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Biomass Utilisation in District Heating Plants

European Commission
Horizon 2020
European Union funding
for Research & Innovation

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This project is funded under the LCE 14 2014 Support Programme „Market uptake of existing and emerging sustainable bioenergy“, as part of the Horizon 2020 Framework Programme by the European Community.

Contents

1. Basic Technical Rules

1.1. Introduction to bioenergy heating systems

The term "Bioenergy heating systems" refers in this project to plants with heat production based on different types of biomass and without electrical power generation. The maximum boiler temperature is often restricted to 120°C and the design pressure is max. 6 bar, - the specific parameters are subject to national regulations. The typical size of such plants is within the range of 100 kW to 10 MW. The plants are operated as district heating plants in towns, in hospitals, military camps, schools and similar large building complexes.

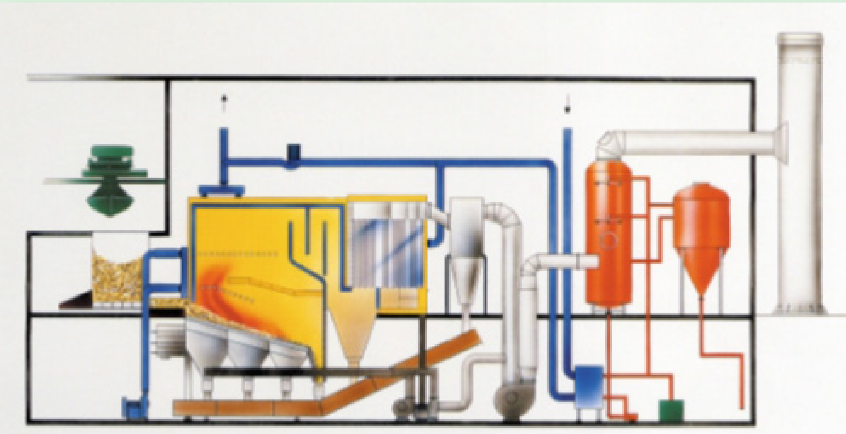

Figure 1: Typical district heating plant with step grate using wood chips as fuel. The flue gas condenser is shown in red. The condenser regains the evaporation energy of water from the combustion process. The size of such a plant is typicalyl 3-6 MW output. Source: Wood for energy production. Denmark 1999

Efficient and complete combustion is a prerequisite for the usage of biomass as an environmentally friendly fuel. To ensure a high rate of energy efficiency and to avoid the formation of environmentally harmful compounds like unburned gases and fine coal particles the complete incineration of the fuel is required. A correct mixture of biomass and combustion air, more precisely the oxygen in the combustion air is necessary. The ratio of the actual combustion air to the theoretically needed combustion air – the so called Lambda – is 1.4. In other words, 40% more combustion air is needed than the stoichiometric fuel rate – which is theoretically ensuring a complete incineration - requires.

Usually the flue gas cleaning systems consists of a cyclone and a bag filter/wet scrubber. The cyclone catches the larger flue gas particles and the sparks from the combustion process. For straw firing, a bag filter is normally used because it cleans the very fine particles generated by the combustion process. Electrostatic filters (ESP) are sometimes used as well. For wood firing, a scrubber is used sometimes, but is a flue gas condenser is more economical where the energy, latent in the evaporated water, vaporized by the heat of combustion process, is regained. This can increase the efficiency and the resulting heat output of the plant by 20%.

A heat storage tank is mainly used in electricity generating plants (Combined Heat and Power plants; CHPs) because the demand for heat does not always correspond to the demand for electricity. Some district heating plants use heat storage tanks because it makes it easier to close down the plant for weekends in summertime and for maintenance and the efficiency of the boiler can be potentially increased when the heat can be buffered in a storage.

Ash handling systems transport the ash from the grate and the filters to a container. There are wet and dry systems in use. The ash has to be deposited or can be used as fertilizer- depending on the content of heavy metal and other forbidden or unwanted components. The usage and disposal of ash are subject to national regulations.

Boiler control systems and fire control systems are integral parts of the safety system. Both systems are normally operated from the control room in or near the boiler house, but in addition, many plants at this size have got remote control systems as well, which means that persons on duty can stay home during evenings and weekends and monitor the system. Protection of life and health is important. Exposure to dust, gas emission from the biomass storage and risk of fire are forbidden situations.

The housing for the boiler(s), fans, flue gas cleaning devices, control rooms and rooms for persons on duty are designed and built in such a way that the appearance matches the "look" of a conventional industrial area. The size of biomass storage is normally designed for biomass consumption of one week.

1.2 Selection of fuel: Solid Biomass (Wood, Straw, Pellets)

Wood has the best combustion characteristics of the different types of biomass and is by far the most used biomass for energy conversion/ generation. Straw from grain production comes in second.

In this context, this report describes the fuel qualities of wood and straw. In addition an example describes how to mix different types of biomass to a usable biofuel with acceptable characteristics.

The quality of the wood fuel plays an important role in the design of the combustion system and for the plant efficiency. In general, the smaller the system is the higher the quality requirements for the used fuel are. The highest quality wood chips for small installations can be made of delimbed small wood stems . Where lower quality chips can be fired, the chips are made of non-delimbed small trees – using a high share of the entire tree. The key parameters that need to be specified are:

- Moisture content
- Dimensions of the chip
- Origin of the chip
- Ash content

There are other parameters which are relevant, but the four mentioned ones are the most important. The European Committee for Standardization (CEN) has formed a Technical Committee 335 (TC/335) that develops standards for the usage of solid biofuels. One of the standards is EN 14961 : Fuel Specification and Classes with composite parts.
The same standards have to be applied for the raw materials used for wood pellet production. In general it is important to keep the ash content in the pellets low, at best under 0.5%. This means that the share of bark in the raw material must be very low - almost non-existing.

Wood / straw		Wood chips	Wheat straw
Carbon	C % of DM	50	47.4
Hydrogen	H % of DM	6.2	6
Oxygen	O % of DM	43	40
Nitrogen	N % of DM	0.3	0.6
Sulphur	S % of DM	0.05	0.12
Chlorine	Cl % of DM	0.02	0.4
Ash	a % of DM	1	4.8
Volatiles	% of DM	81	81
Calorific value	MJ/kg of DM	19.4	17.9
Typical water content	%	35-45	10-15
Actual calorific value	MJ/kg	9.7-11.7	14.8-15.8

Table 1: Fuel data for wood chips and straw. For wood chips the bark fraction contains approx. 6% ash and the clean wood fraction only approx. 0.25% ash. Source: Wood for Energy Production, Videncentret 1999

1.3 Biomass Storage

Figure 2: A Danish wood chip fired District Heating Plant in Ebeltoft, depicting an in- and outdoor storage as well

The size of the fuel storage depends on various factors, mainly on the fuel supply contract made with the fuel supplier. However, the capacity of the storage for wood chips should equal the consumption of minimum 5 days of heat production at maximum capacity. This approach enables the operation during week-ends and provides for a high security of supply status during extreme weather conditions. Most plants go for an indoor storage solution, thus outsourcing the handling of larger storage volumes to the suppliers of wood chips. However, a few plants also operate an outdoor storage. Due to the risk of spontaneous fire, the wood chips are piled to a height of max. 7-8 metres. In indoor storages there is risk of breathing in allergy-causing dust and micro-organisms, such as fungi and bacteria, during work hence piling to a height of max. 7-8 meters is recommended from this perspective as well. It is strongly recommended never to work alone in wood chip silos. The working environment issues are discussed in Section 9.

Figure 3: District heating plant in Austria. The wood chips storage is located to the right, and the boiler house to the left.

In a straw fired plant, the storage is more space consuming. On average, the plants have storage facilities with a capacity for 8 days of operation at full load - which, for the average plant, is equal to 3.7 MW – corresponding to 400 big bales. The required floor space including driveway etc. for this amount of straw equals to approx. 600 m2. The farmers (straw suppliers) deliver the straw to the plant by trucks or tractor-towed trailers. The plant operator takes care of the unloading with a forklift truck. The bales are weighed on unloading; the water content is determined subsequently. The plants receive straw with up to approx. 20% water content. Bales with a higher water content are returned, since combustion would thereby be too uneven, especially at part load operation. As mentioned in section 9, working in the straw storage can create the risk of breathing in straw dust containing allergy promoting fungus spores and micro-organisms.

1.4 Boiler and fuel feeding system

The boilers for district heating without electricity generation are simple devices, using hot water at relatively low temperature (often 120°C) and at low pressure (often 6 bar) as the medium for heat transportation (often 120°C). The boilers are quite similar for different types of biomass fuels, whereas the design of the biomass feeding system, the combustion area in the boiler and the flue gas cleaning system depends on the biomass fuel type

The combustion air system is more or less similar for different types of biomass fuel. The important factor is that the volatiles, which contribute to 75-80% of the energy output, have to be burnt in the hot zone of the combustion chamber. The residual amount of the energy output is induced by glowing - as charcoal on the grate or in the herd - depending of the combustion system.

Boiler size in MW

The boiler size is calculated to match the maximal demanded capacity on the coldest day of the year. The maximal demanded capacity is composed of the capacity needed to serve the customer needs (room heating and hot water) and the capacity needed to match the loss of the distribution grid. The sum of these figures determines the heat production capacity ex plant. For example, if the maximum heat demand of a town ex plant is 11,200 MWh/per annum, 400-450 single-family houses can be heated. The consumption of hot water amounts to 10% and the distribution grid losses account for 30%.These figures are based on what is assumed will be used for "normal" year of 3,100 heating degree days which corresponds to a "normal" year in Northern Germany, Denmark, Southern Sweden etc.

The calculations look like follows:

Room heating 60%: 6720 MWh
Distribution loss and hot water 40%: 4480 MWh
Boiler size: ((3.2*6720)+4480))/8760 = 3 MW

The factor 3.2 is an empirical figure for the maximum capacity required for room heating purposes on the coldest day of the year (8760 is the number of hours of the year). The boiler is selected for 60-70% of the maximum load. In this example 66% equals to 2 MW. An oil-fired boiler is installed to cover the entire output requirement of 3 MW to be used at peak loads, repairs, or break-downs of the biomass fired boiler.

Biomass feeding systems

The size of the storage of wood chips should equal the consumption of 5-7 days at maximum heat production capacity, in order to ensure operation during week-ends and for security of supply reasons during extreme weather conditions. Often a crane is used to transport the fuel from the indoor wood chip storage to the boiler feeding system. Many plants use a hydraulic feeding system - like a ram-stoker - which pushes the wood chips on to the grate. In general one can say that the feeding systems for wood pellets are simpler and less expensive in comparison to wood chips feeding systems. Pellets are more homogenous, more dry and smaller sized than wood chips. This means that the feeding system can be scaled down and other equipment like small augers can be used in the feeding process.

Feeding systems for straw are mainly constructed as cutters or shredders. Cutters are quite expensive to operate because the electrical consumption is high, on the other hand the work load of the cutter is low, thus high fixed cost percentages per straw unit are generated. The shredder transforms the straw "back" to the condition before the baling process. The bales are conveyed towards the shredder that revolves at up to 30 strokes/min. A set of upward and downward moving racks tears apart the straw. The straw falls through a hopper on a screw stoker or ram stoker that pushes the straw into the boiler. See figure 4.

All firing systems for biomass require the installation of a fireproof tunneling front of the boiler. This device prevents backfiring if the fire burns "against" the system flow direction – so reverse flow - of the fuel feeding, thus could ignite the biomass in the silos and hoppers outside of the boiler.

Figure 4. The automatic crane is in waiting position, until the control system "calls"for straw. The crane lifts the bale up to the straw shredder where the gate opens automatically. The bale is shredded and screwed or stoked into the boiler

Another well-known feeding system is the "cigar burner" where whole big bales, each weighing around 500 kg, are pushed into the boiler in an endless line where they burn from the end entering the boiler. The unburnt straw and ash falls on a water-cooled vibrating grate for final combustion. See figure 5.

The boiler for wood

Wood chips are burned on a grate in the combustion chamber. The most common type of grate in wood chip-fired systems in district heating plants is the step grate/ or inclined grate.

See Figure 1. Another type is the so-called chain grate/ or travelling grate. For both grate types, the primary combustion air is supplied from underneath the grate and passed up through the grate carpet. If burning wet biomass like wood chips in a range of 30% - 55% moisture, the combustion chamber must have refractory linings at the fuel inlet and in the bottom of the combustion chamber along the grate which ensures that the fuel is dried out at the inlet of the boiler, that the fuel is ignited by heat radiation from the refractory and which ensures a high combustion temperature. Without refractory in the boiler it is not possible to effectively burn wet biomass.

When firing with dry fuels, e.g. wood pellets, the refractory lining does not provide any added value to the combustion process quality. Rather the opposite is the case. Since there is no need to dry out the fuel, the combustion temperature might become too high, thus the risk of too fast ignition of the fuel and the risk for slagging formation on the grate might occur. This is a good example why the type of fuel and the water content in the fuel must be determined in the design phase.

About combustion air systems. See below.

The boiler for straw

The grate for straw burning is often an inclined, water-cooled vibration grate, frequently divided into several combustion zones admitting the primary air for the combustion air to be transported through the grate. The air flow can be controlled in each zone in order to secure a complete incineration of the straw. See figure 5. To ensure a high rate of energy efficiency, the combustion process should be complete in order to avoid the formation of environmentally harmful compounds like unburned gases and fine coal particles. The basic pre-conditions to ensure a complete combustion are therefore:

- A correct mixture of biomass and oxygen (oxygen in the combustion air) at a controlled ratio. The recommended ratio is 1.4 (the air excess called Lambda). This means that it is necessary to use 1.4 times more combustion air than theoretically necessary to ensure a complete combustion

- A correct distribution of primary and secondary air at the correct air pressure and via air nozzles – placed at positions which intensively support the combustion process. The primary air, which is supplied through the grate, helps to dry the fuel, cool the grate and burn out the charcoal. The secondary air has to be distributed through many air nozzles - installed in the boiler wall - in order to burn out the volatile gases.

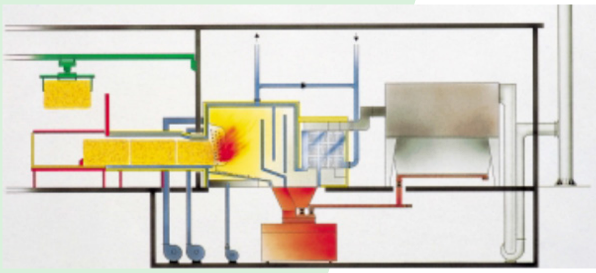

Figure 5. A district heating plant with cigar-fired boiler for straw. The automatic crane places the big bales in the feeder box, and the bales are pushed into the boiler. The flue gas passes through the 4 empty passes in the boiler and through the economiser that consists of vertical fire tubes. All air fans are located in the basement in order to reduce the noise.

1.5 Flue gas cleaning systems

The flue gas, generated by the combustion process has to be cleaned in order to comply with national requirements for emissions. Flue gas cleaning reduces the amount of fly ash, thereby avoiding particles spreading over the surrounding area. Flue gas cleaning equipment may consist of:

- Multicyclone: extracting dust particles from the flue gas by centrifugal flow taking place in vertical tubes, thereby cleaning the flue gas

- Bag filter: The flue gas passes through fine-meshed/pored bags that trap the suspended solid particles.

- Electrostatic filter: The flue gas passes through an electric field, and the particles precipitate on electrodes.

- Flue gas scrubber: The flue gas passes through a water shower so that the particles are trapped/caught in the water. Flue gas scrubbers are not used very often, because condensation is more attractive from an efficiency, and subsequently from an economic, point of view.

- Flue gas condensation: The flue gas is cooled below the dew point, and the particles are absorbed/trapped by the dew.

The normal equipment for a straw-fired district heating plant is (in order of flow direction) first a multicyclone that serves as a spark trap and trap for coarse particles, followed by a bag filter. The multicyclone reduces the dust in the flue gas from 1,000-2,000 mg dust/Nm3 to 500-600 mg/Nm3. Much of the fly ash from straw firing is very fine-grained (below 0.01 mm), thus a bag filter is the best and cheapest solution for most of the plants. The particle content of the flue gas after the bag filter is at normal operation amounts to 20-30 mg dust/ Nm3 (if bags are in good condition). The flue gas temperature has to be lower than 200 ℃ when entering the bags Electrostatic filters are rarely used in straw-fired plants due to the high price of the electrostatic filter and the high maintenance costs of the filter. In wood chip fired district heating plants the situation is a bit different in comparison to straw fired plants. The particles in the flue gas are bigger in size and the moisture content in the flue gas is higher because of the evaporated water from the wet fuel (up to 55% moisture; normal range: 40% - 45%). The fly ash from the combustion of wood chips consists primarily of relatively large particles that can be trapped in a multicyclone. Most plants are equipped with multicyclones where the dust in the flue gas can be reduced to a level of approx. 200 mg/ Nm3. Multicyclones are inexpensive to buy and maintain, and are normally used for pre-cleaning before entering the flue gas condensation unit. Flue gas condensation is a technique that both purifies the flue gas from dust particles to a level almost similar to that of bag filters and at the same time increases the plant efficiency up to 20%.

In straw-fired plants it does not make sense from an economic point of view to invest in a condenser because of the low moisture content in straw, which is around 14-15%.

1.6 Environmental conditions

The authorities and the public are very concerned about the impact on the environment by energy production. Biomass is considered CO2 neutral, and that is the major driver to promote the use of biomass in the energy supply. But the combustion process generates emissions other than dust and CO2 as well, mostly regulated by national limits. These include CO (carbon monoxide), NOx (nitrogen oxides), SO2 (sulfur oxides), HCL (hydrogen chloride), Dioxin and PAH (polyaromatic hydrocarbons). Table 2 indicates typical data from measurements on Danish wood chips and straw fired plants. The limit for CO emission in Denmark is 0.05 volume% at 10% O2. The CO of straw fired plants amounts to 600 Mg/MJ. This magnitude almost two times as high as the limit. Otherwise under normal conditions the plants are able to fulfil the emission limits.

Table 2: Emissions from wood and straw-fired district heating plants in Denmark. Source: Straw for Energy Production 1998 and Wood for Energy Production 1999.

Emissions	Wood chips Mg/MJ	Straw Mg/MJ
CO	n.a.	600
NO_x	90	90
SO_2	15	130
HCL	n.a.	40
PAH	n.a.	0.18

1.7 Heat storage tanks

Installation of heat storage tanks is often tied to straw and woodchip fired district heating plants. For a 3-4 MW plant the average tank is 400 m3. The advantages of installing heat storage tanks are the following:

- Morning and evening peak loads during the winter season can be shaved, thereby avoiding or reducing the usage of the oil firing system.

• During maintenance, the heat consumption can be drawn from the heat storage tank, thereby avoiding oil firing. A 400 m3 heat storage tank – linked with a plant with a full load capacity of 3 – 4 MW - can supply heat for 7 hours at full load.

• At low system load during summer times, the boiler can operate at full load for a short period while the storage tank is warmed up, and then the boiler can be shut down. The result is an improved boiler efficiency and lower emissions in comparison to continuous operation of the boiler at low system load.

• The personnel's planning of the work becomes more flexible, since, e.g., the boiler can be shut down over the weekend during summer. The drawbacks are increased expenses for investment and maintenance of the tank and of course the heat losses of the tank have to be taken into account.

1.8 Ash handling systems

Straw contains 3-5% ash, wood chips contain 0.5-2.0% ash and wood pellets contain 0.3-0.7% ash. Part of the ash falls off the grate into a hopper under the boiler and is subsequently transported via a chain scraper to the ash container. The chain scraper is usually installed in a water bath where an automatic water addition takes place to replace the run-off water. Wet transport of the ash is the most common application at the plants. Additionally a water bath in the chain scraper is an effective device to prevent the introduction of false air to the boiler through the ash conveyor system. The fly ash consists of the suspended solids which flow with the flue gas through the boiler and are extracted in downstream located cyclones and filters. From there, the particles are transported via screw conveyors to the chain scraper.

Ash contains the unburned components of the biomass, including a range of nutrients, such as potassium, magnesium and phosphorus, thus it can be used as fertilizer in the forest and agricultural sector if the content of other substances that might be problematic to the environment does not exceed the threshold. Using the ash as fertilizer requires permission from the authorities; the content of heavy metals in the ash are often a hurdle for the required permissions. The heavy metals in ash from biomass are: Cadmium, Mercury, Lead, Nickel and Chromium.

1.9 Security and personal safety

Theplant safety includes fire safety and personnel safety. Before commissioning the plant must be approved by the local fire authorities. The plant should be divided into fireproof sections, e.g., as follows:

• Biomass storage
• Biomass feeding system
• Boiler room
• Other rooms: Control room, offices, canteen, workshop etc.

Fire in the biomass storage or explosions caused by dust or flue gas are regarded as risk. Having said this, the biomass feeding system has to be sealed off from the storage room with a fireproof wall to prevent fire from moving backwards from the combustion chamber to the storage. In most plants, the feeding systems are equipped with an airtight "plug" of biomass and a sprinkler system located just before the combustion chamber.

Attention should be paid to the risk of flue gas or dust explosions. Unburned gases in mixture with atmospheric air may cause extremely violent explosions if gases, e.g. due to an over pressure in the combustion chamber are leaking into the boiler room or the fuel feeding system. Flue gas explosions may also occur in the combustion chamber if the biomass has been glowing on the grate for some time due to a shutdown of the boiler and atmospheric air is introduced to the boiler by opening an inspection door or similar devices. Dust from handling of biomass in a special mixture with atmospheric air can be ignited by sparks from electric switches or tools. This can cause very serious explosions.

In relation to wood pellets and the thereto linked risks it was clearly shown that pellets can be categorized with respect to their activities, which in this case are related to: speed of oxygen consumption, speed of CO and CO2 emissions, and the potential for heat development. These factors have correlated well, which means that pellets, which consume oxygen fast, also emit CO and CO2, and heat. The differences between inactive and active pellets were significant. Trials on small and large scales have shown that active pellets, contrary to inactive pellets, can:

- Consume all available oxygen within 1-2 days.
- Emit CO to levels higher than 10,000 ppm
- Emit 10 times more heat than inactive pellets, which can lead under certain conditions to self-ignition.

The size, shape, moisture content and the type of biomass directly influence the possible way of transport, handling and storage. One important health and safety risk in handling and transporting biomass is connected to inhaling dust (particularly in situations where biomass is loaded and unloaded). The harm from dust depends on the chemical (and mineralogical) composition, dust concentration and particle size and shape. Handling wet solid biofuels (wood chips) provides a favourable environment for the growth of many species of bacteria and fungi. These micro-organisms produce a large number of microspores (< 5 μm in diameter) which are easily inhalable and which can penetrate the respiratory system and cause allergic reactions.

Figure 6. Wood chips unloaded at a Danish district heating plant. Very high concentrations of mould spores may prevail around the truck and inside the store during unloading, requiring personal protection for employees. Photo: Simon Skov, University of Copenhagen

Truck transport with biomass is done over relatively short distances. It mainly concerns

- transport of wood chips from producers/harbors to a district heating plant
- transport of wood pellets from producers/harbors to an indoor storage at a plant.
- transport of straw bales from farms to plants

The health risks from these operations occur mainly during loading and unloading activities where high dust concentrations may result in a risk of dust explosions and human exposure to dust and microspores.

Health and safety challenges in straw handling at the farms are limited since loading of bales on the truck often takes place outdoors with tractors using fork lifts. The compressed bales do not emit significant amounts of spores or dust. The truck load of straw is covered with a net in order to prevent loose straw to end up along the roads. If the straw is delivered to a district heating plant, individual straw bales are typically unloaded by using a fork lift in an indoor storage hall. This type of operation can expose the employees to significant dust concentrations, thus precautions are needed.

Figure 7. During unloading straw bales the driver and or employee at the heating plant remove the net. This gives an exposure to dust and spores from the straw.

1.10 Quality Management System

Many European countries subsidize the construction of biomass (mainly wood) district heating systems. Investigations in Switzerland, Austria and Germany showed that many of the biomass district heating plants cause much higher energy production costs than expected. They results of the investigations of the analyses indicate that specific investment and operating costs are closely related to the technical design of the plant. High technical quality alone is not sufficient for financially sound plants. Professional management in organization and finance as well as an efficient marketing organization are essential components for a successful plant construction and operation. Other reasons for unexpectedly high-energy production costs are unprofessional project management and poor planning in the construction phase. More details see: www.qm-heizwerke.at.

Main Technical Deficiencies are:

o heat demand of consumers is overestimated
o too big reserve capacity in the heating plant
o oversized pipeline-system
o size of the fuel silo much bigger than necessary
o low utilization ratio of the wood boiler
o fuel quality does not meet the quality requirements of the installed boiler
o faults in the hydraulic and the control system lead to high operational costs.

With professional project management and planning most of these deficiencies could have been avoided. The objective of the tool qm heizwerke is to ensure, that plants are built with:

o high technical and operational performance,
o high utilization ratio,
o low emissions and
o low investment and operational costs.

References

1. Straw for Energy Produktion, Videncentret, Denmark 1998. www.videncenter.dk
2. Wood for Energy Production , Videncentret, Denmark 1999. www.videncenterr.dk
3. LandesEnergieVerein Steiermark, Quality Management. 2006 www.qm-heizwerke.at
4. Health and Safety Aspects of Solid Biomass Storage, Transportation and Feeding. IEA Bioenergy Task 32, 36, 37 and 40. February 2013.
5. Personal communication. Simon Skov, University of Copenhagen
6. Fact Sheet No. 87/ 1995. www.videncenter.dk
7. Large Scale Utilization of Biopellets for Energy Applications (LUBA). Energinet.dk. 2013

2. Examples of Successful Cases

2.1 High efficiency biomass cogeneration plant in Huedin city, Romania

General description of the project

The Company, Paulownia GreenE International SRL took over the public DH service of Huedin city, Cluj County in 01.02.2015, by means of a contract for the transfer of public services, for a period of 20 years, with the possibility of both parties to apply for prolongation by mutual consent. The contract assignment followed the procedures of public bidding.

The old DH system, which has been refurbished, consisted of a 4 MW sawdust boiler while the new one will consist of a DH CHP unit of 1.4 MW (heat) and 1 MW (electricity), using high efficiency gasification technology.
The plant shall supply all the heat produced to natural persons and legal entities in the area of Huedin city, while the electricity generated during the process shall be delivered to the national grid, by means of a conversion unit placed in the vicinity of the plant.

The strategic objectives of the company for the following period are the following:

1. The increase of the number of consumers served by the DH plant

2. The extension of the consumers' network to include the local hospital, schools, kindergartens, courthouse, police and others.

3. The installation of a new cogeneration system using biomass through the gasification process. The capacity of the CHP unit is 1.4 MWh (heat) and 1 MWh (electricity).

4. The plantation of a surface of 130 ha with Paulownia trees for wood and energy exploitation.

Energy conversion

General information	
Technology (e.g. in-house biomass boiler, biomass DH, etc.)	Biomass DH – CHP technology
Year of installation	2004 – the existing plant 2016 – the new unit using biomass through gasification process
Net capacity of the biomass boiler(s)	Existing: 4 MW (heat) New: 1 MW (electricity) and 1.4 MW (heat)
Total annual energy production from biomass	Existing: 3,234 MWh (heat) New: 7,500 MWh (electricity) and 10,500 MWh (heat)

Biomass Fuel(s)

General information	
Type of biomass fuel(s)	Existing: solid biomass – sawdust New: wood chips
Annual amount of biomass fuel(s) needed (fresh or absolute dry substance)	2,200 tonnes / year
Average humidity of the biomass fuel(s)	~ 20%
Average biomass fuel(s) cost (fresh or absolute dry substance)	33 EUR / tonne

Biomass supply chain

The biomass necessary for the existing unit (sawdust) is delivered by companies active in the wood industry, from areas located in a radius of between 3 and 30 km. The biomass supply contract is valid for a period of 3 years.

There are two storage facilities: a larger one, used during winter times, and a smaller one, adequate for the production needs during summertime. The capacity of both storage facilities corresponds to a load capacity equivalent to the biomass needs of 30 operational days. The ash generated by the combustion process is removed by the local sanitization company.

The price of the biomass is directly dependent on the competition within the wood industry sector and on the regulations with regard to forestry exploitations.

In order to prevent the situation of non- or insufficient biomass availability, the company concluded firm contracts with many companies (actually they have ensured the double quantity of what is actually needed). In the near future, in order to reduce the risks and also to cut the costs, the company has already implemented an energy crops plantation (paulownia). From the surface of 130 ha available, 15 ha have already been planted.

Energy consumers and heat distribution

Total annual energy sold / delivered	3,234 MWh
Grid losses	283 MWh / year
Grid length	1,600 m (currently, another 1,700 m are under construction)
Electricity consumption for the grid pumps and the boiler	122 MWh / year
Average price of heat sold / delivered	54 EUR / MWh
Duration of the heat delivery contract	20 years
Parameters determining the heat delivery contract	- price - continuous delivery
Type of consumers	- public institutions - private legal entities - natural persons – individual households - blocks of flats

Investment and financing

The project was financed by a mix of available financing sources. The total investment amounted to EUR 3.3 million and is composed of equity (1.3 million), and a loan of EUR 2 million granted by the Romanian Energy Efficiency Fund (FREE), for a period of 5 years.

The company shareholders are 4 natural persons (Aron Marton Bikfalvi, administrator and technical coordinator, Dinu Gheorghe Tosa, administrator of the company, Maria Tosa, Project Manager and Marla Tosa – Development Manager).

Main difficulties / barriers encountered in the realization of the project

The main difficulties experienced throughout the development of the project concerned the incoherent legislation and the national energy strategies as well as the lack of financing options for this type of investment (it was really difficult to find someone prepared to invest in this project).

Lessons learnt from this investment

The major difficulty was the financing. When the agreement finally came about, the company received only a part of what was needed. The factors that contributed to the success were professionalism, good organization and seriousness of the investor.

Recommendations for other investors / operators

- Evaluate the risks carefully
- Secure biomass supply
- Secure the end consumers

2.2 Biomass DH in Zürs am Arlberg, Austria

General description of the project

Zürs am Arlberg is one of the oldest and most traditional skiing destinations in Austria, located at 1,700 m altitude at the heart of the Alps. Nowadays it is a modern ski resort with approximately 1,400 guest beds in 28 hotels and other buildings. This led to very favourable conditions for the construction and operation of a DH plant (few, large consumers, short network, and high heat demand in winter). Other benefits of the project include an improved air quality in the region (many decentralised oil boilers with a total oil consumption of approximately 1.6 million l/yr substituted by one central biomass heating plant), visible commitment to high-class sustainable tourism, comfort- and reliability are gained in operating the heating system (hotel operators do not have to worry about boiler maintenance anymore) and a considerable space gain in the hotels due to the omission of individual boilers and fuel storage. The biomass heating plant and DH network was constructed in the summer of 2010 and went into operation in the winter season of 2010/2011.

Energy conversion

General information	
Technology (e.g. in-house biomass boiler, biomass DH, etc.)	Biomass DH
Year of installation	summer 2010
Net capacity of the biomass boiler(s)	3.5 MW (heat) biomass boiler base load
Net capacity of the fossil fuel back-up / peak load boiler (if any)	6 MW (heat)
Type of fossil fuel	Oil
Buffer storage	85 m^3
Total annual energy production from biomass	11,800 MWh
Total annual energy production from fossil fuels	0 MWh

Biomass Fuel(s)

General information	
Type of biomass fuel(s)	Woodchips, untreated timber (e.g. pallets)
Annual amount of biomass fuel(s) needed (fresh or absolute dry substance)	16,800 m^3 / year (fresh, loose)
Average humidity of the biomass fuel(s)	50%
Average biomass fuel(s) cost (fresh or absolute dry substance)	19 EUR / tonne (loose, fresh substance)

Biomass supply chain

All biomass burned in Zürs is grown within a radius of 150 km from the plant or is coming from sawmills within a radius of 100 km. This helps to minimize transport cost, strengthen the local value-added chain and minimize negative environmental side effects. In general, biomass is bought from a diverse spectrum of suppliers on the free market, minimizing dependencies on one specific supplier. The biomass supply contract has a duration of 1 year.

The storage facility is sufficient for 150 days. This large storage facility is necessary because of the remote location and possible restrictions in accessibility due to avalanche risk. Because of the large storage size, it is possible to wait for good opportunities to buy the coming seasons' fuel demand.

The project has about 2-3 containers of grate ash and about 1 container of the fly ash per year. One spare container helps ash handling logistics. In case of biomass supply disruptions/restrictions the available back-up oil boiler can be put into operation. In addition, the owners use a diverse mix of different suppliers in order to minimize this risk.

Energy consumers and heat distribution

General information	
Total annual energy sold / delivered	11,000 MWh
Grid losses	800 MWh / year
Grid length	3,000 m
Electricity consumption for the grid pumps and the boiler	14 MWh / year (total electricity consumption of the plant)
Average price of heat sold / delivered	83 EUR / MWh
Duration of the heat delivery contract	15 years
Parameters determining the heat delivery contract	All consumers pay the same price. The heat price escalation rate is linked to following 3 factors: › Oil price index (1/3) › Consumer Index (1/3) › Fixed (1/3)
Type of consumers	Mainly large hotels, a few buildings with flats and offices.

Investment and financing

Roughly 1/3 of the total investment should come from shareholders (equity), 1/3 was planned as a bank loan and 1/3 was supposed to be subsidized by the state. With regard to the subsidy, the project owners had to take a bridging-loan, in order to be able to deal with the timely unknown flow of the subsidy to the operator (timeframe:probably within 5 years.
The legal entity operating the DH system is owned at 25% by the municipality and at 75% by the hotels themselves or by people from the management. No external investors participated in the project. This means that the DH system is owned by the same stakeholders consuming the heat, and they all have a collective interest in a safe supply and fair energy prices in the future.

Main difficulties / barriers encountered in the realization of the project

One of the biggest difficulties in the realization of the project was to find consensus within the community for the project, e.g. the operator of one of the major hotels in the village has not participated from the beginning, because he installed a new oil boiler just a few years earlier. Still the system needed to be designed in a way to also meet the needs of this potential consumer in case he decides to switch to DH (which he eventually did 3 years later).

One technical barrier was owed to the fact that Zürs is an exclusive winter destination. Due to the constrained situation of the village in a high alpine valley, finding a suitable location for the plant was quite challenging.

Another issue was that during summer times all hotels are closed and there are only the local families living there. While the energy demand in winter times was relatively easy to be calculated, the energy demand in summer times was completely unknown and it was very difficult to estimate this variable. It was expected that the summer demand will be far too low to keep the biomass boiler in operation. One hotel agreed to keep its oil boiler operational and adapt the DH system to allow feeding into the grid for the summer demand. However, it turned out that in combination with the very large 85 m^3 heat buffer storage the boiler could be kept in operation also during summer times. Because of the large peak in heat demand during the afternoons, when most guest come home from skiing and take a shower at the same time, the heat buffer storage was a critical element for an economic design of the system. It was dimensioned to the largest possible extent; the limiting factor being the road-width for the transport of the tank.

Lessons learnt from this investment and recommendations for other investors

The project owners certainly recommend getting all (potential) stakeholders around the table from the beginning of the planning phase. Early cooperation increases the chances that the project succeeds and leads to better results for all stakeholders. In general it also has proved very successful to convince all the major heat consumers to become shareholders of the new heating plant.

From a practical point of view, the project owners strongly recommend not to underestimate the importance of a careful biomass logistics concept. A sound concept will substantially facilitate easy and smooth operation of the plant. The project owners recommend assigning an experienced and reliable engineering company for the planning and realization of the project. Good planning also increases the chances that the construction budget is not exceeded in the end.

2.3 Biomass DH system in the city of Pokupsko, Croatia

General description of the project

The municipality of Pokupsko is a small town with 2,500 citizens located on the river Kupa, in Zagrebačka County, Croatia.

In 2015, development of a biomass DH system was initiated (now it is in the finalisation stage) to cover the heating needs of the municipality. Currently, many citizens indicate interest to be connected to this new system, which will be put into operation in the heating season 2015.

The developer of this project is ENERKON from Zagreb, Croatia. ENERKON provides services in the field of engineering, consulting and construction of thermal power and process plants.

The capacity of the biomass boiler is 1 MW (heat) and the total annual energy production from biomass is 2,000 MWh.

Energy conversion

General information	
Technology (e.g. in-house biomass boiler, biomass DH, etc.)	Biomass DH
Year of installation	2015
Net capacity of the biomass boiler(s)	1 MW (heat)
Total annual energy production from biomass	2,000 MWh

Biomass Fuel(s)

General information	
Type of biomass fuel(s)	Wood chips (G100)
Annual amount of biomass fuel(s) needed (fresh or absolute dry substance)	940 tonnes / year
Average humidity of the biomass fuel(s)	~ 30%
Average biomass fuel(s) cost (fresh or absolute dry substance)	35 EUR / tonne

Biomass supply chain

40% of the biomass is supplied by Hrvatske šume, a national company selling wood; the residual 60% are supplied by the surrounding agricultural biomass. The duration of the biomass supply contract with Hrvatske šume is 1 year. So far, the company has not been faced with any difficulties in relation to biomass availability.

The storage facility has a load capacity equivalent to 7 operational days' biomass needs. The ash resulted from the combustion process is disposed as communal waste.

The price of the biomass is directly dependent on the price of the raw material, but it is, more or less, constant.

Energy consumers and heat distribution

General information	
Total annual energy sold / delivered	~ 3,600 MWh
Grid losses	~ 140 MWh / year
Grid length	~ 1,400 m
Electricity consumption for the grid pumps and the boiler	~ 30.8 MWh / year
Type of consumers	Public buildings such as schools, hospitals, local governmental buildings and a few residential buildings

Investment and financing

The project was financed by a mix of available financing sources. The total investment amounted to EUR 800,000, financed by means of EU-, local- and national Funds dedicated to RES projects. The project is considered a green-field investment. The beneficiary / owner of the project is Pokupsko municipality.

Main difficulties / barriers encountered in the realization of the project

The first assessment of the project investment was not realistic and the project had to be modified (smaller in size and cheaper components) to match the available resources provided by the Funds.

Lessons learnt from this investment

The main problem in developing DH systems using biomass as fuel or another RES in Croatia is that the project developer has to invest also in the heat distribution network.

Recommendations for other investors / operators

The projects have to be well-prepared with all necessary permits including the building permit in order to obtain funding from EU.

2.4 Biomass DH system in Łąck municipality, Poland

General description of the project

The DH biomass plant was built in 2004 in order to provide heat for the municipal offices, a primary and a secondary school, a health centre and a sports hall in the Łąck municipality, which owns the installation. In total, the DH plant provides heat for 8,500 m2. Biomass is acquired from roadside greenery maintenance (trees and shrubs) and forest wood waste.

The heat is transmitted through pre-insulated pipes. The heating plant consists of 3 biomass boilers, two with a capacity of 0.5 MW (each) and one boiler with a capacity of 0.2 MW. All of the boilers are used to generate heat during the heating season.

Energy conversion

General information	
Technology (e.g. in-house biomass boiler, biomass DH, etc.)	Biomass DH
Year of installation	2004
Net capacity of the biomass boiler(s)	1.2 MW (heat)
Total annual energy production from biomass	1,055.5 MWh

Biomass Fuel(s)

General information	
Type of biomass fuel(s)	Sawmill woodchips
Annual amount of biomass fuel(s) needed (fresh or absolute dry substance)	10,000 m3 / year, 7,700 tonnes / year (fresh)
Average humidity of the biomass fuel(s)	35%
Average biomass fuel(s) cost (fresh or absolute dry substance)	50 zł / m3

Biomass supply chain

The biomass is supplied by a local woodchip producer. The supplier is responsible for the entire supply chain. The supplier was chosen through a public tender. The duration of the contract for supplying biomass is 1 year and is renewed annually.

The storage facilities are sufficient to secure 30 to 45 days of demand during the heating season. The ash produced by the combustion process is disposed of by the heating plant itself.

The main parameters determining the biomass price are the calorific value, the humidity, and the granulation of the wood chips.

In case of insufficient biomass delivery, the heating plant uses woodchips and wood residues from the town greenery maintenance.

Energy consumers and heat distribution

General information	
Total annual energy sold / delivered	1,055.5 MWh
Grid losses	52.7 MWh / year
Grid length	1000 m
Electricity consumption for the grid pumps and the boiler	5.5 MWh / year
Average price of heat sold / delivered	5.2 zł / m2(net)
Parameters determining the heat delivery contract	› Fixed and variable costs › Monitoring › Equipment operation
Type of consumers	Public buildings

Investment and financing

The investment amounted to zł 1.2 million; the construction and infrastructure was financed by the Voivodeship Fund for Environmental Protection and Water Management (WFOŚiGW) from its Eko Fund.

Lessons learnt from this investment

Biomass should be purchased locally, in the same region where the heating plant is operated.

Recommendations for other investors / operators

- It is important to analyse biomass availability in the area around the heating plant at a very early stage in the conceptual phase
- The careful planning of the biomass storage facilities allows easy fuel transport.

2.5 'Stadsverwarming Purmerend' (SVP): DH system utilising domestically available woody biomass residues, The Netherlands

General description of the project

`Stadsverwarming Purmerend` (SVP) is located in the Dutch city of Purmerend. On July 1st 2014, SVP changed from a traditional heat distributing company to an integrated DH company when it also became responsible for the heat generation. SVP is a chain integrated company that is involved in heat production, distribution and heat supply to the customers. These activities are performed by separate business units as part of one larger holding. The 'Productie B.V.' unit is responsible for the production of heat while 'SVP Distributie and Levering B.V.' is responsible for operating and maintaining the warm water distribution grid. All entities of the holding are obliged to follow the rules and regulations set out in the Dutch Heat Act.

Besides the Biomass Heating Installation 'de Purmer', SVP operates two auxiliary boilers fuelled by natural gas to cover the peak load. The DH system provides heat in the form of hot water to 24,000 households and 1,000 businesses.

The Biomass Heating Installation replaces a gas-fired power plant which was owned and operated by Nuon. The power plant was old and has now been dismantled.

The Biomass Heating Installation 'de Purmer' has 44 MWth installed capacity. It uses nearly 100,000 tonnes of fresh woodchips annually to produce about 936,000 GJ heat. The biomass fuel feedstock is regularly provided by the Dutch Forestry Services (Staatsbosbeheer; SBB) that manages the largest share of the publicly owned forests and nature area in the Netherlands.

On average, SVP produces 80% renewable heat and 20% fossil heat, but SVP has the ambition to become completely independent from fossil fuels.

Energy conversion

General information	
Technology (e.g. in-house biomass boiler, biomass DH, etc.)	Biomass DH and 2 natural gas fired auxiliary boilers
Year of installation	BHI: 2014, HWC1: 1982, HWC2: 2014
Net capacity of the biomass boiler(s) – base load and medium load (if any)	44 MW (heat)
Net capacity of the fossil fuel back-up / peak load boiler (if any)	90 MW (heat) 35 MW (heat)
Type of fossil fuel	Natural gas
Total annual energy production from biomass	~ 260,000 MWh (heat)
Total annual energy production from fossil fuels	~ 65,000 MWh (heat)

Biomass Fuel(s)

General information	
Type of biomass fuel(s)	Domestic woody biomass from forest management activities in the form of fresh woodchips
Annual amount of biomass fuel(s) needed (fresh or absolute dry substance)	~ 100,000 tonnes / year
Average humidity of the biomass fuel(s)	45%

Biomass supply chain

The fresh woody biomass residues are supplied by SBB, originating from their forest maintenance activities. Forest maintenance is carried out between July and April (according to the rules and regulations applied to protect indigenous bird species during the nesting season), which corresponds largely to the heating period with the largest demand of district heating. During the months May and June, woodchips are taken out from the storage facilities.

Wood chips are produced with the use of heavy machinery (that uses diesel as fuel) and then are being directly sold or stored until further usage. Energiehout, a subsidiary of SBB, is responsible for the buying/selling/marketing of woody biomass products, including woodchips. They offer long term agreements to customers such as SVP to guarantee the constant supply of biomass. For SBB, it is of interest to have a relatively constant/steady demand for their chipped wood, which facilitates the planning and logistics operations for forest management activities. Transportation distance of wood chips to SVP on average is around 100 km.

A contract duration of 10 years is currently established with SBB with options to extend it. Wood chips are stored under low pressure in closed storage facilities with enough capacity to guarantee 7 days of continuous heat production at full load capacity.

Prices are negotiated in mutual cooperative discussions, taking into account, amongst others, unexpected extra costs such as higher handling or storage costs.

Long-term contracting with SBB guarantees the constant supply of biomass and in combination with regular mutual discussions, the risks of non- or insufficient biomass delivery can be significantly reduced. SBB has in addition an operational and strategic interest in securing a steady and relatively predictable demand (i.e. demand security) because of forest operations management.

Fly and bottom ashes are being deposited at a disposal site where the quality of the ash is analysed. Depending on the quality, the ash can be used in construction. At present, a research project is being carried-out to investigate the opportunity to return the ash to the woods which would be very favourable in terms of circular mineral management.

General information	
Total annual energy sold / delivered	~ 206,389 MWh (in 2014)
Grid losses[6]	~ 107,777 MWh / year7 (in 2014)
Grid length	~ 550 km ???
Electricity consumption for the grid pumps and the boiler	~ 6,000 MWh / year
Average price of heat sold / delivered	~ 80 EUR / MWh (in 2015)[8]
Duration of the heat delivery contract	The contract is for an indefinite period and may be terminated in accordance with the Terms and Conditions by both the consumer and SVP.
Parameters determining the heat delivery contract	The heat supply contract includes the following: › price rates › general terms and conditions on heat › grid connection terms and conditions
Type of consumers	24,000 households and 1,000 businesses

Energy consumers and heat distribution

General information	
Total annual energy sold / delivered	~ 3,600 MWh
Grid losses	~ 140 MWh / year
Grid length	~ 1,400 m
Electricity consumption for the grid pumps and the boiler	~ 30.8 MWh / year
Type of consumers	Public buildings such as schools, hospitals, local governmental buildings and a few residential buildings

Investment and financing

The Municipality of Purmerend is the sole (100%) shareholder of the company . The main part of the investment (~ EUR 46.7 million) was provided by bank loans (50/50 by BNG Bank and Triodos Bank) under municipality guarantee. In addition, three types of subsidies were granted for this particular project: EUR 1.8 million by the European Investment Bank (under the ELENA funding scheme), EUR 1 million by RVO (the Netherlands Enterprise Agency) and subsidy per every GJ renewable heat (under the SDE+ subsidy scheme for the duration of 12 years).

Main difficulties / barriers encountered in the realization of the project

- Unpredictable regulations
- Unpredictable policy on subsidies
- Missing level playing field for heat within (renewable) energy options

Recommendations for other investors / operators

- Involve local stakeholders
- Use realistic planning

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Contacts

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Horizon 2020
European Union funding
for Research & Innovation

This project is funded under the LCE 14 2014 Support Programme „Market uptake of existing and emerging sustainable bioenergy", as part of the Horizon 2020 Framework Programme by the European Community. All publications of this project reflect solely the views of its authors. The European Commission is not liable for any use that may be made of the information contained therein. The Bioenergy4Business consortium members shall have no liability for damages of any kind including, without limitation, direct, special, indirect, or consequential damages that may result from the use of these materials.

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