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Integration of biomass fast pyrolysis and precedent feedstock steam drying with a municipal combined heat and power plant

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ABSTRACT

Biomass fast pyrolysis (BFP) is a promising pre-treatment technology for converting biomass to transport fuel and in the future also for high-grade chemicals. BFP can be integrated with a municipal combined heat and power (CHP) plant. This paper shows the influence of BFP integration on a CHP plant's main parameters and its effect on the energetic and environmental performance of the connected district heating network. The work comprises full- and part-load operation of a CHP plant integrated with BFP and steam drying. It also evaluates different usage alternatives for the BFP products (char and oil). The results show that the integration is possible and strongly beneficial regarding energetic and environmental performance. Offering the possibility to provide lower district heating loads, the operation hours of the plant can be increased by up to 57%. The BFP products should be sold rather than applied for internal use as this increases the district heating network's primary energy efficiency the most. With this integration strategy future CHP plants can provide valuable products at high efficiency and also can help to mitigate global CO_2 emissions.

1. Introduction

The reduction of CO_2 emissions and increasing independency in energy supply leads to more sustainable use of local and renewable energy sources. For instance, EU directives on the promotion of cogeneration (2004/8/EC) and on the promotion of energy from renewable sources (2009/28/EC) demand for efficient and sustainably increased utilisation of biomass for energy and transport purposes.

In Finland, apart from use in the wood and pulp & paper industry, lignocellulosic biomass is mainly used for heat and power generation. Biomass-based combined heat and power (CHP) production or cogeneration is an established and efficient technology that has proven to be competitive with conventional energy generation under current tax regimes that account for the high CO_2 emissions related to fossil fuels. However, increased use of biomass will raise the prices for limited biomass feedstock in the future and might hamper the economy of municipal biomass-fired CHP plants. Fig. 1a shows a typical heat duration curve of a district heating (DH) network under Nordic conditions. It can be observed that full load operation of the plant is only possible on approximately 70 days of the year; the plant will be operated under less

Abbreviations: BFP, biomass fast pyrolysis; CHP, combined heat and power; DH, district heating; PE, primary energy.

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Nomenclature

q_a	daily district heat demand after calculated load variation [MWh]
q_i	daily district heat demand initial value [MWh]
x	number of the day on the heat duration curve [–]
η_{tot}	overall efficiency
f	primary energy factor [–]
Q	heat (district heat or fuel heat on lower heating value-base) [MW]
P	electricity [MW]
BM	biomass
FO	fuel oil

efficient part load conditions during 145 days per year and will be shut down eventually for about 150 days which clearly exceeds the time required for yearly maintenance. In other words such plants offer a huge potential of available boiler capacity that could supply heat for thermo-chemical conversion processes, such as gasification or pyrolysis. In such concept the heat required for the thermochemical conversion would be supplied by the fuel boiler and low-grade heat potentially rejected at the cold end of the conversion process could be utilised in the DH network, thus increasing the overall efficiency. Such integration would bear the potential of increasing the boiler capacity utilisation and adding an additional biomass product to the plant portfolio, which could increase the competiveness and allow CHP plants to be a part of the currently establishing bio-economy.

Biomass fast pyrolysis (BFP) is the thermal conversion of preferably dry biomass in the absence of oxygen at temperatures of approximately 500 °C and atmospheric pressure. It yields a mixture of approximately 13 wt-% non-condensable gases (mainly, CO and CO_2), 75 wt-% pyrolysis oil (incl. water) and 12 wt-% solid char. The fast pyrolysis process requires approximately 15% of the feedstock energy for providing the heat for the endothermic fast pyrolysis process (BFP requires heating up the biomass to reaction temperature and heat for the actual decomposition reactions) and thus has a high energetic efficiency as all products can be energetically used within the process [1].

Available reactor technologies for BFP have been recently reviewed and research units comprise mainly of the fluid bed type (bubbling and circulating). However, regarding industrial application, also screw feeder driven reactors are applied [1,2].

Most recently, Fortum OY started operation of the world's first industrial BFP unit producing 50 kt/year of pyrolysis oil in Joensuu, Finland. In this plant, the BFP process has been integrated with a municipal CHP plant, but neither the influence on the power and heat generation nor on the part-load behaviour has been reported yet. Fast pyrolysis occurs in a circulating fluidised bed reactor with heat transferred by sand

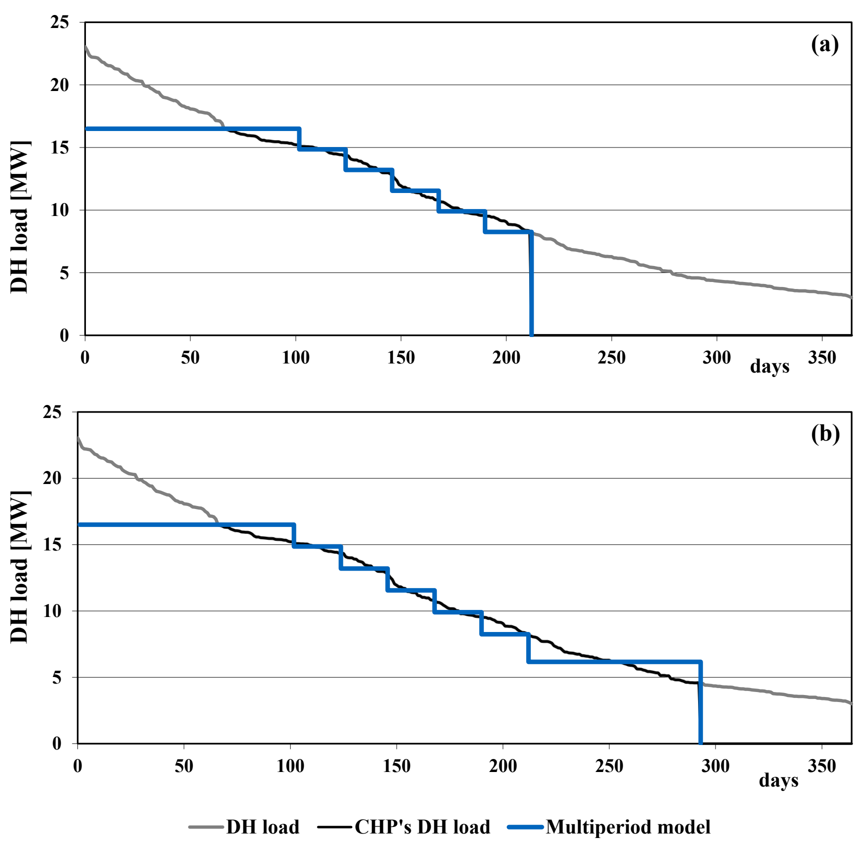

Fig. 1 – Heat duration curve and DH load multiperiod model (a) Stand-alone CHP plant and (b) integrated case with subload.