Mobile energy generation system based on biomass waste gasification

A.I. Tanase[1], N. Slavu[1,2], C.K. Banica[3], A. Hadar[4,5], C. Dinca[1,2,5]

[1]Department of Production and Use of Energy, Power Engineering Faculty, University POLITEHNICA of Bucharest, Bucharest, RO-060042, Romania
[2]SC AUDIT IT&C SRL, Bacau, RO-600293, Romania
[3]Department of Measurements, Electrical Devices and Static Converters, Electrical Engineering Faculty, University POLITEHNICA of Bucharest, Bucharest, RO-060042, Romania
[4]Department of Strength of Materials, Faculty of Industrial Engineering and Robotics, University Politehnica of Bucharest, 313 Splaiul Independenței, 060042 Bucharest, Romania
[5]Academy of Romanian Scientits, 3 Ilfov Street, 050045 Bucharest, Romania
Keywords: biomass, gasification, energy from waste, resources recovery
Presenting author email: alexandra.coman@upb.ro

Mobile energy generation system based on the gasification of biomass waste is an alternative green energy solution that can be used to generate electricity and/or heat in rural locations, on poultry and agricultural farms, or in other areas remote from energy grids. The system is based on the conversion of biomass into electricity and/or heat through the gasification process. The technology can be used to valorise agricultural residues, such as straw, leaves, or crop residues, which are often burnt or abandoned, producing harmful emissions and missing an important opportunity to generate green energy.

The mobile energy production technology based on biomass gasification consists of the following components: a dryer to reduce the moisture content of the biomass to a maximum of 10%, a gasifier to obtain syngas from the biomass introduced, purification of the syngas using a cyclone filter, a plasma filter and two electrostatic filters, an electric generator based on a gas turbine installation and a control panel to automate the whole process, all located in a mobile container.

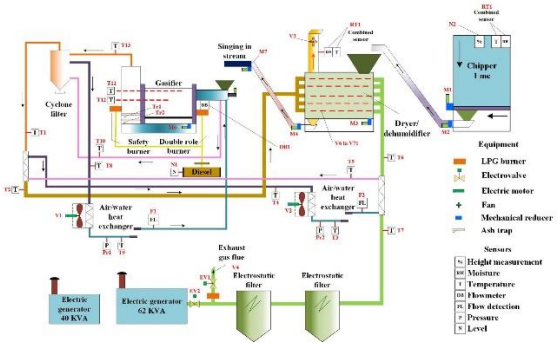

Figure 1. Process diagram

The aim of the article is to analyse from a techno-economic point of view the mobile gasification technology for biomass waste. The waste analysed in the study is presented in Table 1 with its elemental composition [1] and lower heating value (LHV). The composition of the syngas obtained from the gasification process is also presented (Figure 1).

Tabel 1. Elemental composition of the analysed waste and of the syngas obtained

Element (wt %)	C	H	O	N	S	A	W	LHV, kJ/kg
Poultry waste	28.04	2.44	17.57	4.84	0.10	33.41	13.60	10 710
Syngas composition								
Element (mol %)	H_2	CH_4	N_2	H_2S	CO	CO_2	LHV, kJ/kg	ER, -
Syngas	28.37	0.25	33.04	0.05	33.46	4.83	7 742	0.2

Modelling of the waste gasification process was carried out using ChemCAD software to obtain mass and energy balance information to be used to determine technical and economic performance indicators. The performance of the waste gasification system is directly influenced by the ER ratio ($ER=Air_{real}/Air_{stoichiometric}$) and the energy, financial and environmental benefits of gasification are highly dependent on the selection of an optimal

ER ratio. The optimal ER ratio at which the maximum value of the cold gas efficiency indicator was obtained (93%) is 0.2 as shown in Table 1.

The flow rate of biomass introduced into the mobile energy system is 100 kg/h mixed with air at an optimal ratio ER=0.2. The flow rate of syngas introduced into the gas turbine (1 x MT250) and the steam turbine (1 x SST-040, in counterpressure) is 129.5 kg/h.

The energy and economic indicators of the energy syngas conversion into electricity and/or heat are presented in Table 2. It should be noted that the heat energy obtained by condensing the steam (the back pressure is 4 bar) is used directly for drying the biomass waste before it is fed into the gasifier. In Figure 2 the annual net present value (NPV) is shown. Starting from year 5, the NPV has a positive value.

Table 2. Energy and economic indicators

Energy indicator		Economic indicator	
Combustion chamber temperature, ºC	800	Discount rate, %	10
Compression ratio, -	8	Lifetime, years	25
Internal efficiency GT, %	90	Specific investment, €/kW	3 603.6
Live steam pressure, bar	40	Specific fixed O&M costs, €/kW	90.1
Live steam temperature, ºC	400	Specific variable O&M costs, €/MWh	4.1
GT power, kW	87.5	Total investment costs, €	436 964
GT efficiency%	29.4	Annual fixed O&M costs, €/year	10 924
ST power, kW	33.7	Annual variable O&M costs, €/year	3 764.9
GT – ST net power, kW	121.2	Electricity price, €/MWh	100
Global efficiency GT – ST, %	40.7	Environmental waste tax, €/kg	0.41
CO_2 emission factor, kg/MWh	847.6	CO_2 emissions tax, €/tCO_2	80
Electricity produced, MWh/year	909.4	Levelised cost of electricity, €/MWh	69.6

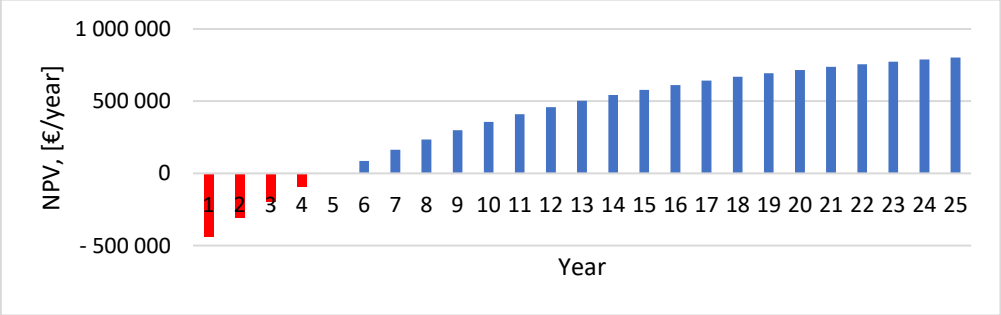

Figure 2. Annual net present value

Conclusions

The implementation of the mobile energy system to produce energy from biomass waste can reduce its environmental impact. The waste is neutralised and the beneficiary no longer pays the related fees for its disposal. Another advantage is that electricity is produced, which the beneficiary can use for their own consumption or deliver to the grid. The levelised cost of electricity is 69.6 €/MWh and the investment payback period is 5 years.

Acknowledgment

The study has been funded by the UEFISCDI within the International project NO Grants 2014 - 2021, under project contract no. 13/2020, EU Horizon2020 GA: 101000612/2020 - In-No-Plastic and through Romania's "Competitiveness Operational Programme 2014-2020" Priority Axis 1: Research, Technological Development and Innovation (RD&I) to Support Economic Competitiveness and Business Development Action 1.2.1. Innovative Technological Project Cod My SMIS: 121404/2020 – SyCON.

References

[1] Zhu, Shijun, Yun Liu, and Seong Lee. "Optimization process of biomass combustion in the advanced fbc using factorial design and response surface methodology." International Conference on Fluidized Bed Combustion. Vol. 41839. 2005.