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Techno-economic performance analysis of energy production from biomass at different scales in the UK context

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ABSTRACT

This paper compares the results of a techno-economic performance analysis of three combustion plants for the recovery of energy from three types of biomass: solid recovered fuel (SRF), forestry waste wood chips (FWWC), and crude rape seed oil (RSO). Small and medium scale plants have been investigated, 50 kilo tonnes per annum (ktpa) and 160 ktpa combustion plants utilising FWWC, 50 ktpa and 100 ktpa plants treating SRF, and an internal combustion engine plant at 27 ktpa and 40 ktpa utilising RSO. The technical assessment includes calculations for electricity generation, heat produced and overall system efficiency. The economic viability of the different processes is investigated through a discounted cash flow analysis. The levelised cost is used to calculate the cost of production of one unit of electricity. The effect of changing model input parameters on the economic performance is evaluated. Seven different system variables have been chosen and the effect of a ±10% change on the levelised cost has been examined. The results showed that the levelised cost of the SRF plant is mainly affected by calorific value, turbine efficiency, capital and operating costs. The parameters which affect the FWWC biomass plant are the calorific value, steam turbine efficiency, capital and operating costs. Whereas, parameters affecting the RSO biomass plant are the calorific value, engine efficiency, capital and operating costs. A techno-economic analysis of the plants indicates the SRF plant is economical at both scales. The RSO plant and the FWWC plant are only economical at the medium scales investigated. The 40 ktpa RSO plant is found to be the most efficient one at 52% compared with 28% efficiency for the SRF plant, it is also the most economically viable option with a 25% IRR compared to 17% IRR for the FWWC plant, and 10% IRR for the SRF plant.

1. Introduction

Global warming is the increase in average temperature of the Earths surface, air and oceans. As a result, increases in flooding, ice caps melting, climate change, and changes in animal habitat have been reported. The Intergovernmental Panel on Climate Change (IPCC) [1] concluded that the increase of greenhouse gas concentrations is the result of human activities, such as fossil fuel burning and deforestation [2].

The Department of Energy and Climate Change (DECC) reported that emissions fell from 483 $MtCO_2$ to 431 $MtCO_2$ between 2008 and 2009, where, power stations are the largest single contributor (151 $MtCO_2$) [3]. Over the years, CO_2 and other greenhouse gases, such as methane and ozone, have resulted in global warming [4]. Other by-products of fossil fuel combustion include sulphur oxides and nitrogen oxides, both of which contribute to acid rain [5]. In order to reduce the amount of CO_2 released to the atmosphere, we are to act now by using renewable forms of energy to lower our emission of fossil carbon into the atmosphere and help the overall balance of carbon in the atmosphere in an economically attractive manner.

95% of the current overall demand of UK energy (220 million tonnes of oil equivalent) is derived from fossil fuel resources [3,4]. DECC is responsible for ensuring the UK continues to enjoy secure and competitively priced energy. The UK is importing energy and competition for energy resources can make prices volatile. In 2008, a spike in oil prices demonstrated the extent of the fluctuations in prices for energy and fuel [6]. The UK energy mix includes ten nuclear power stations consisting of 19 operating reactors which supply 18% of the electricity generated [7]. In 2009, the UK coal supply amounted to 48 Mt with 38 Mt being transformed to electricity [8]. Oil and gas remain vital parts of the UK energy mix. Both of these fossil fuels are used to produce electricity. In 2009, the UK supply of primary oil was 75 Mt [9]. In 2009, the UK supply of natural gas was 1,000,000 GWh with 350,000 GWh being transformed to electricity [10]. In the near future, fossil fuels will remain a dependant source

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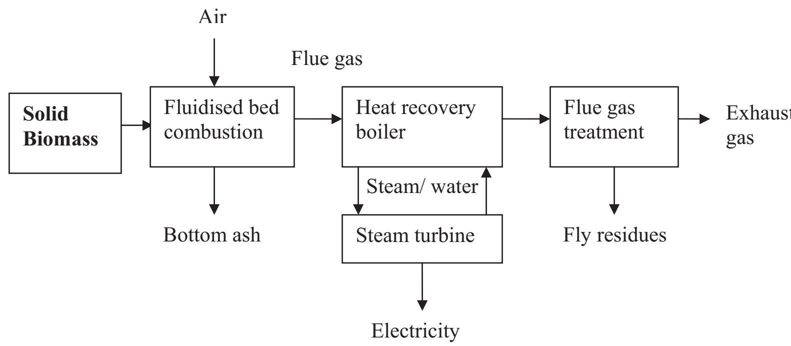

Fig. 1. Energy recovery from solid biomass utilising fluidised bed combustion technology.

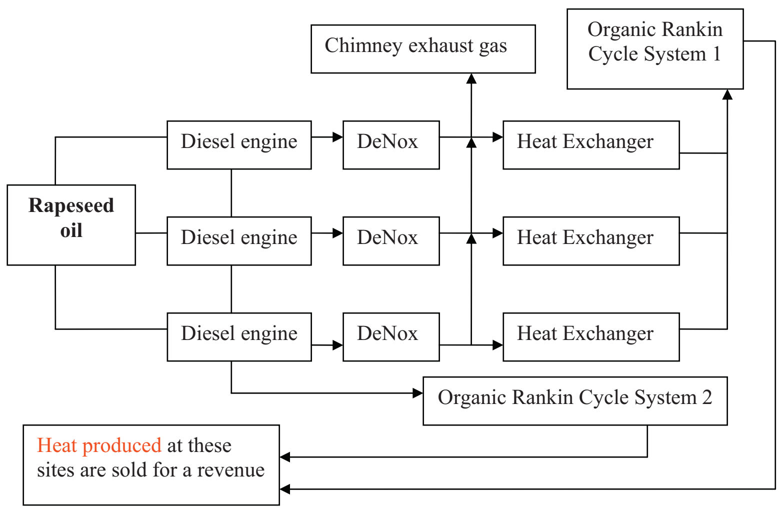

Fig. 2. Energy recovery from crude rapeseed oil biomass in internal combustion engines.

of UK energy. However, an increase in renewable energy is required to meet our UK target and help reduce climate change. Therefore, the future supply of UK energy is associated with the economy and the need to accelerate a move towards low-carbon energy security [6]. Climate change is an issue which encompasses finance and economic as well as energy and environmental ministries [11].

The UK Government targeted an 80% reduction in carbon emissions by the year 2050 compared to those emitted in 1990. A 12.5% reduction by the year 2012 [12] was introduced in 2002. The UK further showed its continued commitment and concern towards climate change at the Copenhagen Climate Change Summit in 2009, by encouraging a global agreement on reducing climate change. The result of the Copenhagen Summit was the signing of the so-called Accord, which emphasised that deeper cuts in climate change are to be achieved, adaptation to adverse effects of climate change and funding issues must be achieved in order to reduce climate change; unfortunately, no quantitative goals were stated in the Accord.

Reducing our greenhouse gas output can be achieved by using other feed sources rather than fossil fuels, such as biomass. Biomass

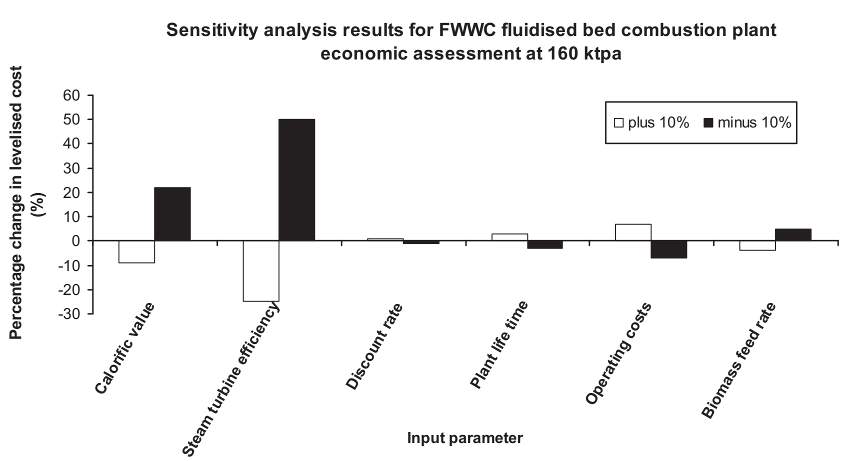

Fig. 3. Sensitivity analysis results for FWWC fluidised bed combustion plant economic assessment at 160 ktpa.