IEA Bioenergy
Technology Collaboration Programme

Industrial Process Heat: case study 1

Combustion of wood chips and composting residues for process steam generation in a potato processing industry

Contribution of Task 32 to the intertask project on industrial heat

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Preface

The role that bioenergy plays in the global energy mix has expanded over the last decades, from predominantly domestic space heating and industrial heat until the 1990's to increased use in the electricity sector and more recently also large scale production of transportation fuels. According to the IEA SDS scenario, the use of biomass to produce high temperature heat in industry will not decrease, but quadruple from 8 EJ today to about 24 EJ in 2060.

Traditionally, the application of bioenergy in industry was performed in industries that can use their own biomass process residues to cover (some of) their own heat demand, e.g. sugar, palm oil, wood processing, pulp and paper, etc. With the increasing motivation in industry to reduce CO_2 emissions, several other industry sectors are also shifting towards biomass based heat generation in cases where there are suitable biomass resources and technologies available nearby.

While there is a large potential to displace fossil fuels with biomass fuels in the large and energy intensive industries (steel, cement, etc), there are also many small and medium sized process industries such as food industries, paper industries, etc. In contrast to the larger energy intensive industries where these case typically require that large volumes of biomass are shipped to an individual site, the heat demand in these smaller industries can often be better matched with the biomass resources that may be locally available, resulting in smaller transporation distances.

This case study is part of a series of reports on the use of bioenergy in industry to supply process heat. In the framework of an intertask project, five of the tasks involved in the IEA Bioenergy Technology Collaboration Programme collaborated to produce four case studies and a policy synthesis report on biomass based industrial heat. The cases were selected carefully to illustrate that a wide diversity of bioenergy conversion technologies is readily available for market application, the optimum configuration depending on local availability of biomass resources, characteristics of the heat demand, availability of space, capital, etc. The cases are:

1. Combustion of wood chips and composting residues for process steam generation in a potato processing industry
2. Gasification of paper reject to displace natural gas usage in a pulp and paper process
3. Process steam in a dairy factory via fast pyrolysis bio-oil
4. Waste-to-Energy for production of steam for paper production

Early in 2021, a policy synthesis report will also be published that provides strategic information on market opportunities/potential and effective ways to address technical and non-technical barriers to implement bioenergy based process heat. The report builds upon the lessons learned in the cases, but also provides a more generic analysis of the market potential, and how its implementation can be supported, in order to unlock the enormous potential already mentioned above. All reports are available on the project website http://itp-hightemperatureheat.ieabioenergy.com/

Summary

Since 2015, the waste processing company Attero operates a biomass fired boiler that generates process steam for PEKA KROEF BV, a potato processing company near the village of Odiliapeel in the Southern part of the Netherlands.
The 10 MW biomass boiler uses very low-grade wood chips and composting residues to produce 10 tph of saturated process steam (18 Bar) for PEKA Kroef. The steam is used to convert fresh potatoes to various peeled, cut and precooked potato products, which are then delivered to various supermarkets around Europe. The biomass fuel displaces over 8 million m3 of natural gas annually.
The biomass boiler installation is highly efficient through the use of flue gas condensation, and avails of an advanced flue gas cleaning system, including SNCR, SCR, bicarbonate injection and a baghouse filter, leading to very low emissions.
The project demonstrates that the substantial investment can still be justified economically, since the plant is operating year-round to supply the baseload of the industrial heat demand, while using an inexpensive low-grade fuel that is locally available and has no competition from higher value applications. Since the size of the project and the steam demand is typical for many food processing industries worldwide and the project is based on locally available and underutilised, low grade biomass resources, it is expected that the concept can be replicable to many other locations.

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BACKGROUND INFORMATION

The waste company Attero operates a 10 MW biomass boiler on low grade composting residues to produce 10 tph of process steam for a PEKA Kroef, a potato processing company near the village of Odiliapeel in the southern part of the Netherlands.

Previous situation

The idea for realisation of this bioenergy plant dates back to 2010, when the five local municipalities Bernheze, Oss, Veghel, Uden and Sint-Oedenrode jointly published a request for proposals for a 12 years processing contract for local green waste. Besides costs, sustainability and CO_2 mitigation were important decision factors.

In 2012, the waste processing company Attero won the tender with a proposal to accept the green waste and use its woody fraction for process steam production at PEKA KROEF, a local potato processing industry in a 10 MW steam boiler. Generation of process steam from green waste would substitute for over 8 million m^3 of natural gas per year for process steam generation.

The green waste that originates from the public works is of relatively low quality in terms of moisture and ash content. The woody fraction in it (total volume approx. 14 kton/year) is also insufficient to satisfy the total heat demand of PEKA Kroef, equivalent to approx. 27 kton/year. As a regional waste company with several other processing sites for various types of waste already in operation, Attero posesses significant quantities of other low grade woody residues such as compost sieve overflow (the woody residue left after composting green waste) that can be used to complement the volume from the local municipality. In addition, Attero has adequate biomass processing facilities (sieving, comminution, drying) to upgrade these and other biomass residues to standardised qualities that can be used for particular purposes, including the biomass combustion plant in Odiliapeel.

The main driver for PEKA KROEF to switch to biomass-fueled process heat

PEKA Kroef is a family owned business, that processes potatoes to consumer products. Since 1970 PEKA Kroef has been developing innovative potato based, semi-finished products for the food service, retail and consumer markets: chilled short shelf life products and chilled long shelf life products. Washing, peeling, cutting and pre-boiling are typical processes carried out at PEKA Kroef. The motivation to application at PEKA Kroef is particularly interesting since significant quantities of process steam are needed in several of these process steps 24/7 and year-round, resulting in a large number of full load hours of the biomass combustion plant. In addition, the capacity of the plant is sufficiently high to benefit from economy-of-scale effects. The combination of both factors enables economically feasible operation of the plant. For PEKA Kroef, this leads to a reduction of 8.2 million m^3 of natural gas every year, and a corresponding CO_2 mitigation of 14.5 kton per year.

PEKA Kroef uses the steam mainly for steam peeling and blanching of potatoes. The factory has a processing capacity of 150 ktons of product per year. In contrast to the use of steam in conventional closed loop power generation cycles, the process steam is in direct touch with the product, and therefore cannot be immediately recycled since the resulting wastewater contains significant amounts of organic and inorganic matter. PEKA Kroef currently operates a UASB reactor to process its wastewater, this produces biogas that can be used as a fuel. But cold and fresh boiler make up water is still needed to produce new steam. Although this results in a significant demand for process water at the moment, the low temperature of the fresh water makes it possible to optimally use the installed flue gas condenser to preheat it. There are plans to process wastewater in the future so that it can be re-used for generation of process steam.

While the biomass combustion plant provides the baseload of the company's steam demand (10.2 tph at 20 Bar / 215 °C), two new gas fired steam supplying boilers provide for incidental backup and peak steam demand. These are currently fuelled on natural gas, but after realisation of the aforementioned biogas plant, they can also be fuelled with biogas. This will further reduce the carbon footprint of PEKA Kroef. A schematic diagram of the water and energy flows at PEKA Kroef is shown in Figure 1, an artist impression of the possible future setup of the installation is shown in Figure 2. The artist impression also shows an anaerobic digestor that could possible be producing biogas from the available potato process residues, however for the moment this material is still being used as animal feed.

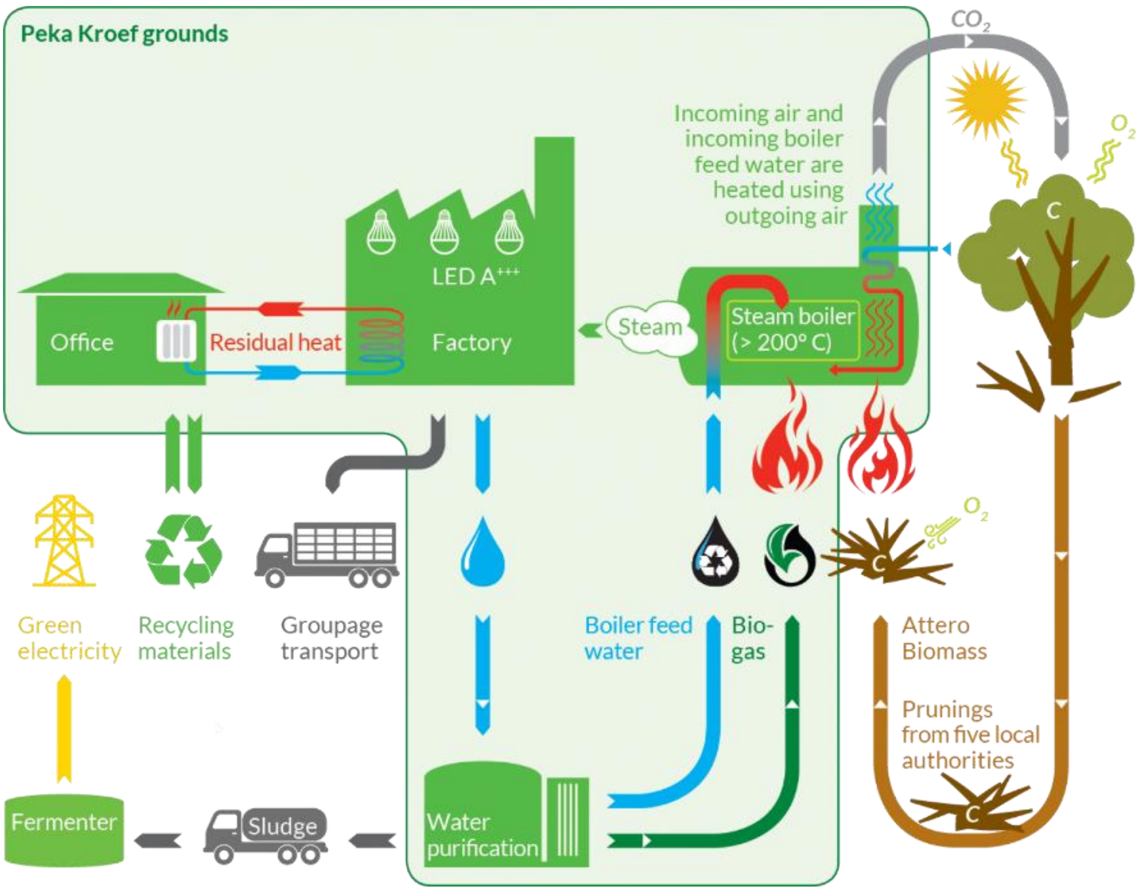

Figure 1. Schematic diagram of anticipated water and energy streams at PEKA Kroef. In addition to the biomass boiler, part of the energy requirements may in future be provided by biogas from the fermenting wastewater sludge and process residues (PEKA KROEF, 2020).

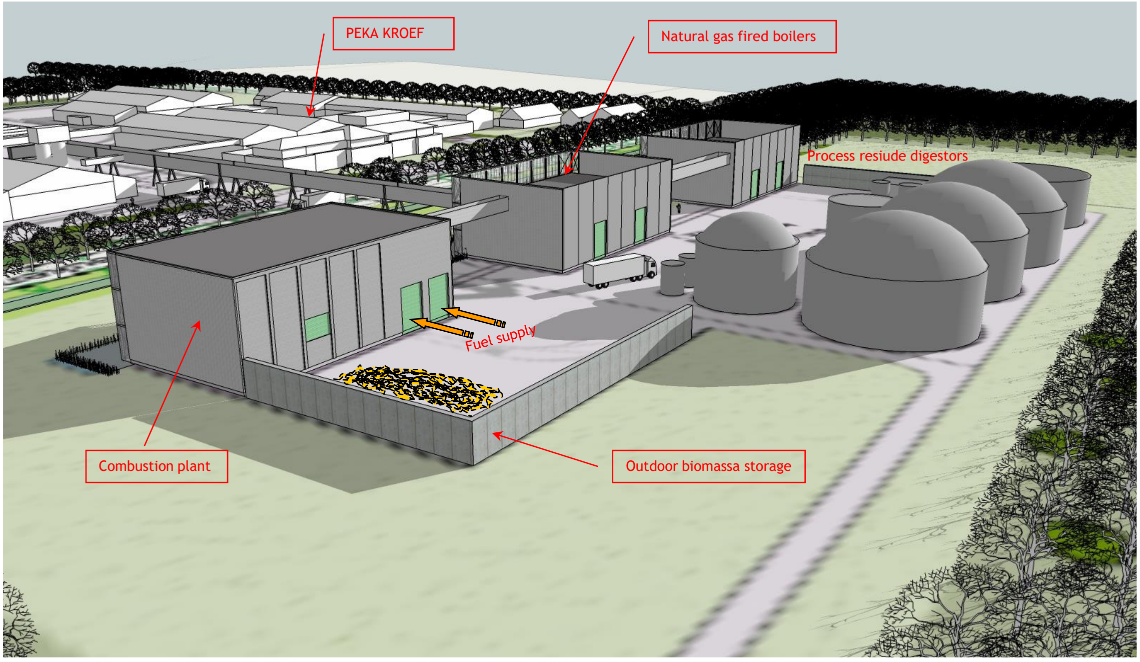

Figure 2. Artist impression of the future situation including the existing biomass combustion plant, the existing natural gas fired boilers and a planned anaerobic digestor for wastewater sludge and process residues.

Project preparation and permitting procedure

During the preparatory phase of the project in 2011, extensive interaction with local stakeholders was organised, in order to be able to respond to possible sensitivities. The local village of Odiliapeel had already faced a number of challenges with respect to noise and smell, as it is not only situated close to PEKA Kroef, but also in the direct vicinity of a military airport and a poultry litter processing and drying plant. In the discussion with local stakeholders, the village council acted as discussion partner. Information evenings were organised to inform local inhabitants of the plans.

An extensive environmental impact assessment was then carried out on the proposal to evaluate all possible impacts on noise, smell, air quality, safety, landscape integration, nature, nitrogen deposition on nature conservation areas, soil, water, archaeology, etc. (Henderickx, 2013). This investigation was the basis for the decision of the local municipality to allow such operation on this location through a construction and operation permit. The permitting procedure took place in 2012 and 2013. All permits were in place in April 2014.

With respect to traffic safety, PK Kroef agreed to contribute financially to a new bypass road that should significantly reduce heavy traffic through the village of Odilliapeel related to PEKA Kroef and the new bioenergy plant.

Fuel quality

The fuel mixture contains approx. 50% low grade wood shreds produced from municipal green waste, and 50 % compost sieve overflow. This results in a fuel with a high amount of ash (typically around 22 % on dry basis), moisture content (up to 60 %) and nitrogen (up to 2 % on dry basis). When comparing the fuel specifications with normal wood chips, it is evident that the fuel has really challenging combustion properties.

Table 1 Fuel specifications, and a comparison with conventional wood chips

Parameter	Value of the fuel used at Attero	conventional wood chips
Lower Heating Value	6.7-11.5 GJ/ton	8-12 GJ/ton
Moisture content	25-49% on wet basis	25-50%
Average ash content	22% on dry basis	<5% on dry basis
N	< 2.05% on dry basis	< 0.4% on dry basis
S	< 0.2% on dry basis	<0.02% on dry basis
Cl	<0.36% on dry basis	< 0.02% on dry basis
F	<130 mg/kg on dry basis	

A first aspect of the fuel quality that should be noted, is that due to the presence of leaves, needles and sand, the fuel not only has a very high ash content, but also with a low melting temperature. This leads to large amounts of molten bottom ash. The bottom ash is removed in a wet removal system. Once every 3 days on average it is removed and used by Attero itself as a waste processing company, to construct temporary roads on the waste disposal sites that are still in operation.

Figure 3. Typical samples of the fuel used, containing typically 22 % ash and up to 60 % moisture.

Secondly, the fuel has relatively high nitrogen contents. As NOx formation is almost completely related to the presence of fuel nitrogen, this would potentially lead to high NOx formation. In order to avoid this, the plant incorporates both SNCR and SCR systems.

Finally, it is noted that the amount of sulphur is relatively high. As SO_2 would significantly affect the integrity of the SCR catalyst, it is removed first by injection of sodium bicarbonate (see below).

TECHNICAL ASPECTS

The whole boiler installation was produced and delivered by Vyncke, and is schematically shown below.

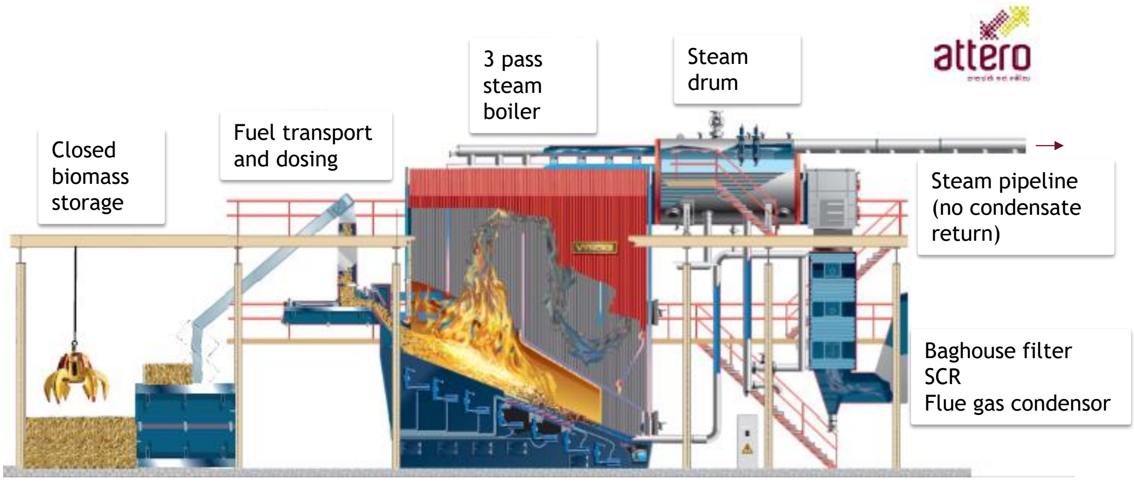

Figure 4. Schematic overview of the Vyncke boiler system (flue gas system not shown here).

Figure 5. The two doors for entrance to the discharge pit. Fuel is delivered using walking floor trailers.

Biomass fuel is delivered to the plant by truck and dumped in an indoor concrete dumping pit. A fully automatic overhead crane is used to take fuel from the unloading bunker to the main storage, where it is mixed and stored for typically 4 days. From here, the same crane delivers the fuel to a fuel hopper that feeds the chain conveyor to the boilers. The fuel storage hall is equipped with aspiration detection, to detect self-heating and the production of hazardous off-gases.

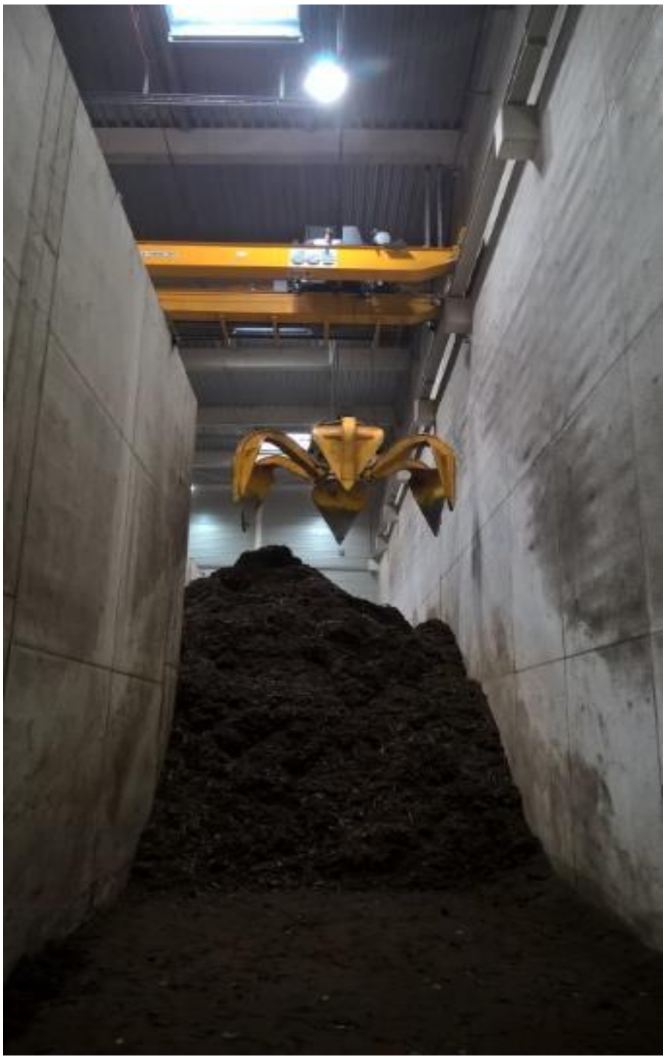

Figure 6. The fully automatic overhead crane takes material from the dumping pit, transports it to the main storage where it is mixed, and then loads the fuel hopper to the boiler

From the fuel hopper, the chain conveyor brings wood chips to the fuel dosing system that feeds the boiler. Inside the combustion chamber, wood chips are burned on a water-cooled moving grate furnace. The hot flue gases are cooled down in a three-pass steam boiler, which is a combination of a firetube boiler and a watertube boiler. Here 10.2 tph of saturated steam (max 20 Bar / 215 °C) can be produced, for direct delivery to PK KROEF. As the factory is currently only able to accept steam of 12 Bar, the boiler is in practise operated at more moderate conditions.

After the flue gases have cooled down to approx. 200 °C, dust is first removed in a cyclone and then a baghouse filter. Next, an SCR catalyst is used to reduce NOx to a level below the emission limit of 145 mg/m^3 at 6 %O_2. Sodium bicarbonate is injected in the flue gas just before the bag filter to bind SO_2, so that it can be removed as solid Na_2SO_4 with the fly ash. This is mainly done to extend the lifetime of the catalyst, by protecting it from poisoning by SO_2.
After the SCR catalyst, an economiser + flue gas condenser are installed to take out the sensible and latent heat from the flue gas before it leaves the chimney. In the flue gas condenser, the produced heat is used to preheat the fresh boiler make up water. This leads to an overall efficiency of 92% on HHV basis.

Figure 7. Detail of the firetube boiler with sootblowers

Figure 8. The bottom ash pit, from where lumped ash is taken for road construction.

PROJECT ECONOMICS AND FINANCING

The overall investment for the biomass combustion plant amounted to approx. 7 million Euros. The plant is fully financed, owned and operated by Attero, which acts as an energy service company to PEKA Kroef.

Other details that determine the economic performance (fuel costs, steam value etc) are not disclosed, however it is obvious that the key success of this project is related to the combination of a high number of full load hours and the use of low-grade inexpensive fuel.

ENVIRONMENTAL ASPECTS

The plant needs to comply with the Dutch 'Activiteitenbesluit' for installations between 5 and 50 MW. This results in the following emission limits:

Table 2 Emission limits for the plant (hourly values at 6% O_2)

Component	Limit
NO_x as NO_2	145
Dust	5
SO_2	200
NH_3*	5

*this emission limit is in addition to the regular emission limits

Particularly the limit for NOx is a challenge, since the fuel used contains up to 2% of nitrogen, four times higher than for normal wood chips as can be seen in Table 1. In the absence of a deNOx system this would normally result in an emission of approx. 400-500 mg/m^3. Although the SCR can effectively reduce emissions to the wanted level, it may result in high ammonia slip emission. For this reason, there is an additional limit of 5 mg/m^3 of NH_3 slip to which the plant needs to comply. This can be met through the application of flue gas condensation.

The actual emission of SO_2 is much lower than what the emission limit requires (200 mg/m^3), since SO_2 needs to be reduced anyway to protect the catalyst. This is done by the injection of sodium bicarbonate, which reacts with SO_2 to form solid sodium sulphate that can be removed.

The emission limit for dust can be met by the application of a baghouse filter. Bottom ash and fly ash are collectively processed and used for road construction.

The high concentration of Cl in the fuel implies that care needs to be taken for both for high and low temperature corrosion.

The consumption of clean water for the production of steam is approx. 16 m^3 per hour. Since a number of measures were implemented recently, about 12 m^3/h of this demand can be produced from recycled and cleaned process water from PEKA KROEF.

ORGANISATIONAL ASPECTS

During daytime, the plant is operated by Attero crew. At night-time, the plant is monitored remotely together with some of the other plants that the company has in operation.

Figure 9. Jan Willem Steyvers, project manager for the Odiliapeel plant.

SOCIAL AND MARKETING ASPECTS

Attero and PEKA Kroef jointly carried out the preparatory phases of the project, where a public consultation and elaborate environmental impact assessment study were performed.
The motivation of PEKA Kroef to host the bioenergy project was that it would provide long term certainty of process heat supply with a reduced dependency of natural gas. Regretfully, it is not easy to translate the improved carbon footprint of the company into a higher customer appreciation and corresponding product sales price, as PEKA Kroef does not sell their products only to final customers though supermarkets and therefore has to compete with other producers on price.

LESSON LEARNED/RECOMMENDATIONS

Size of application meets local availability of low-grade biomass resources: There are a large number of companies such as PEKA KROEF that continuously use significant amounts of process steam in the same order of magnitude as PEKA KROEF (10 MW). This case study shows that this scale may fit very well with the application of a robust biomass combustion plant that can handle various low-grade biomass resources that may be regionally available and do not yet face competition from alternative sectors. The large number of full load hours of constant industrial steam use is essential for the economic performance.

Design your plant according to accurate fuel specifications. This example shows very clearly that it is essential to design a plant according to the detailed fuel specifications that are expected. In this case it was designed to handle challenging fuels with high content of ash, nitrogen, sulphur and chlorine.

Adapt the plant design to local conditions: In this case, the large demand for fresh steam make up water makes it particularly attractive to apply flue gas condensation, leading not only to high energetic efficiency but also the ability to remove unwanted ammonia slip. By cleaning and re-using wastewater from PEKA KROEF, the plant has been able to reduce external make up water consumption. The sizing and redundancy aspects of steam production need to match the demands from the consumer.

Involve local stakeholders and listen to local sensitivities: In order to avoid overlooking specific local sensitivities and save time and resistance in permitting procedures, it is advised to make sure that the location is suitable and optimal, by involving both experts for the minimisation of all possible environmental impacts, and local representatives to try to accommodate possible requests.

Obtain long term contracts: This biomass plant is built to fulfil a specific industrial heat demand. It is therefore essential that long term offtake contracts are signed, and that the fuel is also secured. In this case the fuel originates from the plant owner itself.

Work with solid partners: Attero decided to implement this project with Vyncke, a biomass boiler company with a long track record in using challenging fuels other than typical wood chips.

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Further Information

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