biomass supply of the installation if they are in charge of the operation.

Some energy services/engineering companies have in their business model to be part of an energy community while others do not, this fact should also be taken into account depending on the business model to be selected by the energy community to be formed.

Equipment manufacturers

The selection of the proper equipment for the installation to be designed it is important, even though this process normally it is being done by the previous stakeholder (energy services/engineering companies), since they have agreements with several equipment manufacturers, and they choose the best technology for each particular case.

Public/Local institutions

To develop district heating installation, generally, it implies the use of public resources, as for instance administrative license and the use of urban ground where the piping network should be allocated (buried), for this reason it is fundamental the involvement of the administration (regional and state) and local bodies (town councils), and also to account with an urban development plan that allows the permits processing for the occupation and use of urban ground in order to speed up the development of the project for the implementation of the heat network. As well as coordination between the different administrations for the processing of permits (e.g. the licence from the Department of Industry for the construction and operation of the generation plant) and the optimisation of the system in the case of supply to buildings under different public ownership.

These public institutions can be also the final consumers of the heat, or even the promoters of the idea of carrying out a district heating in the area to supply the public buildings and the homes and businesses of local residents who want to be part of the community.

RESCoops

Current RESCoops already account with the expertise in community models, and they can expand its services lines through the promotion of district heating in the areas where they account with associate and the project it will be feasible, so therefore they can be promoters of new district heating installations. But, also, if the promoters are other stakeholders, they can be an interesting stakeholder to be contacted and communicated the idea since they can help you in the development of the community model, disseminate the initiative, or even they can be interested and being involved in this new local community.

Consumers

Final consumers can be a wide variety of different stakeholders as: individual houses, community of neighbours, commercial premises, local industries, or even some of the stakeholders previously mentioned as RESCoop and buildings of public institutions. They will be the “clients” of the DH, and therefore, they will expect to achieve financial savings, and to contribute to the environmental and social aspects in the area by being part of this community based on DH.

They should be open to adapt its current substations (if they already account with that) for being connected to the district heating network.

Transversal stakeholders (as research centre, biomass associations, investors)

In addition to the stakeholders previously indicated, which are the most necessary in this value chain, there are others, that in some cases, could help to assess/give advice/finance/etc the development of bioenergy communities based on biomass district heating, some of them are:

- Research centres: it could be interested to contact with this stakeholder if the promoter of the idea doesn´t account with the necessary technical information to assess if it could make sense to go further. The research centre can carry out a first feasibility study (being completely impartial) and if it is feasible to facilitate the contact with energy service companies or even being the technical expert (as representative of the promoter) in this communication with the ESCO. Additionally, it can provide support to prepare some documentation in order to obtain financial grants to develop the project.
- Biomass association/local action groups: this stakeholder can inform to the promoter about stakeholders that can help them in order to develops its initiative, can inform them about other success cases based on biomass DH, open financial grants, etc.
- Investors: a DH it required a huge initial investment as was mentioned in the point 4, so it is frequently to some external funding, so in this case investors can provide support. Before contacting the investor, it is important to have a feasibility study, and the idea of the project well organized in order to capture its attention from the beginning.

In case the promotor of the idea needs to contact or find out a specific stakeholder, it is advisable to visit BEcoop e-market platform where you can find useful information in this regard.

6. Steps to be followed

This section aims to summarize and establish a chronology order of general steps to be performed by the promoter of the idea of a biomass district heating unit starting from the beginning.

Table 5. General steps to be followed to develop a biomass DH from the beginning.

Order	Action	Description	Stakeholders that can help
1	To define the buildings to be covered by the district heating and the energy demand to be covered	Should be considered to understand the capacity of the district heating to be developed. See chapter 3.2.1.	All the final consumers of the DH, as individual homes, commercial buildings, public institutions, RESCoops, etc.
2	Current energy demand of these building	It is needed to assess the current situation and to compare with the future DH. See chapter 3.2.2 about the information required	All the final consumers of the DH should provide this information. If support is needed, they can contact Research centres or ESCOs to carry out an energy audit or doing some estimations.
3	To do a pre-feasibility assessment about the implementation of a DH unit	Based on the information described in chapters 3 and 4. It is needed in order to decide whether go further with this idea or not.	It should be done by an expert in this field, it could be a Research centre or even the ESCO that if feasible will be in charge of the design and implementation.
4	To identify and contact different ESCOs and communicate the initiative	Preliminary contact with ESCOs should be done with the goal of communicating the project and investigate if they are interested to collaborate.	It can be done by the promoter of the idea with the support of the company that carried out the pre-feasibility assessment (if previously wasn't done by an ESCO)

5	To start with the definition the business model and to identify the members of the community	Who will design and implement the DH? Who is in going to be in charge of the operation of the DH? Which is the business model selected? In the case of public institutions these are the more frequent models: - Concession model (by public tender) by the city council for the operation and maintenance of the facility ceded to a private company. - Public company operating model, with the council's own resources (subcontractors). - Operating model with a company or investee company. - Mixed public-private operation model. Who will be in charge of the investment? What stakeholders are interested in being part of the energy community? Etc. See chapter 5 about stakeholders than can be needed and the main role that of each of them can provide, and the BECoop "Business and Financial Catalogue"	The previous conversation with the ESCOs can help, but also RESCoop can provide support about community business models.
6	To select the business model and the company in charge of the design and the implementation	According to the information previously indicated, the final decision about the stakeholders selected and role of each of them should be defined. In the case of public institutions, public tenders are needed.	It should be done by the promoter and/or stakeholders currently involved in the community. Also, if needed, the company in charge of the pre-feasibility assessment can provide support

			about technical support to facilitate the decision-making to the promoter.
7	To carry out the design and the implementation of the DH	To develop the project of the biomass DH and the implementation, selecting the biomass to be fed, the equipment needed, to obtain the administrative licenses, etc.	By the ESCO selected.
8	To guarantee the supply of the biomass	Biomass should be guaranteed with the proper quality for the design of the installation carried out.	It depends of the business model selected, and the role of each stakeholder of the community. Normally, the agreement with the biomass supply it is carried out by the same stakeholder that is in charge of the operation and maintenance of the DH.
9	To star with the operation of the DH and distribution of the energy to the final consumers	To guarantee the correct operation of the installation, securing the energy supply to the final consumers and the correct maintenance of the installation to ensure its useful life.	ESCO or the stakeholders selected to be in charge of the operation and distribution of the energy.

7. Success cases

In this section some initiatives already implemented will be described seeking to raise awareness regarding the possibility to successfully develop a biomass district heating and get a better idea of the average cost. This section will be updated in the second version of this catalogue in January 2023.

7.1 Vilafranca del Penedés, Spain (500 kW_{th})

Vilafranca del Penedés is a town located in Catalonia (Spain), in which the project VinyesXCalor (http://vineyards4heat.eu/es/) was developed. The initiative was promoted by the municipality of Vilafranca del Penedés as a political commitment to set an efficient low carbon economy through the use of an abundant source of biomass in the area (vineyard prunings), currently underused with the goal of covering the energy demands (heating and hot water) of four buildings (one more is expected to be connected to the network in the near future), Figure 5. For this purpose, multiple local public and private actors have been involved to create a new and sustainable value chain guaranteeing the profitability of the energy production from vineyard prunings: farmers, a harvesting service company, an energy service company, several consumers and the municipality. This value chain starts from the collection phase of the resource until the generation and distribution of the energy.

Figure 5: Scheme of the District Heating in Vilafranca del Penedés.

Part of the motivation came from the subscription of the Municipality to the Covenant of Mayors for Climate & Energy (EC initiative) in which several Sustainable Energy Action Plans were promoted. The rest of the motivation was triggered: (1) by the reality of the pruning residues management, which needed to be improved; (2) by the willingness to increase the competitiveness of the county economy; and (3) following the wine tourism local initiatives in the area, promoting sustainability and a zero km economy as a flag.

The selection of the equipment was performed according to the biomass to be consumed, average moisture content of 20 % on wet basis, an ash content of 6 % on dry basis, a low heating value of 14.8 MJ/kg and a particle size distribution classified as G50. The low density and irregular shape make the hog fuel required an adaptation of the boilers feeding system: the silo was designed to avoid bridges and the feeding screw is prepared for particles with longer size. Regarding the combustion system, the higher ash content and lower density compared to regular forest wood fuels, was taken into account in the selection of the system and in the operational parameters. As a result, a Heizomat RHK-AK-500 boiler of 500 kW was installed. It fully runs on vineyards pruning wood hog fuel. The saving in natural gas and electricity are up to 153 and 13 MWh, respectively, thanks to the use of biomass.

The total investment of the installation was 600.000 €, the consumption of biomass from vineyard pruning it is of 225 t/y (on average during the project although the potential can be up to 30,000 t/y in the area) that comes from 375 ha in a radius lower than 15 km. The emissions avoided are 125 t CO_2/y, and 4 permanent jobs were created in the entire value chain.

This information was obtained from uP_running project [7].

7.2 Sabando, Spain (400 kW_{th})

Sabando it is a small village of 40 houses that belong to the town of Arraia-Maeztu located in Euskadi (Spain). The village of Sabando, with 89 inhabitants, is situated in a hidden valley, surrounded by mountains, beech and oak forests.

One of the residents of the villages, had the idea of taking advantage of the existing resources seeking to (i) use the local biomass, (ii) reactivation of the rural environment, (iii) generation of local employment, (iv) reduction of carbon dioxide emissions. In order to achieve these goals, the decision focused on the creation of a small district heating to supply sanitary hot water and heating through micro heating networks in the municipality (all the houses), optimising the performance of these common systems with respect to the individual ones, generating local work and contributing to cleaning the forest, with all that this implies in terms of fire prevention.

In 2013, the installation and undergrounding of networks was undertaken (Figure 6) and the appropriate tests were carried out prior to paving. Two biomass boilers of 200 kW each, were installed with an accumulation vessel of 5.000 liters. For this installation, 300 t/y of local forestry biomass was consumed (with an average of 35-45 % of moisture) and stored in the village.

Figure 6. Civil engineering carried out to develop the district network in Sabando.

Regarding the economic data, the investment reached 582.128 €, with 80 % funded by the Basque Government and 20 % by the Sabando Administrative Board. Furthermore, the inhabitants had to pay 1,000 € for connecting to the district network and 300 € for maintenance. As a result, the final price of kWh_{th} was at 0.025 €/ kWh_{th}. Taking into account these data, the annual savings obtained were around 40 % per habitant, the average heating cost was of around 2,500 €/year (using heating oil) and now is around 1,500 €/year (with the DH, and taking into account the heating but also the hot water).

This information was obtained from Promobiomasse Interreg project [8]and REHAU [9].

8. Conclusions

This catalogue intends to provide the user with a better idea of what a district heating is, the information that should be retrieved in order to carry out an economic assessment such as the energy demands of the building to be covered by the DH, how to assess the power of the installation, the amount of biomass needed, and how to calculate the economic profitability based on simple equations. Additionally, it provides a guideline of the common steps to be followed and the group of stakeholders than can provide support if necessary.

Taking into account all this information, this report can serve as general guidelines/ handbook for a stakeholder willing to promote a district heating unit, but who lacks of technical knowledge or a general overview of the steps that need to be followed prior to investing.

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