**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. 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 NOx 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 Herup 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.
**Stakeholders involved**

- Dall Energy
- Sønderborg District Heating Company (client)
- FORCE technology (CFD analysis)
- COWI (consultant)
- 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;
- Low emissions of NO\(_x\) (<180 mg/Nm\(^3\)), CO (<5 mg/Nm\(^3\)) and particulates (<20 mg/Nm\(^3\));
- Unmanned operation;
- Low power consumption (10,3 kW\(_e\)/MWh heat);
- Clean ash (0,5% carbon in ash);
- High efficiency (110% based on Lower Heating Value);
- Turn-down ratio of 10-100% load

**Constraints:**

...
IEA Bioenergy, also known as the Technology Collaboration Programme (TCP) for a Programme of Research, Development and Demonstration on Bioenergy, functions within a Framework created by the International Energy Agency (IEA). Views, findings and publications of IEA Bioenergy do not necessarily represent the views or policies of the IEA Secretariat or of its individual Member countries.

9 MW Dall Energy biomass plant in Sønderborg

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**Info provided by:** Jens Dall Bentzen, Managing director of Dall Energy

**More information:**

- [http://www.dallenergy.com/media/151007_Paper_IT3_Houston.pdf](http://www.dallenergy.com/media/151007_Paper_IT3_Houston.pdf)
Denmark, a Green Energy Leader, Slows the Pace of Its Spending

BY MILLY EDDY

SUNDENBERG, Denmark — Not long ago, Denmark was seen as the leader in renewable energy, having cut its reliance on fossil fuels and committed to being carbon neutral by 2050. But in recent months, the country has faced criticism for its failure to meet key climate targets.

Lars Christian Lilleholt, minister for the environment, recently acknowledged that the government had not been able to reduce carbon emissions as planned. He said the country still faced a predicted deficit of 3.3 percent last year. "I think the criticism is overdone," he said in an interview last month.

One lesson they may learn from other countries is that even when the talks end this week, the world’s largest economies in the developed world and in the developing world will continue to work towards reducing fossil fuel subsidies. "I doubt that eliminating the fossil fuel subsidies will be a one-time success story," said Fatih Birol, executive director of the International Energy Agency. "It’s going to be a journey, not a destination."

In the United States, a long-standing coalition of environmentalists and libertarians has used the issue of fossil fuel subsidies as a tool to push for a more sustainable energy future. "We shouldn’t want to achieve three countries’ local policies in the backs of their own citizens," said Michael A. Levi, an energy expert at the Carnegie Endowment for International Peace.

In the developing world, many countries may have difficulty sustaining the gains because of the need for public funds in Denmark. "We have built two other furnaces for the same purpose," he said.

Global Fuel Subsidies Dwarf Funds for Climate Change

A period of strong demand for fossil fuels has boosted revenue for oil companies, but experts who track subsidies warn that many governments have not managed their spending for research into green technologies effectively. "There’s no amount of money that’s too much. We need to increase the spending for research into green technologies," said Michael Liebreich, executive chairman of the Carbon Tracker Initiative, a financial research organization.

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Fuel flexibility and low emissions in biomass-fired power plants

Jens Dall  Dall Energy, Hørsholm, Denmark
Karoline Bentzen  Dall Energy, Hørsholm, Denmark

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, NOx 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).
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.

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

Plant construction
Warwick Mills, New Hampshire, 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 website 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
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.

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...
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:

<table>
<thead>
<tr>
<th>Demand</th>
<th>Operating strategies</th>
</tr>
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<tbody>
<tr>
<td>high Energy demand</td>
<td>increase of primary air until energy demand fulfilled</td>
</tr>
<tr>
<td>high VOC destruction demand</td>
<td>increase of (VOC loaded) tertiary air</td>
</tr>
</tbody>
</table>

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

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).

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

Acknowledgements
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REFERENCES

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**Operation** | **Unmanned**
---|---
dust directly out of Furnace: & 30 mg/Nm³
Dust in Chimney: & 10 mg/Nm³
CO₂: & 0 mg/Nm³
NOₓ: & 150 mg/Nm³
O₂: & 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%.