EUROPEAN BIOMASS CHP IN PRACTICE

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ABSTRACT: European BIO-CHP project aims to promote biomass CHP production in Europe. Operational data from about 60 CHP plants in Denmark, the Netherlands, Austria, Germany, Sweden and Finland was collected and analysed during a one year period. Among the participating 60 plants conversion technologies vary from anaerobic digestion, to gasification and combustion. Fuel range is also wide. Whereas large-scale combustion plants in Finland and Sweden use wood chips, wood-based residues from forest industries and peat, many Danish plants make good use of straw, for example. German plants are represented by solid biomass combustion plants, biogas plants and one MSW plant. Dutch speciality in this project are the large incineration plants and small-scale plants using landfill gas. Half of Austrian plants are solid biofuel plants, another half biogas plants.
Presentation of each participating plant with key figures is shown at the project web-site http://bio-chp.dk-teknik.dk. Data on fuel consumption, heat and electricity production, plant usage, operational problems and environmental performance was collected in periods of one month. Different performance indicators were calculated for each plant. Benchmarking of plants in each technology category was done and comparisons of different technologies were drawn.
Monthly figures will be collected for another one year period. Analysis of operational data for the total two years period will be presented in a "Best Practice" guide. The aim of the project is to provide authorities, investors and future plant owners information about what performance to expect from biomass CHP plants and about best available technologies. This will help ensuring high quality of future plants. The final results of the project will be presented at a workshop in Vienna, Austria in March 2006.
Keywords: combined heat and power generation (CHP), co-combustion, co-gasification, biomass conversion, biogas.

1 OBJECTIVE

The overall purpose of the BIO-CHP project is to promote biomass CHP within the EU and to transfer experiences from existing plants to new projects. Project provides information on typical plant performance and best available technologies for authorities and future plant owners. This will help ensuring high quality of future plants. The project presents experiences from solid biomass (including co-firing), Municipal Solid Waste (MSW), anaerobic digestion gas and landfill gas fuelled CHP plants and highlighting plants with the best operation. This work enables benchmarking and thus identifing the improvement potential of the existing European CHP plants.

2 PROJECT PARTNERS

A total of 6 EU countries are participating in the project, each covering CHP plants in their home country. All these countries have substantial amount of biofuel fired CHP production. Project partners are: Östereichische Energieagentur - Austrian Energy Agency, Austria, BTG Biomass Technology Group BV, The Netherlands, VTT Processes, Finland, Swedish Bioenergy Association Service AB, Sweden, Institute for Energy and Environment, Germany and FORCE Technology, Denmark. The project is coordinated by FORCE Technology.

3 SELECTED PLANTS

A large number of combined heat and power plants located in the participating countries were invited to take part in the project as suppliers of key plant data and specific monthly operational figures and statistics. In return the plants receive access to a large data material covering similar installations in their home country and in other countries, which enables them to compare their own performance with others. This way changes can be made in operational patterns, in installations etc. to enable the plants to achieve an improved economic and environmental performance.

The selected plants fall into different technology categories in a following way:

- 19 biogas and landfill gas fuelled plants
- 4 gasification plants
- 10 CFB (circulating fluidized bed) plants
- 11 BFB (bubbling fluidized bed) plants
- 15 grate-fired steam boiler plants using uncontaminated biomass
- 8 grate-fired steam boiler plants using MSW as

a fuel

- 1 dust fired steam boiler plants

4 DATA COLLECTION

4.1 Plant descriptions

At the first stage of the project a detailed description of each participating plant was drawn. These key figures, published in the project web page, include:

- Details on plant ownership
- Details on contractor(s)
- Short description of the plant
- Commissioning year
- Year of major reconstruction(s),
- Technology used for fuel conversion.
- Technology used for power generation
- Main biofuel used at plant.
- Plant control principles (e.g. by heat demand, by electricity demand or other)
- Total nominal thermal input capacity of plant
- Gross power output at full load in CHP mode
- Net power output at full load in CHP mode
- Heat output at full load, including flue gas condenser
- Nominal electrical efficiency
- Nominal overall efficiency
- Water consumption [m³/year] as planned
- Operational hours per year as planned
- Comments on fuel storage
- Heat usage
- Details on waste water
- Details on discharge of ash
- Details on fuels
- Description of the fuel feeding system
- Description of the flue gas cleaning devices
- Plant investment costs
- Photograph of the plant and process schemes when available.

4.2 Monthly data

In order to evaluate the plant operation and performance, data on fuel consumption and energy production was collected during 12 months. Participating plants delivered data in 1 month periods. Data collection started in September 2003 and was completed in August 2005.

The following data was collected (when available):

- Amount of biofuels used, per fuel
- Amount of fossil fuels used, per fuel
- amount of biogas or landfill gas produced (m^3)
- Electricity produced (MWh), gross and net
- Heat produced (MWh), gross and net
- Own heat and electricity consumption (MWh)
- Steam sold for industrial purposes (MWh)
- Usable heat cooled off (MWh)
- Separate heat production from peak and reserve (backup) boiler(s) (MWh)
- Hours out of operation due to revision, and/or hours out of operation due to unexpected shut-down
- Tonnes of fly ash and slag discharged
- Type and amount of chemicals used, and description of usage
- Emissions to air
- Comments on operation, such as repair jobs, operating failures, encountered problems.

As expected, it was not possible to get all this information from all plants, but the idea was to collect as much information as possible in order to get a good idea on operation and problems in the plants.

5 RESULTS OF THE FIRST 12 MONTHS

The operational data collected from power plants during the first 12 months was entered to a data base and analysed. For each of the fuel conversion technologies covered by this project, the key performance indicators were calculated. These parameters are the key to assessing operational performance from one month to the next, and in comparison with other plants:

- Utilisation period and availability versus plant size
- Energy production versus efficiency
- Biogas production versus plant size (only for biogas plants)
- Practice versus theory for efficiencies
- Efficiency over time
- Efficiency versus plant size.

To give an idea of the results, the summary of results for CFB boiler plants is presented here.

5.1 Availability and utilization period for CFB plants

Utilisation period factor (for electricity production) of a single plant describes how efficiently the installed electric capacity has been utilized. It is calculated:

$$\frac{E_{tot}/P_e}{T}$$

Where E_{tot} is total annual electricity production (MWh), P_e (MW) nominal electric output and T (h) time (e.g. hours of a year).

Availability factor describes to what extent to the plant is ready for operation (not necessarily in operation). Calculated as:

$$\frac{T_{rto}}{T}$$

Where T_{rto} (h) is hours "ready to operation" means 100% - (weighted hours of out of operation due to damage + hours out of operation due to of revision) and T (h) hours of one year.

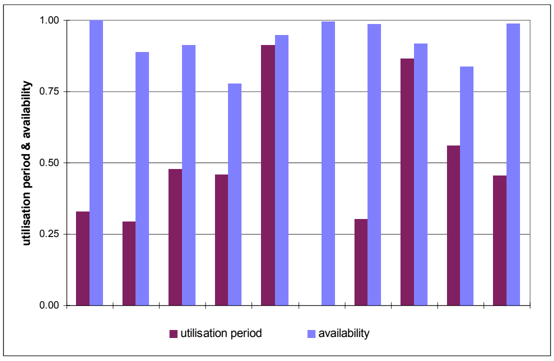

Figure 1: Availability and utilisation period of participating CFB plants.

The plant size does not have an effect on availability factor, but when plants are sorted by the nominal electric output, the utilization period of large plants is generally higher than that of smaller plants.

5.2 Plant efficiency in CFB boiler plants

Annual operational efficiency vs. energy production for individual plants is shown in figure 2. Plants with nominal total efficiency more that 1 are equipped with flue gas condensing unit. Practically all plants are co-firing plants (figure 4). NOTE: peat is classified here as renewable fuel. In Finland and Sweden considered as slowly renewable fuel based on biomass. Fossil fuels are typically used in CFB boiler as support fuel, or because of problems with supply of large amounts of biofuels, or in order to add some protecting compounds (such as sulphur) into the fuel mixture to avoid slagging, fouling or agglomeration related problems

Operational efficiency of the first 12 months was compared with the nominal efficiency (figure 3). Especially the electric efficiency is quite disappointing, less than 30% in most cases. In some cases the high electricity price may change the operation strategy so that part of the electricity is produced in condensing power mode. This explains partly the low total efficiency for some plants. The larger plants show a significantly better electric efficiency than the smaller plants. Total efficiency is not dependent on size

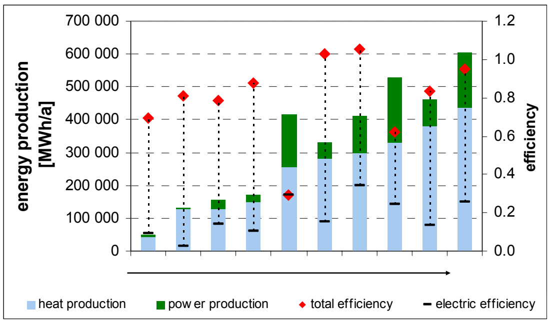

Figure 2: Annual operational efficiency and energy production for individual plants

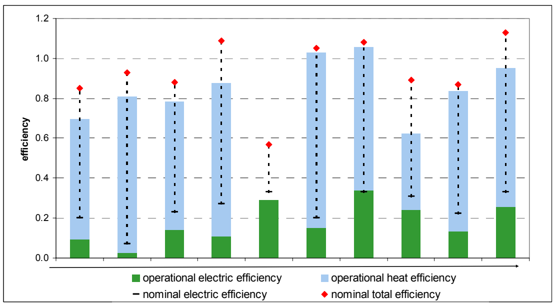

Figure 3. Nominal efficiency vs operational efficiency for individual plants.

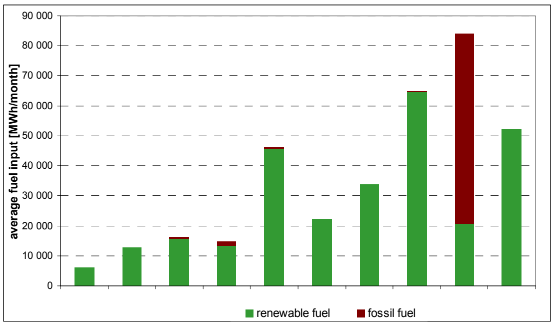

Figure 4. Fuel input classification.

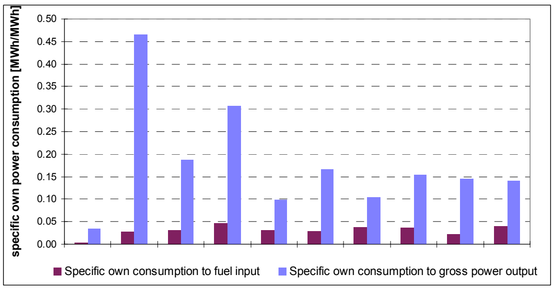

Figure 5: Own power consumption compared to fuel input and gross power output.

5.3 Fuel conversion technologies

Conversion technologies covered in this project were compared. Power output of the selected plants range from 0.1 to 200 MW_e (Figure 6). However, the plant with highest electric output is an exception: gasifier fuel capacity is 60 MW, the main part of fuel conversion is from fossil fuels in a pulverized-fuel boiler where the product gas is also combusted.

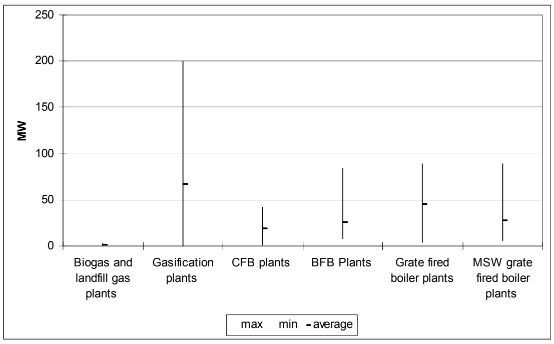

Figure 6: Power output of participating plants.

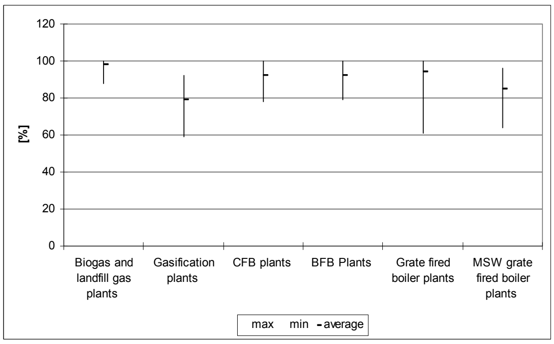

Figure 7: Availability

The biogas and landfill gas plants have the highest plant availability, where as the gasification plants have lowest.

Municipal solid waste grate fired boiler plants have the highest utilisation period of maximum load (Figure 8).

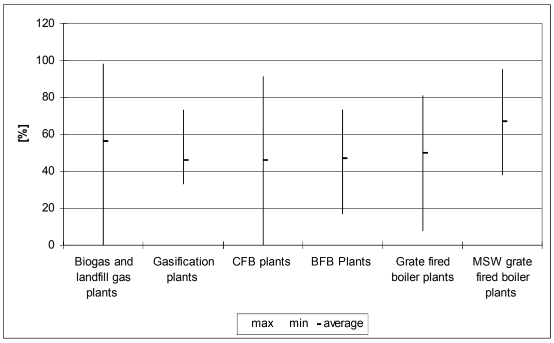

Figure 8: Utilisation period of maximum load (electric)

In average, the plants with fluidized bed boilers, have the highest total efficiency (Figure 9.). The figure for average electric efficiency (Figure 10) is quite different. Biogas and landfill gas plants have the highest electric efficiency, where as the plants with the lowest are the MSW grate fired boilers.

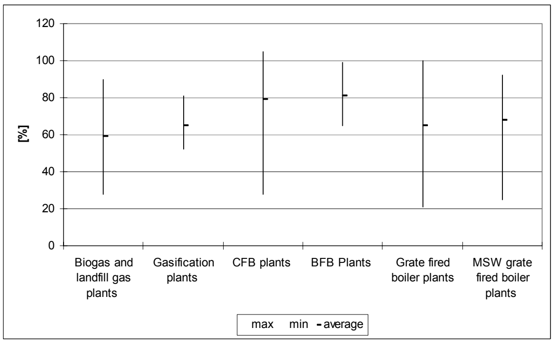

Figure 9: Total efficiency.

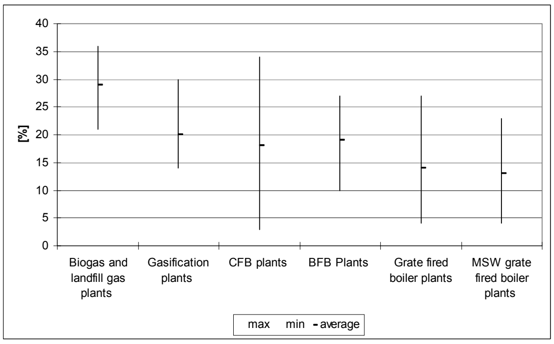

Figure 10: Electric Efficiency

6 SUMMARY

The operational data collected from 68 power plants during the first 12 months was entered into a data base and analysed. For each of the fuel conversion technologies covered by this project, the following key performance indicators were calculated: utilisation period and availability versus plant size, energy production versus efficiency, biogas production versus plant size (only biogas plants), practice versus theory for efficiencies, efficiency over time and efficiency versus size.

In general, the plant efficiencies are far from the design values. There are a lot of operational problems, often related to poor fuel quality. Biofuels are more challenging than traditional fossil fuels.

At this stage only small share of data has been analysed; more results will be available after detailed analysis of all the data covering 24 months. The final results of the project will be presented in the final report and in a workshop "EUROPEAN BIOMASS CHP IN PRACTICE" March, 2006 in Vienna, Austria. For further information, please visit http://bio-chp.dk-teknik.dk.

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