Techno-economic assessment of supercritical carbon dioxide integrated with anaerobic digestion

A. Shabruhi Mishamandani*, F. Asfand*, S. Fadlallah* , M. Jafari*, J. Allport*, G. M. Campbell **

**School of Computing and Engineering, University of Huddersfield, Huddersfield, United Kingdom*

***Department of Chemical Sciences, School of Applied Sciences, University of Huddersfield, Huddersfield, United Kingdom*

(E-mail: Arian.shabruhimishamandani@hud.ac.uk)

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Abstract

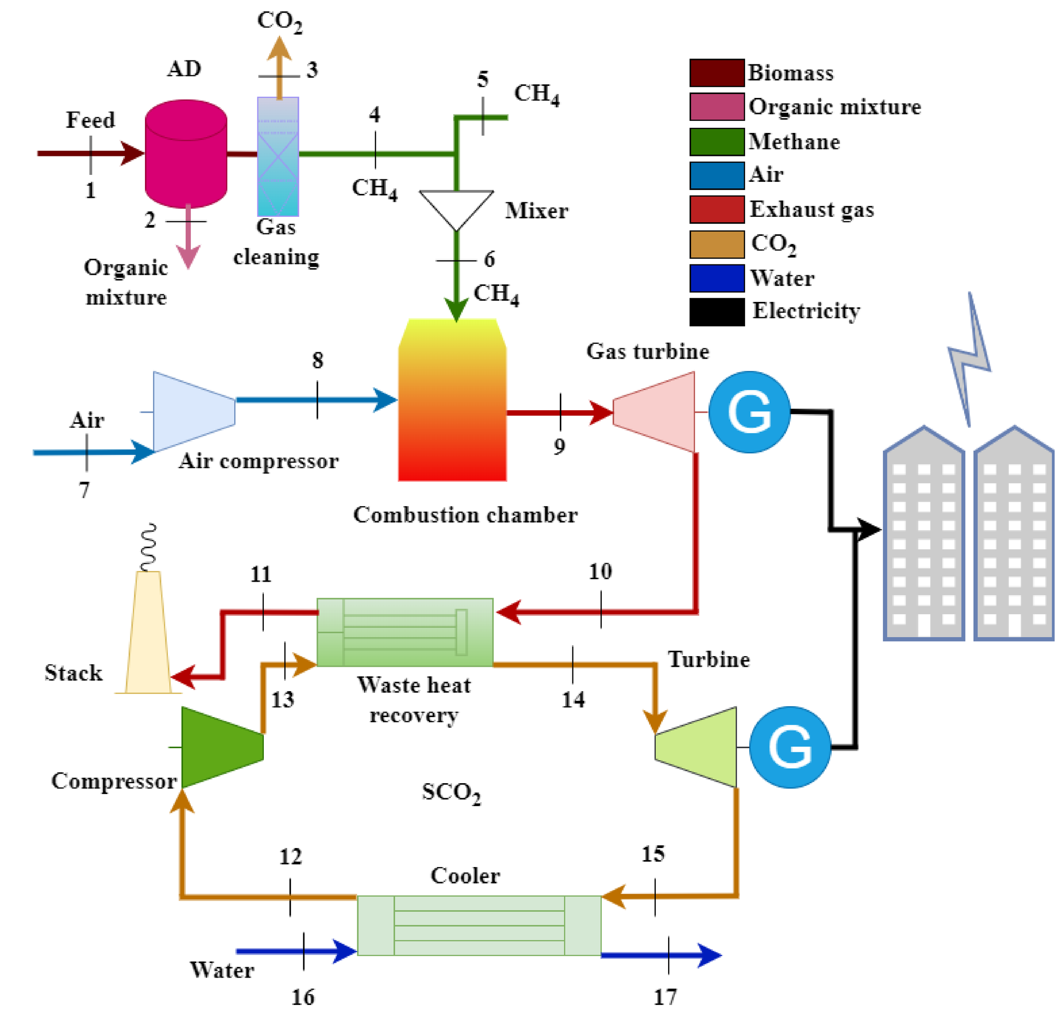
Biomass conversion to energy is of paramount for the future of renewable energy production. In this study, supercritical carbon dioxide power cycle is integrated with a gas turbine to recover the waste heat of exhaust gas from combusting the biogas derived from anaerobic digestion (AD). AD is fed with a mixture of biomass and pyrolysis-derived biochar to improve its stability and biomass to methane conversion efficiency. A technoeconomic assessment of the proposed system has been carried out. According to results, thermal, exergy efficiencies and net work output and payback period are 39.76%, 38.57%, 9936 kW, and 4.835 years, for Case 4, respectively.

Aims and objectives

- Investigation of biochar addition effects and different Case scenarios for CH_4 production from AD on the overall performance of the system
- Implementing Techno-economic assessment of the proposed system
- Sensitivity analysis of influential parameters effects on overall performance of the system

System description

- Schematic diagram of the proposed system



Mathematical modeling

Global reaction of the AD:

- $C_xH_yO_z + wH_2O \rightarrow x_1CH_4 + x_2CO_2$

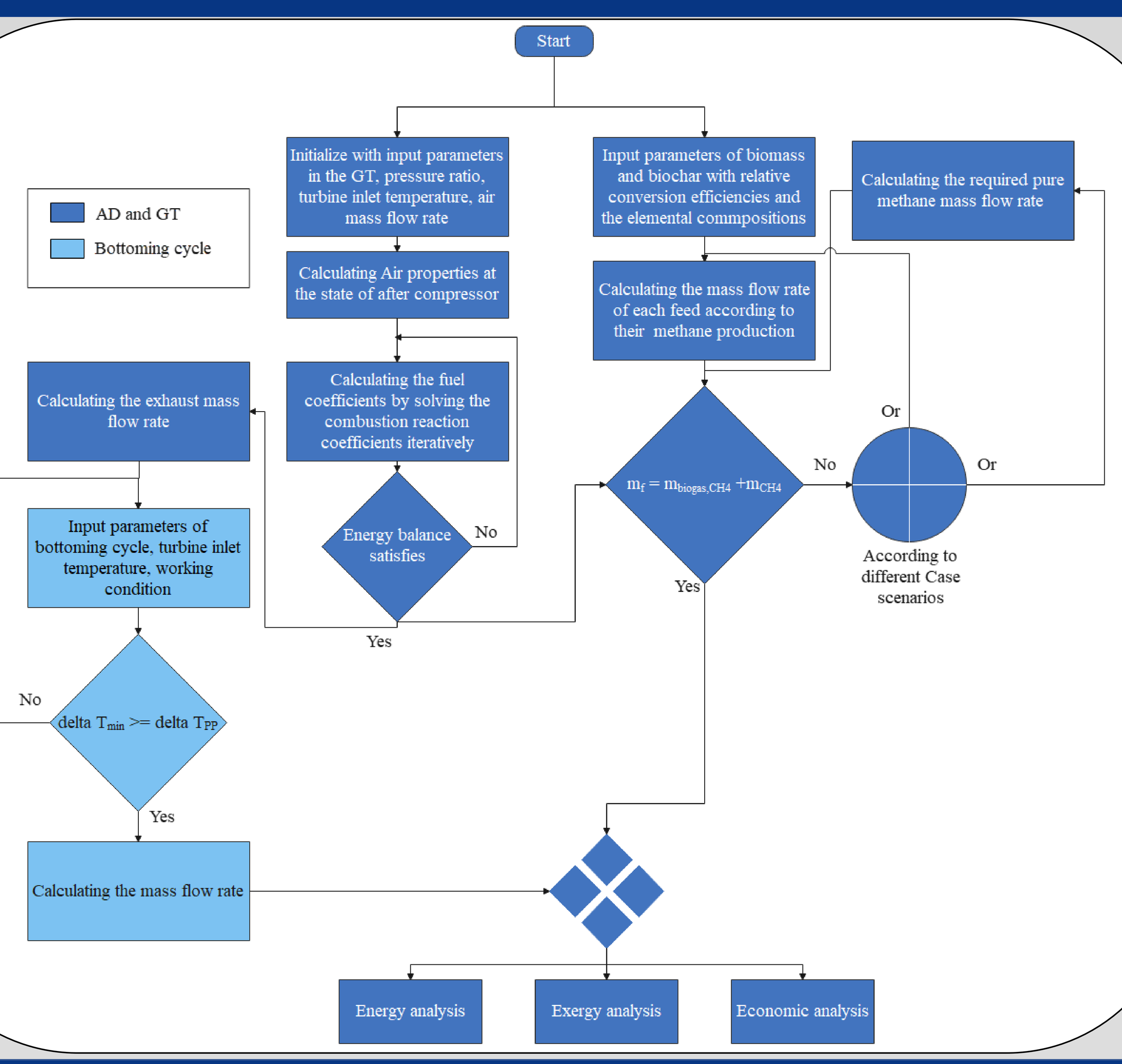
Thermodynamic assessment:

- $\dot{Q} - \dot{W} = \sum \dot{m}_{out}h_{out} - \sum \dot{m}_{in}h_{in}$
- $\dot{E}_Q - \dot{E}_W = \sum \dot{m}_{out}e_{out} - \sum \dot{m}_{in}e_{in} + \dot{E}_D$

Economic assessment:

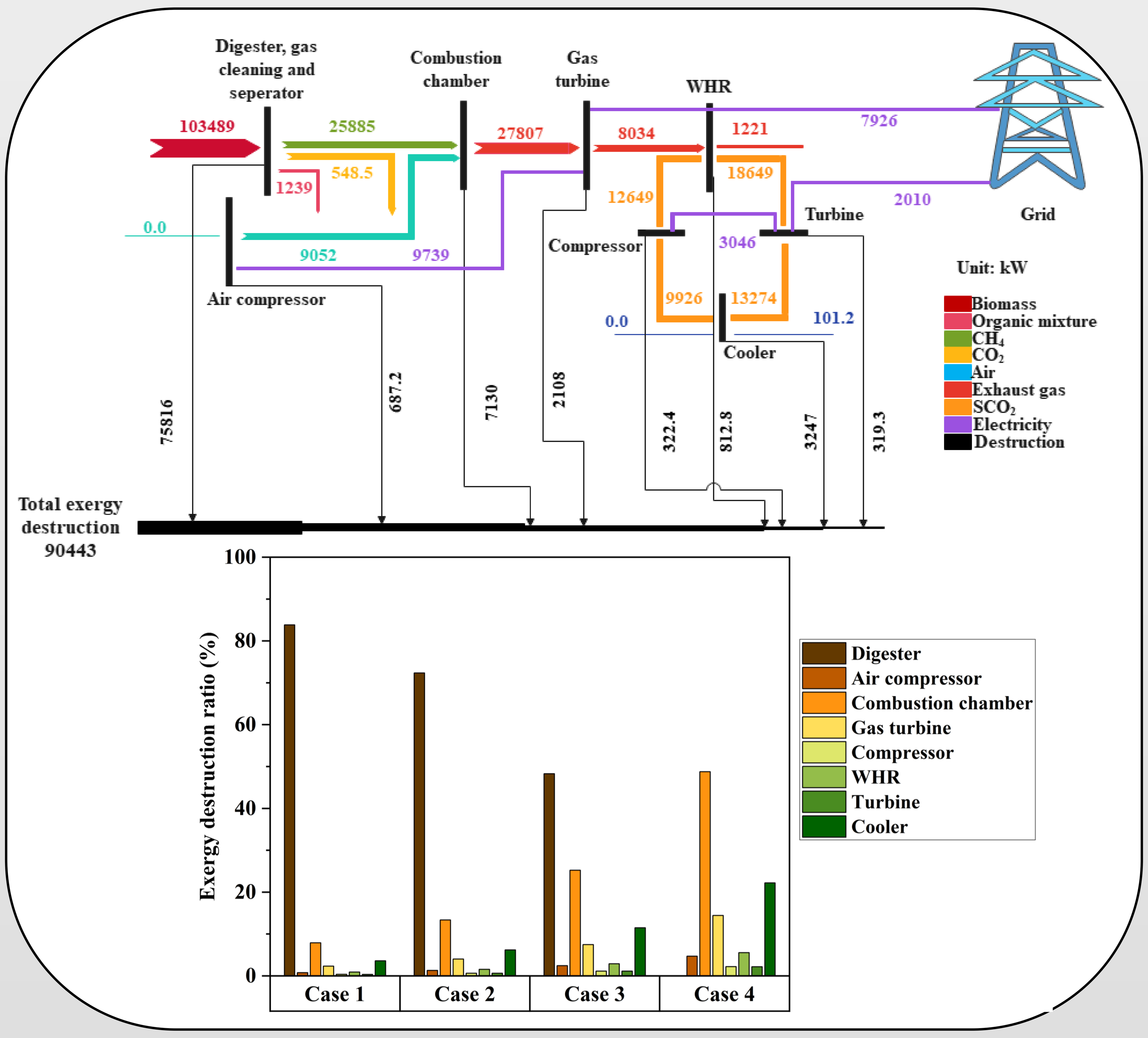
- $Total\ Annual\ Cost = \dot{C}_{inv} + \dot{C}_{O\&M}$

Flowchart of calculation

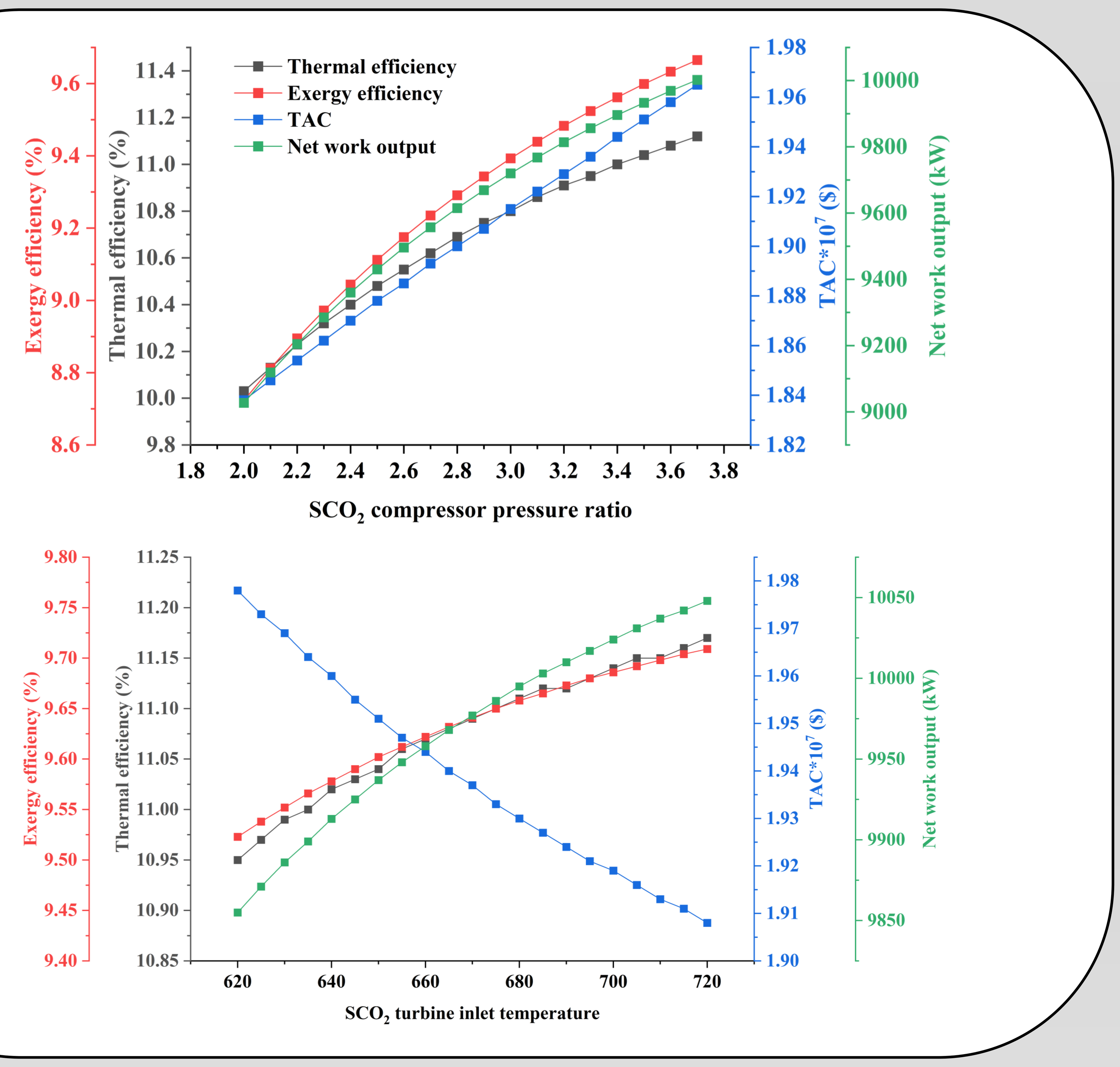


Results and Discussion

- AD has the highest exergy destruction in Case 1 (75,816 kW).
- Combustion chamber has the second-highest exergy destruction (7,130 kW)



- By increasing the temperature, thermal, exergy efficiencies, and net work output increased by 0.22%, 0.185%, and 193 kW, respectively, while total annual cost (TAC) decreased by 700,000 $ (Case 1).
- By increasing the pressure ratio, thermal efficiency increased by 1.09%, exergy efficiency has seen an increase by 0.942%. net work output and TAC, both increased by 975 kW and $0.127 * 10^7$ $, respectively (Case 1).



Conclusion

This study presents utilization of biochar in biogas production for power generation industry. The highest theoretical achievable thermal, exergy efficiencies and net work output are 39.76%, 38.57%, and 9936 kW, respectively. In comparison with similar studies, it shows that the proposed system has superiority in the energy market.

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[2] M. Arslan, C. Yılmaz. Thermodynamic Optimization and Thermoeconomic Evaluation of Afyon Biogas Plant assisted by organic Rankine Cycle for waste heat recovery. Energy. 248 (2022) 123487.