창원대학교
CHANGWON NATIONAL UNIVERSITY

34th JSMCWM annual meeting &
3RINCs Autumn

Hydrogen production from Organic waste using reforming reaction

Contents

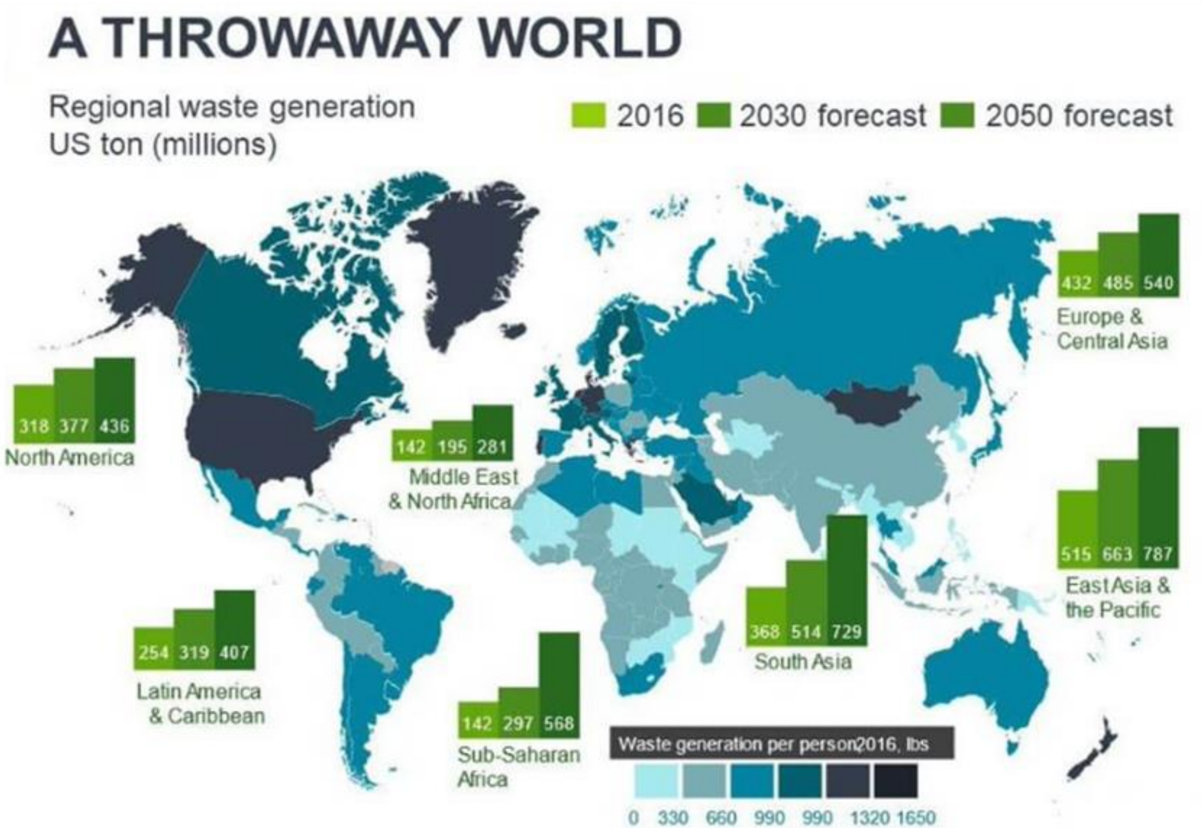
Waste to Hydrogen Laboratory
based on Smart Process Analysis

I

Introduction

창원대학교 CHANGWON NATIONAL UNIVERSITY WtH2 4.0 Lab.

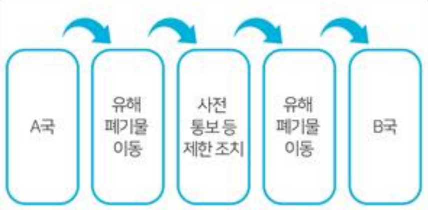
Waste to energy



Increase of waste

Ocean disposal X

Lack of landfill



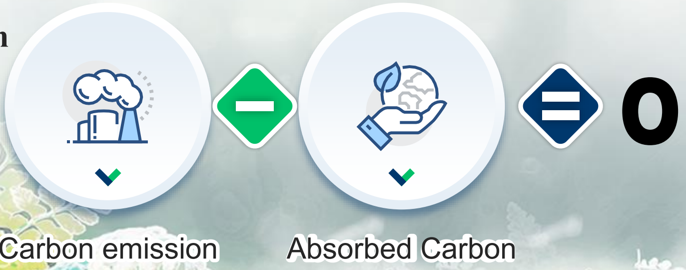
Limitation of waste trade

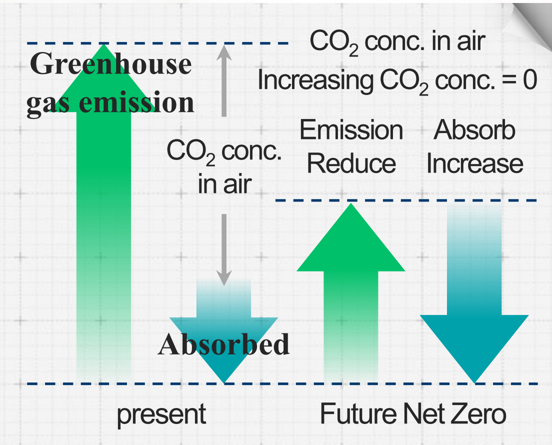
폐기물의 기존 처리 방법(해양투기, 매립, 소각 등)을 대체할 수 있는 전략 마련의 필요성이 증대됨

Carbon neutrality, Net Zero

- Net zero means that CO_2 emissions due to the human activity are in balance with global absorption, so that the concentration of CO_2 in the atmosphere does not increase further
- It is necessary to reduce anthropogenic emissions of CO_2 and increase the amount of absorption (removal) using forest restoration and negative emission technology*

Amount of Carbon emission = Absorb or removal amount of Carbon
Substantial Carbon emission will be 'Zero'





To become within 1.5 ℃ of increasing average temperature

Necessity of Net Zero 2050

Greenhouse gas emission in Korea (2018)

11th

(*Among the OECD 5th)

After Paris agreement (2015), Net Zero declaration

By 134 countries

(Sep. 2021)

Korea set 2030 greenhouse gas reduction compared to 2018

26.3% to 40%

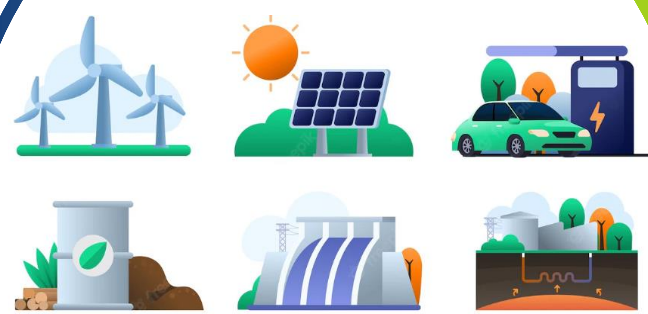
Hydrogen energy

Alternative energy

The way to replace fossil fuels

High energy efficiency

2~3 times higher than thermal engine



Hydrogen energy

Eco-friendly and clean

Less greenhouse gas emission and pollutants

Sustainable energy

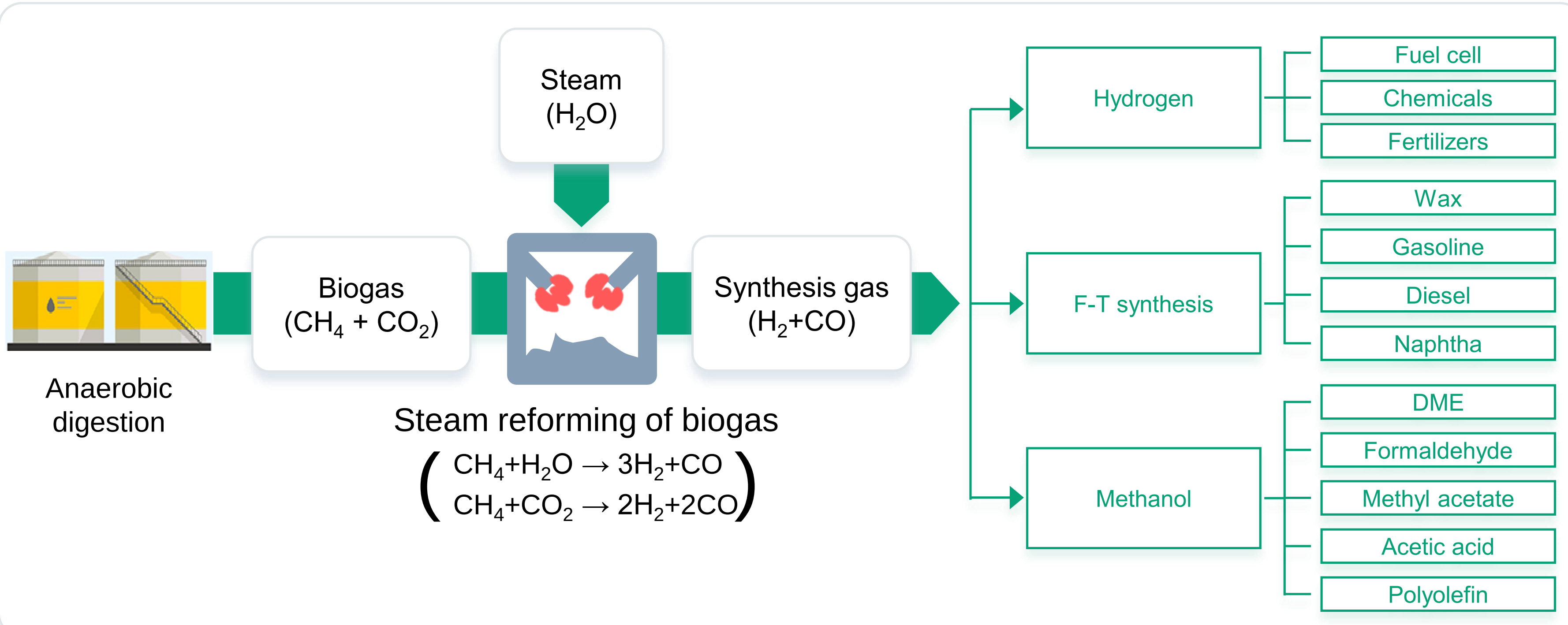
Unlimited amount energy source comparing to fossil fuels

Organic waste to hydrogen

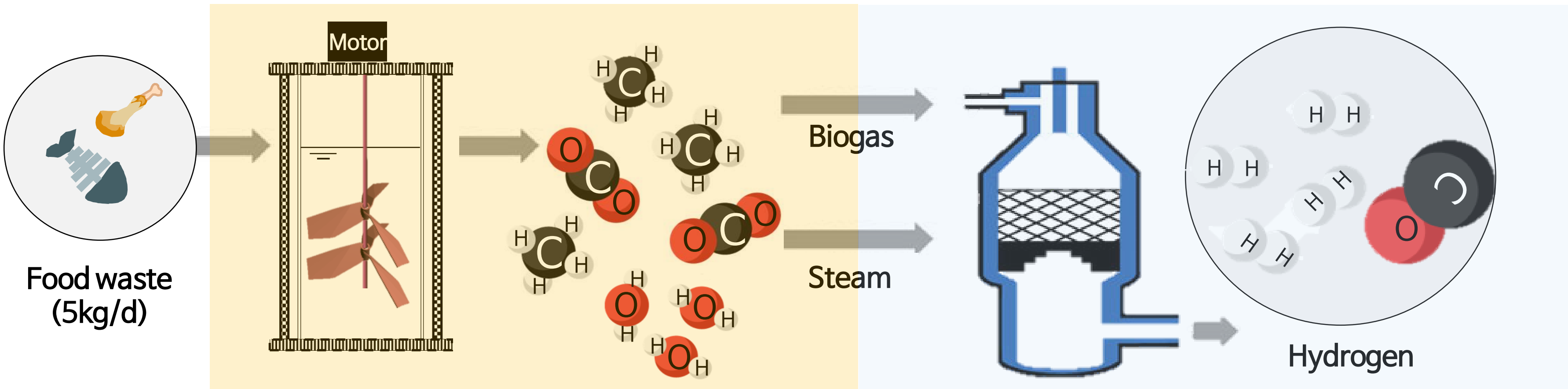
Steam reforming of biogas

Hydrogen production from biogas generated from organic waste
(Converting CH_4 and CO_2 into H_2 and CO through reforming of biogas with steam)

Steam reforming of biogas | Instead of combustion of biogas to produce heat



Research goal



Biogas & H_2 production

01 Optimization of anaerobic digestion

Optimization of digester

02 Optimization of reforming

Optimization of reaction condition & Development reforming catalyst

The development of system for organic waste to hydrogen is required

Ⅱ

Research 1. Anaerobic digestion

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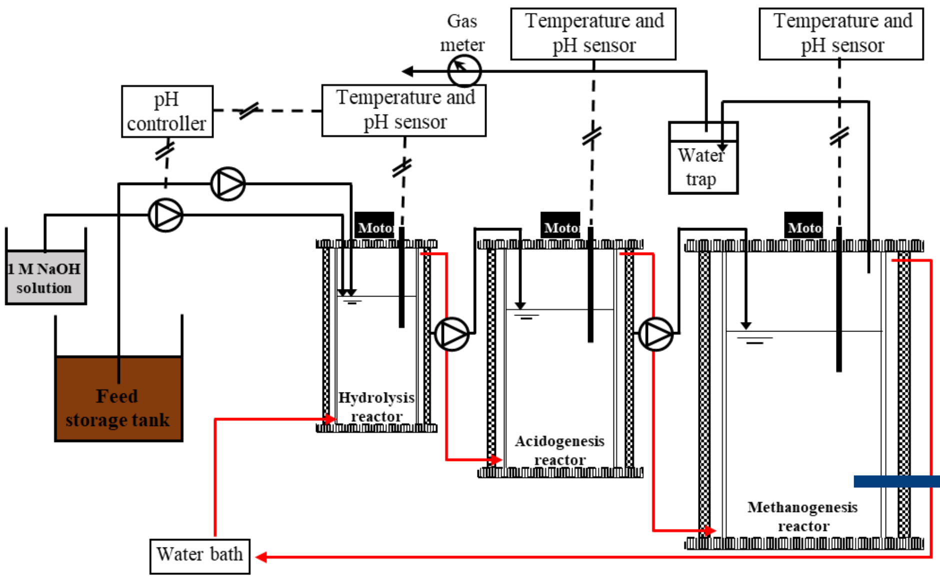
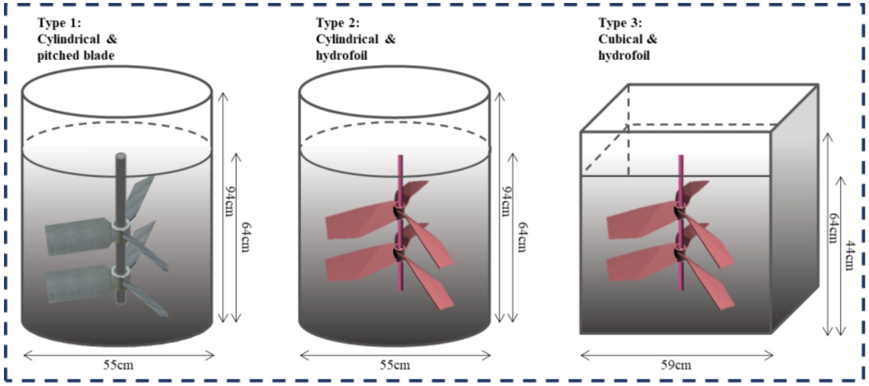
❖ Anaerobic digestor

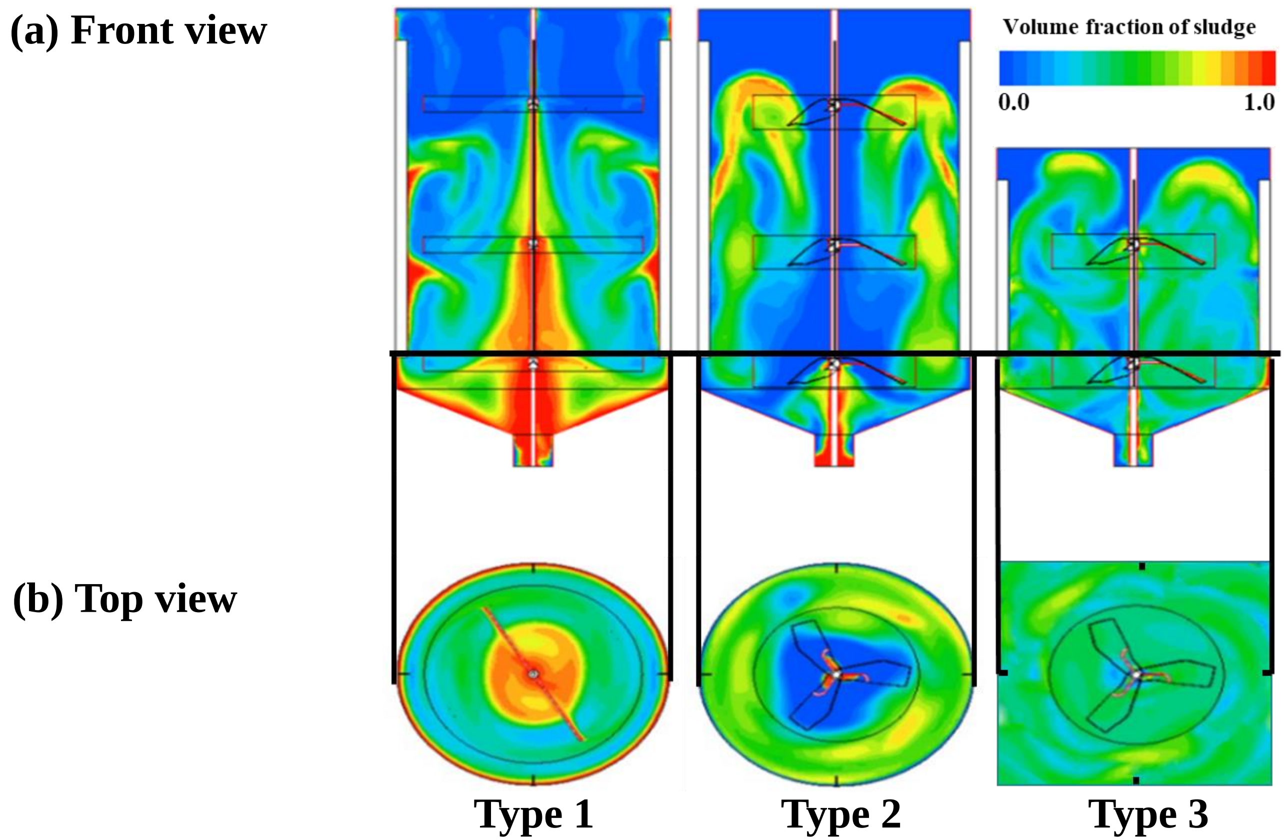


Type of reactor and agitator



Simulation results (computational fluid dynamics)

Volume fractions of sludge with different type of reactor obtained by CFD



- Highly dispersed volume fractions of sludge is resulting from better mixing efficiency
- Type 3 reactor showed the highest distribution of volume fraction due to the axial flow caused by Hydrofoil agitator and enhanced turbulence flow in edges of cubical reactor.

Monitoring results

Pollutant removal efficiencies and biogas production

Indicator		Type 1 Cylindrical shape Pitched blade	Type 2 Cylindrical shape Hydrofoil	Type 3 Cubical shape Hydrofoil
Removal efficiency	TCOD (%)	65.8	66.3	76.5
	TS (%)	62.1	62.6	72.2
	VS (%)	62.2	62.8	72.4
Biogas production	Biogas yield (L/kg FW*)	72.3	72.9	84.1
	Methane yield (L/kg FW)	42.1	44.3	51.3
	Methane content (%)	58.2	60.8	61.3

- A comparison of types 1 and 2 showed that hydrofoil agitator exhibited a higher removal efficiency and biogas production due to the axial flow caused by the hydrofoil agitator
- A comparison of types 2 and 3 revealed that the cubical reactor enhanced the COD, TS, and VS removal efficiencies and biogas production, which resulted from the turbulence flow

III

Research 2. Reforming of biogas

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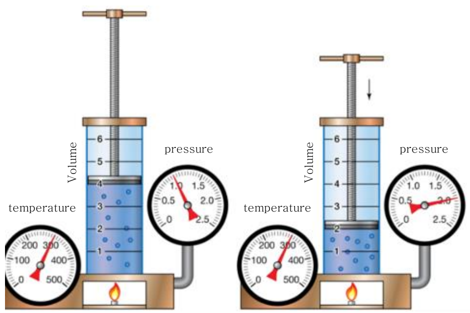
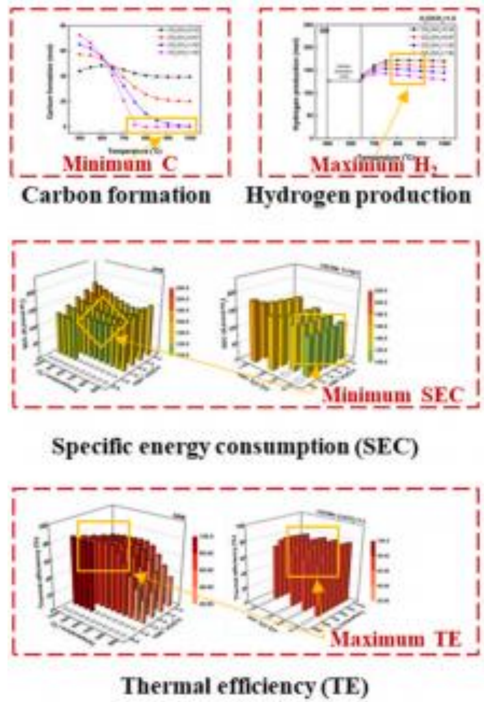
Optimization of reforming of methane

Parameters

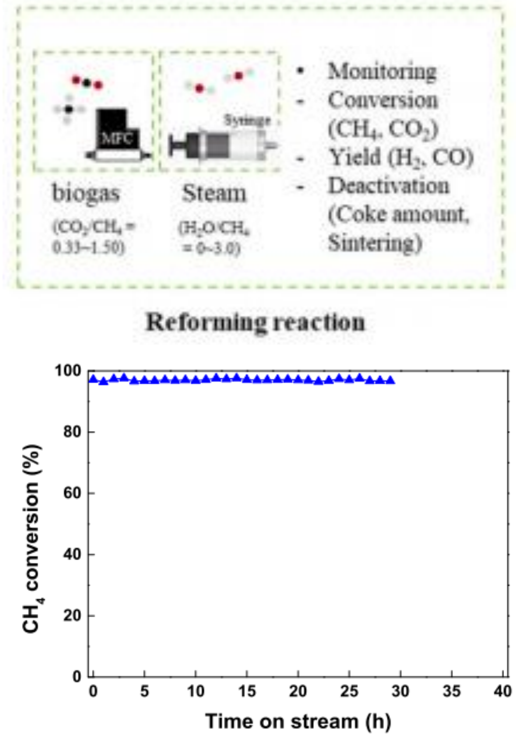
- Reaction temperature
- Oxidant/CH_4 ratio
- Oxidant type



Simulation



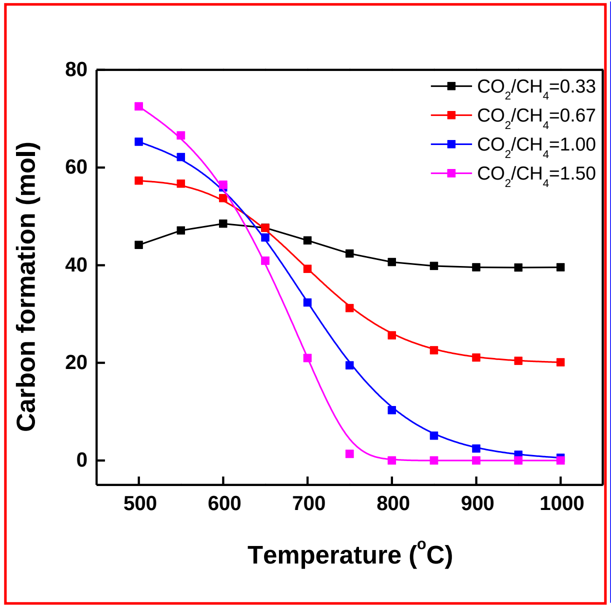
Validation



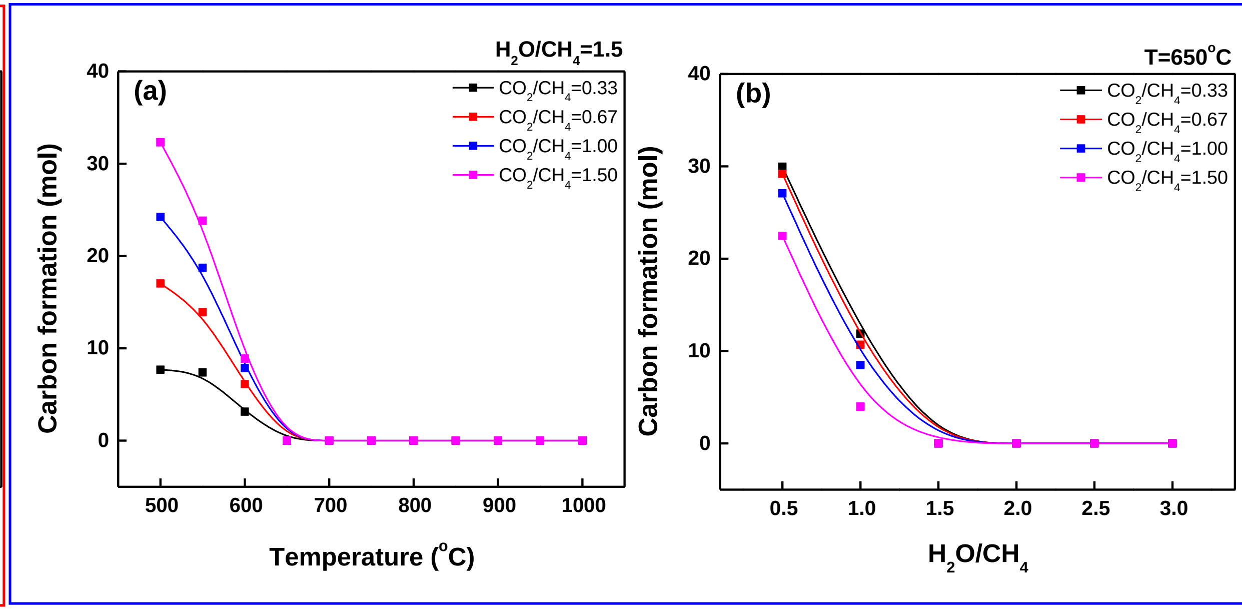
Simulation results (optimization of oxidant)

The relationship between oxidant and carbon formation

Biogas reforming



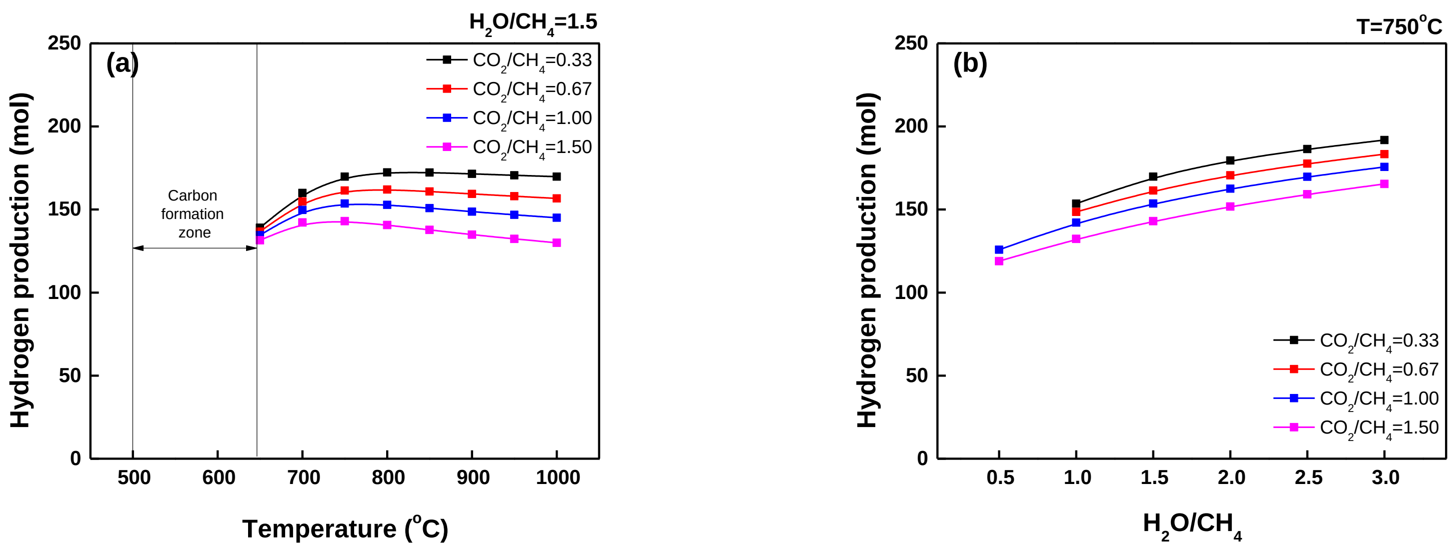
Biogas steam reforming



- In biogas reforming, carbon formation can be suppressed by maintaining a reaction temperature of > 800 °C and a CO_2/CH_4 ratio of > 1.50.
- In biogas steam reforming, H_2O/CH_4 ratio > 1.5 and temperature > 650 °C were required to prevent the carbon formation.

Simulation results (Reaction conditions and H_2 production)

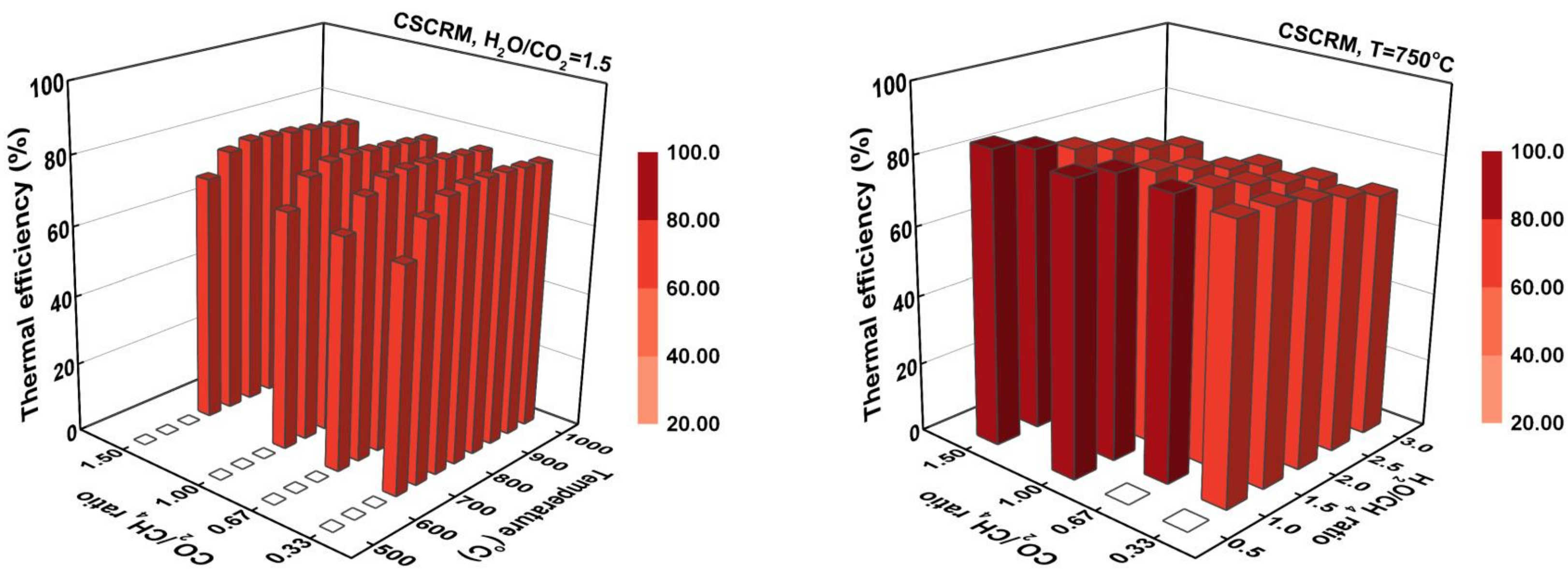
The relationship between reaction conditions and hydrogen production



- H_2 production increased up to 750 °C and decreased thereafter, regardless of the biogas composition
- Hydrogen production increase with increasing steam/CH_4 ratio and increasing CH_4 content in biogas

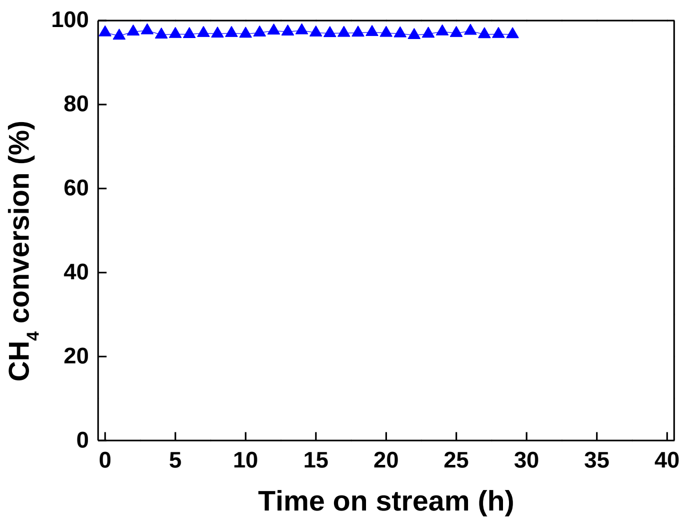
Simulation results (Reaction conditions and H_2 production)

The relationship between reaction conditions and thermal efficiencies



- At > 800 °C, thermal efficiency decreased with increasing temperature; thus, 750 °C was the optimal temperature for the steam reforming of biogas.
- Although a high thermal efficiency was achieved at a low H_2O/CH_4 ratio. However, low H_2O/CH_4 ratio causes carbon formation, the optimum ratio was fixed at 1.5.

The catalyst activity test and deactivation study



Catalyst	Coke (g/g_{cat})	Ni crystallite size (nm)	
		Reduced	Used
$Ni\text{-}MgO\text{-}CeZrO_2$	0	11.33	15.19 (34%)

- **CH_4 conversion over the Ni–MgO–$CeZrO_2$ catalyst was maintained for 30 h without a significant decrease, indicating that the optimized reaction conditions were energy effective and favored stable H_2 production in the real biogas steam reforming reaction.**
- **No carbon was deposited on the catalyst during biogas reforming under optimized conditions.**
- **Ni crystallite size slightly increased but it was not affect to deactivation of catalyst.**

IV

Future research plans

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Demonstration project for hydrogen production

Scale up

Process scale up

- Catalyst production scale
- Plant scale

Data acquisition

Biogas data

- Composition
- Impurities

Scenario study

Techno environ. Analysis

- Economic efficiency
  Environmental impact


감사합니다.
창원대학교 특화분야 연계 및 지원 확산을 위한
“폐자원에너지화 특성화대학원” 사업 출범식
(창원대학교 가족회사 기업네트워킹 데이 개최)
주최/주관 : 폐자원에너지화 특성화대학원사업단, 경남대학교, 창원대학교 LINC+사업단
일시 : 2019. 7. 5.(금) 16:00~
장소 : 인터내셔널 호텔 3층 다이아몬드홀
LINC+