WESTERN MICHIGAN UNIVERSITY
COLLEGE OF ENGINEERING AND APPLIED SCIENCES
DEPARTMENT OF MECHANICAL AND AEROSPACE ENGINEERING
DESIGN OF A PORTABLE BIOGAS PURIFICATION AND STORAGE SYSTEM

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Anilkumar Kosna and Dr. Bade Shrestha

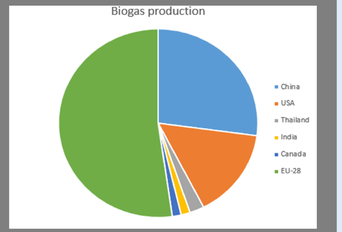
Objective

The objective of this study is to propose and design a commercial portable purification and storage system to commercialize biogas (which mainly consists of 45 - 75 % of methane and 15 - 16% of carbon dioxide), produced from household/non-commercial biogas plants. The selection of purification process is based on the portability of the purification system.

Motivation

- Global bioenergy statistics 2017 reported that the global biogas production was 58.7 billion Nm^3.

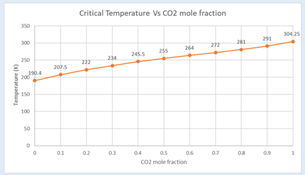
⇒ Industrial/commercial plants (>300 m^3)
⇒ Farm scale/Community plants (100 – 250 m^3)
⇒ Household/Domestic plants (2 – 10 m^3)

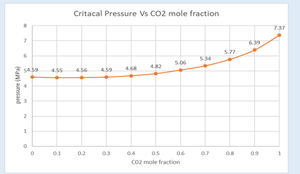


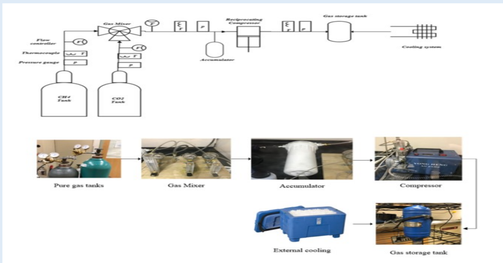
- The biogas is commercialized by converting it into biomethane. Biomethane is the purified form of biogas which is produced by removing carbon dioxide from biogas using various purification methods.
- The purification process is available for large-scale plants , there are no such process available for small-scale plants.
- Currently , there are more than 55 million small - scale biogas plants operating worldwide .
- The successful development of a portable purification technology provides a venue to commercialize the small-scale biogas production, create self employment, and make people more energy independent.

Process design

- The commercial cryogenic method (which uses desublimation of CO_2) meets some of the requirements of a portable purification system. The only draw back of the system is the high energy consumption to maintain the sublimation temperature of CO_2 (-78.5 ^oC).
- The proposed system uses condensation of CO_2 instead of desublimation. This condensation process takes place under critical conditions.
- The critical points of biogas of various mixture compositions were identified from the equation of state of biogas.
- An experiment was designed to validate the equation of state of biogas. The experiment was performed for Pure CO_2, 80% CO_2 - 20% CH_4, and 50% CO_2 - 50% CH_4.



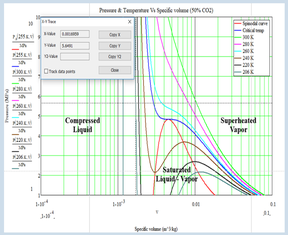


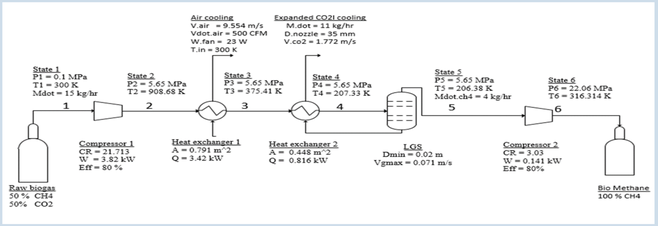


Mixture	$m_{mixture}$ (kg)	m_{CO2} (kg)	m_{ch4} (kg)	$v_{mixture}$ $(\frac{m^3}{kg})$	P (MPa)	T (K)
Pure CO_2	----------	0.532	----------	2.846×10^{-3}	12.49	318.41
80% CO_2	0.280	0.257	0.023	5.403×10^{-3}	12.50	302.43
50% CO_2	0.173	0.127	0.046	8.761×10^{-3}	12.51	299.17

Mixture	$T_{saturated}$	$P_{saturated}$ (theoretical)	$P_{saturated}$ (Experimental)	Error %
Pure CO_2	301	6.91	7.16	3.49
80% CO_2	261	3.96	4.94	19.83
50% CO_2	224	2.83	3.87	26.87

- For the preliminary design the composition of biogas is assumed as 50% CH_4 - 50% CO_2. A condensation point is chosen at 206 K (-67 °C), 5.65 MPa (819.46 psi) in liquid region.
- The operating principle for the proposed system is to compress and cool the biogas until the carbon dioxide changes its phase from gas to liquid.
- This total weight of the system is estimated including the piping and control system as 11.853 kg.
- This system only requires 7% of pure methane's energy to purify the biogas.





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