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Objective

The objective of the follow-up programme is to collect and analyse data from established plants in order to evaluate the different technologies with respect to environment, energy and economy.

This evaluation and the continuous communication of the results is expected to help the development and implementation of the most promising technologies for CHP plants fired with biomass.

The programme is further described in the publication 'Danish Follow-up Programme for Small-Scale Solid Biomass CHP Plants'.

	Assens	Harboøre	Haslev	Hjordkær	Høglid	Junckers-7	Junckers-8	Masnede	Måbjerg	Rudkøbing	Skarp Salling	Slagelse
Put into operation ¹	1999	1993/00	1989/99	1997	1994/98/00	1987	1998	1996	1993	1990	1999	1990
Contractor	Vølund	Vølund	Vølund	Sønder Jyllands Maskinfabrik	Hollensen	FLS Miljø	Vølund	FLS Miljø	Vølund	FLS Miljø	Reka	Aalborg Ciseriv, FLS Miljø Vølund
Fuels	Wood chips, sawdust	Wood chips	Straw	Wood chips, bio waste	Wood	Sawdust, chips, bark, shavings	Sawdust, chips, shavings, dust	Straw, wood chips	Straw, wood chips, natural gas, waste	Straw	Wood chips	Straw
Technology	Steam turbine	Updraft gasifier	Steam turbine	Steam turbine	Downdraft gasifier	Steam turbine	Steam turbine	Steam turbine	Steam turbine	Steam turbine	Stirling engine	Steam turbine
Pressure	77 bar	-	67 bar	30 bar	-	93 bar	93	92	65	60	-	67
Temperature	525°C	-	450°C	396°C	-	525°C	525°C	522°C	520°C	450°C	-	450°C
Steam production	19 tons/h	-	26 tons/h	4.4 tons/h	-	55 tons/h	64 tons/h	43 tons/h	123 tons/h	12.8 tons/h	-	40 tons/h
Power output, gross	4.67 MW	1.3-1.5 MW	5.0 MW ²	0.6 MW	0.13 MW	9.6 MW	16.4 MW ³	8.3 MW ⁴	28 MW ³	2.3 MW	28 kW	11.7 MW ³
Heat output	10.3 MJ/s ⁵	6-8 MJ/s	13 MJ/s	2.7 MJ/s	0.16 MJ/s	-	-	20.8 MJ/s	67 MJ/s	7.0 MJ/s	90kJ/s	28 MJ/s
Electrical efficiency, gross	27%	32-35%	25%	16%	22%	-	-	28% ⁶	27%	22%	18%	29%
Overall efficiency, gross	87% ¹	105%	86%	86%	57% ⁵	-	-	91%	88%	87%	87%	-
Storage tank	2 x 2500 m ³	1050 m ³	3200 m ³	1000 m ³	-	-	-	5000 m ³	5000 m ³	2500 m ³	8 m ³	3500 m ³

- Put into operation or renovation
- Power output, net
- With flue gas condensation the heat output increases to 13.8 MJ/s and the overall efficiency increases to 106 %.
- At maximum electricity production

Approach of the Danish Follow-up Programme

In the programme a wide range of different technologies for the conversion of solid biomass is included. The programme covers solid biomass fired CHP plants.

Conclusions

Over the last years the programme has proven to be very important when it comes to collecting and analysing data related to construction, performance, operation and maintenance of different biomass processes.

The data provides a clear picture of characteristics related to specific technologies with respect to environment, energy and economy.

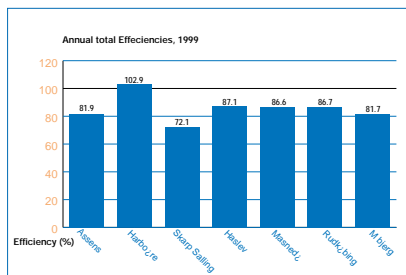
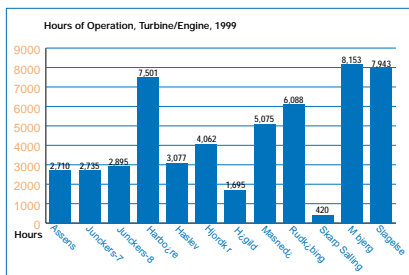
It is concluded that technologies, still only in the state of R&D or pilot plant state, contains great potential for improving the overall Danish production of heat and electricity from biomass, combined with a decrease in emissions.

The follow-up programme ensures that the progress for projects concerning development of CHP technologies from biomass, are compared each month. This provides the Danish Energy Agency with a clear picture of the status for the operation conditions both from commercial technologies, but also from developing technologies.

Plant	Quantity of Fuel ¹	Other Energy ²	Hours of Operation ³	Heat Production	Electrical Production	Efficiency, total	Efficiency, electrical	Heat Consumption	Electrical Consumption	Water Consumption
	GWh	GWh	Hours	GWh	GWh	%	%	MWh	MWh	m ³
Assens	51.80	0	2.710	31.60	10.75	81.9	20.8	15	458	3.579
Harboøre ⁴	12.10	2.03	7.501	14.50	0	102.9	-	85	396	1.246
Haslev	58.00	0	3.077	38.50	12.06	87.1	20.8	-	2.186	-
Hjordkær ⁵	20.10	0.26	4.062	15.70	1.78	86.1	8.9	-	387	787
Høglid	1.02	2.05	1.695	1.89	0.18	-	18.0	19	27	1.297
Junckers-7	93.10	3.67	2.735	-	15.01	-	15.5	-	-	-
Junckers-8	147.10	1.55	2.895	-	40.79	-	27.4	-	-	-
Masnede	151.50	0	5.075	94.00	37.20	86.6	24.6	-	4.418	-
Måbjerg	231.10	522.30	8.153	449.40	166.10	81.7	22.0	-	16.486	-
Rudkøbing	61.40	0.31	6.088	42.00	11.48	86.7	18.7	-	1.807	10.243
Skarp Salling	0.07	0	428	0.04	0.01	72.1	12.0	-	1	-
Slagelse ⁶	111.00	99.40	7.943	182.50	48.29	-	-	-	-	-
In total	938.29	631.57	-	870.13	343.65	-	-	119	26.166	17.152

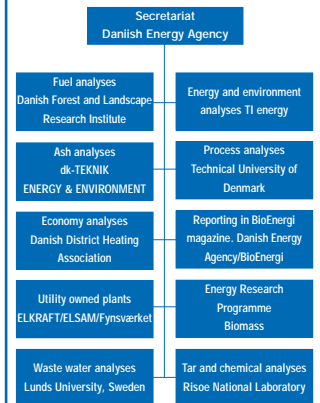
Production data for the small-scale CHP-plants in 1999.

- The quantity of fuel is biomass input.
- Haslev, Masnede, Rudkøbing and Slagelse have separate distribution companies where other energy is maintenance heat etc.
- Hours of operation is for the engine or the turbine.
- Hours of operation for Harboøre is for the gasifier and is calculated as the percentage of the year, where the fuel is wood related to the total quantity of fuel.
- In Hjordkær the heat sales are given because the production and consumption is not registered. The quantity of fuel is estimated from a total efficiency of 87%.
- For Slagelse the electrical values are net values. No efficiencies are calculated since the plant is provided with steam from a waste incineration plant. The efficiencies are calculated on a yearly basis.



Organisation of the Work and Results

In the programme data on environmental impacts, energy and economy is collected, analysed and published by a number of different specialists in possession of special knowledge and expertise in the respective fields. The work is co-ordinated by the Danish Energy Agency.



Detailed Technical and Economical Information on 20 biofuelled CHP-plants in Denmark

As a part of the national Danish policy the Biomass Agreement of the 14th of June 1993 implies that the electric utilities must incorporate the use of 1.2 mill. tons of straw and 0.2 mill. tons of wood before the year 2000.

The Danish follow-up programme for small-scale solid biomass CHP plants has been established by the Danish Energy Agency to provide a detailed technical insight in the performance and economic conditions of a wide range of energy producing plants using biofuels.

Denmark has 50 wood chip fired heating plants, 25 wood pellets and 75 straw fired. It is a political decision, that these 150 heating plants have to investigate whether it is economically viable to convert the energy production to combined heat and power.

The 20 combined heat and power plants fired operated with biofuels are addressed in the programme. This includes the gasification plants at Harboøre, Høglid, Blære and pilot Open Core plant, the pyrolysis project in Haslev, the steam turbine plants at Haslev, Slagelse, Masnede, Maribo/Sakskøbing and Rudkøbing all owned by the utilities. Also the industrial plant at Junckers and the municipality owned plants at Assens, Hjordkær and Kibæk are included. Furthermore, two Stirling engines at 9 and 35 kW are addressed.