Validation of an Emerging Technology for Intensified Biomass Gasification and CHP Production at Large TRL

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The ongoing global warming poses nowadays a significant risk, potentially leading to critical "turning points" with irreversible effects on global climate, humans and ecosystems. Consequently, it is crucial to limit global warming to well below 2 °C, ideally 1.5 °C, relatively to the pre-industrial temperature levels. In order to address this climate crisis, it is necessary to shift towards a climate-neutral economy, following the principles of the circular economy to "reduce, reuse and recycle", thus move away from the conventional approach of "make, use and dispose". Focusing more on energy resources, the transition from a fossil-fuel reliant economy to a decarbonized one that explicitly utilizes renewable resources (RES) becomes imperative.

Following the relevant EU and national legislations and directives, Greece has developed an action plan to enhance the use of RES and to promote energy savings by 2030. Among others, the major goals of this action plan are to: (a) implement biomass projects up to 250 MW capacity in total, (b) produce final energy from biomass equal to 0.27-0.41 Mtoe, (c) strengthen the available district heating installations, especially those using RES, and (d) exploit the biomass that is produced from agricultural and agro-food industries.

Currently, the licenses that have been granted by the Greek Regulatory Authority for Energy (RAE) for the establishment of new power generation units add to a total capacity of 303 MW; they specifically focus on biomass, agricultural residues and other by-products of the agricultural sector as resources. However, the implementation of these licensed projects, particularly those involving biomass gasification plants, remains at a significantly low level. This is primarily due to the lack of fully automated systems, needed to effectively handle crucial operations within the gasification process, as well as unresolved environmental issues regarding tar and wastewater management. Moreover, the utilization of woody biomass, which is the primary resource for gasification plants, poses significant economic and availability challenges, because of its high cost and the large demand for competing applications. These conditions presently hamper the economic viability and continuous operation of gasification units. Consequently, in order to ensure the feasibility of gasification technology and increase the implementation rate of biomass gasification projects, it is crucial to address several key aspects, including: (a) the enhancement of reliability and automation of biomass gasification systems; (b) the efficient utilization of several types of biomass, beyond individual woody materials; (c) the establishment of a sustainable and economically viable biomass supply chain; and (d) the mitigation of the environmental impact, associated with gasification plants.

Aligned with the above objectives, ENGAIA S.A. has designed, developed and implemented a biomass gasification plant for combined heat and power (CHP) generation at a Technology Readiness Level (TRL) of 7. The ENGAIA S.A. gasification plant produces synthesis gas (syngas) at an average rate of 105 Nm^3/hr by utilizing 70 kg/hr of biomass. It should be noticed that it is the first gasification system that was entirely designed and constructed in Greece. The pilot gasification unit comprises various components, including: (1) a PLC automation panel, speed controllers and PCs; (2) a compressed air circuit; (3) a feeding hopper and biomass conveyor; (4) an hourly feed buffer with a drying exchanger; (5) auto-feed gasifier screws; (6) a downdraft gasifier; (7) an automatic ash extraction system; (8) a cyclone; (9) a gas cooling exchanger and liquid waste extraction; (10) a gas purification filter; and (11) a dual fuel (syngas/bioliquids) generator.

Within the scope of the i-GAS project, ENGAIA S.A. aims to further enhance the efficiency of its pilot gasification system. More specifically, the objectives are to further improve the process automation and control system, optimize the feeding system, explore different types of gasification reactors as the means to accommodate various types of biomass feedstocks, enhance the gas cleaning system, and reduce waste generation during syngas purification. ENGAIA S.A. has the ambition to commercially exploit the project's outcomes, both in terms of products and knowledge, for the development and construction of biomass gasification plants, initially in Greece and eventually worldwide.

In this framework, the present study highlights the ongoing efforts of ENGAIA S.A. to improve the efficiency and in general intensify the gasification system under development. To do so, advanced process simulation techniques were employed to determine the optimal values of operational parameters for different biomass feedstocks and streamline operations, to reduce human intervention, and to maximize electricity generation. The feeding system was specifically optimized by carefully analysing the characteristics of different

biomass feedstocks, ensuring a consistent and efficient supply. Factors such as particle size, moisture content and feeding rate, which directly affect gasification efficiency, were quantitatively considered. In addition, to enhance the economic viability of the gasification unit by utilizing a wider range of biomass feedstocks, a fluidized bed gasifier was selected over the initial downdraft gasifier. This reactor design is expected to maximize efficiency, ensure optimal biomass-to-syngas conversion, and reduce tar production. Finally, initial steps have already been taken towards optimal ash management and waste generation reduction and treatment.

ENGAIA S.A. by successfully commercializing their enhanced gasification system, aims to significantly contribute to the adoption of sustainable and carbon-neutral energy solutions, leveraging biomass as a renewable energy resource for a greener future.

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