



IEA Bioenergy
Technology Collaboration Programme

Industrial Process Heat: Case Study 7

Combustion of wood chips in a dairy in Denmark

Contribution of Task 32 to the series of industrial heat cases

May 2025





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March 2025

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ISBN 979-12-80907-58-5

Published by IEA Bioenergy

Preface

The use of biomass for energy in industry is growing rapidly in the last 15 years or so. Until about 2010, the use of biomass residues for process heat in industry was originally limited to industry sectors that had their own residues available to cover (some of) their own heat demand, e.g. sugar, palm oil, wood processing, pulp and paper, etc. By processing these residues, a waste problem could be avoided while generating useful heat at the same time.

With the increasing demand for cost effective renewable heat however, also other industries have recognized the opportunity for biomass based heat provision to reduce the carbon footprint of their processes. This is particularly the case in situations where there are suitable biomass resources and technologies available nearby. According to the IEA SDS scenario, the use of biomass to produce high temperature heat in industry will increase rapidly, from 8 EJ today to about 24 EJ in 2060.

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 already be locally available, resulting in smaller transportation distances.

This case study is part of a second series of reports on the use of bioenergy in industry to supply process heat. In 2021, five of the tasks involved in the IEA Bioenergy Technology Collaboration Programme collaborated to produce case studies and a policy synthesis report on biomass based industrial heat. In 2024, another 5 examples were prepared by Task 32 on application of biomass combustion in industry.

These additional cases represent a large diversity of applications and illustrate that biomass combustion can be a commercially attractive option for lowering the carbon footprint of companies. The examples also illustrate that the optimum configuration depends on local availability of biomass resources, characteristics of the heat demand, availability of space, capital, etc. The additional cases are:

6. Combustion of waste wood for electricity generation and process heat in two neighboring factories in the Netherlands
7. Combustion of wood chips in a dairy in Denmark
8. Process heat from forest residues for the battery industry in Austria
9. Process heat from forest residues for powder-coating process in Austria
10. Replacing coal with biomass at Golden Bay Cement, New Zealand

All reports are available on the project website
<http://itp-hightemperatureheat.ieabioenergy.com/>

Summary

Bioenergy in Denmark constitutes a significant portion of the country's renewable energy sources, accounting for 31% of the total energy supply (2). The main application of bioenergy is in the district heating sector, where over 60% of district heating is produced from biomass. Additionally, biogas production contributes more than 15% of the country's gas consumption.

NORDEX FOOD, a family-owned dairy company in Denmark, made a strategic decision to convert its production site from using gas to biomass in 2016. The conversion was financially supported by a renewable energy subsidy offered by the Danish state.

The dairy chose the biomass-based solution over a new gas boiler solution due to higher annual savings and a more favourable cash flow projection over ten years. The plant can run on A1 wood chips with up to 30% moisture and wood pellets with 8% moisture and has a capacity of 2,6 MW.

The investment in biomass proved to be a good decision, with the payback time estimated at 5,5 years based on the gas and wood chip prices at the time. However, in early 2021, the dairy's production site suffered a fire due to an electrical fault.

From an environmental standpoint, using A1 wood chips is considered environmentally friendly, and the boiler is equipped with an economizer and dust filter to minimize environmental impacts.

Operationally, the facility is managed by three blacksmiths who supervise the plant on shifts. The biomass boiler is approved for 72 hours of operation, eliminating the need for supervision on weekends.

Overall, the transition to biomass has proven to be a successful investment for NORDEX FOOD, providing environmental benefits and contributing to its competitive advantage in the market as well as to the image.

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BACKGROUND

Bioenergy in Denmark

According to the 2023 report from Danish Statistics (Danmarks Statistik, n.d.), bioenergy in Denmark's total energy supply makes up 31% total energy demand and bioenergy contributes with 68% of the renewable energy supply in Denmark. The main application of bioenergy is within the district heating sector where more than 60% of the district heating in Denmark is produced from biomass. (IEA, 2024) Another utilisation is within the production of biogas which in 2022 amounted to more than one third of the gas consumption of the country according to the Confederation of Danish Industries. (DI Energi, 2023)

Introduction to the case

The company NORDEX FOOD founded in 1984 is a family-owned dairy with headquarters in Dronninglund, Denmark which has production sites in Himmerland, Denmark; Pöggstall, Austria and Campulung, Romania.



Figure 1 NORDEX FOOD production sites in Denmark, Austria and Romania (from left to right), photo credit: NORDEX FOOD

In 2016 the dairy production site in Denmark converted from using gas to using biomass in their production processes. In the summer of 2016, the dairy was contacted by a company called Focus Bio Energy who advises on and supplies companies with small steam generating heating plants as well as combined heat and power plants based on biomass with up to 15 MW thermal capacity. They proposed the dairy to replace their old gas boiler and presented them with both the technological and economic perspectives of the conversion to biomass.

At that time, the Danish state also gave a subsidy for converting to CO₂ neutral energy via the Renewable Energy for Process scheme. The scheme was introduced in 2014 and was supposed to run until 2021 but already stopped at the end of 2016.

The two proposed options were to either, Case 1, convert to biomass or to replace their old gas boiler with a new one, Case 2.

Table 1 Alternatives for replacing old gas boiler system in the dairy

Case 1: Alpha 2 Flex, 3.8 t/h steam	Case 2: Danstoker gas boiler, 3.8 t/h steam
Replaces natural gas: 505,000 m ³ /year Value: DKK 1,900,000/year	Replaces natural gas: 0 m ³ /year Value: 0 DKK/year as approx.. the same amount is to be used in the new boiler
Gross investment: DKK 9,500,000 Subsidy, renewable energy process 45% (443,000m ³ N-gas) DKK 4,030,000 Net investment: DKK 5,470,000	Gross investment: DKK 4,000,000 Subsidy: DKK 0 Net investment: DKK 4,000,000

Annual cost: DKK 450,000 This post incl. fuel, maintenance and personnel Annual savings: DKK 1,450,000 Simple payback period: 3.77 years Cash flow - 5 years: + DKK 1,780,000 Cash flow - 10 years: + DKK 9,030,000	Annual cost: - DKK 100,000 This post incl. less maintenance and less manpower Annual savings: DKK 100,000 Simple repayment period: 40 years Cash flow - 5 years: - DKK 3,500,000 Cash flow - 10 years: - DKK 3,000,000
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The old gas boiler (Danstoker) which had a capacity of 2 MW had reached the end of its lifetime, so the dairy had to choose a solution. Although the biomass solution had a higher investment cost than a new gas solution, the annual savings of a biomass-based solution would have been 14 times higher and the cash flow in 10 years was projected to be 3 times higher than the one if a gas-based solution would have been used.

Focus Bio Energy applied for a subsidy on behalf of Nordex Food for a 2 MW plant in summer 2016 from the Danish Energy Agency and was granted a subsidy of DKK 4.5 million.

Main drivers for conversion to biomass

Although the dairy was approved for the subsidy, they decided to take another approach which was to take the opportunity and scale up in order to accommodate the dairy's future plans. The result was a decision to build a completely new "Supply building" containing a new biomass boiler, a new backup gas boiler and a new wastewater treatment plant - all in a new separate building located at a good distance from the dairy for expansion possibilities.



Figure 2 Production site of the dairy in Denmark (left) and the new facility (right), photo credit: NORDEX FOOD

The conversion to biomass was a great solution for the dairy especially due to the timing i.e. being able to get the subsidy and having a plant that needs to be decommissioned. The authorities also have been an active and positive partner in the entire process and no legal issues were encountered during the acquisition and implementation procedure.

Fuel quality

The plant can operate on wood chips up with to 30% moisture and wood pellets at 8% moisture. The current fuel that is being used is A1 wood chips. A1 wood chips should have a premium quality and should produce the least amount of ash. It is a wood waste as it consists of natural and untreated wood which has only been processed mechanically. (Interreg Central Europe, 2023)

The first year of operation the dairy had a supply of A1 waste wood chips via a German supplier with delivery directly from Germany. However, the dairy dealt with poor fuel quality such as large variation in particle size and a high content of impurities. Once, the operators found a horseshoe in a load of chips. The relatively low price of around 4€/GJ could not make up for the low quality and recently, the dairy started sourcing fuel locally which is more environmentally friendly and more in line with the company's DNA. The price of this higher quality fuel matches the normal level of wood chips in Denmark.

The fuel is delivered on fixed days of the week (3 times per week). Unloading and sampling is handled by the driver. The container has a smart control system that allows the plant operators to follow on their smartphones when the container is open, closed and when is being unloaded. The dairy's activities have grown over recent years and so has energy consumption which is why the dairy has acquired a second fuel container.



Figure 3 Truck being unloaded into the fuel container, wood chips up close (photos from left to right), photo credit: NORDEX FOOD

TECHNICAL ASPECTS

The capacity of the biomass boiler is 2,6 MW. Steam generation capacity is 3,8 tonnes per hour at about 30 bars. The boiler can, however, operate at 60 bars. The higher pressure enables the system to compensate for consumption spikes. The biomass containers are each 150 m³. There is a condensate tank of 16 m³.

The system is equipped with a new natural gas boiler that can run with 4 t/h at 13 bars for peak load and backup. It has a calculated efficiency of about 92%.

The schematic below illustrates the operation of the biomass boiler used for process heating in the dairy. The system begins with the combustion of the biomass fuel in the combustion chamber. Heat from the combustion process it heats water into steam in the boiler section and thus generates the necessary thermal energy required for various dairy processes.

The steam produced is distributed throughout the plant for process heating. After passing through an economiser, the flue gases produced during combustion are directed through a series of cleaning stages to ensure environmental compliance and boiler efficiency.

The key components in the cleaning process are the a multicyclone and a bag house filter. While the cyclone captures the coarse particulate matter, the bag house filter captures fine particulate matter and other pollutants from the flue gases, preventing them from being released into the atmosphere. This filtration system is crucial for maintaining air quality and adhering to environmental regulations.

After passing through the bag filter, the cleaned flue gases are expelled through the chimney. The remaining ash and residues from the combustion process are collected in an ash container. This container is designed to handle the by-products efficiently, ensuring that the residues are safely stored and can be disposed of or utilized in an environmentally friendly manner.

By integrating these components, the biomass boiler system not only provides sustainable and efficient process heating for the dairy plant but also minimizes environmental impact through effective pollution control and waste management.

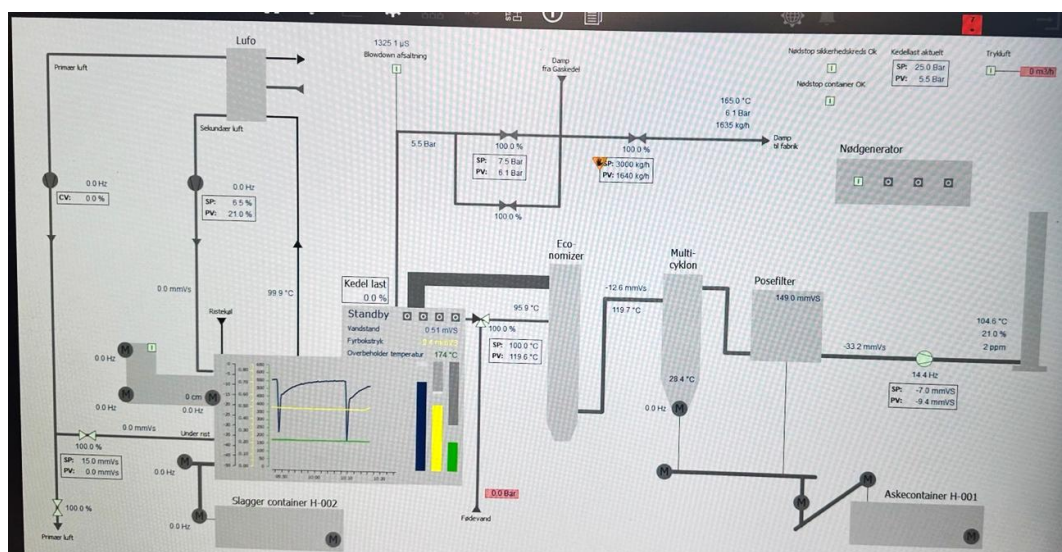


Figure 4 Plant schematic, photo credit: NORDEX FOOD

PROJECT ECONOMICS AND FINANCING

The economics of the investment for both the biomass boiler and new gas fired back up boiler are summarized below:

Table 2 Main economy figures for that biomass boiler plant investment

	Amount (EURO)
Budgeted expenditure for biomass boiler	1.570.000
Investment in biomass boiler	1.755.000
Gas boiler + other	145.000
<i>Total investment</i>	<i>1.900.000</i>
Subsidy	604.000
Total own investment	1.296.000

In addition to the investment costs the dairy considered the prices of the gas and A1 wood chips at the time. The gas price at the time of investment was DKK 3.5748 /m³ which corresponds to EUR 44/MWh and the A1 wood at the time of investment was DKK 30/GJ corresponding to EUR 15/MWh.

With an estimated annual consumption of 8.000 MWh, the payback time was estimated at 5,5 years.

However, this has proved to be an even better investment when looking into the 2022-23 gas prices as reference.

Unfortunately, the boiler system site burned down in the beginning of 2021 due to an electric fault. The incident had nothing to do with the biomass boiler itself. Luckily, the dairy had an insurance and managed to rebuild the boiler system site in the same way again. The rebuilt facility was taken into operation in May 2023.

ENVIRONMENTAL ASPECTS

Since only A1 wood chips are used, it is considered that there are no concerns about the environment, however, should wood chips be used at some point, they dairy would get certified sustainable wood. Additionally, the boiler was built with economizer and dust filter. Since the dairy uses a dry fuel, there are no problems with CO formation, but the dairy has to keep track of the emissions of NO_x. The dust filter ensures that dust is not a problem.



Figure 5 Wood chips in a container and the new facility (from left to right), photo credit: NORDEX FOOD

In 2024, NORDEX FOOD undertook a comprehensive emission measurement to assess the environmental impact of its operations. This meticulous process, which spanned approximately three hours, was conducted on both the gas and bio boilers, focusing on a range of critical pollutants and operational parameters. The emission measurement on the gas boiler targeted:

- Carbon Monoxide (CO)
- Nitrogen Oxides (NO_x)
- Oxygen (O₂)

These measurements are crucial for understanding the combustion efficiency and the environmental footprint of the gas boiler. The results are shown in a table below, outlining that the gas boiler measurements are within the given thresholds.

Table 3 Gas boiler measurements

Parameter	Unit	Measurement	Threshold value
CO	Mg/m ³	43	125
NO _x (NO+NO ₂)	Mg/m ³	82	100
O ₂	Vol %	3,2	-

For the biomass boiler, the scope of the measurement was broader, encompassing:

- Particulate matter
- Carbon Monoxide (CO)
- Nitrogen Oxides (NO_x)
- Oxygen (O₂)
- Additionally, Flue Gas Temperature, Water Vapour Content and Volume Flow were also measured.

These parameters provide a comprehensive overview of the bio boiler's performance and its emissions, which are essential for ensuring compliance with environmental regulations and optimizing operational efficiency. The table below summarises the results from the measurement and as seen none of the parameters were exceeded.

Table 4 Bio-boiler measurements

Parameter	Unit	Measurement	Threshold value
Particulate matter	Mg/m ³	2	50
CO	Mg/m ³	>456	850
NO _x (NO+NO ₂)	Mg/m ³	265	500
O ₂	Vol %	5,9	-

The data collected from these measurements will help NORDEX FOOD in its ongoing efforts to minimize its environmental impact and enhance the sustainability of its operations. By closely monitoring and managing emissions, the company demonstrates its commitment to environmental stewardship and regulatory compliance.

ORGANISATIONAL AND OPERATIONAL ASPECTS

The facility is operated by 3 blacksmiths who supervise the plant on shifts. The old gas boiler was approved for 24-hour operation, i.e., daily supervision 7 days a week. The new biomass boiler is approved for 72 hours of operation, so no supervision is needed on weekends. In the picture below, one of the meters that are part of 72 hours operation is seen. The whole system can be controlled directly from a mobile device. All in all, the plant needs approximately 350 hours annually, including statutory 72 hours of supervision.



Figure 6 Operator in the facility, photo credit: NORDEX FOOD

OTHER ASPECTS

The authorities have been an active and positive partner in the entire process.

The employees of the dairy have been very positive and have seen the conversion as something positive for the company and it now has a greener and more sustainable profile. Nevertheless, there has been some scepticism towards using biomass and the stable operation of the plant mainly from the employees who have boiler responsibility. However, after a few months of operation this has changed, and everyone is very positive. It is now an attraction for the operators to visit the plant and do inspections.

With the primary market being in the Middle East, the company initially did not expect any benefit from a “greener” profile. However, there has been a drastic change over the last 1-1½ years. At present, the transition away from fossil fuel it is a clear advantage, and the company happily talks about it. The transition is now considered to give the company a competitive advantage on the market.

Driven by a commitment to exceed their sustainability goals, the company has embarked on an ambitious project to enhance their green energy initiatives. They installed a 2,6 MW solar PV field adjacent to their plant (see Figure 7), which is significantly contributing to the facility's energy needs. This solar installation generates enough green electricity to cover approximately two-thirds of the dairy facilities' total energy consumption.

To ensure that the remaining one-third of their energy requirements are also met sustainably, the company will source wind-generated green electricity. This wind energy will be certified with green certificates, guaranteeing its renewable origin. By combining solar and wind power, the company is taking a significant step towards reducing its carbon footprint and promoting a more sustainable future.



Figure 7 The biomass plant and newly added solar PVs at bird's view, photo credit: NORDEX FOOD

LESSON LEARNED/RECOMMENDATIONS

Lessons learned

The experience from the conversion was split in 3 phases.

Start-up phase:

There has been the usual start-up and break-in period. This entire part has been taken care of by Focus Bio Energy who helped NORDEX FOOD to design the plant.

The training phase

Although the biomass plant is quite advanced, the technique behind its operation is remarkably straightforward. Once the operating staff became familiar with the controls, they encountered no significant issues beyond those typically associated with a gas boiler. This ease of operation underscores the plant's efficiency and the effectiveness of its design, making it a reliable and sustainable energy source.

After 6 months of operation

After the initial running-in period, the plant has been operating smoothly without significant issues. However, during the first six months, the plant faced challenges with fuel quality, leading to several outages. These issues were quickly addressed by working closely with suppliers and implementing stricter quality control measures, ensuring the fuel met the required standards.

Despite these initial setbacks, the plant's team demonstrated resilience and adaptability, resolving the issues, and returning to optimal operational capacity. This experience highlighted the importance of robust quality control mechanisms and continuous improvement, setting a strong foundation for future operations.

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ACKNOWLEDGEMENTS

Gratitude is extended to NORDEX FOOD for their invaluable support and cooperation. Special thanks to Karsten Præstiin Nielsen for providing crucial information and for his openness throughout the process.

Deep appreciation is also expressed to Focus Bio Energy for their assistance. Sincere thanks to Jens-Ole Aagaard Jensen for his willingness to share insights and for his transparency, which greatly enriched this article.



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