- *A district heating plant using wet wood chips (30 to 55% moisture content) as a fuel is a good way to utilise a green fuel*
- *A combined heat and power plant is much more complicated than a DH and needs to be of much larger size*
- *The layout of the grounds of the plant is very important for a smooth operation*
- *The plant should preferably have its own weighbridge*
- *The silo of the plant should be large enough for 10 days operation at full load*

District heating, using wood as a fuel

Pieter D. Kofman

Introduction

In a previous COFORD CONNECTS Note we have seen that District Heating (DH) can use a number of energy sources and fuels, but woodfuel is certainly one that should be considered as:

- Wood is readily available across Ireland
- Woodfuel is renewable
- Woodfuel is an indigenous fuel, which can replace imported fossil fuels
- Wood harvest for district heating purposes will create and sustain employment in rural areas
- Using wood as a fuel in modern district heating combustion plants will reduce emissions of fine dust and other unwanted materials
- During harvest, unwanted trees, double stems, unwanted species, deformed trees, small trees can be sustainably removed from the forest and used as a fuel, thus improving the quality of the remaining stock and concentrating the growth on fewer, better trees to the benefit of the owner and the wider construction wood industry.

Woodfuels

In principle, DH plants could use several different wood fuels:

- firewood
- wood pellets
- dry wood chip
- wet wood chip.

The use of firewood in DH is almost unthinkable because it is very hard to imagine how such a plant could be automated in fuel feeding.

Wood pellets should not be used in DH because they are a manufactured and expensive fuel and are best reserved for home-heating in areas where district heating is not feasible.

In the Irish climate it is difficult and expensive to produce sufficient quantities of dry woodchip (let us say of below 30% moisture content).

However, producing wet woodchip of between 30 and 55% moisture content is fairly easy. Most District Heating plants on the continent run on wet wood chip with an average annual moisture content of around 45% but permitting a range of

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between 30 and 55%. By using specialised techniques, these plants have a good output of heat. Coarse wood chips (P45 or P63, see ISO 17225-4) are very suited for district heating plants (see figure 1).

Figure 1: Coarse wood chip.

This COFORD CONNECTS Note will focus on woodchip in the 30-55% range as a fuel for District heating, or for Combined Heat and Power plants (CHP).

When considering fuels, it is worthwhile to study the ISO standards on Solid Biofuels, especially ISO 17225-1 Solid biofuels - Fuel specifications and classes - Part 1: General requirements and ISO 17225-4 and 9 which detail requirements for wood chips and industrial wood chip and hogfuel respectively.

By the end of 2024 or early in 2025 a new ISO Technical Specification (TS) will be published that elucidates the use of ISO standard of solid biofuels. This TS19595 is called: Guidance for characterization of wood chip fuel – Essential information for producers and users.

This TS as well as all the relevant standards are for sale by NSAI in Dublin.

Location

An obvious point though not always possible is that the DH plant should be as close as possible to the heat users. However, woodfuel, especially woodchip is inherently a high volume, low energy density material, meaning that a lot of truck movements will be needed to supply the plant with fuel. Since the reception silo of any wood-fired plant is limited in size, truck arrivals must be spread over the day to receive the fuel. The unloading of the supply vehicles may cause some noise and some dust. So, for these reasons and the overall amount of space needed, wood-fuelled DH systems are best located in an industrial area or outside town.

The main elements in a wood-fired DH system

A wood-fired DH system is composed of several elements:

- A fuel reception area
- A main fuel silo
- A fuel feeding system
- A boiler or boilers
- A flue gas cleaning system and chimney
- A flue gas heat recovery system
- An ash removal system and ash storage facility
- The principal heat exchanger
- Water treatment and pumping system and heat storage tank
- Administration and technical facilities.

Most of these elements can be found in Figure 2.

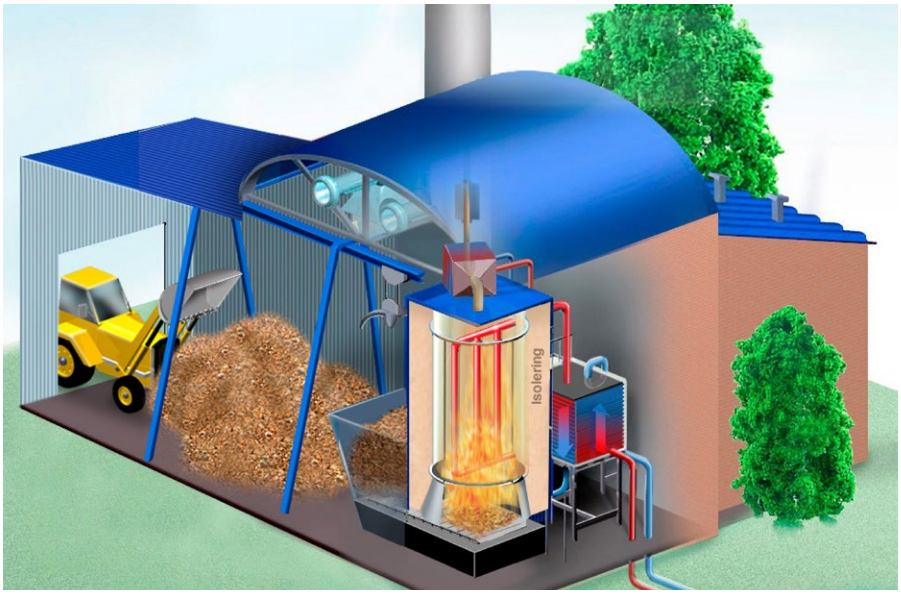

Figure 2: A simplified view of a district heating plant on wood chip (By kind permission of Fjernvarmeskolen.dk).

Fuel reception area

Woodchip is a high volume, low energy density fuel and is usually transported in either walking floor trucks or in containers on a truck and trailer combination. Both are unwieldy and need a lot of space to turn around.

Plants of 2 MW installed capacity or more should have their own weighbridge to determine the mass of the truck on arrival and departure and hence the mass of the delivered fuel. If the plant does not have its own (certified) weighbridge, an external weighbridge has to be used and the trucking company needs to deliver the weighbridge receipts (both in and out) to the plant.

A clever solution for the location of the weighbridge on the fuel reception area is in front of the building with an entrance and exit road in the form of an U. The truck can drive in on one leg of the U, be weighed, and then drive almost out of the other leg, before backing towards the fuel reception pit at the side of the boiler house. In larger plants, there are reception pits on both sides of the boiler house.

In Figure 3 an aerial photo of the DH plant in Rye, Denmark is shown. The light-coloured roof is the original fuel silo, the dark coloured one the extension when a second boiler was installed. In front of the chimney one can see the weighbridge, which can be accessed from both driveways. The round silos are the heat storage tanks.

Figure 3: Aerial picture of Rye District Heating plant.

The fuel reception pit should be sufficiently large and deep for a full load of woodchip from a walking floor truck (about 100-110 m^3) to be offloaded without overspilling from the reception pit. The reception pit is kept closed during normal operation of the plant and is only opened during fuel reception. A raised bar prevents the truck from reversing into the pit. If tipping trucks are used, then the opening should be high enough to match the full height of the offload from the truck. The reception pit is emptied by the overhead crane (see Figure 4).

Figure 4: The grab of the overhead crane is emptying the reception pit.

During unloading the truck driver remains in his cabin to avoid dust and the risk of personal injury. The gate of the reception plant is closed unless there is a fuel delivery. This is a safety precaution that no-one can fall in the pit and that dust and fungi spores are kept within the building.

Main fuel silo

The main fuel silo should be large enough to contain the amount of woodchip that would be consumed at full power over a period of about 10 days. This makes it possible to cease fuel deliveries during holiday periods such as between Christmas and New Year or extended periods of bad weather.

The fuel is taken from the fuel reception pit by the grab of an overhead crane. Usually, the fuel is spread over the entire area of the fuel silo as it being unloaded, so that it is well mixed as it enters the boiler, thereby making for a more uniform moisture content in the fuel, see Figure 5.

It is good practice to pull the combustion air for the boiler from the main fuel silo area. This high volume of air will draw dust and any fungal spores from the silo area directly into the boiler. The silo is thereby more or less at a slight underpressure compared to outside.

Figure 5: The wood chips are spread over the main silo area.

In large plants with a lot of fuel movement, it can be a good idea to install a screen through which the fuel has to pass. Large oversize particles can then be sieved out and will not block the auger.

Care must be taken with both systems that the fuel cannot burn back to the fuel silo. That is also the reason why the fuel should be taken from the silo by an overhead crane and dumped in a reception hopper. If a burn back occurs, only the amount in the hopper can catch fire and not the large volume in the silo.

The silo should be separated from the rest of the building to keep dust and spores from the main building. If there is a door between the main building and the fuel silo, is important that it is self-closing after passage. The door also should have a safety switch to shut down the overhead crane while there are people in the silo area.

Woodchip is a live material when it arrives in silo. The micro-organisms living on the chip will consume oxygen and produce carbon dioxide. Therefore, one should never enter a below ground fuel reception pit nor silo without a fresh air supply. It is also good practice to work with two people, where one person always is outside the silo. In case the person in the silo faints, the outside person can raise the alarm. Do not attempt to rescue the fainted person but wait for the emergency services with breathing apparatus.

The fuel will be relatively wet on arrival, meaning that the fuel will start to self-heat due to microbial activity of fungi and bacteria, but if you maintain the principle of first-in, first-out for the fuel, then the storage period will not be long enough for that self-heating to become a problem in the form of self-combustion.

Fuel feeding system

Somehow the fuel has to be transported from the fuel silo into the boiler. The overhead crane will take fuel from the silo and dump it in the fuel reception hopper of the boiler. From there the fuel can be transported by an auger or by a hydraulic push system.

The hydraulic push system is the most reliable system because of its force it is almost indifferent to oversize particles. An auger system is sensitive to oversize particles, which may block the system.

Boiler

For use as a heat source in a wood-based district heating plant, grate-based boilers are the obvious choice. They come in a large variation of sizes and are a reliable way to produce heat.

The boiler should be capable of handling woodchip from 30% to 55% moisture content, and generally an annual average level of around 45%. This means that the boiler is equipped with a brick lining that reflects the heat of combustion onto the woodchip and thus assists in the evaporation of the moisture from the fuel. If such a boiler is fed woodchip that is too dry, so below 30% moisture content, then the boiler will burn too hot and there is a risk that the brick lining may be damaged.

Of course, these boilers should have automatic de-ashing. The ash can either leave the boiler dry or it can fall in a water bath to quench any glowing particles. The ash is after both systems transported into a container for disposal.

Deciding on the size of the boiler is an extremely important step in plant design. A boiler which is over-dimensioned for the task will never burn well and will cause a lot of pollutants to be emitted. A boiler that covers 60% of the peak load of the boiler will cover almost 95% of the demand over time. For the remaining 5% a heat storage tank or a back-up boiler can be used.

When starting a DH system, it is likely that the number of customers will grow over time, so a slightly larger boiler will capture that demand in the first years. It is good practise to consider how the DH system will grow over time and plan for that eventuality. If one builds all buildings to fit the initial boiler only, then the costs of adding a second boiler will be almost the same as for the initial one. It is much better to build the boiler house so large that a second boiler can be placed next to the first boiler.

The fuel silo should also be planned in such a way that it easily can be enlarged to accommodate extra fuel should a second boiler be installed. This may mean that the overhead crane initially is slightly oversized, but it will save a lot of money if that crane does not have to be replaced when and if the capacity of the DH is enlarged.

Flue gas cleaning, heat recovery and chimney

When the gasses from the burning chips leave the boiler, they pass through a filter that retains fine dust. These systems are standard on boiler systems provided for use in the EU.

The hot flue gasses then pass a heat exchanger where the return water from the DH system is heated by the flue gasses which in turn are cooled to below 65 ^{o}C. This causes the moisture in the flue gasses to condense and release most of the energy that has been used to evaporate the water from the fuel. This raises the efficiency of the DH system considerably, and it is now a standard feature in modern plants.

During the condensing of the water in the flue gasses, a kind of raindrops are formed in the condenser. These capture most of the remaining fine dust from the flue gasses, while they drop down. The flue gasses are now so cold, that a ventilator is needed to blow the gasses out of the chimney.

The visible "smoke" coming out of the chimney is thus the condensing of the remaining moisture in the gasses and not really smoke at all. It rapidly and safely disperses to the surrounding air.

The condensate from the condenser is still rather hot at around 65 ^{o}C and contains fine dust. The condensate can be used in a water-to-water heat pump to regain as much energy as possible. That heat pump transfers the energy to the DH water system.

A flocculant is added to the condensate which causes the fine dust particles to clump together. These small clumps are then filtered from the water before it is released to the sewage system, see Figure 6.

Ash removal and storage facility

The ash is usually removed from the boiler by an auger that takes the ash all the way to a closed container.

There are three sources of ash:

- Bottom ash
- Fly ash from the filters
- Fly ash from the condense water filter,

The bottom ash is what falls off the grate after the chips are burned out. This ash may contain slag, which is formed from sand and other ash. Because of the heat in the boiler, these particles my clump together. Some can be so large that they must be broken up by hand before they can leave the boiler by the ash auger.

The fly ash is from fine dust particles that are caught in the flue gas filters.

Figure 6: Sludge filter that takes the fine particles out of the condensate.

During the incineration of the fuel the few heavy metals that are in the fuel by nature will evaporate and condense on the fine dust particles. The sludge from the condense water filters likewise contains more heavy metals than the bottom ash.

If the bottom ash is to be used as a fertilizer in the forest, the fly ash and the sludge should be kept separate from the bottom ash. These two fractions are landfilled.

If the ash is not used as a fertiliser, then the fly ashes can be deposited in the same container as the bottom ash.

Care should be taken when handling ash. The ash is highly alkaline and will burn the fingerprints from your fingers if touched without gloves. When the ash encounters moisture it will settle like concrete, forming hard lumps.

Principal heat exchanger

In the principal heat exchanger, the heat energy from the water in the boiler mantle will be conveyed to the district heating water. That water will have a temperature of around 70 to 80 ^{o}C when leaving the plant and will return to the plant at about 45 ^{o}C.

Water treatment and pumping system and heat storage tank

On the premises of the DH plant there will be a large array of pumps and other equipment.

To reduce the corrosiveness of the water, oxygen should be removed from the DH water by adding some chemicals, likewise chemicals can be added to make the water "smoother" so that the friction and loss of energy in the piping system is reduced.

The quality of the circulation water is monitored at all times.

The pumping system to circulate the hot water to the buildings always has a back up to allow for maintenance and repairs. All DH pipes are well insulated to reduce transmission losses, see Figure 7.

Figure 7: A new supply of main district heating pipes has arrived at the plant.

Administration and technical facilities

Obviously, a DH plant cannot run without an administration nor without a workshop.

The DH building should contain offices for the operational staff and the administration, plus normal canteen and other facilities. This canteen can also be used to receive visitors, because it can be expected that some of the first DH plants on wood fuels will receive a fair number of delegations from other areas that come to learn.

A DH system contains many mechanical, electrical, hydraulic and other components. Therefore, a well-equipped workshop is needed to be able to carry out as many repairs in-house as possible. Usually, the staff of the plant also maintain the piping system in the town and the heat exchangers at the individual consumers, so a well-equipped service vehicle is also a must.

In the technical facilities there should also be space where the quality of the fuel can be checked. So there needs to be a drying cabinet to check the moisture content of every delivery, so payment can be made on a delivered-in energy basis. There should be a room where samples of each load can be stored in airtight containers for a period (months or at least as long as it can be reasonably expected that that cargo of fuel has been burned) to document the quality.

In the technical area there should also be space for a diesel operated generator that can keep the plant up and running in case of an external power failure.

To even out the load on the boiler, a heat storage tank or silo is normally part of the of the DH system. When the boiler is producing more hot water than is consumed at that moment, the surplus is fed to the storage tank. The surplus can be used when the heat demand exceeds the boiler capacity at that moment.

A heat storage tank can also be beneficial in periods of very low demand, for example on hot summer days. One could then run the boiler at a good capacity during a limited period. The heat is stored in the tank, and the boiler can be shut down automatically. Several days later this procedure can be repeated, so that the boiler is not left running idle for prolonged periods of time. An idling boiler will not run properly and will emit of lot of dust and unburned carbohydrates.

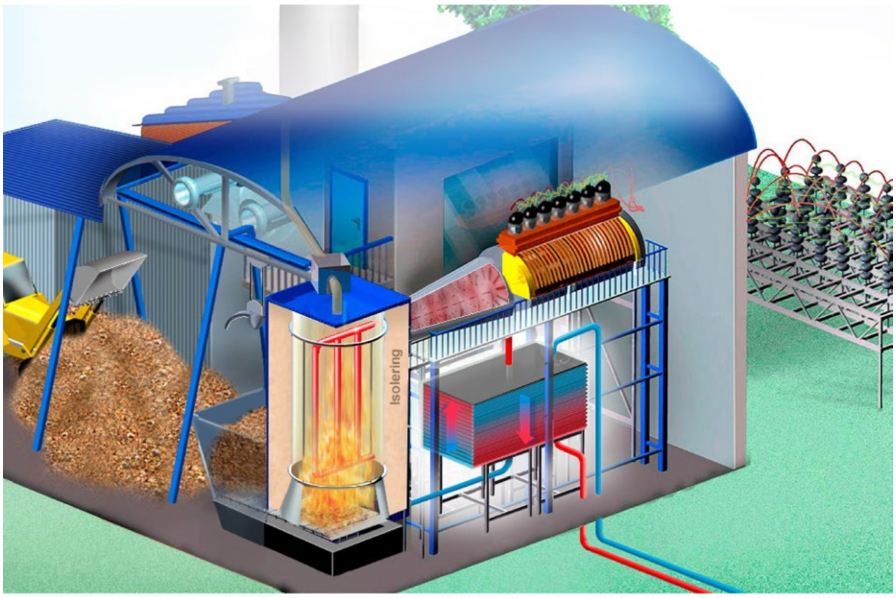

Figure 8: A simplified view of a combined heat and power plant on wood chip (By kind permission of Fjernvarmeskolen.dk).

Extending a DH system to a combined heat and power plant

To extend a DH system to a combined heat and power plant makes the system much more complicated, as can be seen from Figure 8. Compare this figure to Figure 2.

Also CHP plants come in a large variation of sizes, but it must be stated that the smaller ones all need a dry and homogenous fuel to operate properly. These plants are often based on a gasification system, that produces a gen-gas from wood. This gas is than used as a fuel in a piston engine, that in turn drives a generator. Because the fuel gas is used in an engine it must be very clean from dust and tars. Tars are often generated when the gasifier and the subsequent gas cleaning are not working optimally.

More usual is to go for a much bigger plant, that produces steam to power a steam turbine, that in turn drives the electric generator. Because the turbine and the generator are expensive pieces of kit, the lower size of the plant should start around 5 MW electric. This means then also a surplus heat production of around 15 MW. This is a lot of heat. In fact, one should consider if the electricity is the main product, or if the heat should be the main product. It is very important to find an outlet for the heat and to get rid of 15MW heat a fairly large town is needed to absorb that amount through a district heating scheme. Without an outlet for the heat the CHP might not be viable.

The advantage of the stand-alone heating plant is simplicity of design and operation. CHP plants need more sophisticated engineering, but they have a role where there is a demand for dispatchable power and a district heating need.

From a rather simple incineration plant, suddenly the plant needs to produce steam to power a turbine that drives the generator. The steam pressure and temperature must be closely controlled.

At the elevated temperatures needed for a steam producing boiler the chemical substances in the wood may turned extra corrosive, so the materials used to construct the boiler will need to be of a much higher quality.

A CHP system also need staff around the clock, while a DH system on wood only is staffed during normal working hours and outside that period, the plant will run fully automatic.

The investment in a CHP is very much higher than for a wood burning DH.

It should be remembered that for every MW electricity that is produced by a CHP, 3 MW heat are to be disposed of. This means that a CHP needs a larger town to supply the heat to.

Advice

When considering a DH (or a CHP) an experienced consultancy should be engaged to advise on the many factors to be considered in designing and costing the plant, and in determining the supply chain needed for cost effective operation. It should be considered to look for consultancy firms in countries that have a long-time history of constructing and running DH or CHP systems on wood, like Denmark, Sweden, Finland, or Austria amongst others.

Visits to existing plants in these countries would be a good way to get an overview of the complexity of these installations.

Bioenergy with carbon capture and storage (BECCS) may be considered in the design of very large installations only, due to the large additional costs of such operation.

Further reading

A number of COFORD Connects Notes should be consulted in conjunction with this note:

- Quality wood chip fuel
- Units, conversion factors and formulae for wood for energy
- Ordering and receiving wood chip fuel
- Delivery and storage of wood chip fuel.
- Handling and using wood fuels in a safe manner with regard to Carbon Monoxide (CO).
- Review of worldwide standards for solid biofuels, revised April 2021
- Software to help the wood for energy community

These notes are accessible on the homepage of COFORD: www.coford.ie/publications/cofordconnects

or on

www.woodenergy.ie/softwarepublications/cofordconnectsnotes/

There is also a model contract for the supply of wood fuels, available from

www.coford.ie/media/coford/content/toolsservices/ModelContractWoodfuel2021291021.pdf

The book "*Wood as a Fuel*", available at Amazon and other outlets is also recommended for those scoping an investment of wood-fuelled district heating.

Acknowledgements

Illustrations 2 and 8 in this COFORD Connects Note are kindly provided by Fjernvarmeskolen.dk in Denmark, an organisation that provides teaching materials on district heating to schools in Denmark.