IEA Bioenergy

# Bioenergy Success Stories

IEA Bioenergy: 02 2018

# Dall Energy, Denmark

## Low emission fuel flexible biomass furnace

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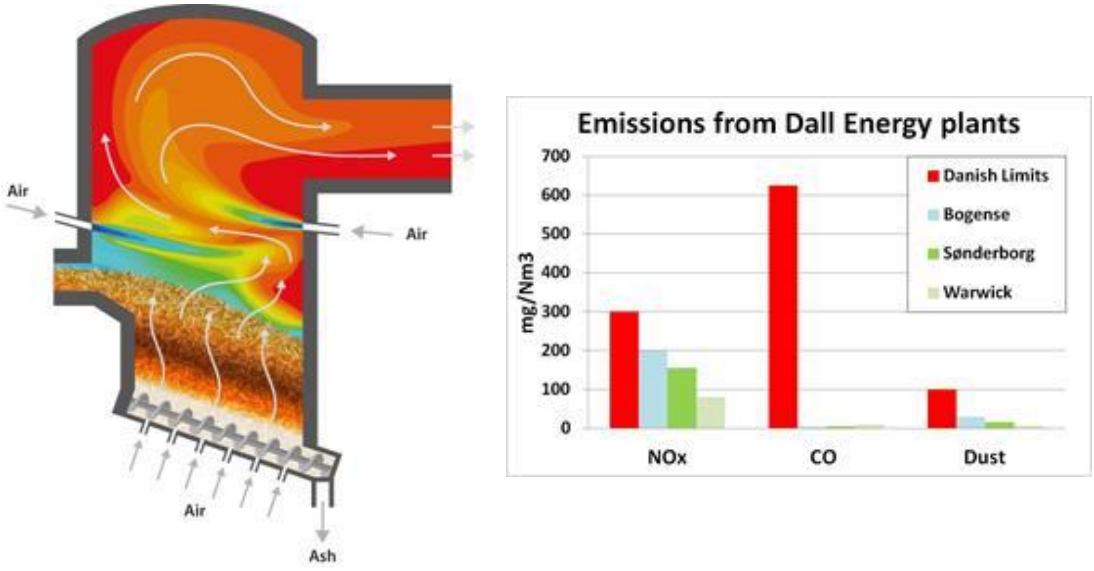
|---|---|
| **Year of implementation:** | 2015 |
| **Location:** | Sønderborg district, Denmark |
| **Technology:** | Updraft gasification and gas combustion |
| **Principle feedstocks:** | Residues/wastes in forestry & Residential or industrial organic wastes.<br>During 2016-2017, various fuels including spent grain from Carlsberg, and fibers from biogas plants were tested |
| **Products/markets:** | Heat and Power |
| **Technology Readiness Level (TRL):** | TRL 8 – system complete and qualified |

## DESCRIPTION

The Dall Energy biomass furnace combines updraft gasification and gas combustion into one unit, which offers advantages to operation and maintenance, emissions reduction, and turn-down ratio. Evidence for this comes from a pilot plant, a demonstration project, a 2 MW plant and a 9 MW plant in Denmark. Next-generation heat and power production plants represent the next steps in this technology and several of these projects are now at the planning stage.

The technology can use multiple fuels, including wood chips, garden waste, spent grain or manure fibres. The Dall Energy biomass furnace combines updraft gasification and gas combustion. There is no need to include a particulate filter, because of the extremely low dust from the biomass furnace. The technology includes a two-stage gas combustion for low $NO_x$ emissions, and a two-stage flue gas condenser for high efficiency.

During 2013-2014, a 9 MW plant was planned and built in Sønderborg, Denmark, for the local district heating company. The Dall Energy heating plant supplies the towns of Vollerup and Hørup Hav with district heating with the purpose to supply cheap and renewable heat with low emissions. The cost of the total project was 8 million Euro, of which 2.2 million Euro for the biomass plant (0.8 million Euro for the Dall Energy Furnace). The plant was started up in January 2015. Emission tests were carried out in March 2015. The plant has been in unmanned operation since October 2015. The low emissions of the plant were verified.




*Dall Energy biomass furnace (left) - Emissions from Dall Energy plants (2015) (right)*

| | |
|---|---|
| **Stakeholders involved** | Dall Energy<br>Sønderborg District Heating Company (client)<br>FORCE technology (CFD analysis)<br>COWI (consultant)<br>Markedsmodningsfonden (grant of 0.8 million €) |
| **Contribution to Sustainable Development Goals** | The projects contribute sustainably to improved air quality (SDG 3), affordable local energy (SDG 7), economic development in the region (SDG 8), sustainable industrialization (SDG 9), sustainable consumption patterns (SDG 12) and reduced GHG emissions (SDG 13). |
| **Employment:** | *No information available* |
| **Replicability and scale-up potential:** | The technology has medium replicability and scale-up potential at local level (depending on district heating infrastructure), and medium to high at regional, national and international level. |
| **Success factors:** | Multiple fuel capability: wood chips, garden waste, spent grain, manure fibres;<br>Low emissions of $NO_x$ (<180 mg/$Nm^3$), CO (<5 mg/$Nm^3$) and particulates (<20 mg/$Nm^3$);<br>Unmanned operation;<br>Low power consumption (10,3 $kW_{el}$/MWh heat);<br>Clean ash (0,5% carbon in ash);<br>High efficiency (110% based on Lower Heating Value);<br>Turn-down ratio of 10-100% load |
| **Constraints:** | … |

*9 MW Dall Energy biomass plant in Sønderborg*

| | |
|---|---|
| **Info provided by:** | Jens Dall Bentzen, Managing director of Dall Energy |
| **More information:** | http://www.dallenergy.com/<br>https://www.nytimes.com/2015/12/06/world/europe/denmark-a-green-energy-leader-slows-pace-of-its-spending.html?_r=0<br>https://energyhub.theiet.org/users/57022-jens-dall-bentzen/posts/18661-fuel-flexibility-and-low-emissions-in-biomass-fired-power-plants<br>http://www.dallenergy.com/media/151007_Paper_IT3_Houston.pdf |

**CLIMATE TALKS**

# Denmark, a Green Energy Leader, Slows the Pace of Its Spending

By MELISSA EDDY

SONDERBORG, Denmark — Not long ago, Denmark was making headlines for harvesting so much wind power that it was leading the way in generating renewable energy, while becoming a center of innovation and growth for green and clean technology.

Then, in June, a center-left government was replaced by a right-wing, minority coalition determined to tighten spending and balance the budget in a program to grow the economy.

The budget cuts include a key fund that was used to seed green technology projects — a government subsidy that environmental advocates said had paid itself off many times over.

"This funding has proven instrumental for Danish advances in clean tech for many years, and it is incomprehensible why it is being cut now," said Soren Houmoller, whose 1st Mile consulting company helps businesses apply for public funds in Denmark.

Mette Abildgaard, a spokeswoman for green energy affairs for the opposition Danish Conservative People's Party, said the timing of the cuts was disappointing.

"I believe this is a very bad signal to be sending the world, for Denmark to be taking a step backwards just before the Paris climate summit," she said last month.

The debate going on in Denmark may serve as a cautionary tale for leaders of the 195 countries now meeting in Paris and trying to reach a global deal to rein in dangerous greenhouse gases that have been linked to climate change.

Should the negotiators be able to put aside their conflicting agendas, and sign an accord when the talks end this week, they will then face another challenge: meeting their national goals.

One lesson they may learn from Denmark is how it is possible to substantially replace fossil fuels with clean and renewable energy. But even when progress is made in reducing environmentally harmful carbon emissions, countries may have difficulty sustaining the gains because of politics, economic concerns and, in places like the United States, ideological disputes.

The new government in Denmark argues that spending on alternative energy and innovation is still high, but that the budget must be reeled in as the country faces a predicted deficit of 3.3 percent in 2015. Shortly after taking over in June, the new government was forced to cut its forecast for economic growth to 1.5 percent this year and 1.9 percent in 2016, citing a slow recovery in domestic demand.

"I think the criticism is over the top," Lars Christian Lilleholt, Denmark's energy minister, told the Politiken newspaper last month. He said the country still planned to invest 800 million krone, or $114 million, in green energy research in the coming year. "There is less money, but it is still a lot. And I sit in a government that must find a way for the Danish economy to make ends meet."

But people who have relied on government funds and other incentives to help finance their energy projects said the cuts were a mistake.

One of them is Jens Dall Bentzen, who eight years ago began thinking about how to burn wood chips, grass clippings and other organic matter more efficiently to generate heat. He had an inkling he could contribute to Denmark's efforts to wean off fossil fuels by 2050, but he worried about quitting his job as a researcher to pursue his idea.

With the help of a grant of 2.5 million Danish krone, or $448,000, he developed a prototype of the low-emissions furnace he had imagined. He started his own company, Dall Energy, and was able to sell the furnace to Warwick Mills, a manufacturer in New Ipswich, N.H. Since then, he has built two other furnaces for Danish municipalities, and attracted interest from elsewhere in Europe and the United States.

He said the grant from the Energy Technology Development and Demonstration Program made it possible.

"I found it more tempting to leave my job and start a company," he said in an interview inside the heating plant in this Danish coastal town, where his furnace was turning the damp chill into cozy warmth. "I started realizing it could be achievable."

Denmark, a country of 5.6 million people, was able to generate 40 percent of its energy from wind turbines last year. Germany, by comparison, generates less than 30 percent of its energy from renewable sources, primarily wind and sun.

The new governing party, Venstre, or Liberal, reached an agreement on its 2016 financial plan last month. The budget cut spending for research into green energy sources to 127 million krone, or $18 million, from 385 million krone, or $55 million.

The cuts are troubling to Soren Hermansen, who runs a renewable project, the Energy Academy, on Samso, an island off the eastern coast of Denmark's main peninsula. Delegations from Maine to China have visited to observe its success at energy independence through a combination of wind, solar and geothermal production.

MICHAEL DROST-HANSEN FOR THE NEW YORK TIMES

Jens Dall Bentzen at a furnace in Sonderborg, Denmark, that is built on a design he developed with a government grant. It burns organic matter to generate heat.

Around 20 percent of its annual budget of about $100,000 comes from the government. Mr. Hermansen said that with the cuts, he would have to reduce his small staff and shelve a biofuel project to convert methane waste from local farms to liquid natural gas to power the ferry to the island.

"This is hurting everybody," Mr. Hermansen said. "How can you take that away?"

The fund that helped Mr. Dall Bentzen develop his biomass furnace will be among the most deeply cut. Over the past eight years, the fund has paid out about three billion krone, said Aksel Laurids Beck, a special adviser to the fund. Starting next year, it will be cut to about 40 percent of its 2015 budget.

Unlike conventional furnaces that burn only one organic fuel, usually dried wood chips or straw, Mr. Dall Bentzen's system can use a variety of materials. It converts them to gas, which is then burned. That results in dust emissions that are 95 percent lower than those produced by conventional biomass burners, and significantly lower carbon and nitrogen oxide emissions.

"We want to provide heat as cheaply as possible, and if we can use garden and other waste as fuel, that will bring down the prices for us, for our customers," said Erik Wolff, who runs Sonderborg District Heating, which bought the furnace from Mr. Dall Bentzen's company with similar government support.

This year, the Energy Technology Development and Demonstration Program, which was started in 2007, distributed 380 million krone, or $54 million, to some 88 solar, wind and geothermal energy projects, as well as to systems to better integrate and use them.

In the best scenario under the new budget, the government next year will provide support for one in every eight project applicants, instead of the current rate of one in every four.

Besides setting a poor example for the climate summit meeting, critics said, the cuts are ill-timed. With the green technology sector taking off, and many people looking to Denmark for examples of successes, jobs and new businesses may be in jeopardy, critics said.

Projects seeded by the fund have had a success rate of 84 percent, a quarter of which led to exports. Overall exports of green and clean technology grew 15.4 percent last year to 43.6 billion krone, or $6.2 billion, according to the country's energy ministry.

"The government is saying that we have always been one step ahead in the green technology, so we have room to maneuver," Ms. Abildgaard said. "But being one step ahead is what gives us many jobs in this area. It is very important that we keep them."

Mr. Wolff said the furnace his company bought from Mr. Dall Bentzen was more expensive than conventional models and had not yet been tried on a large scale. But the grant he received made it possible for him to take the risk associated with investing in a new technology.

"When we bought the plant, we knew we would not have any guarantees, that we would not hit the bull's eye every time with every decision we make," Mr. Wolff said.

The cuts will not hurt Mr. Dall Bentzen. With his invention now patented and his company profitable, he no longer relies on the government fund.

"We are beyond the research stage now — our projects are funded by the clients," he said. "But those who come after me, they may not have the same chance."

# *Global Fossil Fuel Subsidies Dwarf Funding Commitment to Climate Change*

By JOHN SCHWARTZ

As representatives of nearly 200 countries gathered in Paris to discuss ways of reducing emissions from fossil fuels, many pointed to what they consider a simple and obvious way to change behavior: Stop widespread subsidies that encourage the use of fossil fuels.

Industrialized nations agreed to start phasing the subsidies out after an agreement at the Group of 20 summit meeting of the world's largest economies in 2009, and some progress has been made. The International Energy Agency said its $490 billion estimate for worldwide fossil fuel subsidies in 2014 would have been $610 billion if not for changes since that agreement.

But calls for greater cuts continue. The energy agency issued a statement last month identifying the elimination of subsidies as one of the most effective strategies for reducing greenhouse gas emissions. The subsidies are "public enemy No. 1 in terms of sustainable development," said Fatih Birol, executive director of the agency.

On Monday, the first day of the climate conference, representatives of 35 governments and hundreds of businesses and organizations issued a call for countries to take aggressive action to phase out fossil fuel subsidies. Christiana Figueres, executive secretary of the United Nations Framework Convention on Climate Change, said, "The huge sums involved globally could be better spent on schools, health care, renewable energies and building resilient societies."

In their simplest form, fossil fuel subsidies amount to government spending to keep the price of fuel low for citizens. They are why gasoline in Venezuela costs about 2 cents per gallon. The International Energy Agency estimates that global subsidies total about $490 billion a year. Those direct subsidies are found chiefly in the developing world and in oil-producing nations.

Industrialized countries like the United States are less likely to reduce the cost of fuel at the pump with government money, but experts who track subsidies say that America, too, finds ways to support fossil fuel use through tax breaks and in backing for exploration and production. The Organization for Economic Cooperation and Development has counted 800 ways that rich industrial nations use taxpayer money to support fossil fuel producers.

A new report from Oil Change International, an energy research and advocacy group, estimates that aid to the coal, oil and natural gas industries came to $452 billion last year. The group said the situation amounted to governments "allowing fossil fuel producers to undermine national climate commitments, while paying them for the privilege."

"We have to stop using government funds to support the industry that is causing the problem," said Stephen Kretzmann, executive director and founder of Oil Change International. "That would seem to be the low-hanging fruit of solving climate change: When you're in a hole, stop digging. And yet we really haven't made much progress."

The International Monetary Fund has come up with a much higher estimate for the global total of fossil fuel subsidies — $5.3 trillion, which includes the costs of the effects of energy use on people's health, the environment and climate change. That figure constitutes 6.9 percent of the global gross domestic product.

Whatever the estimates, they stand in sharp contrast to the money being spent on reducing the effects of climate change. Even the lowest subsidy estimates far exceed the pledge by advanced industrialized nations to spend $100 billion a year by 2020 to fight climate change.


CARLOS GARCIA RAWLINS/REUTERS

A mural depicting the state petroleum company in Venezuela, where gas is 2 cents a gallon.

A recent report from the Climate Policy Initiative, a nonprofit research and policy organization funded by the financier George Soros, suggested that to keep the global temperature from rising more than two degrees Celsius would require about $1 trillion per year.

Bill Hare, chief executive of the nonprofit research and policy group Climate Analytics, said taking action on direct subsidies could have a profound effect. "Emissions could be reduced by up to 20 percent from what would otherwise occur if you removed fossil fuel subsidies," he added.

Critics of subsidies say their greatest benefits go to the middle class and the rich, who can better afford cars.

By keeping conventional fuels at low prices, subsidies also make alternative energy sources less affordable in comparison. The International Energy Agency's 2014 World Energy Outlook report warned, "Fossil fuel subsidies rig the game against renewables and act as a drag on the transition to a more sustainable energy system."

That report noted that some countries spent a greater share of their gross domestic product on fossil fuel subsidies than on health or education.

Going into the Paris climate talks, China, Ethiopia, India, Mexico, Morocco, Singapore and Vietnam had committed to addressing subsidies, Mr. Kretzmann said. "Governments have a lot of incentive and opportunity to eliminate those now, with oil prices so low," he added.

And as prices have dropped, subsidies have been reduced in many countries, including India, Indonesia, Mexico and the United Arab Emirates, said Dr. Hare of Climate Analytics.

While attempts to cut subsidies have led to social unrest, more recent efforts, including a gradual phaseout to soften the blow, have enjoyed quiet success.

But previous efforts have often been abandoned when global fuel prices rise and consumers are pinched. "If you look at the history of fuel subsidy reform, it doesn't always stick," said Michael L. Ross, a professor of political science at the University of California, Los Angeles, who studies energy subsidies.

A study from the Carbon Tracker Initiative, the Institute for Energy Economics and Financial Analysis and other groups suggested that eliminating production subsidies for the Powder River Basin coal region in Wyoming and Montana alone would raise the price of that coal enough to reduce demand for it by 30 percent in the long term, which the study estimates would equal the emissions from as many as 32 coal-burning plants.

Michael A. Levi, an energy expert with the Council on Foreign Relations, said that fuel subsidies were an inefficient way to help the poor, anyway. However, he noted that better ways were not necessarily available. Giving money directly to the poor to make up for the lost fuel savings would require a banking and credit infrastructure that often cannot be found in the developing world.

"You shouldn't want to solve these countries' fiscal problems on the backs of their weakest citizens," Mr. Levi said.

In the United States, a long-standing coalition of environmentalists and libertarians has sought to eliminate tax breaks and policies that support the fossil fuel industry. Eli Lehrer, the co-founder of the R Street Institute, a free-market think tank in Washington, said the oil industry did not need many of the tax breaks it received.

"I doubt that eliminating the intangible drilling cost write-off would reduce oil production at all," he said.

Carlton Carroll, a spokesman for the American Petroleum Institute, said the tax breaks for his industry "are similar to other manufacturing sectors." He added, "As an industry, we pay higher taxes than any other."

Such arguments do not convince Mr. Lehrer, whose group is part of the Green Scissors coalition that includes environmentally conscious budget cutters across the political spectrum. "These subsidies on fossil fuels are a very good, transideological issue," he said. "To the left, it's a terrible act of environmental destruction. To the right, it's crony capitalism. And both sides are true."

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# Fuel flexibility and low emissions in biomass-fired power plants

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## Abstract
The Dall Energy biomass furnace combines updraft gasification and gas combustion. Combining updraft gasification and gas combustion into one unit offers several advantages to operation and maintenance, emissions reduction, and turndown ratio. These advantages have been evinced in a pilot plant, demonstration project, a 2 MW plant and a 9 MW plant. Next-generation heat and power production plants represent the next steps in this technology and several of these projects are now at the planning stage.

## Introduction: the two-stage furnace
Initially Dall Energy was focused on gas cooling and flue gas condensation but after research into inlet conditions for the flue gas cooler system, decided to extend the focus to low emission combustion. During 2008 the company developed a novel biomass two-stage furnace. The Dall Energy biomass furnace combines updraft gasification and gas combustion:

- Gasification of the biomass, which takes place in the bottom of the furnace, is the first stage. Here the solid material is transformed into a combustible gas and fine ash. The gas velocity in this section is very low hence the particles remain resulting in very low dust and particle emission from the furnace.
- The gasification gas from the bottom part of the furnace is burnt in the top section during the second stage. The gas combustion itself is in terms of flow, temperatures and emissions, very stable.

Combining updraft gasification and gas combustion into one unit offers several advantages: the plant becomes simpler to operate and maintain, more fuel flexible, the emissions of dust, $NO_x$ and CO are reduced and the turndown ratio of the furnace can be as high as 10–100% (Fig. 1).

## Process verification

### 2 MW Pilot Plant
In 2009 Dall Energy received a grant from the Danish Energy Agency to establish a pilot plant which could function as proof of concept. During 2010 a 2 MW pilot plant was built in co-operation with SEM Steel Industry A/S, a manufacturer and supplier of machinery and components to the power and environmental industries. Verification with woodchips was completed in 2010 and an additional grant was awarded by the energy agency to build an 8 MW full scale demonstration plant (Fig. 2).

### Demonstration project: Bogense
During 2010, Dall Energy prepared an 8 MW full scale demonstration project, to supply the town of Bogense with district heating from wood and garden waste. The purpose of the project was to verify the good results of the pilot plant in terms of emissions and stable operation. Furthermore, the purpose was to investigate the fuel flexibility of the technology. The project was prepared together with SEM and Weiss A/S. SEM was the Dall Energy partner for the Furnace, Weiss was the turn key contractor. The plant was built during 2010/2011 and commissioned during 2011/12 (Fig. 3).

Results of the demonstration project: Environmental technical verification (ETV) FORCE Technology made an ETV of the Dall Energy Furnace. The purpose of the ETV was to have an independent body to verify the emissions and the turn down ratio. The ETV measurements were made in March 2012, and the low emissions, turn down ratio and stability of the process was verified [1]. Furthermore, it was verified during operation of the plant over subsequent years, that alternative fuels such as garden waste could be used as fuel. Moisture content up to 60% can be used in the Bogense plant (Fig. 4).

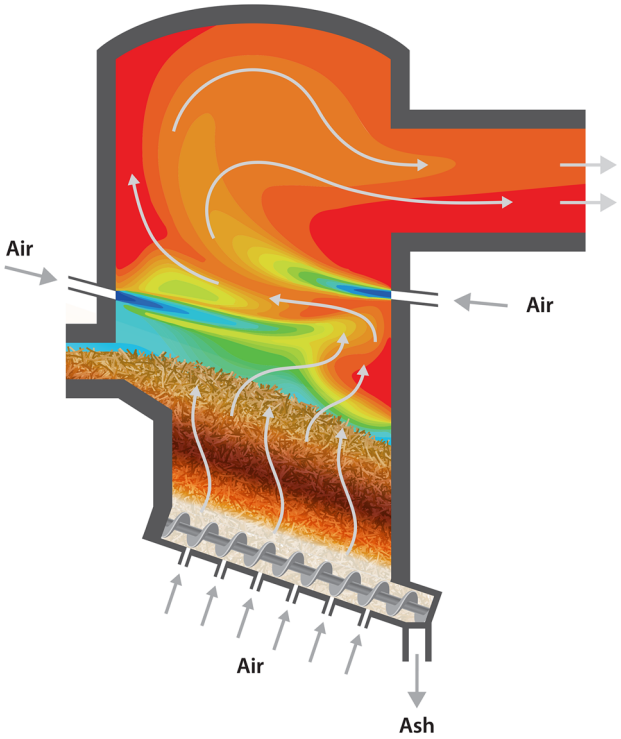


**Fig. 1** *Principle diagram of the Dall Energy biomass furnace*

Economics of the demonstration plant: The turnkey contract value of the biomass plant was €2 million. The use of alternative fuels, such as garden waste, have been an economic success for Bogense. Since the establishment of the Dall Energy Furnace the heating price has been reduced twice: in 2012 from 513 kr/MWh to 425 kr/MWh of heat, and in 2016 the price was reduced again to 300 kr/MWh. The latter is a reduction of more than 40% compared with the start of the project, and a record low heating price in Denmark.

**Fig. 2** *2 MW pilot plant*

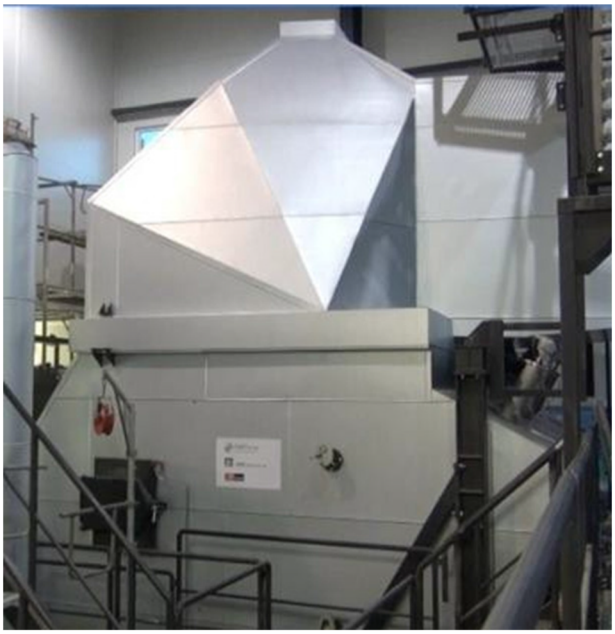

**Fig. 3** *8 MW Furnace in Bogense*

## 2 MW plant for volatile organic compounds (VOC) destruction at Warwick Mills

### Plant construction

Warwick Mills, New Hamphire, USA is a leader in the engineering of technical textiles for protective applications. The advanced manufacturing of safety equipment includes coating of woven materials with organic solvents. The ventilation air from the coaters contains VOC which needs to be combusted in a thermal oxidiser before the ventilation air can be sent to the stack.

Warwick Mills could not find a biomass technology locally that could fulfil the emission regulations, but in 2010 the plant manager, Mr Howland found the web site of Dall Energy, who had published the results of the pilot plant. Mr Howland decided to visit Dall Energy in January 2011 to see the pilot plant and the Bogense plant which at that time was under construction. Dall Energy and Warwick Mills made thereafter an agreement for the design and



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**Fig. 4** *Fuel samples from Bogense (photo by Biopress)*

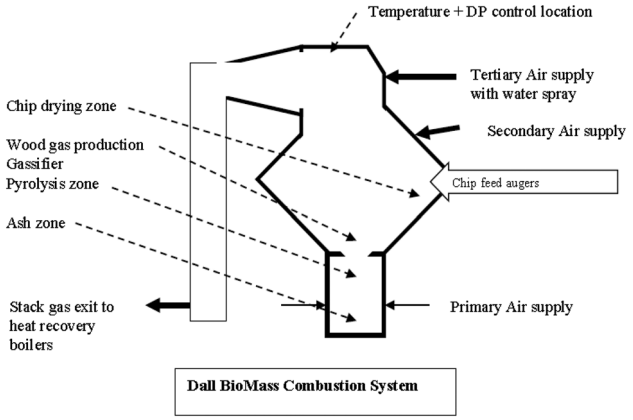


**Fig. 5** *Principle diagram of Dall Energy Furnace at Warwick Mills*

build of a biomass plant for Warwick Mills which would have several purposes:

- Destruction of VOC.
- Production of steam.
- Control strategy of the plant so destruction of VOC was independent of steam production.
- Low load for 'stand by' during weekends.
- Low particle load in the chimney.

During 2011–2012 the building permits were obtained and construction of the plant began. The size of the plant for Warwick Mills was the same as the pilot plant built in 2010; and as the pilot plant was no longer in use, Dall Energy-Warwick agreed that Warwick Mills could buy the pilot plant.

Hence the pilot plant was dismantled and shipped from Denmark to the USA. The first start-up of the plant took place in April 2014. During the first week of operation, various points were located to be optimised and adjusted. The plant was shut down and the list of adjustments was made. The plant was started up again in June 2014 and has been in operation since then [2] (Fig. 5).

## Emissions testing

The plant is used for destruction of organic solvents in the ventilation air (VOC). It was written into the permit that an emissions test was required at least 6 months after starting the plant. The emissions test must verify

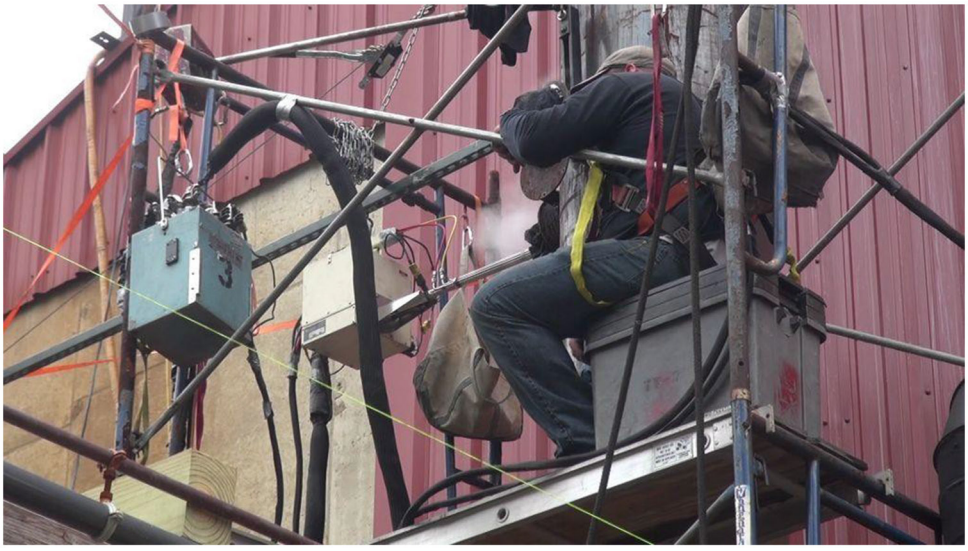

**Fig. 6** *Emission test. Warwick Mills, 2014*


**Fig. 7** *Filters after emission test. Warwick Mills, 2014*

that the VOC destruction efficiency was at least 98% and particulates in the flue gas had to be below 40 mg/Nm$^3$. The stack test was scheduled for two days: September 30 and October 1 2014.

*Test results from September 30, 2014:*

The VOC content in the combustion air was at maximum: 10.000 ppmv.
The VOC content in the stack was below 1 ppmv.
The VOC destruction efficiency was 99.98%.
Also the particulate content and the $NO_x$ in the flue gas was measured.
The particle content was below 10 mg/Nm$^3$.
The $NO_x$ was below 60 mg/Nm$^3$ (30 ppmv)

*Test results from October 1, 2014:*

The VOC content in the combustion air was approximately 3000 ppmv.
The VOC content in the stack was below 3 ppmv.
The VOC destruction efficiency was 99.8%.
Also the $NO_x$ in the flue gas was measured.
The $NO_x$ was below 80 mg/Nm$^3$ (40 ppmv).

Ambient air contains VOC from various sources such as degradation of wood in forest, traffic, chimneys, etc. The VOC content in ambient air, outside the stack, was about 5–10 ppmv, thus higher than inside the stack (Figs. 6 and 7).

## Plant operating strategies

The biomass plant at Warwick Mills has two main purposes:

- Destroy VOC from factory.
- Produce steam to the factory.

The amount of VOC-loaded air and the need for steam are not related hence a new strategy of operating the plant was developed:

| Demand | Operating strategies |
|---|---|
| high Energy demand | increase of primary air until energy demand fulfilled |
| high VOC destruction demand | increase of (VOC loaded) tertiary air |

The factory is normally shut down during weekends. An operating strategy for 'low chip consumption' was developed, hence the plant can keep warm during weekends and only use a very small amount of wood chips. On Monday morning the plant can go from 'weekend mode' to 'full load' in few hours (Fig. 8). Read more about the Warwick Mills plant in [3].

## 9 MW plant in Sønderborg

During 2013–2014, a new 9 MW plant was planned and built in Denmark. The client was Sønderborg district heating company. The Dall Energy heating




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**Fig. 8** *Gasification plant operator, Marcel Alex, (left) and Managing director Charlie Howland (right) at the Gasifier, June 2015*

plant supplies the towns of Vollerup and Hørup Hav with district heating. The purpose of this plant is to supply cheap and renewable heat to the Sønderborg district.

The plant was started up in January 2015. Emission tests were carried out in March 2015. The plant has been in unmanned operation since October 2015. The low

**Fig. 9** *9 MW Dall Energy plant in Sønderborg*

emissions of the pilot plant, the Bogense plant and the Warwick plant were verified. Further improvements have been made in the Sønderborg plant, for instance the turn down ratio of this plant is 10–100%. Read more about the Sønderborg plant in [4].

## Conclusion

Dall Energy combustion technology provides new opportunities for combustion of biomass with very low emissions, high fuel flexibility and turn down ratio. A summary of results achieved can be seen in the table and figures below (Fig. 9).

| Operation | Unmanned |
|---|---|
| dust directly out of Furnace: | 30 mg/Nm$^3$ |
| dust in Chimney: | 10 mg/Nm$^3$ |
| CO: | 0 mg/Nm$^3$ |
| $NO_x$: | 150 mg/Nm$^3$ |
| $O_2$: | 4% (dry) |
| moisture content in fuel: | 20–60% |
| fuels | wood chips, garden waste, willow. |
| carbon in ash: | <0.5% |
| load: | 10–100% |
| temperature out of furnace | (±10 °C) |
| efficiency: | 115% (LHV) |
| VOC destruction efficiency | 99.87%–99.98% |

## Next-generation projects

Dall Energy is currently preparing new projects in Denmark and abroad, in Europe, North- and South America and Asia. The projects range from heat only projects to next-generation heat and power production.

### CHP with organic Rankine cycle (ORC)

For a Danish Client we prepare a heat- and power project where we will use the ORC technology to produce heat- and power. The contract value will be app 5 million €.

### Power production with Steam

In central America we prepare power projects in the size range of 1–4 MW electricity.

### Heat only without boiler

A next generation heat-only system is being prepared for a Danish client. In this concept we cool the flue gas with evaporative cooling, thus saving the boiler. The CAPEX of the plant can hereby be reduced with 10%.

## About Dall Energy

Prior to starting the company Mr Dall was an R&D engineer in the Danish engineering and consulting company COWI A/S, in charge of research and development of new biomass technologies. Mr Dall had been involved in several innovative technologies including upscaling of a two-stage gasification process, optimisation of straw fire heating plants as well as software for determining energy efficiency and economics of biomass boilers. Mr Dall had also invented a gas cooling and heat recovery system, the patent for which he then acquired from COWI when he set up Dall Energy.

Dall Energy and our technologies have received various awards and recognitions including:

2010: Innovation price, Spain
2011: European Inventor Award: https://www.epo.org/learning-events/european-inventor/finalists/2011.html
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