ATBEST

Applications of Biogas in Chemical Energy Storage and Liquid Fuel Production (ESR 5.4)

Rawan Hakawati

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First Research Exposure (MIT)

Massachusetts Institute of Technology

- Worked with people from different backgrounds and nationalities
- Attended Lectures on "How to conduct a scientific research"
- Attended workshops on "Presentation skills"
- Research Topic: "Adhesion of Keratinocytes to Peptide Coated Surfaces"

UNDP Internship

Application of Fuel cells in
Energy (Clean Energy)

UFRRJ Internship

MCM Catalyst (Mobil Catalytic Material) &
SAPO Catalyst (Silica-alumina phosphate)

- Sample Preparation
- Sample Analysis

I. Introduction

Population	Energy Consumption
8.9 billion by the year 2050 (36% inc)	77% inc
Exhaustion of available resources	

<u>Solution</u>

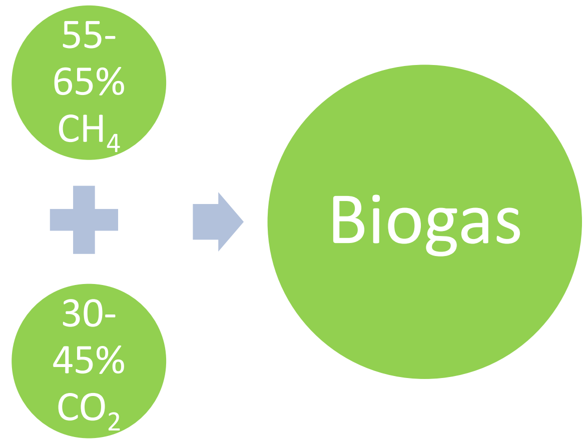
European union → shifting to renewable-energy based systems to produce electricity

This transformation is highly affected by the fluctuating sources such as wind or solar

→ power generation will be limited by their partly predictable availability

RE generators → surplus of electricity → integrated with other energy systems that can offer high predictability and availability

II. Biogas
(Source and Utilization)



- Generated from the anaerobic digestion or fermentation of biomass including sewage sludge, municipal solid waste, and agricultural wastes …etc

- Its utilization → considerable reduction of solid-waste volume in EU land-fills

- Biogas was not widely used for energy → high percentage content of carbon dioxide→ decreases the heating value of the gas mixture

- Increased amount of CO, NO_X and unburned hydrocarbons produced when combusted in a turbine or boiler

- Flared or burned and released to the atmosphere as carbon dioxide and water without taking advantage of the latent chemical energy

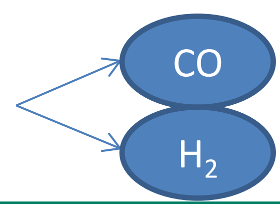
- Produced biogas can be cleaned from impurities → resulting in a pure methane stream → injected into the "natural gas distribution network"

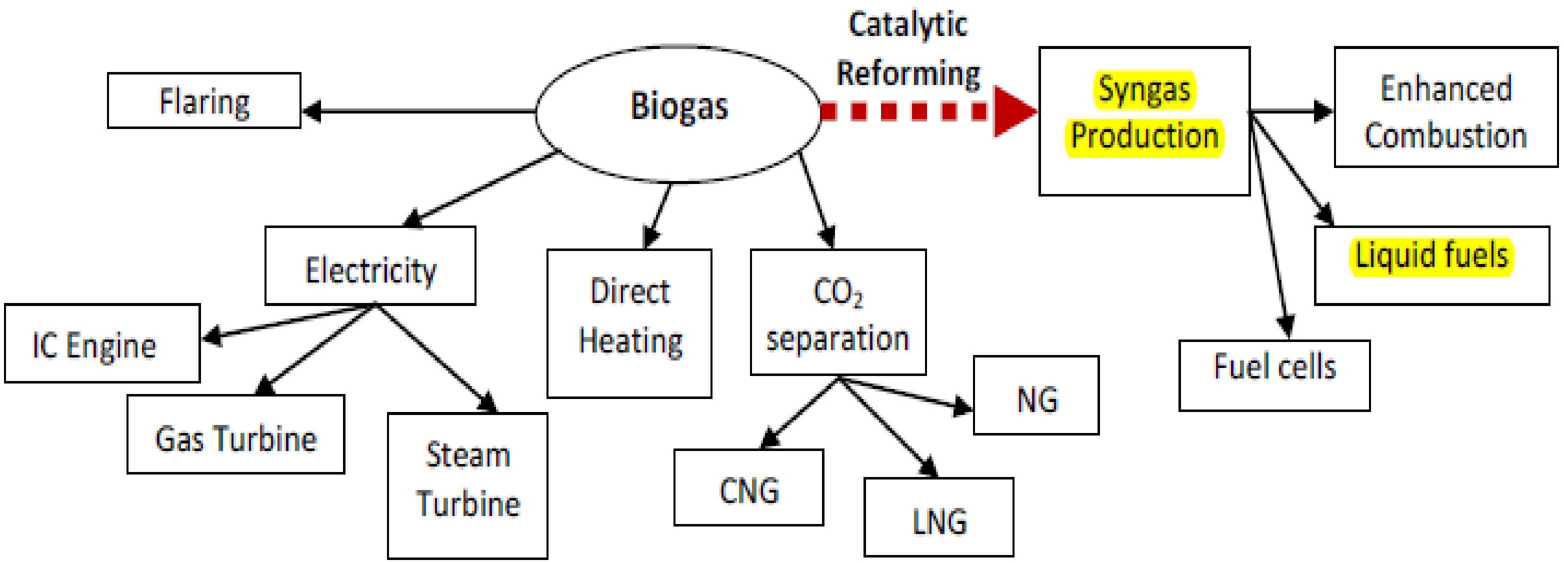
→ can be used as a compressed natural gas (CNG)

→ liquefied natural gas (LNG) that is suitable as a form of transportation fuel

- Feedstock to different reforming technologies that were previously applied extensively for natural gas reforming

- Transformation of biogas to synthetic gas




Catalytic Reforming
Flaring
Biogas
Syngas Production
Enhanced Combustion
Liquid fuels
Fuel cells
Electricity
Direct Heating
CO2 separation
IC Engine
Gas Turbine
Steam Turbine
NG
CNG
LNG

III. Reforming Techniques

Steam Reforming

- oldest and preferred method for hydrogen production

  → low cost

  → low environmental impact

- Biogas with steam (H_2O) according to the following equation:

  $CH_4 + H_2O \rightarrow 3H_2 + CO \quad H_2{:}CO = 3$

- Another essential reaction takes place in such system and it is known as the water-gas shift reaction WGS

  $CO + H_2O \rightarrow CO_2 + H_2$

- Disadvantage, Intensive amounts of energy needed → due to its overall endothermic nature

Partial Oxidation Reforming

- $CH_4 + 0.5O_2 \rightarrow CO + 2H_2$ (moderately exothermic)
- Partial oxidation is an alternative method for hydrogen production with reduced energy costs
- Methane is oxidized partially to hydrogen and carbon monoxide
- Disadvantage, sometimes a slight decrease in the selectivity of carbon monoxide

$\rightarrow$ complete combustion of methane

$\rightarrow$ carbon dioxide

$\rightarrow$ results in high T rise

$\rightarrow$ coke formation on the surface of the catalyst

Auto-Thermal Reforming

The auto-thermal reforming (ATR) is a combination of the endothermic reforming described before (SRM) with the exothermic oxidation (PROX).

The heat needed by

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

can be supplied from

$CH_4 + 0.5O_2 \rightarrow CO + 2H_2$

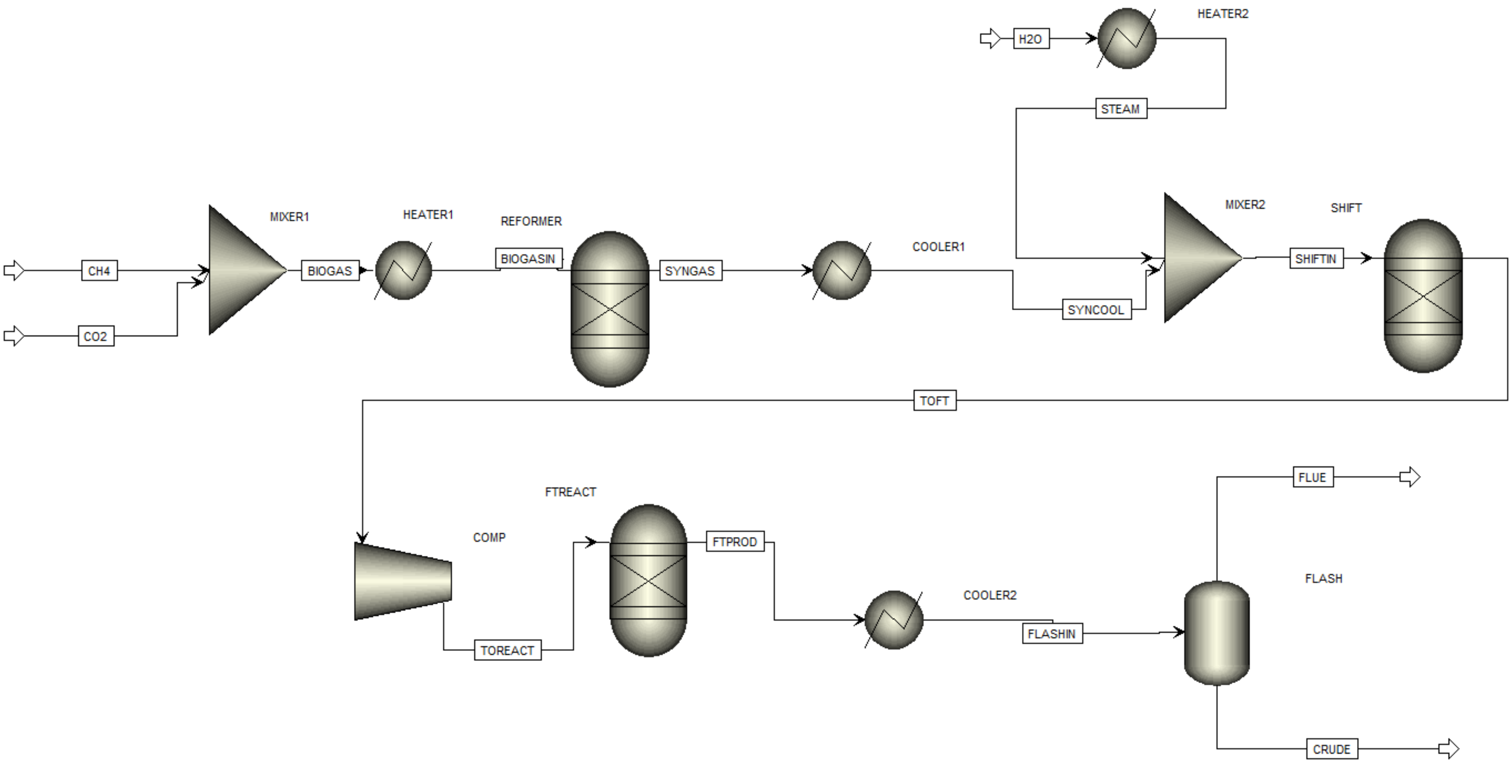
Dry- Reforming

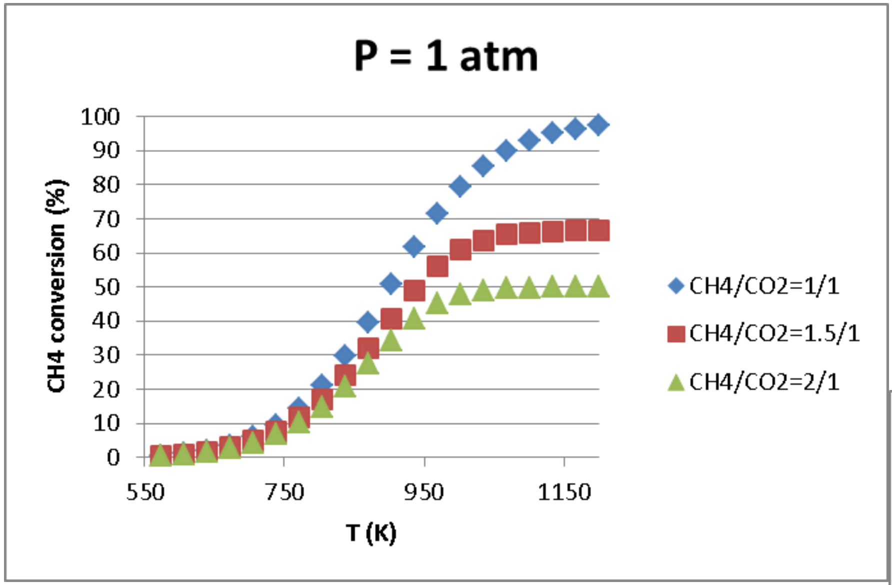
- $CO_2 + CH_4 \rightarrow 2H_2 + 2CO$
- H_2:CO =1 and reach up to 2
- The reverse water gas shift reaction RWGS: $CO_2 + H_2 \rightarrow H_2O + CO$ takes place in parallel with the endothermic dry reforming reaction
- Disadvantage of coke formation on the surface of the catalyst due to the series of side reactions that result in carbon formation and cause blockage on catalyst surfaces resulting in their poisoning and deactivation
- These reactions are Boudoird: $2CO \rightarrow CO_2 + C$

  CH_4 decomposition: $CH_4 \rightarrow 2H_2 + C$

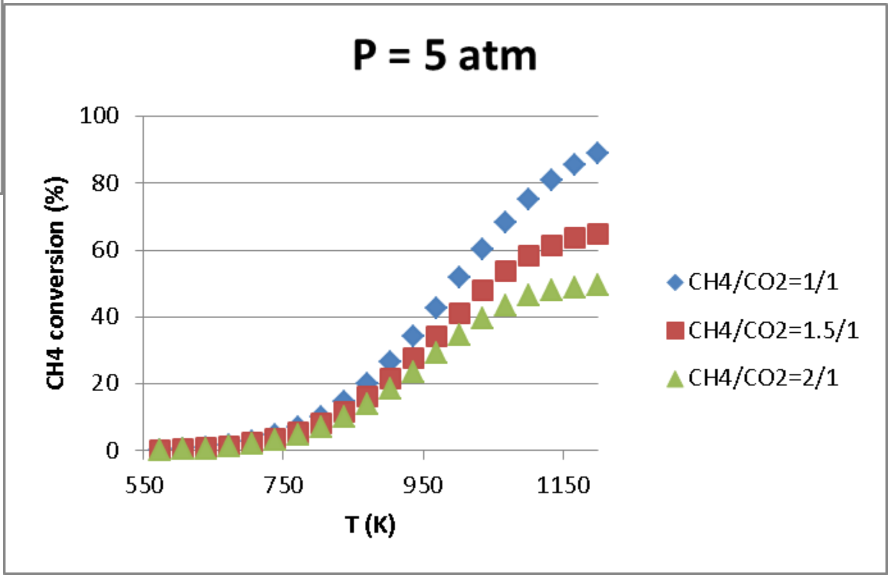
  CO reduction :$CO + H_2 \rightarrow H_2O + C$

IV. Preliminary Aspen Simulation





Max conversion: 100% (1:1)
70% (1.5:1)
At T= 1000K



Max conversion: 90% (1:1)
60% (1.5:1)
At T= 1000K

V. Methanol/DME Production

The formation of methanol from synthesis gas takes place according to the following two main equations:

Methanol synthesis (substitutes gasoline)

$$CO + 2\ H_2 \leftrightarrow CH_3OH \quad [1]$$

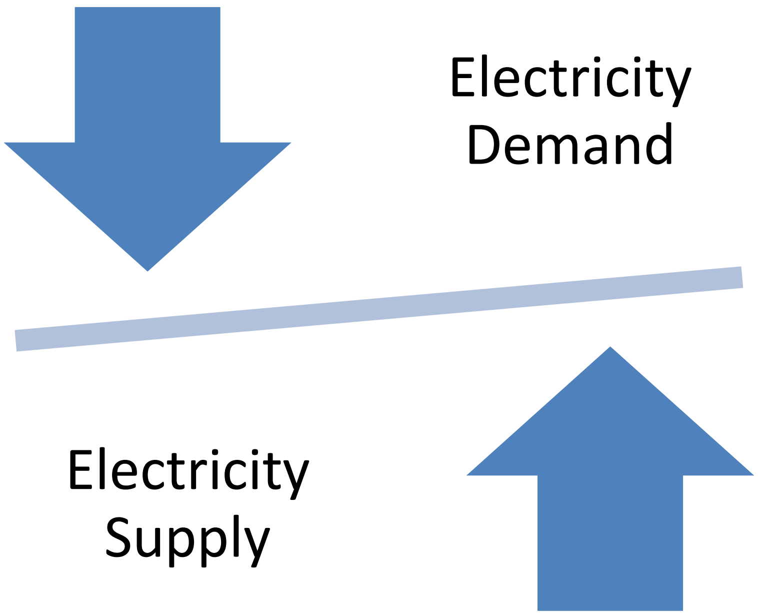
Water-Gas Shift reaction

$$CO + H_2O \leftrightarrow CO_2 + H_2 \quad [2]$$

Methanol dehydration reaction is presented by the following relation,
DME (substitutes diesel)

$$2CH_3OH \longleftrightarrow CH_3OCH_3 + H_2O$$

VI. Chemical Energy Storage



<u>Solution</u>

- Store biogas
- Store the excess of wind energy

<u>How</u>

- **Electrolyzers:** transform water and excess electricity to hydrogen

- **Liquid Fuel Production:** Methanol, DimethylEther (DME) and other fuels via FT

- **Compressed Air Energy Storage (CAES):** store excess energy (from wind) and transform to electricity when needed köszönöm תודה! děkuji

mahalo 고맙습니다

thank you

merci 谢谢 danke

Ευχαριστώ شكرا

どうもありがとう gracias

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