

# Thermal Biomass Gasification in Denmark

IEA Bioenergy Task 33 Country Report 2019



Skive District Heating Plant, Denmark  
Photo: Torben Skøtt

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Energiteknologisk udvikling og demonstration



Ea Energy Analyses

## Thermal Biomass Gasification in Denmark

### Task 33 Country Report 2019

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# 1. Introduction

In 2017, a World Bank report declared Denmark as the 'leader in green energy' based on the best framework conditions when it comes to energy efficiency, sustainable energy and access to energy (WB, 2017). Same year, the World Energy Council named Denmark's energy system the world's best, for the fourth year in a row (WEC, 2017).

The Danish energy policy emerged as a policy area in the wake of the oil crises in the 1970s, with an initial focus on energy prices and security of supply. Later, the climate dimension was added to the area.

Today, the Danish climate and energy policy largely derives from the commitments made in international and European contexts. Some of the objectives originate back from UN negotiations, where EU committed as a single union. These commitments transfer to Denmark via the EU in the form of national reduction targets. Additionally, general EU regulation has direct effect in Denmark. Therefore, the EU plays a decisive role in Danish climate and energy policy. However, Denmark's leading role within renewable energy stems from decades of specific Danish efforts to transition the energy system.

Denmark aims to be independent of coal, oil and gas by 2050, and in the electricity and heating sectors, fossil fuels are expected to be phased-out even earlier. In summer 2018 it was agreed that coal should be phased out by 2030. Integration of wind energy is one of the major components of the Danish renewable energy transition with an aim to meet 50 percent of electricity demand with wind power by 2020. In summer 2018 it was agreed to aim at a total share of renewable energy in the energy sector of 55 percent by 2030.

## SUBSIDIES AND TAXES IN THERMAL BIOMASS GASIFICATION

Today, thermal gasification can gain a subsidy for electricity production of up to 1.15 DKK/kWh (in addition to the electricity price). In this case, gasification gas for electricity production is equated with biogas, which receives the same subsidy. On the heating side, thermal gasification can realise a tax advantage when compared to heat produced from fossil fuels because biomass is tax exempt. Overall, thermal gasification for cogeneration has a subsidy advantage of up to approx. 150-160 DKK/GJ biomass compared to fossil fuel-based cogeneration.

Gasification gas can also be used for production of bio-SNG, which can feed into the natural gas network. There is currently no subsidy equality between upgraded biogas and bio-SNG from gasification of e.g. biomass. Bio-SNG is not subsidised, while upgraded biogas could receive a grant of 136 DKK/GJ gas in 2017 (in addition to the natural gas price). Additionally, it is possible to sell certificates for each produced unit of biogas, which is currently not possible for bio-SNG. Bio-SNG thus has no support and therefore has a competitive disadvantage.

With thermal gasification of biomass in combination with the Fischer-Tropsch process, 2nd generation biofuels (F-T syndiesel) can be produced. Today, the technology is far from being competitive with diesel. Syndiesel currently receives two types of subsidy benefits: Exemption from CO<sub>2</sub> tax and mandate for mixing biofuels. The latter means that from 2012 and onwards it has been required that 5.75% of the consumption of diesel and gasoline is biofuels. This is an indirect support for biofuels where the various types of biofuels including F-T syndiesel compete against each other to be prioritized to fulfil the requirement. Today, however, it is permissible that 1st generation biofuels can contribute to meeting the requirement, which is generally associated with lower production costs.

## **THIS REPORT AND FURTHER INFORMATION**

This report provides an overview of current stakeholders, activities and implementations within thermal gasification of biomass in Denmark. The work has been made as a part of the Danish representation in IEA Bioenergy Task 33 which has been partly funded by the Danish Energy Technology Development and Demonstration Programme (EUDP).

Further information on the Danish bioenergy policies and status of implementation of bioenergy technologies in general can be found in the IEA Bioenergy country report "Denmark - 2018 update" at the IEA Bioenergy website: [https://www.ieabioenergy.com/wp-content/uploads/2018/10/CountryReport2018\\_Denmark\\_final.pdf](https://www.ieabioenergy.com/wp-content/uploads/2018/10/CountryReport2018_Denmark_final.pdf)

An overview of the current policy and commitments can be seen at the Danish Energy Agency website: <https://ens.dk/en/our-responsibilities/energy-climate-politics/danish-climate-policies>

## 2. Stakeholders and Activities in Thermal Gasification

### AUTHORITIES AND ASSOCIATIONS

#### Authorities

##### **Danish Energy Agency (DEA)**

Under the Danish Ministry of Energy, Utilities and Climate, the Energy Agency works to develop regulation and framework conditions for Danish energy production, supply and demand, as well as Danish efforts to reduce carbon emissions. The Agency is responsible for supporting the economical optimisation of utilities that in addition to energy includes water, waste and telecommunication. The DEA is also responsible for user conditions, supply obligation and telecommunication statistics as well as water supply and waste management. The Danish Energy Agency was established in 1976 and employs about 360. In 2019, the DEA will change address.

The Danish Energy Agency  
Amaliegade 44  
DK-1256 Copenhagen K  
Telephone: +45 33 92 67 00  
E-mail: ens@ens.dk  
Website: www.ens.dk

##### **Danish Environmental Protection Agency (EPA)**

Under the Danish Ministry of the Environment and Food, the Environmental Protection Agency is responsible for legislation and is in charge of major national tasks as well as particularly complex tasks. The Environmental Protection Agency prepares legislation and guidelines and grants authorisations in several areas. Further duties include the monitoring of chemicals and offshore platforms. Together with the Copenhagen office, the decentralised unit in Aarhus authorises and monitor approximately 400 enterprises and local waste handling facilities.

The municipalities are responsible for granting permits and inspection of other enterprises and also carry out the majority of specific public sector duties. The municipalities are typically the point of contact for the general public and for companies wishing to access information on the environment.

The Danish Environmental Protection Agency  
Haraldsgade 53  
DK-2100 København Ø  
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E-mail: mst@mst.dk  
Website: www.mst.dk

##### **Energinet - the TSO**

Energinet is an independent public enterprise owned by the Danish Ministry of Climate and Energy. The Danish TSO owns, operates and develops the transmission systems for electricity and natural gas in Denmark. Energinet is also involved with energy planning to manage the high security of supply in the Danish systems as well as renewable gases. Energinet handles subsidy schemes on behalf of the DEA for renewable electricity and gases - currently only upgraded biogas from anaerobic digestion.

Energinet  
Tonne Kjærvej 65  
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E-mail: info@energinet.dk  
Website: www.energinet.dk

## **Municipalities**

94 municipalities in Denmark are the primary point of contact for companies wishing to obtain an approval to operate energy plants such as gasifiers. The municipalities are responsible for granting permits and inspection of enterprises and also carry out the majority of specific public sector duties within emissions to the environment and urban planning. More information can be found at the website of Local Government Denmark.

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Telephone: +45 3370 3370  
E-mail: kl@kl.dk  
Website: [www.kl.dk/English/Local-Government-Denmark/](http://www.kl.dk/English/Local-Government-Denmark/)

## **Associations**

### **Danish Partnership for Thermal Gasification**

Hosted at the Danish Gas Technology Center, the Danish Partnership for Thermal Gasification works to ensure that thermal gasification of biomass is utilised optimally in the Danish energy system.

The purpose of the association is to coordinate, strengthen and target Danish research, development and demonstration activities (RD&D) so that thermal gasification can fulfil its role and potential in the expected future Danish energy system.

Several RD&D institutions and manufacturing companies support the project, but the partnership is open to all interested actors.

The partnership received support from Energy Technological Development and Demonstration (EUDP) in 2014 and held the first general assembly on November 20, 2014. Since the start, the partnership has carried through several work packages and played a large role in formulating the needs for an RD&D effort to solve obstacles that prevent thermal biomass gasification contributing to an energy system independent of fossil fuels:

- Status for thermal gasification
  - o Suppliers and technologies and relation to Danish system conditions
- Integration of thermal gasification in the Danish energy system
- Danish framework conditions and feasibility of thermal gasification
- RD&D Strategy for thermal gasification
- Organisation and management of the initial partnership period

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Website: [www.forgasning.dk](http://www.forgasning.dk)

### **DI Bioenergy**

The Confederation of Danish Industry (DI) is a private organisation, funded, owned and managed entirely by approximately 10,000 companies within the manufacturing, trade and service industries.

DI Bioenergy organises manufacturers and other actors with interest in the bioenergy business at large. DI Bioenergy has been involved in formulating R&D strategies within thermal biomass gasification.

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Head of secretariat:  
Ms. Anne Lund Wilhelmsen  
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## NATIONAL R&D PROGRAMMES

An array of national programmes has been instrumental in promoting RD&D gasification projects in Denmark as well as attracting funding opportunities for projects and implementations from international sources and programmes. Over the recent years, the number of funding programmes as well as the available funds have decreased to the [regrets](#) of the Danish industry.

### Ministry of Energy, Utilities and Climate

The three Research, Development and Demonstration programmes in this Ministry have common application documents (Project Description, Gantt Chart/Time Schedule and Project Economics) and economic rates, which are similar to the European funding rates and rules. Applicants must be done on the individual program websites.

### Energy Technology Development and Demonstration Program (EUDP)

EUDP is managed by the Danish Energy Agency and supports development of new efficient and climate-friendly energy technologies that can help Denmark to become independent of fossil fuels by 2050. At the same time, projects should develop Danish business potential for growth and employment. More information can be found on the [EUDP website](#).

### ELFORSK - Danish Energy Association

ELFORSK supports projects that ensure a more efficient use of electricity at the end-users. The projects are located in the full range of the value chain - from applied research through development forward to deployment. Read more on [ELFORSK's website](#) (in Danish).

### Ministry of Education and Research

#### Innovation Fund Denmark

The former Strategiske Forskningsråd (DSF), Højteknologifonden (HTF) and RTI have merged to Innovation Fund Denmark in 2014. Through more programmes, the fund supports strategic research in renewable and environmentally sustainable energy systems and technologies as well as invested in growth opportunities and tangible results, where universities and companies work from basic science, innovation and technology. The focus has been on the market maturation of specific products and technologies. More information can be found on the [website](#).

### Overview of projects

Danish RD&D projects are described at a common portal that can help create an overview of the recent interests and activities. The projects can be found at [Energiforskning.dk](#). Below is a list of recent project descriptions within thermal gasification.

- [Oxy-fired Biomass Gasification for Flexible Power](#) (DTU)
- [Synergy by Integration of Biogas and bio-SNG](#) (DGC)
- [Regenerative Sulfur Removal from Biomass Gasifiers](#) (DTI)
- [Catalytic removal of tar from biomass gasifiers](#) (DTI + HTAS)
- [PolyGas - POLYgeneration by thermal GASification](#) (DTU)
- [SYNFUEL - Sustainable synthetic fuels from biomass gasification and electrolysis](#) (DTU)
- [H2CAP-Hydrogen assisted catalytic biomass pyrolysis for green fuels](#) (DTU)

## **R&D INSTITUTIONS AND CENTRES**

### **Danish Technical University (DTU) - Chemical Engineering - CHEC**

At DTU, the Biomass Gasification Group has played a major role in conceiving innovative biomass gasification concepts. The concepts have been successfully demonstrated in Denmark and they have been a great inspiration internationally for academia, successful emerging manufacturers as well as successful implementations.

The group is currently placed at the Centre for Harmful Emissions Control (CHEC) at the Department of Chemical Engineering at DTU.

It is the aim of the activities to be leading in research, development and innovation concerning thermal gasification technologies for highly efficient combined heat and power production and/or production of clean fuel e.g. methanol or bio-SNG (Synthetic Natural Gas). The established knowledge is used to solve general as well as specific problems related to gasification and pyrolysis and valuable experience is gathered based on work with laboratory, pilot and development projects.

Currently, the group works within a wide variety of focus areas, one of them being further development and demonstration of the DTU TwoStage biomass gasification technology and the PYRONEER (Low Temperature Circulating Fluid Bed) gasification technology for CHP and fuel production.

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Website: <https://www.kt.dtu.dk/english/research/chec/research-areas/gasification>

### **Aalborg University (AAU)**

At the Department of Development and Planning at Aalborg University in Copenhagen and in Aalborg, research is taking place into how thermal gasification can become an integral part of the Danish and Nordic energy system.

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### **Danish Gas Technology Centre (DGC)**

DGC was established by Denmark's natural gas companies in 1988 as a public limited company with the following circle of owners:

- HMN Naturgas (43.3 pct.)
- Dansk Gas Distribution (36.0 pct.)
- Energinet.dk (13.9 pct.)
- NGF Nature Energy (6.8 pct.)

DGC is a specialized consulting and development company within energy and environment. DGC's focus area is gas utilization - also within green gas and thus thermal biomass gasification and bio-SNG. DGC offers consulting services, research and development, laboratory testing, measurement, demonstration projects, and training. DGC participates in Danish and international research projects, thereby continually updating its knowledge and methods.

DGC has conceived the idea of the Danish Partnership for Thermal Gasification and is currently leading the secretariat of the association.

Currently, DGC is leading a lab scale project on feeding syngas from a wood pellet gasifier into an anaerobic digester where bacteria digest the syngas and generate methane.

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Contact person: Mr. Niels Bjarne Rasmussen  
Telephone: +45 2147 1752  
E-mail: [nbr@dgc.dk](mailto:nbr@dgc.dk)

### **The Danish Technological Institute (DTI)**

The Danish Technological Institute is a company in the Danish Advanced Technology Group and has been focused on research and development of measurement methods for energy and environmental performance for different CHP technologies. The Danish Technological Institute has been representing Denmark in the work related to the EU tar protocol and the CEN tar measurement standard. The current focus is also on cleaning of synthesis gas.

Cleaning of synthesis gas from biomass gasification allows you to take the important step towards sustainable production of clean bio fuels with catalytic processes. Biomass gasification, however, develops a significant amount of tar, which contaminates the catalyst. In order to render biomass gasification more attractive, it is therefore necessary to develop the next-generation tar reforming technologies. DTI has obtained good results by extracting tar from the synthesis gas in their pilot reactor. Recently, DTI has developed a regenerative method for sulphur removal that has the potential of reducing

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## **INDUSTRY AND CONSULTANTS**

In recent years Denmark has seen a decreasing industrial involvement in thermal biomass gasification in terms of number of companies along with a number of insolvencies or bankrupts of companies that have either not been reconstructed or that have not been focusing on thermal gasification after reconstruction. The faith of these companies have mostly had nothing to do with the gasification processes themselves but rather with a number of other factors such as a choice of:

- A reluctant market - especially the Danish home market where the main focus point of CHP generation has lost momentum due to an increasing share of wind energy in the energy system and decreasing electricity prices
- Demanding and time-consuming approval of operations permits
- Lack of funding
- Reluctancy towards focussing on international markets
- Poor management decisions
- Poor craftsmanship.

The following is a list of companies that have been involved with successful implementations or that currently have been visible in RD&D projects.

### **Ammongas**

Ammongas is developing an alternating gasifier concept named "Firgas" unlike other concepts. The gasification process is alternating, which means that the two gasification reactors are in operation for a short period each (10-20 minutes) and the gas is stored. Then the gasification is stopped and one of the catalysts is heated with a part of the produced gas (10-20 minutes). Then the gasification is started again in the opposite direction for the same period of time while the heat in the just heated catalyst is utilized for the gasification. In the last of the four operations the second catalyst is heated and then the four operations start over again.

After an initial period, Ammongas has involved B&W Vølund in the development process and subsequently a co-operation with DTI was set up to further refine the process. More information can be found in [2].

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Website: www.ammongas.dk

### **Babcock & Wilcox Vølund**

Vølund manufactures and supplies waste to energy plants, grate fired biomass boiler plants and biomass gasification-based CHP plants. Vølund has been deeply involved in the development, demonstration and commercialisation of the updraft wood gasifier in operation at the Harbøre District Heating Company in Denmark (described below) and several other places worldwide.

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Website: www.volund.dk

## **COWI**

COWI is an independent consultant operating worldwide within all principal fields of engineering and related sciences. COWI holds the rights for the staged gasification process developed by DTU and has taken part in the efforts to upscale the gasifier to the 500 kWe demonstration plant described further below. COWI has been involved in several other projects, e.g. the mechanical and electrical work for the Carbona gasifier at Skive District Heating Company and several international R&D projects.

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Contact person: Mr. Reto M. Hummelshøj  
Telephone: +45 4597 2211  
E-mail: rmh@cowi.dk  
Website: www.cowi.com

## **Dall Energy**

Dall Energy is a supplier of new and improved energy technologies with focus on thermal processes which produce heat for district heating, but also combined heat, power, cooling and syngas production are part of the scope.

Recently, the award-winning Dall Energy low emission furnace has been further developed to resemble an updraft gasifier with partial oxidation to drive the gasification process and subsequent full combustion of the gas to heat an oil based turbine system - an ORC unit. A plant with such a technology has been installed in Sindal in the northern part of Denmark as described below.

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E-mail: info@dallenergy.com

Contact person: Mr. Jens Dall Bentzen  
Telephone: +45 2987 2222  
E-mail: jdb@dallenergy.com  
Website: www.dallenergy.com

## **Danish Fluid Bed Technology (DFBT)**

DFBT conceived the low temperature circulating fluidised bed concept (LTCFB) and developed the concept with DTU. The IPR of the technology concept was acquired by DONG Energy (now Ørsted) and was renamed Pyroneer. The 6 MWth pilot unit that later was built to indirectly co-fire straw at the coal-fired Asnæsværket in Kalundborg was a product of cooperation between Danish Fluid Bed Technology (DFBT) and DONG Energy and several other actors. Plans for upscaling the concept by a factor of 10 and divest the technology could not be carried through and DONG Energy mothballed the pilot unit and dismissed the staff.

DBFT is currently taking part in R&D projects with the technology together with DTU and promoting the technology for interested parties, mainly power stations.

Danish Fluid Bed Technology  
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Contact person: Mr. Peder Stoholm  
Telephone: +45 4088 6327  
E-mail: [psto@dkfbt.dk](mailto:psto@dkfbt.dk)  
Website: <https://www.linkedin.com/in/peder-stoholm-81394223/?originalSubdomain=dk>

## **1rgi**

1rgi is a single person spin-off of B&W Vølund which provides engineering for updraft gasifiers amongst machine engineering services.

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DK-6200 Aabenraa

Contact person: Mr. Thomas Ritz Nissen  
Telephone: +45 6536 2296  
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E-mail: [trn@1rgi.dk](mailto:trn@1rgi.dk)  
Website: <http://1rgi.dk/UK.html>

## **Frichs Ecotech**

Frichs Ecotech is dedicated to solving environmental problems in amongst others the waste water treatment business and in agriculture. The company utilises flash pyrolysis to convert feedstock such as sewage sludge or residual fibres from biogas plants into biochar and gases. The gases to operate a CHP unit.

Frichs Ecotech develops and markets plants that generate fuels from organic waste or biomass, converting the feedstock into useful energy streams by using a proprietary pyrolysis process that separates inorganic from organic waste, and processes the organic waste or biomass into gaseous fuel for consumption in a CHP unit which produces electricity and heat and, thereby, producing net benefit to society from its waste or biomass streams.

Currently, the company operates a demonstration plant in Horsens.

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Sverigesvej 16  
DK-8700 Horsens

Contact person: Mr. Jørgen Krabbe  
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E-mail: [ecotech@frichs.com](mailto:ecotech@frichs.com)  
Website: <http://frichs.com/ecotech/index.html>

### **Gasification Denmark**

Gasification Denmark is a single person spin-off of B&W Vølund which provides engineering for updraft gasifiers amongst machine engineering services.

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### **Green Gas Combustion Technology**

GGCT is a small and relatively young company that initially followed the vision of developing a small-scale biomass-fired gas turbine plant in the size of around 100 kWe for power and heat generation that is CO<sub>2</sub>-neutral and flexible in terms of fuel requirements and ramping times. The focus has now broadened a bit to cover gasification of residual products in order to either operate an IC engine, catalytically generate liquid biofuel or boost the generation of biogas.

The gasifier is a staged gasifier with separate pyrolysis, separate char reduction and separate "hot section" for cracking of the tar fractions. By keeping the processes separated it is the expectation to maintain an ability to keep the temperature relatively low in the reduction zone in order to maintain the nutrients in the ash accessible for plants. The temperature in the "hot section" is controlled by addition of oxygen keeping temperature high to crack tars. In brief the system concept comprises six main components, that is:

1. An up-draft gasifier
2. A gas purification system
3. A gas compressor
4. A gas turbine/genset
5. A recuperator and
6. An air/water heat exchanger

In November 2017 the technology was operated with positive results and improvements at the Biomass Gasification Group at the Danish Technological University. Three types of feedstock were tested and especially granules of sewage sludge and pelletised fibre residues from anaerobic digestion of manure showed promising results.

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### **Haldor Topsøe**

Haldor Topsøe is not directly involved in thermal biomass gasification, however, as a world leader in catalysis, Haldor Topsøe has many touchpoints with gasification.

Haldor Topsøe supplies high-performance catalysts, proprietary technologies, process design, engineering, and services for use in the chemical and oil & gas industries and see themselves as being at the forefront of developing sustainable technologies as their solutions address pressing global challenges, such as improving energy efficiency, enhancing food production for the world's growing population, and protecting environment.

Within thermal biomass gasification, Haldor Topsøe is amongst many other projects involved with SNG methanation (GobiGas, Sweden), catalytic gas cleaning (Skive) and fuel synthesis with the TIGAS process (Skive).

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### **Ørsted**

Ørsted is the former DONG Energy - a utility company owned primarily by the Danish state. Ørsted is focused on becoming an entirely renewable energy-based power supply company and is operating biomass-based new built CHP units as well as retrofitted CHP units throughout Denmark. Ørsted is expanding strongly internationally within wind energy based on the experiences from Denmark. In previous years, Ørsted has developed and demonstrated the Pyroneer gasifier for co-firing biomass at their power station in Kalundborg. Ørsted is the owner of the technology. For more information about Pyroneer, please refer to page 22.

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Website: www.orsted.dk

### 3. Successful Implementations

In Denmark, three biomass gasifiers are in operation on a commercial basis. The gasifiers form the core of three CHP facilities that successfully generate heat for the district heating consumers in the respective towns and electricity for the grid. All three plants are situated in the Northern part of Jutland as it is shown in the Task 33 database. All three have been subject to some level of public funding for demonstration purposes.



Figure 1. Situation of Danish gasification plants.

General data about the plants can be seen in Table 1.

Table 1. Thermal gasification facilities in Denmark

Project name/ location	Technology	Input/ Feedstock	Output/ El./Th.	Usage/ Product	Start up/ Status
<b>Harbøre CHP plant</b> /Harbøre, DEN	<b>Fixed bed - updraft</b>	<b>3,5 MW</b> /forest wood chips	<b>1 MW electric</b> <b>1,9 MJ/s heat</b>	<b>CHP</b> <b>generation</b>	<b>1993 (CHP in</b> <b>2000)</b> <b>/operational</b>
<b>Sindal CHP plant</b> /Sindal, DEN	<b>Staged updraft</b>	<b>5.5 MW</b> /wood residues	<b>0.8 MW</b> <b>electric</b> <b>5 MJ/s heat</b>	<b>CHP</b> <b>generation</b>	<b>2018</b> <b>/operational</b>
<b>Skive CHP plant</b> /Skive, DEN	<b>Bubbling fluidised bed</b>	<b>20 MW</b> /wood pellets	<b>6 MW electric</b> <b>11,5 MJ/s</b> <b>heat</b>	<b>CHP</b> <b>generation</b>	<b>2008</b> <b>/operational</b>

## HARBOØRE CHP PLANT



In 1993 Harboøre Varmeværk established a demonstration gasification plant based on the development achievements at pilot scale by the supplier, Babcock and Wilcox Vølund, and numerous university studies. In 1997, after a large development effort by Vølund and the heating company, the gasification process was considered commercial, and in the course of 2001 the district heating plant was converted into CHP and was taken into commercial operation. Since then, the plant has operated 8,000 hours per year and supplies heat to approx. 698 heat consumers including the municipal buildings of the town.

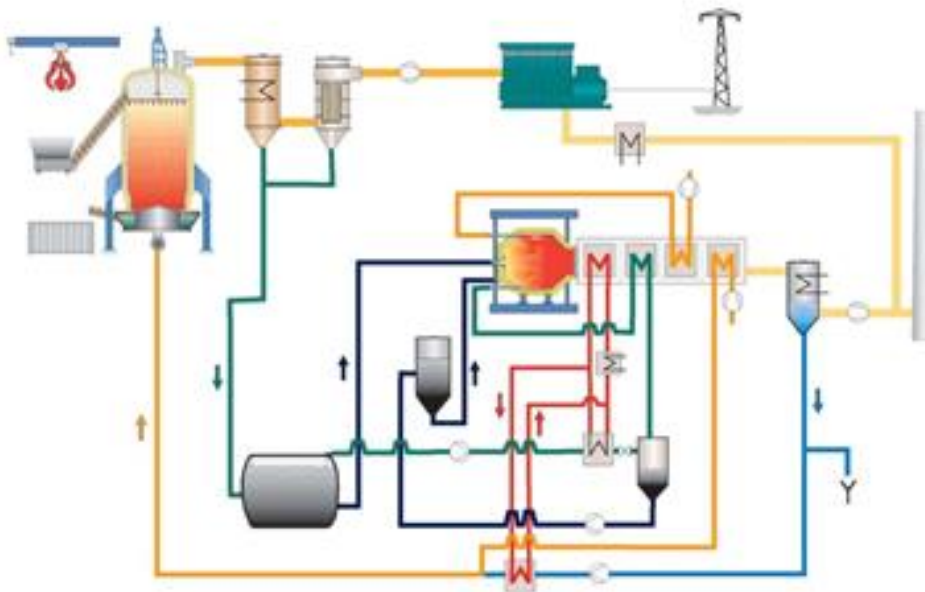


The Harboøre gasification plant is in operation all year round. It burns bio-oil when the gasifier has its main renovation one week per year. The bio-oil is a residue from the process; it is also useful in times of special need, during peak load hours of a cold winter, for instance, when you need more hot water than usual for the district heating grid.

The gas is produced in a modern updraft gasifier designed as a vertical, cylindrical furnace with ceramic insulation. Freshly chipped forest wood chips with a moisture content of 39-50% are used as feedstock. The plant is controlled 100% on the basis of the heat requirement. The gasifier has an output of 4 MWth, and the gas can be burnt in a Low-NOx gas burner built onto a 4 MW hot water boiler.

The Harboøre plant can be divided into the following main components:

- 3.7 MWth up-draft gasifier with fuel feed, ash extraction system, and air humidifier
- Gas cooling and cleaning system
- Two gas engines with generators and exhaust boilers
- Waste water cleaning system named the Tarwac system



*Flow sheet of Harboøre plant*

Public funding for the R&D parts of the project came from the Danish Energy Agency EUDP and the European Commission and the US Department of Energy.

Further information about the Harboøre plant and the technology can be found at

- [The Task 33 status report 2016](#)
- [Brochure from Vølund](#)

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 Website: [http://www.volund.dk/Biomass\\_energy/Technologies/Gasification\\_of\\_biomass](http://www.volund.dk/Biomass_energy/Technologies/Gasification_of_biomass)

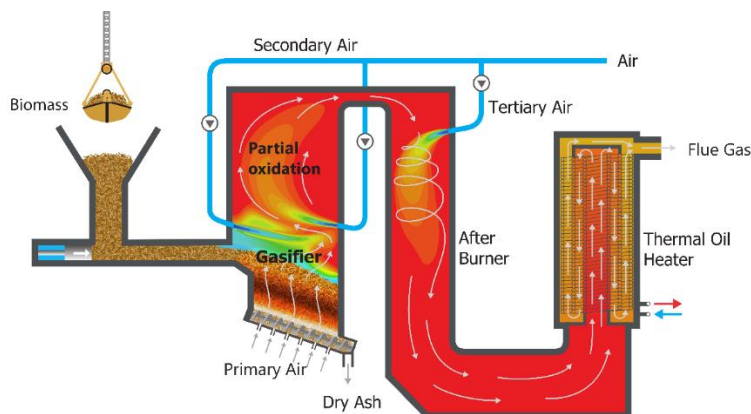
## SINDAL CHP PLANT



Sindal District Heating company was until 2018 using natural gas for district heating, partly by running IC engines and partly by gas boilers. The company was searching for cheaper and more environmentally friendly fuels and chose to build a Dall Energy gasifier with an ORC turbine.

The technology consists of

- An updraft biomass gasifier with partial oxidation
- An afterburner
- A thermal oil heater
- A scrubber system for recovery of heat
- An ORC unit



The plant is a third generation "Dall Energy Furnace" where the first generation was built in Bogense (Denmark) and second generation built in Sønderborg (Denmark) and Warwick Mills (USA). The first plants have verified that the "Dall Energy Furnace" technology offer a number of

advantages compared to other biomass solutions for district heating. With this plant, Sindal District Heating Company obtains:

- Cheap & environmentally friendly fuels (Garden waste, wood chip)
- To run biomass both summer and winter in just one plant
- Low NOx emissions
- Low CO emission
- Low dust emission
- Co-production of heat and power

The project is a demonstration project supported by the Danish R&D fund "EUDP".

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Dall Energy (supplier):

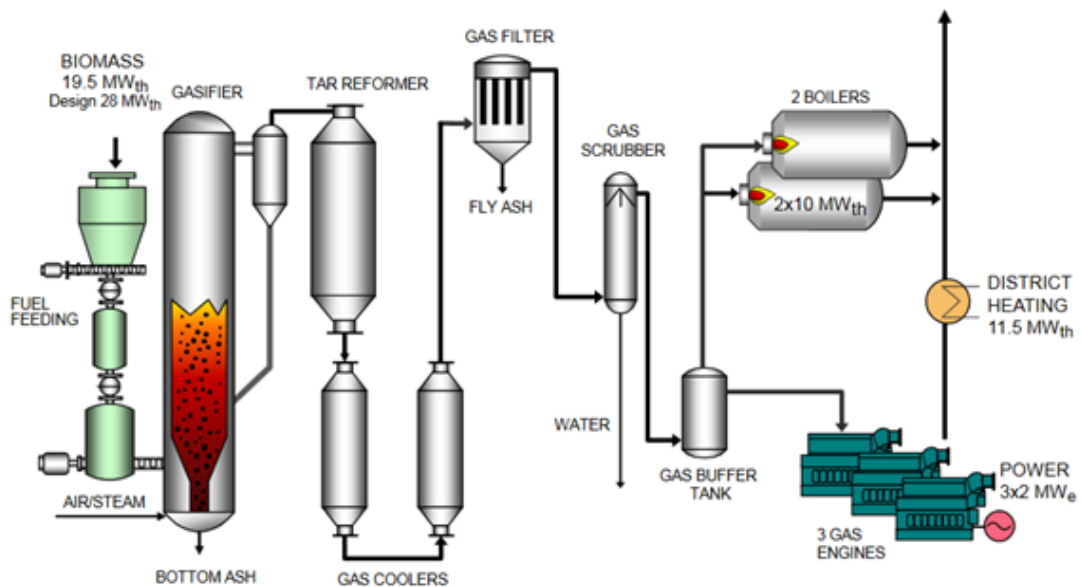
E-mail (contact person): Mr. Jens Dall Bentzen ([jdb@dallenergy.com](mailto:jdb@dallenergy.com))

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## SKIVE CHP PLANT



At the Skive gasification demonstration project in Denmark, a bubbling fluidized bed (BFB) gasifier is used to produce gas from wood-based biomass. This gas is then cleaned catalytically and used in three IC engines in a combined heat and power (CHP) application. The capacity of the plant is 6 MW electricity and 11.5 MJ/s heat based on input of 20 MW wood pellets. The heat is consumed in the local district heating network in Skive and the electricity is sold to the grid.





The commissioning of the plant started in late 2007 and, using one gas engine, operations initially began in the early summer of 2008. The second and third gas engines were installed during summer 2008.

The local district heating company, Skive Fjernvarme, is the owner and acted as the main contractor in the project, having the responsibility for integrating the various components. The gasifier is from Andritz Carbona while the catalytic gas cleaning system was supplied by Haldor Topsøe. Aaen Consultants (now acquired by Niras) were responsible for engineering of the plant. The building is designed by C.F. Møller Architects. Public funding for the R&D parts of the project came from the Danish Energy Agency, the European Commission and the US Department of Energy.

After several years of intermittent operation, the plant has now reached a high availability and operation and outage is fully under control. Persistent efforts to improve fuel quality and alter the catalytic tar reformer have helped decreasing the forced outage and time consumption when maintaining the catalysts. This means that the energy consumption in Skive now primarily is covered by renewable sources. Further on the improvement on the catalytic gas cleaning can be read in [1].

Skive Fjernvarme and Haldor Topsøe has in an EUDP funded project been looking into the opportunity to utilise the gas for production of gasoline and other fuel products via the TIGAS process. The results are described in [1].

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## OTHER GASIFICATION PLANTS

Several pilot plants and demonstration plants have been built in Denmark over the past years. All have ceased operation, and some have been dismantled. The reasons vary but have typically not been related to the core operation of the thermal gasification technology. Three plants should be mentioned here.

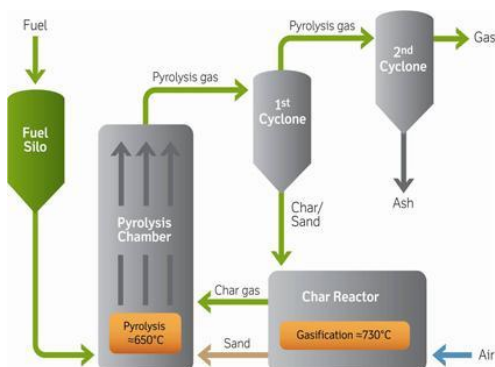
### Kalundborg co-firing, Pyroneer (Ørsted (previously DONG Energy))

Based on R&D activities at the Danish Technical University (DTU) and Danish Fluid Bed Technology (DFBT), a 6 MWth Pyroneer demonstration unit was commissioned at the Asnæs power station in Kalundborg in spring 2011. The gasifier was fed with straw, manure fibres or local residue to co-fire gasified feedstock into the coal fired unit.

The Pyroneer gasifier is a low temperature CFB type and consists of three main components; a pyrolysis chamber, a char reactor and a recirculating cyclone. Cleaning of the producer gas may simply be done with a second cyclone when the gas is co-fired into a coal boiler. Stable and safe unmanned long-time operation was demonstrated. It was demonstrated that the ash and char can be used for fertiliser field tests with impressive results.

There were plans to upscale the technology for a 60 MWth unit and to license or sell the technology. Status by the end of 2015 was that the technology was not sold, the project got mothballed and the staff was moved from Pyroneer or dismissed.

Research is still ongoing at the DTU and the technology is available for interested parties that wish to utilise agricultural residues for energy generation while removing trace metals and maintaining the nutrients in the ash and biochar.



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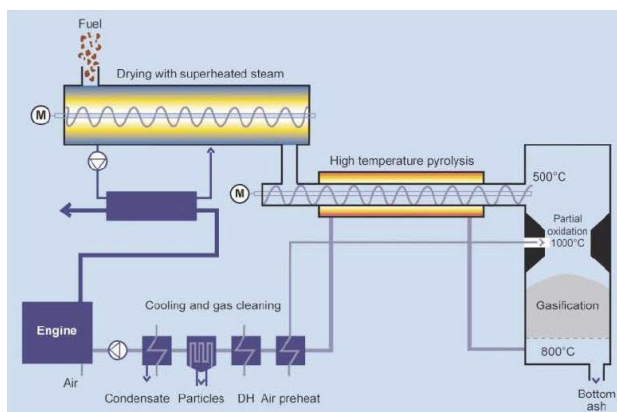
## Hillerød CHP, Weiss

Based on RD&D activities at the Biomass Gasification Group at the Danish Technical University (DTU) and the development of the staged gasifier - the Viking gasifier - the concept was upscaled by DTU, COWI and the boiler manufacturer Weiss to be built for unmanned CHP operation on wood chips (500 kWe/1,000 kJ/s heat) at the district heating company in Hillerød north of Copenhagen.

The unit consists of a dryer where the feedstock is dried with superheated steam followed by a conveyor where the feedstock is pyrolysed and an air-blown gasifier vessel where the char is gasified along with a cracking process that eliminates tar. The concept generates a very clean gas that is ideal for IC engine operation without advanced gas cleaning. Unparalleled electric efficiency for this plant size as well as stable operation has been demonstrated by this concept.

The plant in Hillerød was built and quickly reached stable operation, however, due to factors that look like poor management decisions and poor craftsmanship at the supplier level, the plant faced a breakdown that was never repaired due to funding problems and changing ownership at the supplier. Thus, the plant never came into commercial operation and was dismantled in 2016 [2]. The supplier later filed bankruptcy.

Research is still ongoing at the DTU to upscale the technology and it is available for interested parties that wish to utilise forest residues for efficient energy generation.



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## Hillerød CHP, Biosynergi

Based on several years of development and 4,000 hours of demonstration of a patented open core down draft gasifier concept for efficient CHP generation based on fresh wood chips, the supplier teamed up in an investment company with private and public investors to facilitate upscaling of the technology to capacities of 300 kWe and 750 kJ/s heat to be installed at the district heating company in Hillerød north of Copenhagen.

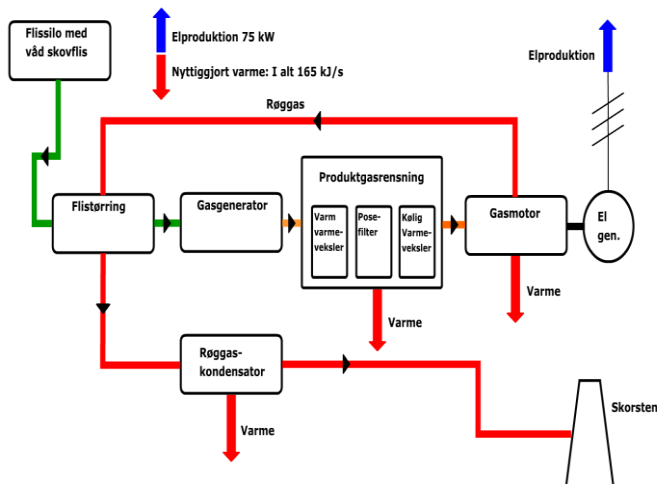
The main vision of the gasifier concept is to develop a unit based on simple processes and commonly available materials to facilitate inexpensive production for the supplier as well as low investment and low operational costs for the owner.

The gasifier is set up with a gas cooler and filtering systems to feed an IC engine genset. Heat from the engine is used for the integrated drum dryer to dry the fuel. The feedstock is freshly chipped wood chips with a typical moisture content of 40-55%. Heat for district heating is produced at three points in the plant:

- Cooling water from the gas engine
- Cooling of product gas in heat exchangers
- Heat from cooling and condensation of flue gas.

The plant was designed for unmanned, automatic operation and has a nominal overall efficiency of 86%. An advantage of having a small CHP plant is that the production of electricity and heat can take place close to the forest areas where the wood for the chip production grows. It reduces the need for road transport of biomass - and thus the CO<sub>2</sub>-emissions of trucks.

All parts of the plant in Hillerød were installed and have been in unmanned operation during 2017. Minor technical challenges in combination with lack of further funding forced the company to cease activities in the last part of 2017. The plant has subsequently been dismantled.



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**IEA Bioenergy**



**Further Information**

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