Large Combined Heat and Power Plants for Sustainable Energy System

Lund, Rasmus Søgaard; Mathiesen, Brian Vad

Publication date:
2014

Document Version
Accepted author manuscript, peer reviewed version

Link to publication from Aalborg University

Citation for published version (APA):
Lund, R. S., & Mathiesen, B. V. (2014). *Large Combined Heat and Power Plants for Sustainable Energy System*. Poster presented at International School on Energy Systems, Kloster Seeon, Germany.

Large Combined Heat and Power Plants for Sustainable Energy Systems

Authors: Rasmus Lund (rlund@plan.aau.dk, +45 9940 2421) and Brian Vad Mathiesen

Aalborg University, Department of Development and Planning, A.C. Meyers Vænge 15, 2450 Copenhagen, Denmark

Highlights

- Feasibility of different CHP plant types is analysed in a 100% renewable energy context
- Three large scale CHP types are compared in full system application
- Four scenarios are constructed and compared on system costs and fuel consumption
- Scenarios are modelled in the energy systems analysis tool EnergyPLAN
- Combined cycle gas turbines plants shows to be the most cost and fuel efficient technology

Fig 1. Photo of the Avedøre (Biomass and coal) CHP plant and wind turbine near Copenhagen [1]

Introduction

Denmark has the ambitious goal of being independent of fossil fuels in 2050. This requires radical changes to the ways energy is produced and consumed today. Large amounts of renewable fluctuating resources like wind and solar will change the role of CHP and power plants from mainly base load operation in the past (Fig. 2) to being a regulating reserve in the future (Fig. 3).

It is important to consider the total energy system rather than electricity, heating, transport, etc. individually to utilize synergies between them. This is illustrated in the potential reduction in fuel consumption from Fig. 2 to Fig. 3 still covering the same energy demands.

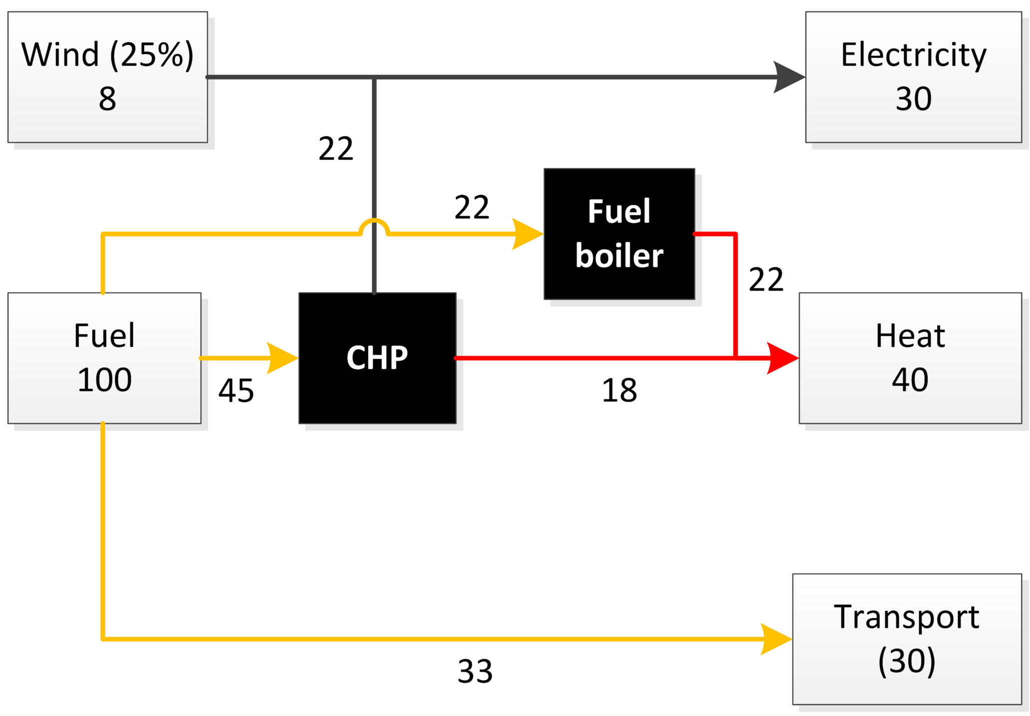

Fig 2. Simplified diagram of a traditional energy system in Denmark with 25% wind power integration. Numbers indicate quantity of energy flows for electricity, heat and fuel; respectively black, red and yellow

Acknowledgments

This project was partially financed by Copenhagen Municipality and The Danish Strategic Research Council financed Research Centre 4DH – an international Research Centre of 4th Generation District Heating (www.4dh.dk).

Methodology

To analyse the feasibility of the three different types of CHP plants (Fig. 4) a numerical analysis of the technical operation of the plants is conducted. The technical and economic data for the plant types are implemented into a smart energy systems model with 100% RE in the Danish energy system, developed in the CEESA project [2].

The energy systems modelling tool EnergyPLAN is used to analyse the scenarios. EnergyPLAN is a deterministic input-output model that operates with an hourly time resolution.

Scenario Analysis

Four scenarios are constructed to represent each of the power plant technologies. There are two scenarios for the CFB because it turned out that the installed capacity is very important for the operation of the system in this case.

There are two main indicative parameters:

1. Total scenario costs are the socioeconomic costs of the total energy system including investments, O&M, fuel and electricity exchange for all energy sectors.
2. Biomass, as the only primary fuel source, is important when assessing the sustainability of the consumption in the scenarios.

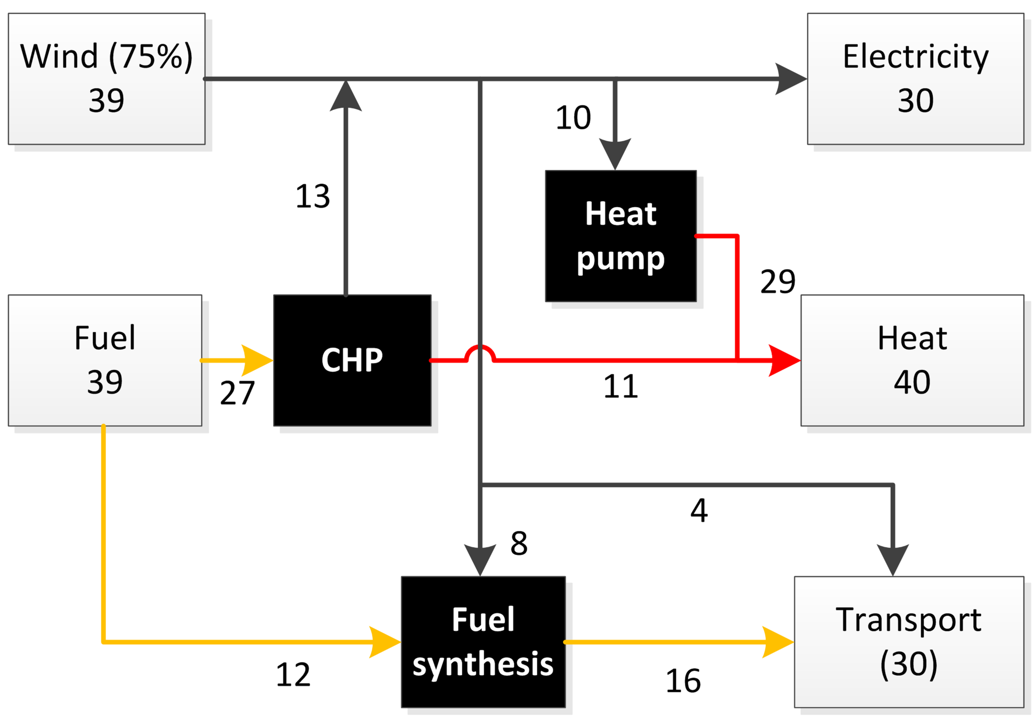

Fig 3. Smart energy system with 75% wind power integration, heat pumps and synthetic fuel production. Numbers indicate quantity of energy flows for electricity, heat and fuel; respectively black, red and yellow

AALBORG UNIVERSITY
DENMARK

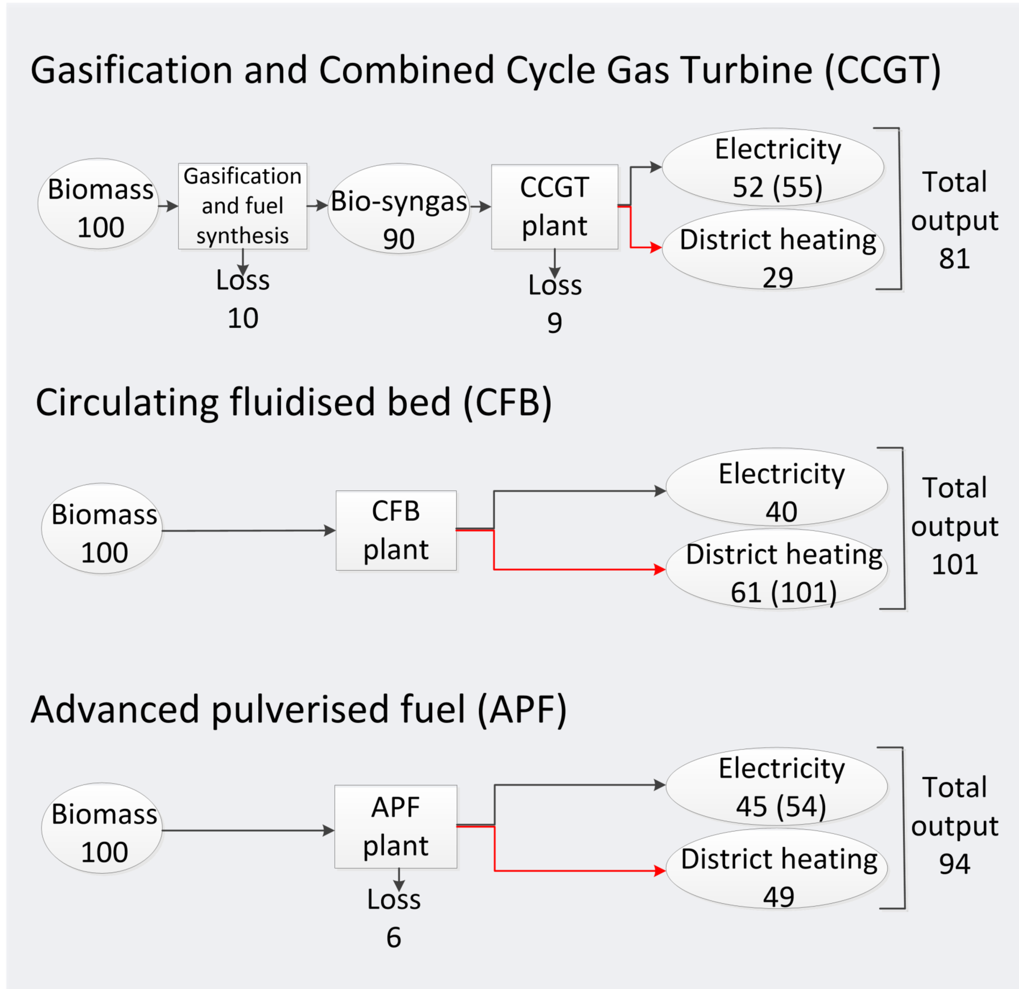

Fig 4. Diagrams illustrating the 2050 technology assumptions of conversion efficiencies for the three CHP plant types analysed. Values in brackets indicate respectively electricity-only or heat-only operation [3].

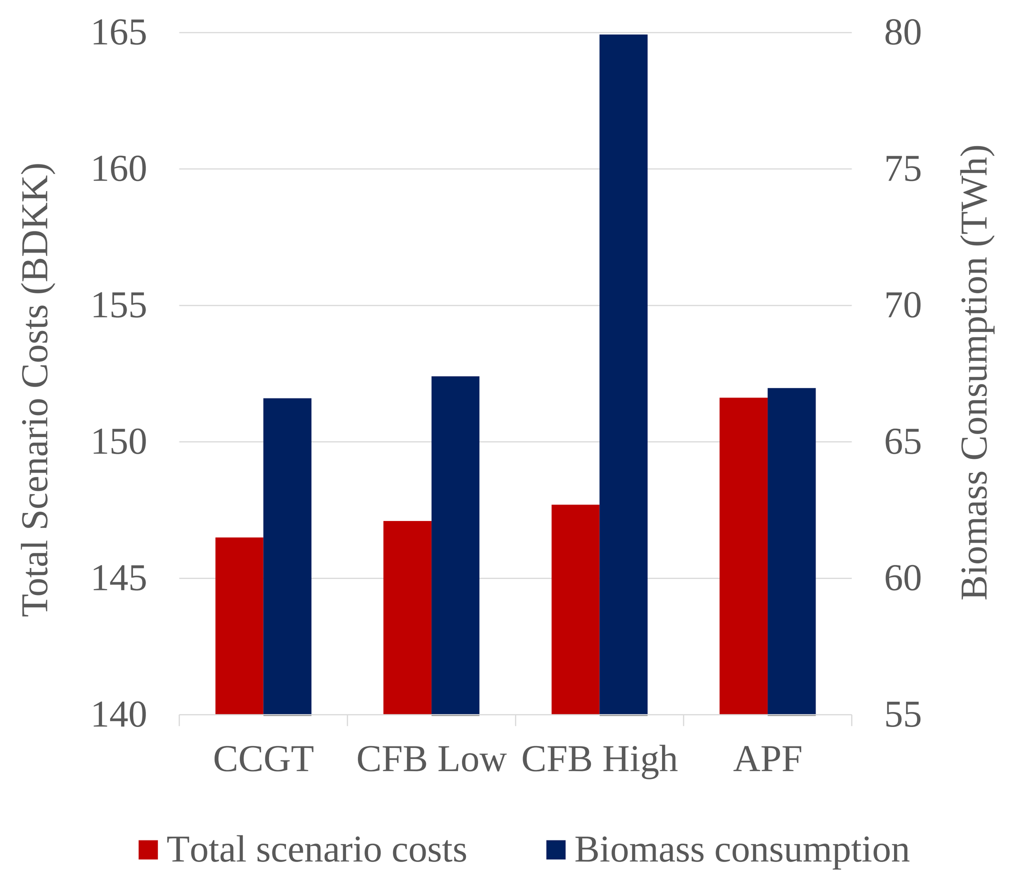

Fig 5. Graph showing the main results of the scenario analysis for the four analysed scenarios.

Results and Discussion

The main results of the analysis can be seen in Fig. 5. The CCGT system has the lowest values for both costs and biomass consumption, and is thereby seen as the best of the analysed alternatives for a RE system in Denmark.

It should be noticed that the CCGT plant individually from a technical point of view (Fig. 4) is not the most efficient system, but in the context of a RE system its better flexibility, a higher electric efficiency and its relatively low investment costs makes it a better choice.

In the light of the long technical lifetime of new power plants it should be considered how CCGT plants can soon start to be implemented to avoid a future technology lock-in to plants poorly suited for RE systems.

References

[1] Weirup, Karsten. 2011. Avedøre Holme. http://weirup.photoshelter.com/image/I0000M9QclrO5OdY

[2] Mathiesen, B. V. et al. 2011. Coherent Energy and Environmental System Analysis (CEESA) 100% Renewable Energy Scenarios Towards 2050.

[3] Danish Energy Agency. 2012. Technology Data for Energy Plants.