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Assessing the Feasibility of Coproducing Biomethane and Synthetic Natural Gas from Wastewater in the Cape Breton Regional Municipality

Background

Anaerobic Digestion (AD)

- The AD process degrades organic material (e.g. wastewater) using various microorganisms in a controlled, oxygen-free environment.
- Two valuable products are created from AD: nutrient-rich digestate and raw biogas.

Green Hydrogen

- Green hydrogen is hydrogen (H_2) produced from a renewable energy source such as wind-, solar-, or hydro-power.

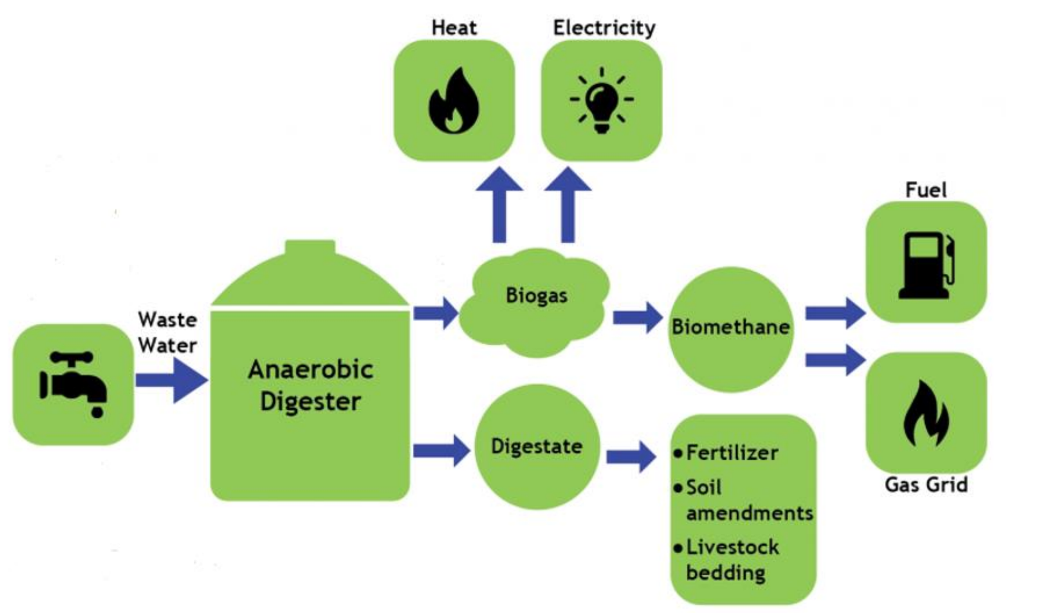


Figure 1: Schematic of the biomethane production process

Design Process

Objective

- Design a modular plant that coproduces two methane-rich products (>95% CH_4) – namely, synthetic natural gas (SNG) and biomethane – using raw biogas and green hydrogen as process feeds.

Key Considerations

- Safety
- Environmental Impacts
- Economic Feasibility
- Downtime Minimization
- Co-production Ratios

Key Technologies

Impurity Removal	Activated Carbon Filters
Gas Upgrading	Hollow-Fiber Membranes
H_2 Production	Water Electrolysis
Methanation	Methanation Reactor
Gas Dehydration	Molecular Sieve

- A detailed design of the impurity removal, gas upgrading, H_2 production, and methanation processes was completed.

Details of Design

Scope

- The plant will be located in the Cape Breton Regional Municipality and process the wastewater of its 100,000 residents to generate 50Nm³/h of biogas.
- Approximately 26.3% of the biogas will be recycled to the digesters to maintain the mesophilic temperature of 36ºC. The remainder will be processed into SNG and biomethane.
- The detailed design of the AD and dehydration units has been excluded from the analysis given the project's time constraints.

Design

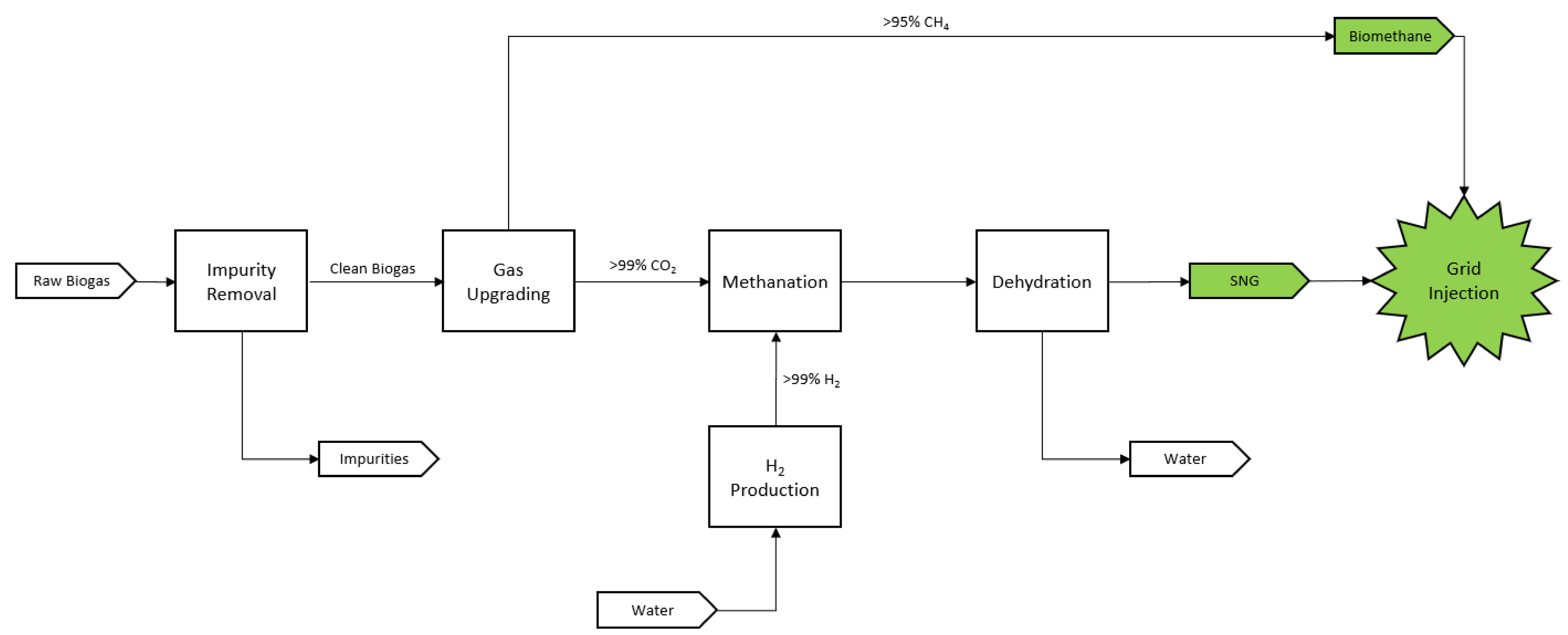


Figure 2: A simplified block flow diagram of the coproduction process.

Step 1: Impurity Removal

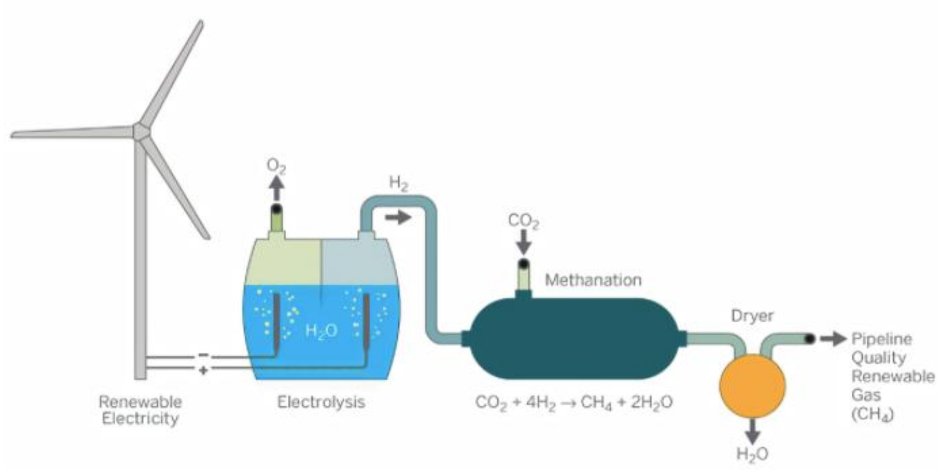
Activated carbon filters are used to purify biogas by removing H_2S as well as other toxic compounds such as NH_3, within acceptable limits for natural grid injection.

Step 2: Gas Upgrading

A hollow-fiber membrane separation system upgrades biogas into two nearly pure streams: carbon dioxide (CO_2) for methanation, and biomethane.

Step 3: H_2 Production

Hydrogen is produced via water electrolysis powered by wind turbines. H_2 is a components in the methanation reactor, which converts raw biogas into methane.



Step 4: Methanation

The CO_2 methanation process utilizes Ni-based catalysts to convert CO_2 into the useful product, CH_4 (SNG).

$$CO_2 + 4H_2 \longrightarrow CH_4 + 2H_2O$$

Conclusions & Recommendations

- Potential hazards
  - Human wastewater leak (microbial/pathogen/methane pollution)
  - Biomethane/SNG leak into atmosphere or soil
  - High pressure operations
  - Flammable/Explosive fluid operations
- Cost
  - High initial capital investment (Reactor, hydrogen electrolysis, wind turbine, materials, assembly, etc.)
  - Operational costs (utilities, such as water and electricity during turbine downtime, pumps, motors, replacements, maintenance and labor).
- Recommendations for future design work iterations
  - It was uncovered that the design resulted in SNG that costs more than the current option for residets of this region. It is recommended that this method of wastewater conversion is explored for a location with higher population to enhance the economic viability.
  - It is recommended that additional feedstocks are explored and co-digested to increase the biogas production capacity to improve the economic viability.
  - It is recommended to explore the economic viability of increasing wind turbine capacity to sell additional power generation to improve economic viability.

References

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