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Design and Analysis of a New Multigeneration System for a Hospital

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I. Introduction

- As many developing countries strive toward industrialization and economic growth, they often use fossil fuels to facilitate their growth and sustain their current society.
- Jamaica primarily consumes fossil fuels.

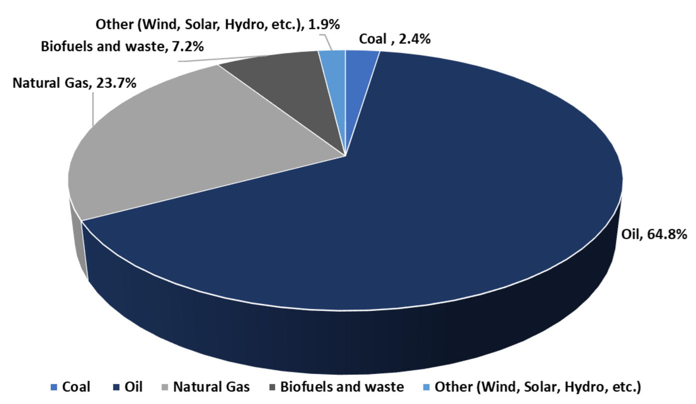

Figure 1. Jamaica energy consumption [1]

- Jamaica has tremendous solar potential, due to its tropical climate.
- Jamaica also has the potential to produce electricity and other useful outputs from sugar cane crops. Several studies suggest sugarcane bagasse in Jamaica can be used for electricity production within a cogeneration system [2].

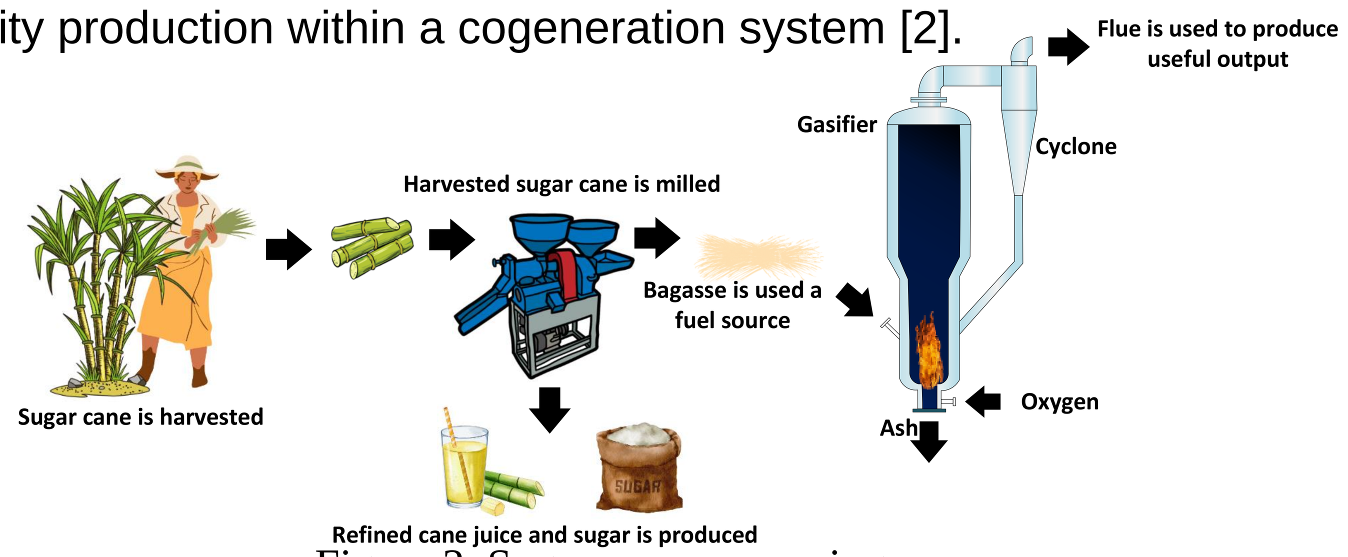

Figure 2. Sugar cane processing

- Parishes such as Trelawny would benefit greatly from electricity production through bagasse, given that most of Jamaica's sugar cane crops are grown here, and power outages occur more frequently within this region.
- Power outages within Trelawny pose a serious safety risk to hospital patients.
- The proposed multigeneration system will be designed to produce hydrogen, and other useful outputs such as oxygen for patients, natural gas, hot water, electrical power, and space cooling.

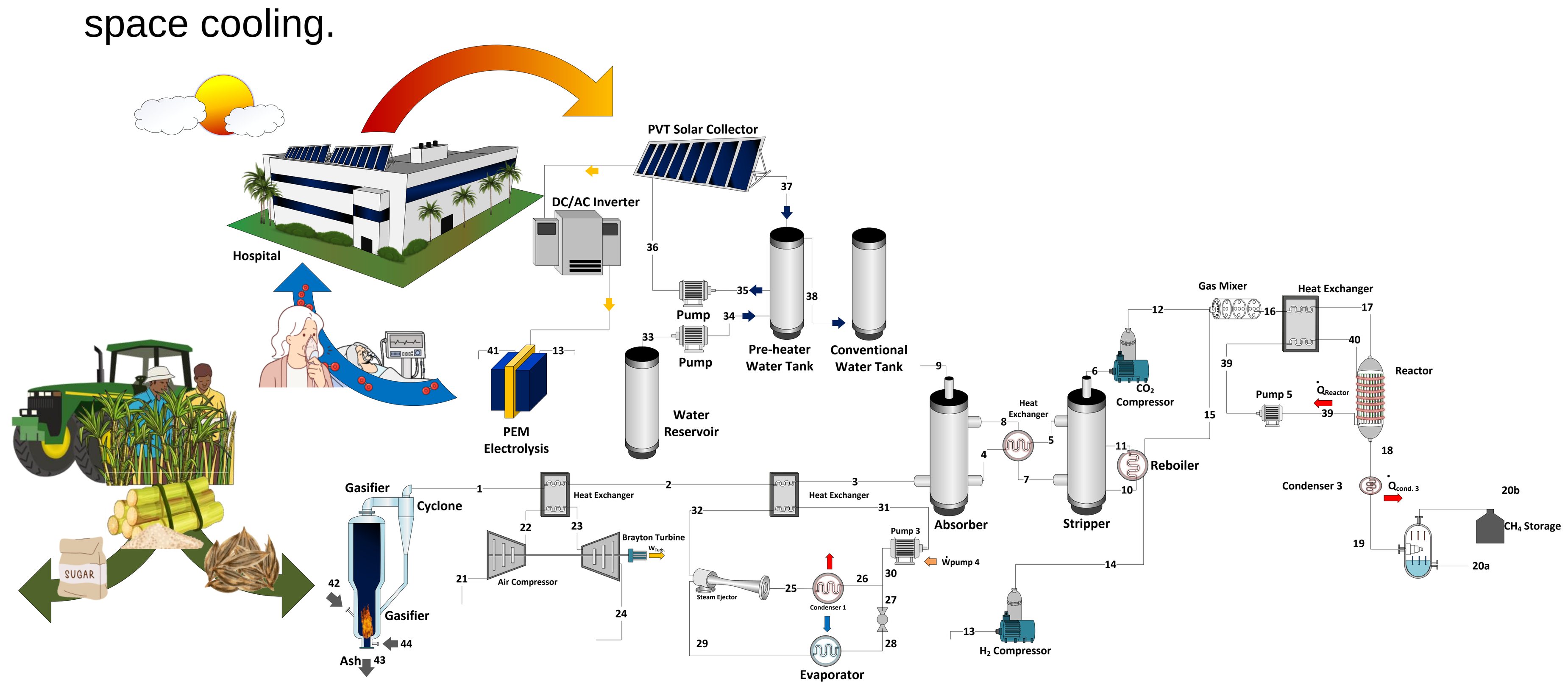

Figure 3. Designed multigeneration system for a hospital

II. Analysis

The electrolysis chemical reactions used to model hydrogen and oxygen production are presented as follows:

Anode: $H_2O \rightarrow 2H^+ + \frac{1}{2}O_2 + 2e^{-1}$ (1)

Cathode: $2H^+ + 2e^{-1} \rightarrow H_2$ (2)

Overall: $2H_2O \rightarrow H_2 + \frac{1}{2}O_2$ (3)

The Sabatier chemical reaction between the captured carbon dioxide and a portion of the generated hydrogen is presented as follows:

$$CO_2 + 4H_2 \rightarrow CH_4 + H_2O \quad \Delta H = -165\frac{kJ}{mol} \quad (4)$$

III. Results and Discussions

The overall performance of the system is largely dictated by the performance of the PVT sub-system. The amount of electrical power generated by the PVT sub-system will dictate the amount of hydrogen, oxygen, and methane produced.

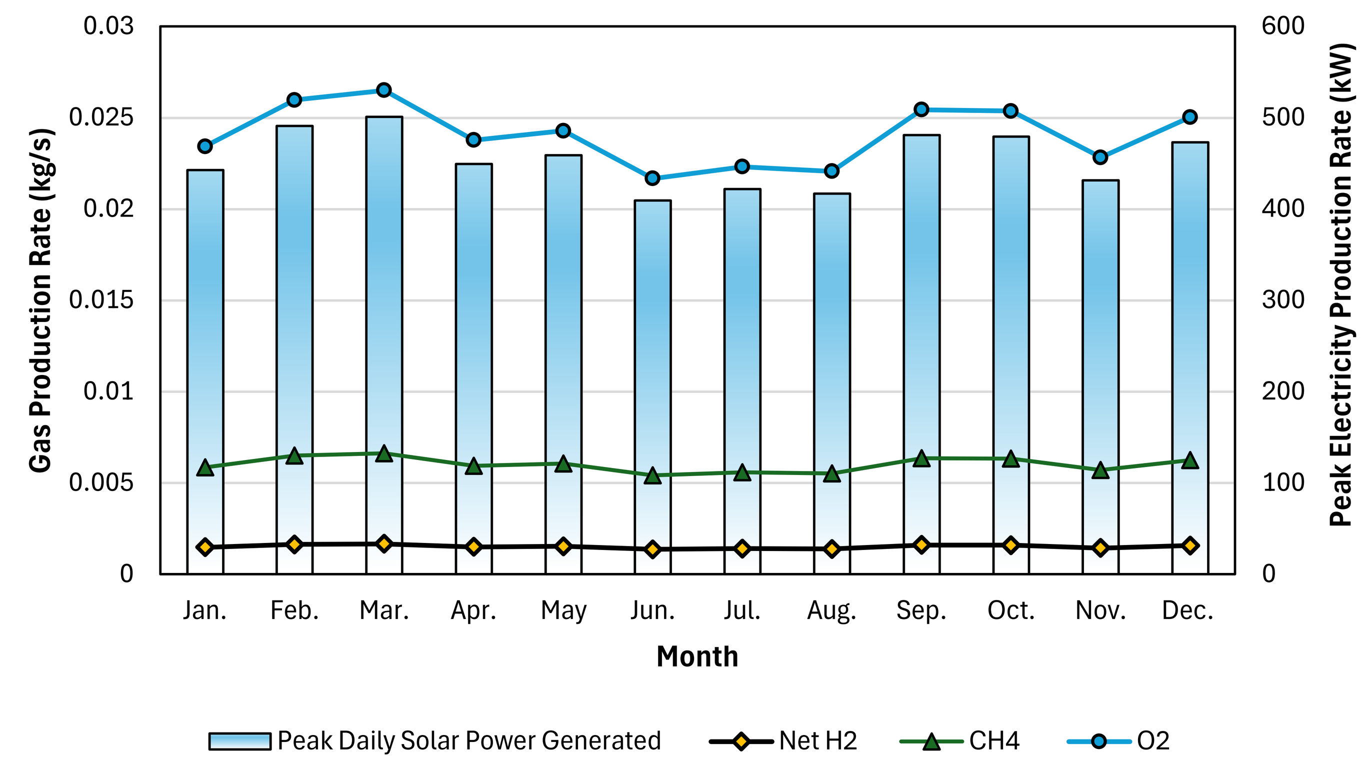

Figure 4. Comparison between H_2, CH_4, and O_2 production rates monthly

All of the useful outputs generated by the system are summarized in Table 1.

Table 1. System Performance Parameter

Useful Output	Value
Average Peak H_2 Production Rate	1.51e-3 kg/s
Average Peak CH_4 Production Rate	6.02e-3 kg/s
Average Peak O_2 Production Rate	2.41e-2 kg/s
Hot Water Production Rate	9.23e-3 kg/s
Net Power Output	367 kW
Cooling Load	73.25 kW

IV. Conclusions

The system produces H_2, O_2, and CH_4 through PEM electrolysis and the Sabatier chemical reaction. The average peak oxygen production rate of 2.41e-2 kg/s has the benefit of helping patients who are connected to ventilators. Additionally, the system can produce a net hydrogen production rate of 1.51e-3 kg/s, and satisfy many other needs for the hospital such as space cooling, hot water, electricity, and natural gas/ methane.

References

[1] International Energy Agency, "Energy system of Jamaica." [Online]. Available: https://www.iea.org/countries/jamaica

[2] R. Contreras-Lisperguer, E. Batuecas, C. Mayo, R. Díaz, F. J. Pérez, and C. Springer, "Sustainability assessment of electricity cogeneration from sugarcane bagasse in Jamaica," J. Clean. Prod., vol. 200, no. 2018, pp. 390–401, 2018, doi: 10.1016/j.jclepro.2018.07.322.