Biomass combined heat and power for renewable power provision in mountain environments: techno-economic assessment of cost factors and competitiveness under different renewable energy market conditions

Lorenzo Menin[1], Aldo Paolillo[1], Stefano Piazzi[2], Daniele Antolini[2], Francesco Ravazzolo[1], Marco Baratieri[1]

[1] Free University of Bozen-Bolzno, Italy; [2] BiSTEMS srl, Italy.

Introduction and methods

Targets concerning the replacement of fossil sources with renewable energy sources are being adopted globally and are especially ambitious in the EU, following the recently approved Renewable Energy Directive III, aiming for 42.5% penetration of renewable energy in Member States by 2030. In this context, bioenergy can represent a significant marginal contributor to a progressively decarbonizing energy mix, especially in mountain areas, where residual biomass sources are abundant and can be harvested in compliance with sustainable practices [1]. However, the regional planning concerning the adoption of bioenergy in mountain regions requires a careful evaluation of bioenergy levelized cost and main techno-economic risks. The present study focuses on bioenergy generated by biomass gasification and combined heat and power (CHP) and makes use of techno-economic modeling based on data retrieved from a sample of real operating plants in the South Tyrol region [2,3] alongside energy market modeling to assess 1) the key techno-economic factors affecting bioenergy LCOE and thus competitiveness, 2) the influence of different future renewable energy market conditions on bioenergy competitiveness and subsidization requirements. The study made use of a synthesis of operational data retrieved from biomass gasification CHP plants in South Tyrol to simulate the techno-economic performance of the average plant and identify the most influential economic parameters via specific sensitivity analyses on plant size, biomass cost and plant capacity factor. Natural gas price forecasts are projected relying on an econometric market model as the underlying price driver for alternative dispatchable energy and the corresponding bioenergy subsidy required to reach price parity over the plant lifetime is estimated.

Main results

The results indicated that under current capital costs, at 379 €/MWh (Table 1), the achievable LCOE is very high relatively to current energy prices (that sat within the 143 – 172 €/MWh range for non-domestic consumers in the EU in the period 2018-2021 [4]) already under a base-case assumption of 8000 operating hours per year and a 200 kW_{el} plant size, pointing to a very limited competitiveness in the current energy market.

Table 1. Main economic results under base case assumptions

Fixed capital investment	OPEX per year	Depreciation per year	Side revenues per year	LCOE per MWh	Total subsidy (millions)
€ 2,427,378	€ 292,222	€ 116,979	€ 48,000	€ 379.2	€ 222.5

Fig. 1 displays the effect of the variation in size and operating hours for base-case biomass cost assumptions, clearly showing how capacity factor represents the most influential cost factor in the economics of bioenergy. The phenomenon is displayed numerically in Table 2 through the relative linear regression statistics.

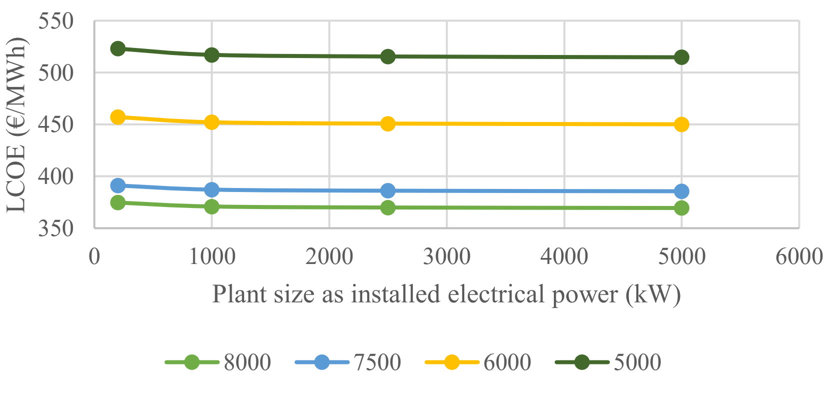

Fig. 1. Effect of size and operating hours variation on bioenergy LCOE. Operating hours per year are shown in the legend.

In a comparison between yearly operating hours and biomass cost, Fig. 2. shows the similar predominant effect of capacity factor on bioenergy LCOE, indicating the latter as the most critical cost factor overall among the ones investigated (Table 2).

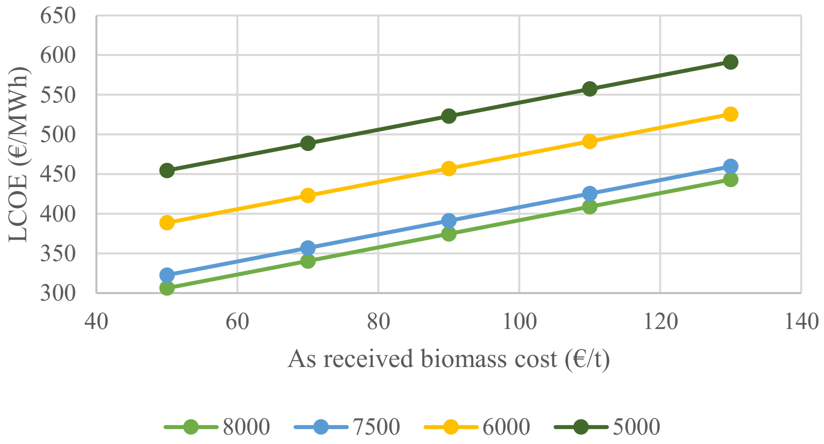

Fig. 2. Effect of biomass cost and operating hours variation on bioenergy LCOE. Operating hours per year are shown in the legend.

Table 2. Summary of linear regression statistics

Parameter	Slope	Intercept
Biomass cost	154.0	374.7
Yearly operating hours	-391.2	300.8
Plant size	-0.2	373.0

Discussion and conclusions

The results of the study show that under current plant capital costs the base-case bioenergy cost that can be expected from gasification-CHP systems at a reference scale of 200 kW_{el} is very little competitive with current retail electricity prices. The sensitivity analyses conducted clearly indicate that capacity factor is the most critical parameter relatively to the bioenergy LCOE attainable by these systems, thus pointing to the instability of biomass supply as the greatest economic risk and as much more impactful than small plant sizes in the ranges considered. The work provides an assessment methodology of use for bioenergy planning in mountain regions and illustrates that the lack of long-term sustainable, secure biomass supply at any point over a plant's lifetime represents the single greatest source of risk relatively to bioenergy competitiveness and economics, thus pointing to the need for a careful selection of plant sizes based on local resource availability. Upcoming developments will include the use of an econometric model to project natural gas prices under several renewables growth scenarios.

References

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