Technical, economical and environmental assessment of biomass waste to electricity techniques in The Netherlands

P. van Schijndel*, K. Ptasinski and F. Janssen
STW 1.28, P.O. Box 513, 5600 MB Eindhoven, The Netherlands
Faculty of Chemical Technology, Eindhoven University of Technology
Phone: +31 40 247 3197; Fax: +31 40 244 66 53; p.p.a.j.v.schijndel@tue.nl

The policy of the Dutch Government is to increase the amount of sustainable electricity generated within The Netherlands. In order to do this several scenarios are possible including power production by wind, water and solar power and biomass (waste) combustion. Using biomass for power production instead of fossil fuels decreases the emissions of CO_2 since growing biomass takes up CO_2 from the atmosphere in what is called the short CO_2 cycle. Although the total area available to grow energy crops within the Netherlands itself is rather limited there are still large amounts of biological wastes available like: industrial organic sludge, sewage sludge, agricultural waste, demolition wood, thinning wood and verge grass. It is expected that by the year 2015 the 3 Mton of biomass waste annually available can supply about 150 PJ, which equals 4% of Dutch power supply. Using this waste seems the easiest way to generate a substantial amount of sustainable, 'green', electricity. However, there is still not enough knowledge about the total environmental burden of sustainable energy sources in respect to fossil fuels. Also there exists no good environmental comparison between the different biomass conversion techniques. Most interesting techniques are the biomass-integrated gasifier with combined cycle (BIG CC), the stand-alone combustor with steam-cycle and the co-combustion of biomass in a regular power plant. Also a comparison can be made with the combustion of biomass in a domestic waste-incinerator, which is the common technique for treating combustible waste in The Netherlands. Other important questions in this matter are the predicted electricity generation costs per kWh of 'green' power and the technical feasibility of these new techniques.

Assessment study

Aim of this particular study was the ranking of biomass to power techniques according to their environmental impact. First a technological assessment was carried out to determine the 5 best techniques in terms of electricity price, development stadium of the technique, exergetical efficiency, flexibility towards the use of different biomass feed types and possibilities of the technique within the 5 –30 MW_e range. The kWh_e price is the most important ranking criteria because it has the largest influence on the feasibility of the technique. Three different technologies taken into account were gasification, pyrolysis and combustion. Different specific options within these technologies have been investigated like stand-alone systems and integrated systems. The best-ranked techniques were evaluated on their environmental impact using life cycle assessment following the standardised CML/SETAC methodology [1]. The inventory-analysis, classification and evaluation are performed with the Simapro software package. Functional unit used in the comparison study was the thermal treatment of 60-kton of biomass with a caloric value of 966 TJ and production of 425 TJ of electricity [2]. This unit is based on the 44% efficiency when co-combusting waste wood in a modern powder coal power plant. For biomass conversion techniques with lower efficiency a surplus of fossil electricity production was added in the LCA. The environmental burden for this extra electricity is calculated from the average Dutch electricity production data. Besides the functional unit based on 60-kton of biomass and 425 TJ_e, a sensitivity analysis using an alternative functional unit based on 1 MJ_e and different biomass input was done. Because the same biomass-input is used in the LCA comparison, the system boundaries are not drawn as broadly as possible, since only the differences have been taken into account. In the sensitivity analysis for the LCA study choice of transport distant, type of biomass and choice of functional unit has been investigated [3,4,5].

Results and discussion

A total of 11 different conversion techniques have been assessed on their economical and technical ranking. Most promising routes are co-combustion, stand alone combustion, co-combustion of gasification gas and stand alone gasification with combined cycle. Pyrolysis techniques did not yet meet the power range criteria. Electricity price of the different co-combustion systems are estimated between 2 and 10 Euro cents per kWh_e, the stand-alone gasification systems generate electricity at about 6 to 12 Euro cents per kWh_e. Most techniques have exergetic efficiencies of 30-40% except for stand-alone combustion with an efficiency of 22-28%. Technical installations necessary for co-combustion of waste wood in coal powder power plants are minimal compared to stand alone biomass to electricity plants. Therefore the co-combustion options score much better than the stand-alone gasification and combustion techniques in terms of technology and infrastructure.

LCA studies were carried out for the stand-alone combustion, co-combustion, stand-alone gasification and waste incineration of waste wood. Co-combustion of gasification gas was not considered because not enough data was available for this technique. Most important environmental impact categories were global warming potential, acidification and heavy metals. The co-combustion technique has the lowest environmental impact score, followed by stand-alone gasification and stand-alone combustion. Although waste incineration plants in The Netherlands have extremely low emissions their environmental impact ranked highest due to a very low, 21%, exergetic efficiency. A thorough sensitivity analysis taking into account the choice of functional unit, transport distant and use of reactants did not change the overall environmental ranking. However the use of cultivated poplar wood compared to poplar waste has a very large effect on the LCA outcome because of influence of pesticides and fertilizer use. Most important factors for the differences between the techniques are gas clean-up systems used and the net power efficiency. Therefore an efficiency improvement of the techniques has a great effect on the environmental impact score.

Conclusions

In general, the best conversion technique, from an environmental, economic and technological point of view, appears to be the combined biomass-coal power plant. The two key-factors in the comparison are the gas clean-up system and the overall net-efficiency. Therefore, the gasification plant scores higher than the stand-alone biomass combustion plant. When special crops are cultivated for electricity production, using pesticides and fertiliser, the environmental burden of biomass is almost comparable to fossil power production. For biomass waste, the biomass power production techniques are better than fossil power techniques. Interesting outcome was the fact that the choice of functional unit was very important but did not change the ranking order of the different techniques.

References

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