Research Overview of Clean Energy

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Korea-EU Horizon Europe Researchers Networking Forum on Energy

IAE 고등기술연구원
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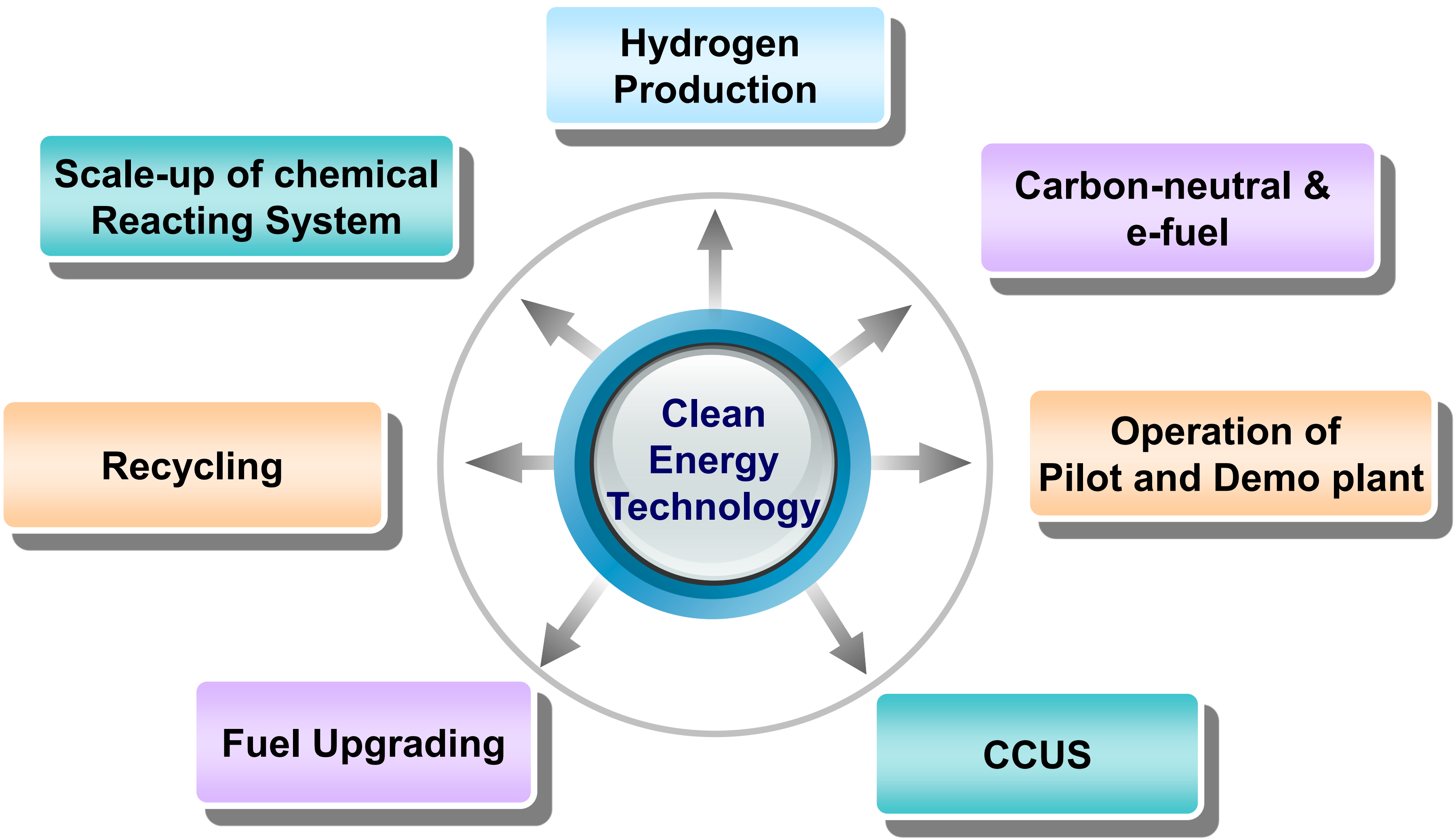
Research Accomplishments



- FB : Fluidized Bed

Decoupling Gasification

Reaction Sequence in Gasifier

Coal, Biomass, Waste, Heavy residue oil Petcoke

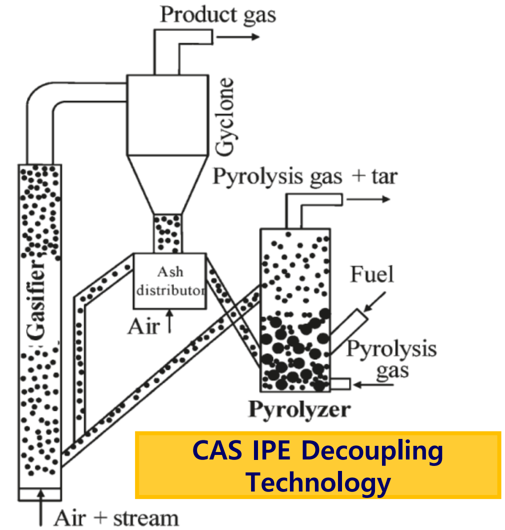
(Solid Carbonaceous Material)

Devolatilization

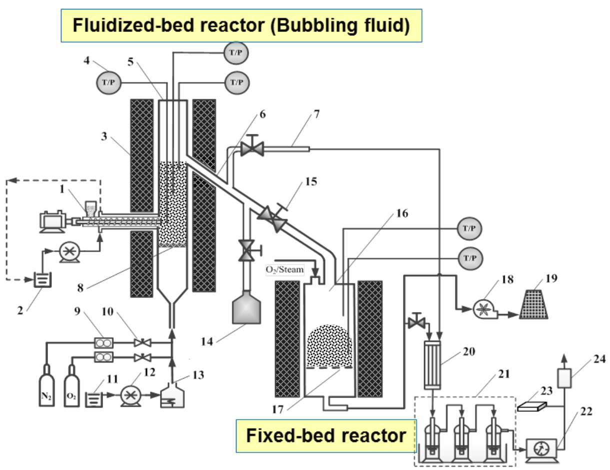
- Pyrolysis gases (CO, H_2, CH_4, H_2O…) / Tar, Oil, Naphtha / Oxygenated compounds (Phenols, acid) → Gas phase reaction (Cracking, Reforming Combustion, CO shift) → CO, H_2, CH_4, H_2O, CO_2 Cracking products
- Char → Char ·Gas reaction (Gasification Combustion, CO shift) → CO, H_2, CH_4, H_2O, CO_2

- general gasification reaction

① Coupling Reaction
② Defect in controlling reaction sequence



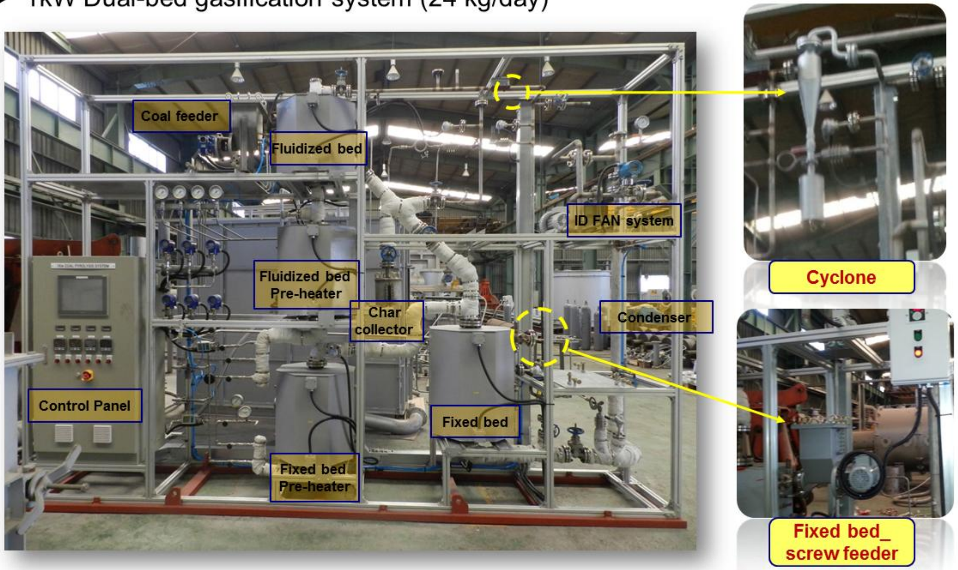
Developing hybrid FB process with CAS IPE



Schematic diagram of dual-bed coal gasification system

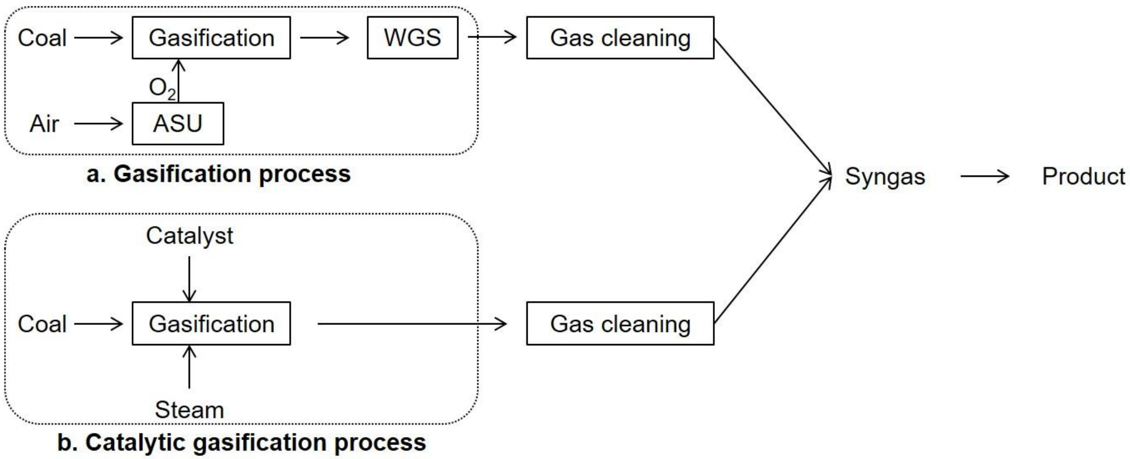
1-Screw feeder; 2-condensate pump; 3-electric furnace; 4-temperature and pressure detector; 5-fluidized bed reactor; 6-overflow tube; 7-gas and tar sampling pipe; 8-gas distribution plate; 9-mass flow meter; 10-needle valve; 11-water tank; 12-pump; 13-steam generator; 14-char collector; 15-ball valve; 16-tar reforming reactor; 17-char bed layer; 18-draught fan; 19-chimney; 20-condenser; 21-Ice-water tank; 22-wet gas flow meter; 23-gas chromatograph; 24-pump

- 1kW Dual-bed gasification system (24 kg/day)

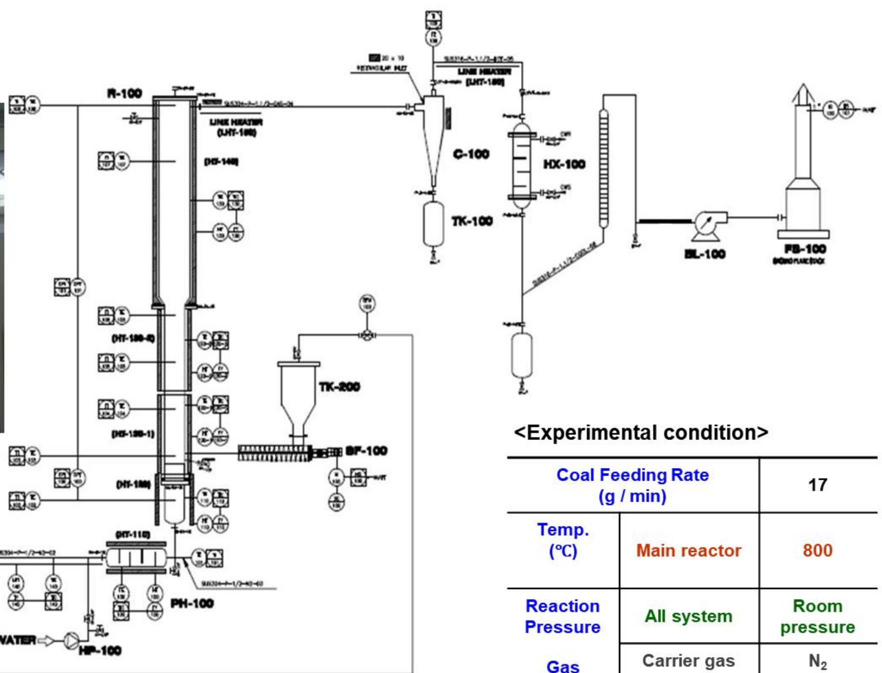


• Installation place : Dangjin in Korea

Steam-Catalytic Gasification



Bench-scale fluidized bed for steam-catalytic gasification



<Experimental condition>

Coal Feeding Rate (g / min)		17
Temp. (℃)	Main reactor	800
Reaction Pressure	All system	Room pressure
Gas Stream	Carrier gas	N_2
	Oxidant	Steam

Catalyst recovery system

Procedure of catalyst recovery

Impregnation coal ⟶ Catalytic gasification with steam ⟶ Syngas

↓

Char

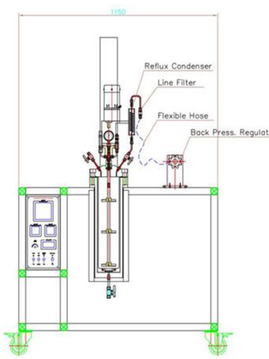
↓

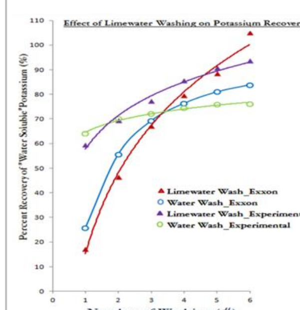
Catalyst recovery
(T: 150 ℃, P: 20 bar, reactor volume: 5L)

↓

1. Char + H_2O (H_2O: 2kg, N_2 condition) → water drain
2. Residue from 1 + limewater (H_2O: 2kg, CaO: 2.5g, CO_2 condition) → water drain

· The catalyst was recovered with a high yield (87%), by evaporating water according to methods 1 and 2.
· To recover potassium, the required energy required to boil 30℃ water was 610 kcal/kg.



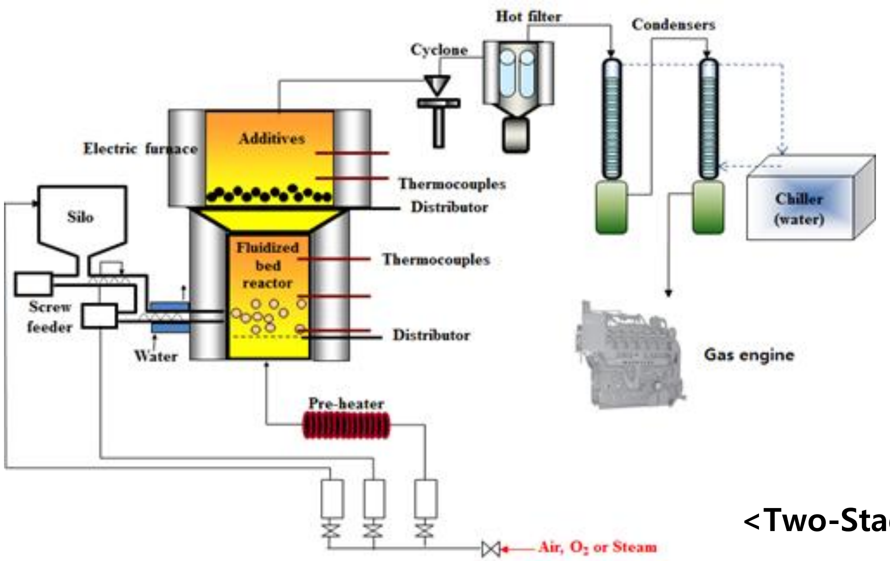


<Experimental Condition>

FB Gasification
- Catalytic steam gasification (at 800 °C, K_2CO_3)
- Carbon conversion : 90%
- Cold gas efficiency : 63 %

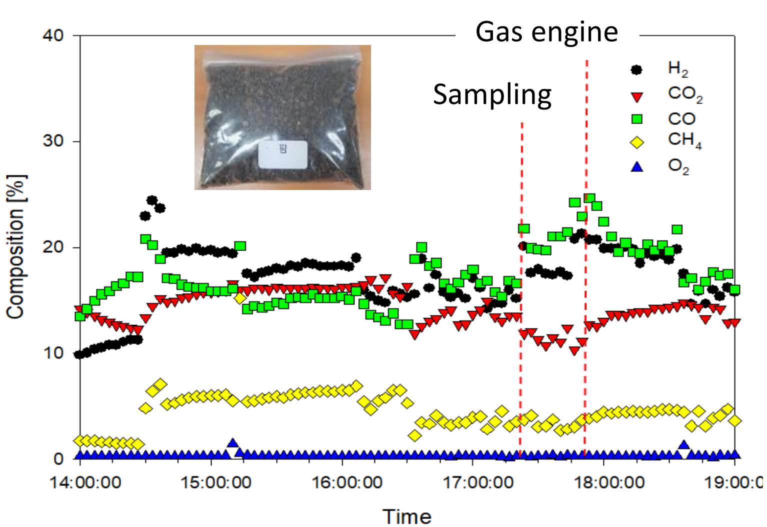
Catalyst Recovery
- Catalyst recovery efficiency: 80~90%

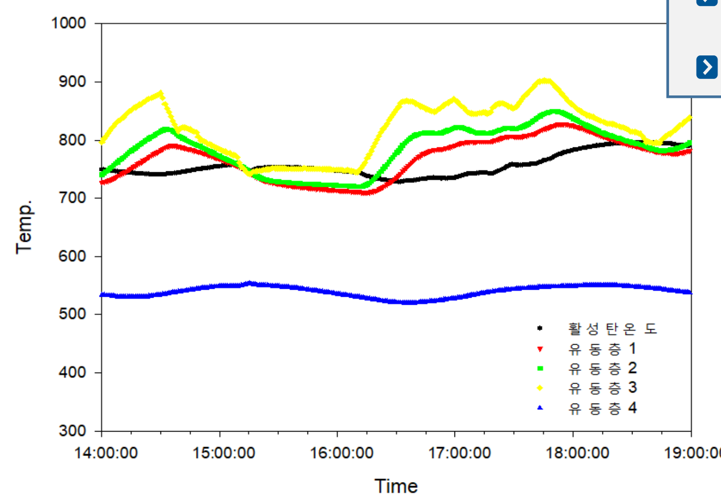
Two-Stage Biomass Gasification



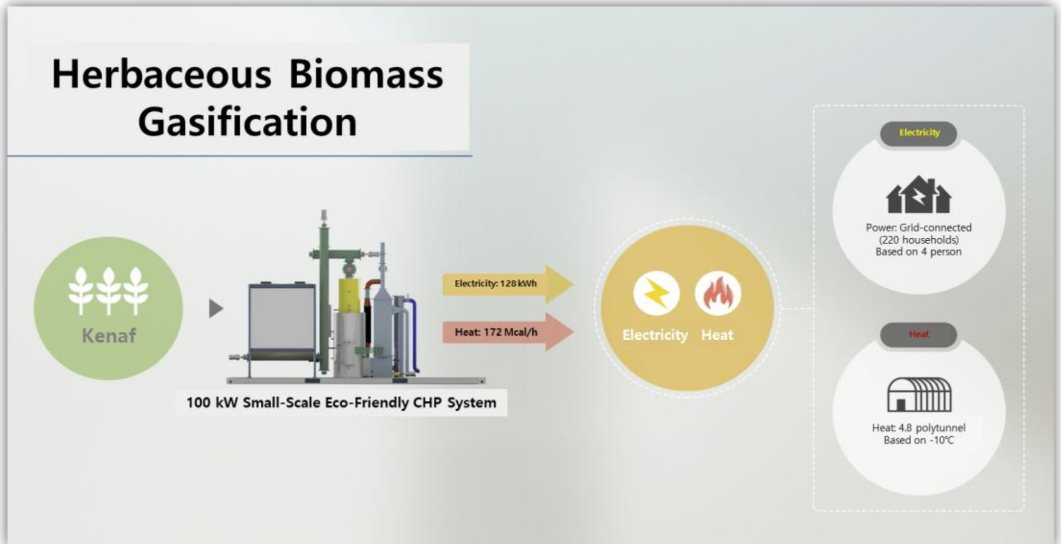
<Two-Stage Biomass Gasification & Gas Engine Power Generation >

- H_2 content: 26%
- Tar Removal: 99.8%
- Power Output: 33kW

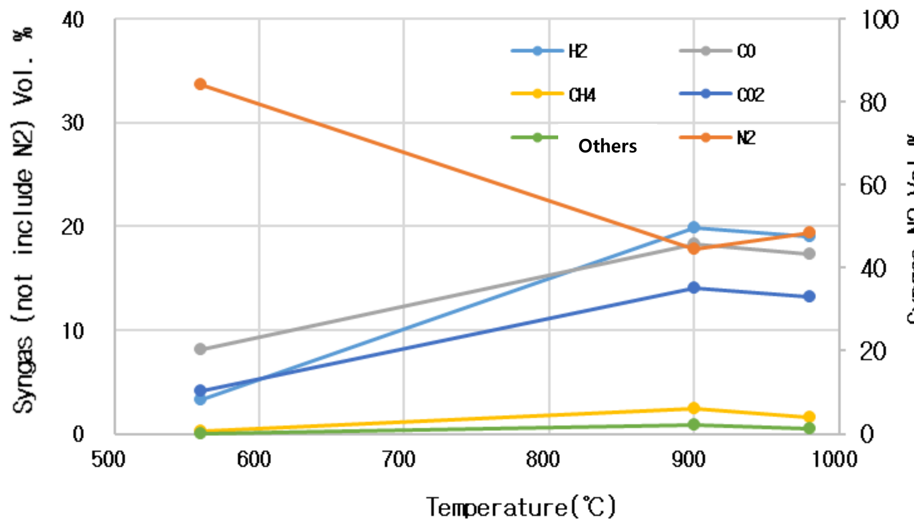




Herbaceous Biomass Gasification



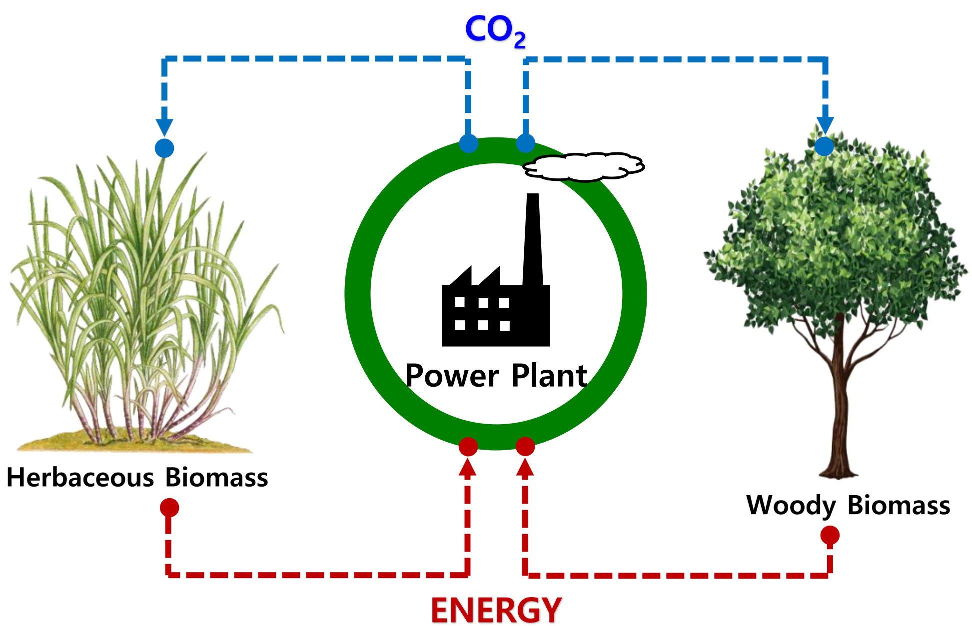
Effect of Gasification Temperature on Syngas Composition



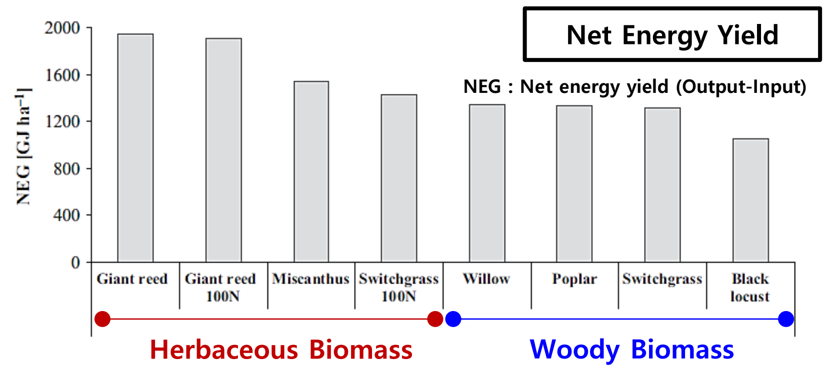
- **Increasing temperature leads to higher yields of H_2, CO, and CO_2, while N_2 decrease.**
- **Near 980℃, the concentrations of H_2, CO, and CO_2 slightly decrease, while N_2 increase.**

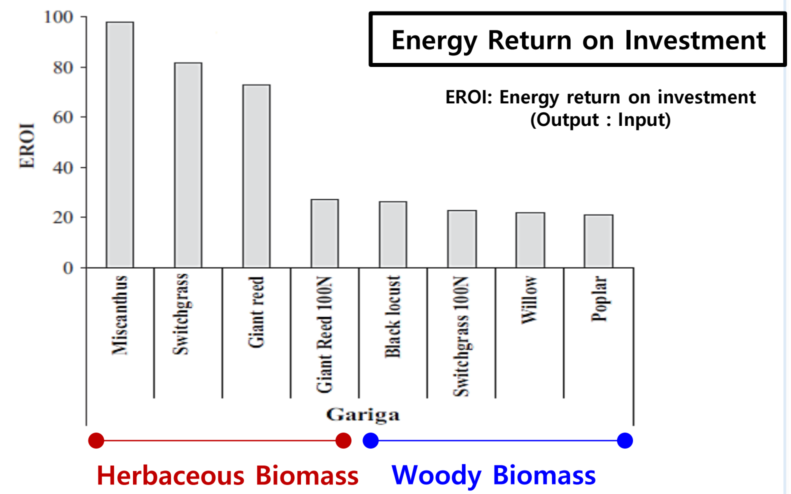
Advantages of Herbaceous Biomass

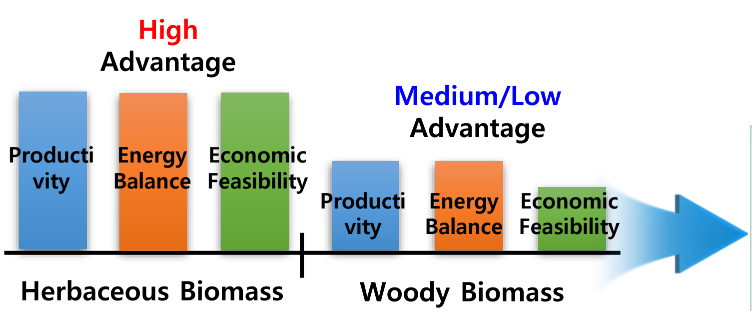
Which one is better as a CO_2 reduction fuel ?



Ref.: S. Amaducci et al, GCB Bioenergy (2017) 9, 31-45.

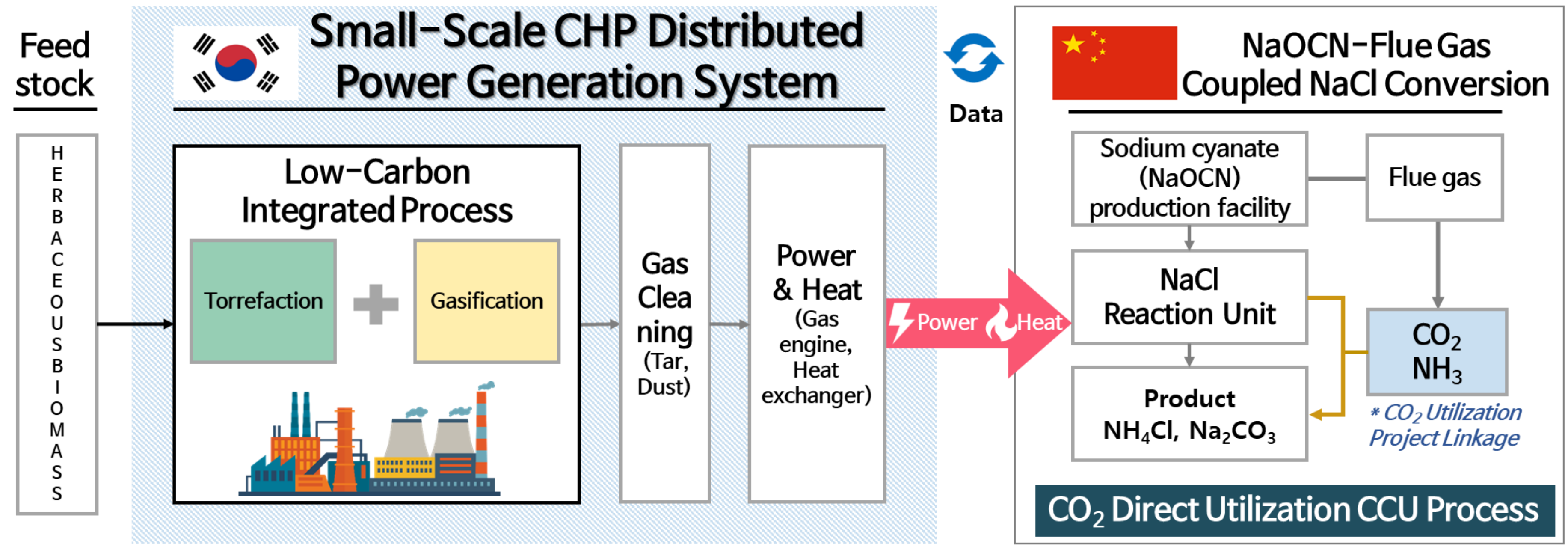






Technology development for utilizing herbaceous biomass as an alternative fuel is essential for achieving carbon neutrality by 2050 and diversifying the energy mix

Distributed Herbaceous Biomass CHP integrated with CCU



- **Direct CO_2 Utilization Technology Linked with Distributed Power Generation Using Herbaceous Biomass**

① **Integrated torrefaction/gasification distributed power generation using herbaceous biomass**

② **Production of Na_2CO_3 and NH_4Cl utilizing NH_3 and CO_2 contained in waste gas from the NaOCN manufacturing process**

Carbon-neutral process for reducing fine dust and greenhouse gas emissions

Dry Reforming of Methane (1)

Dry Reforming of Methane

$CH_4 + CO_2 \rightarrow 2CO + 2H_2$, $\Delta H = 247$ kJ/mol

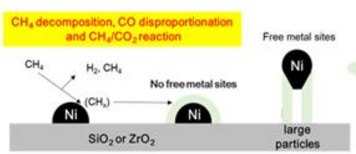
➢ Produced synthesis gas (CO and H_2) can be used…

- Production of oxygenate compounds, acetic acid synthesis
- Chemical intermediates, hydrogenation of unsaturated compounds

Major problem is…

➢ Endothermic reaction → needs high reaction temperature
→ Active metal aggregation

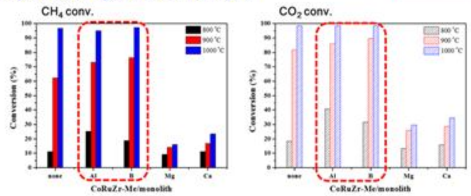
➢ Carbon formation: $CH_4 \rightarrow C + 2H_2$ (CH_4 decomposition)
or $2CO \rightarrow CO_2 + C$ (Boudouard reaction)

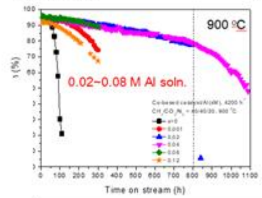


Lab-scale reforming reactor

Catalyst screening (Co-based catalyst)

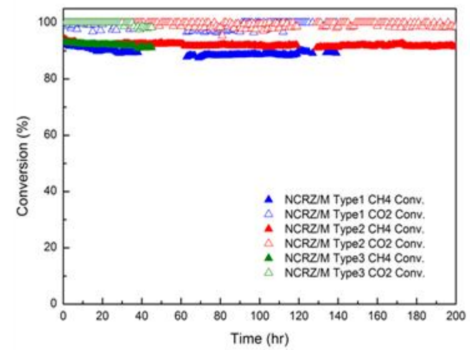
- Pretreatment = 1000 ℃, 10 h, feed condi.
- $CH_4/CO_2/N_2$(%) = 40/40/20
- GHSV = 4,200 h^{-1} (109 $cm^3\ min^{-1}$)
- T = 800-1000 ºC

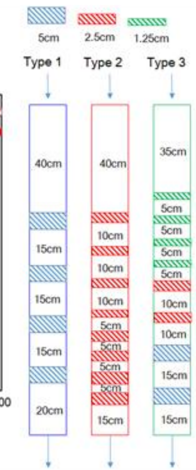




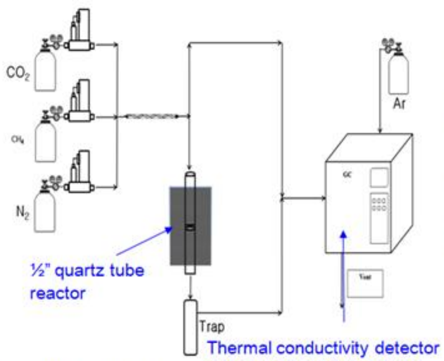
Addition of small amount of Al
→ enhanced catalyst stability
(10 times ↑)

Reaction condition
T = 1000 ℃, P = 1 bar,
CO_2:CH_4 = 50:50(5.6 L/min) SV = 4,425 h^{-1}





Lab-scale reforming reactor



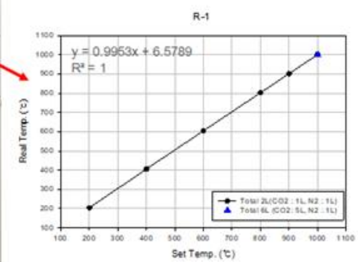
Reactor conditions

✓Pressure: 0.1 Mpa
✓Max temperature: 1,100 ºC
✓Mass flow rate (Brooks): 400 cm^3/min

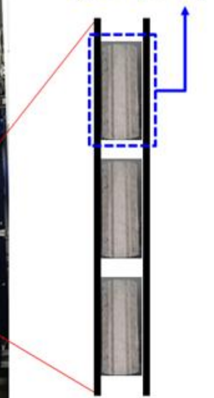
Bench-scale reforming reactor

Reactor size: 1 inch x 1.5 m
Material: alloy 600
Design Pressure: 3.5 barg
Design Temp.: 1500 ºC

- Fixed-bed Inconel reactor
- ID: 2.29 cm, H: 150 cm

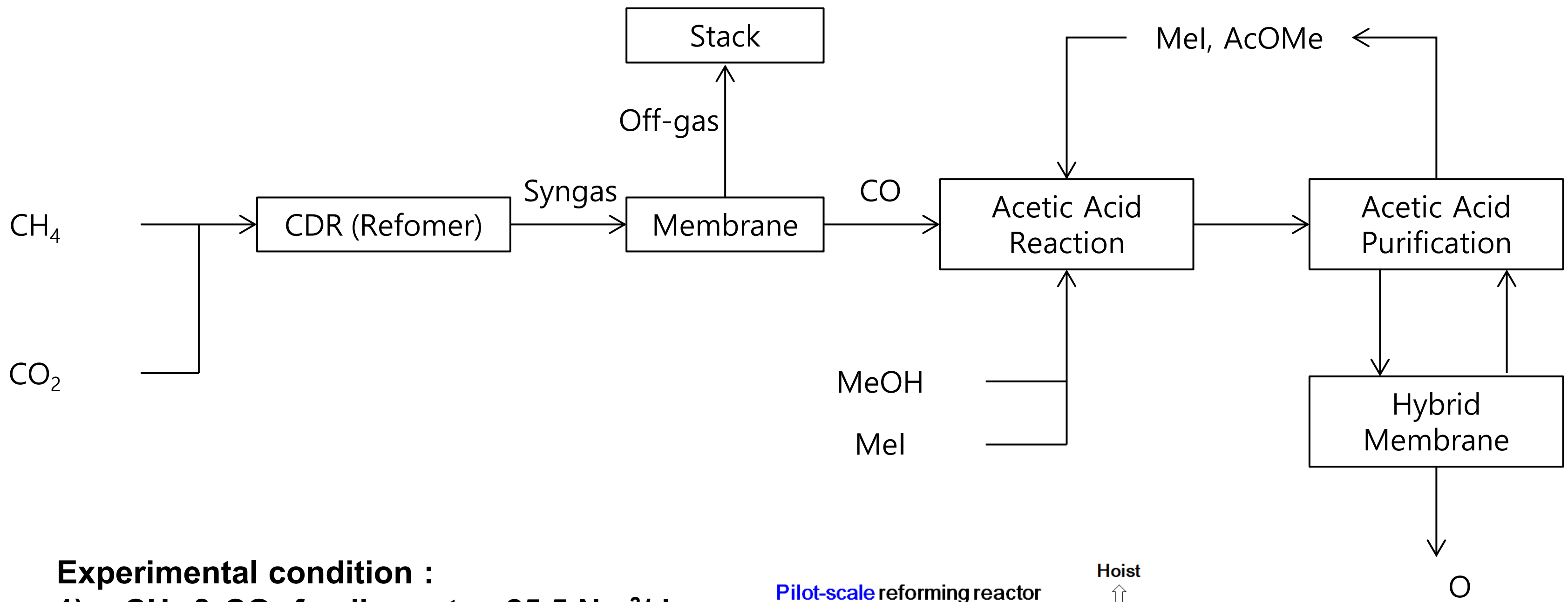


Reforming catalyst: production of 2.8 kg CO per day



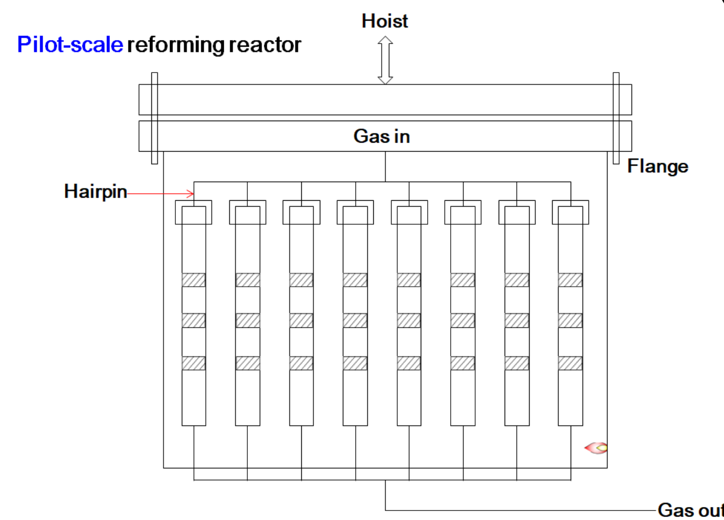
Optimal catalyst bed : 70~80 cm

Dry Reforming of Methane (2)

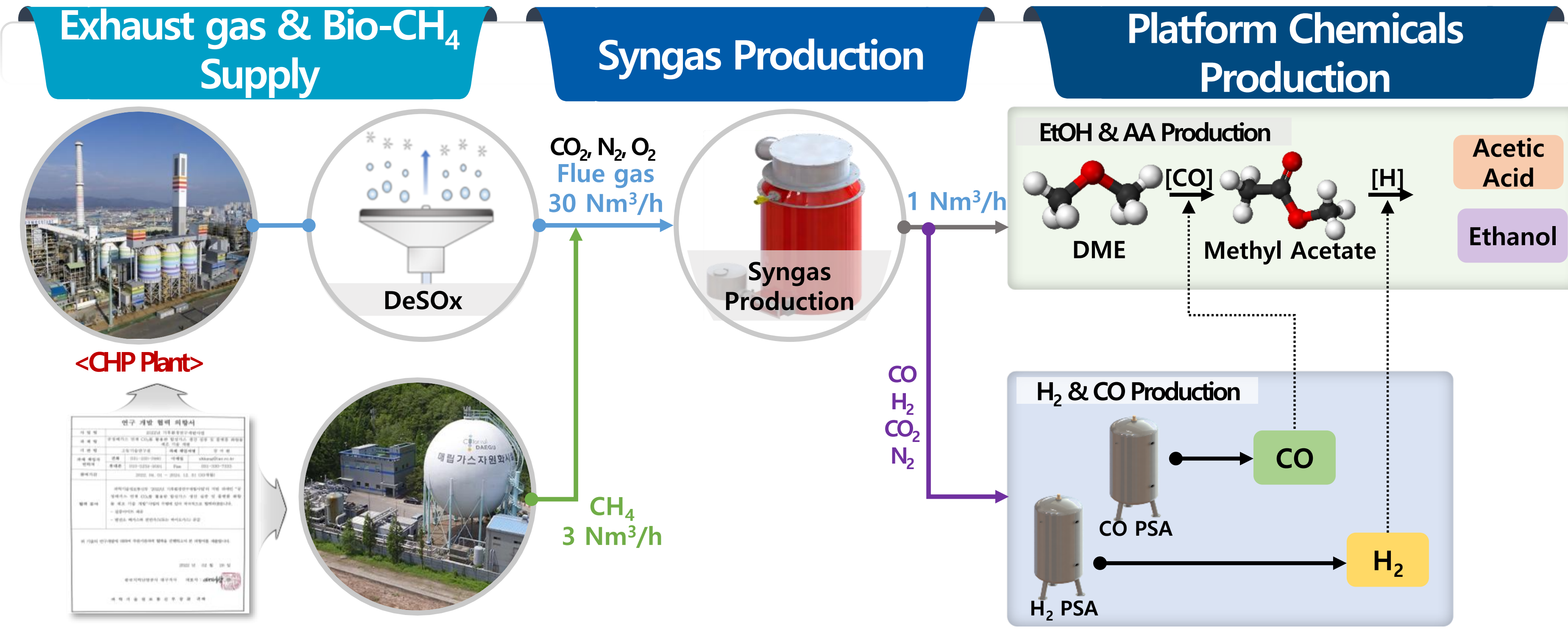


Experimental condition :

1) CH_4 & CO_2 feeding rate : 25.5 Nm³/day
2) DRM temperature : 1,000 ℃
3) Product of Acetic Acid : > 55 kg/day
4) A.A Reaction condi. : 190 ℃, 40 bar



Capture-free, Low-Concentration CO_2 Chemical Conversion (1)



Syngas Production Process Development

- Demonstration of a 30 t/y-scale syngas production process.
- Development of a PDP for 10,000 t/y commercial-scale process

Platform Chemical Production Technology Development

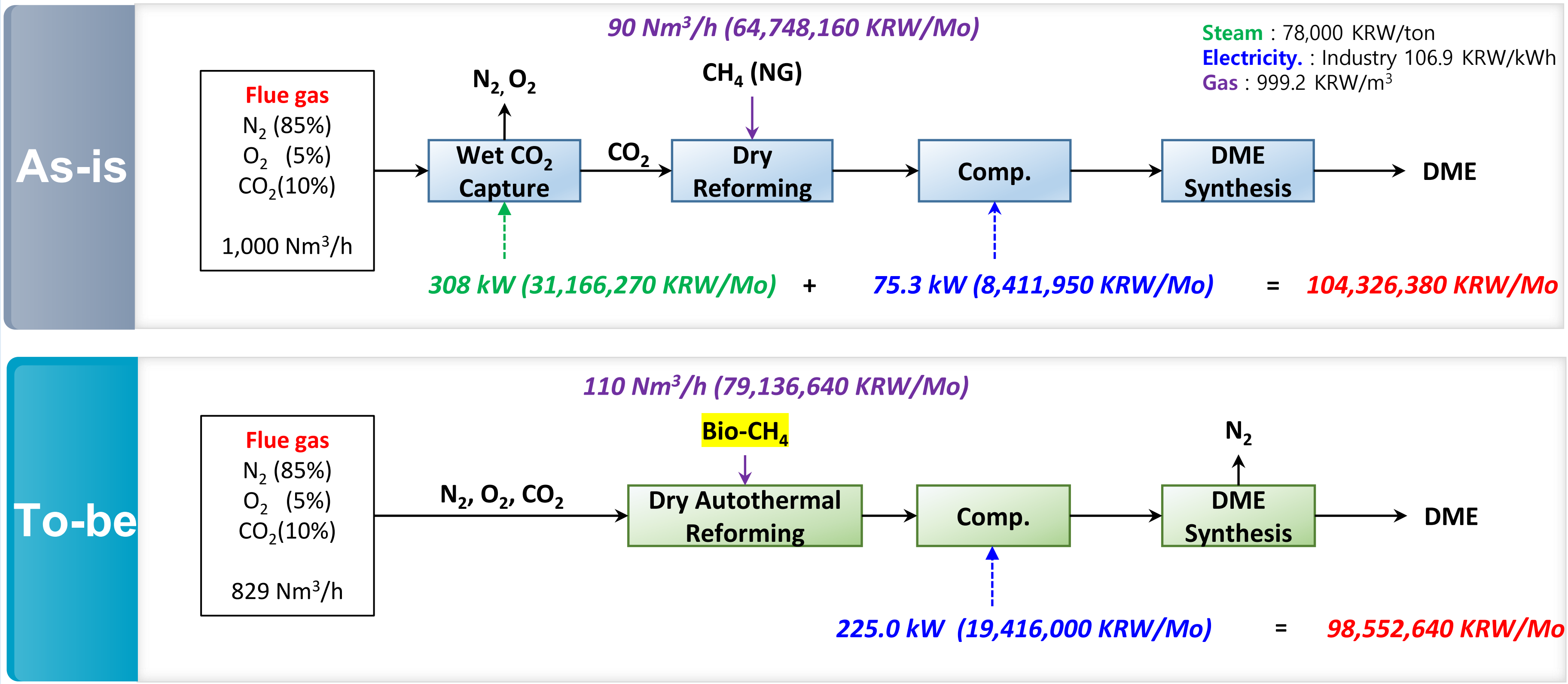
- Construction & Operation of a platform chemical production process utilizing 1 Nm³/h of syngas

Process Analysis & Efficiency Improvement

- LCA and process evaluation
- Development of a Digital Twin Model

Capture-free, Low-Concentration CO_2 Chemical Conversion (2)

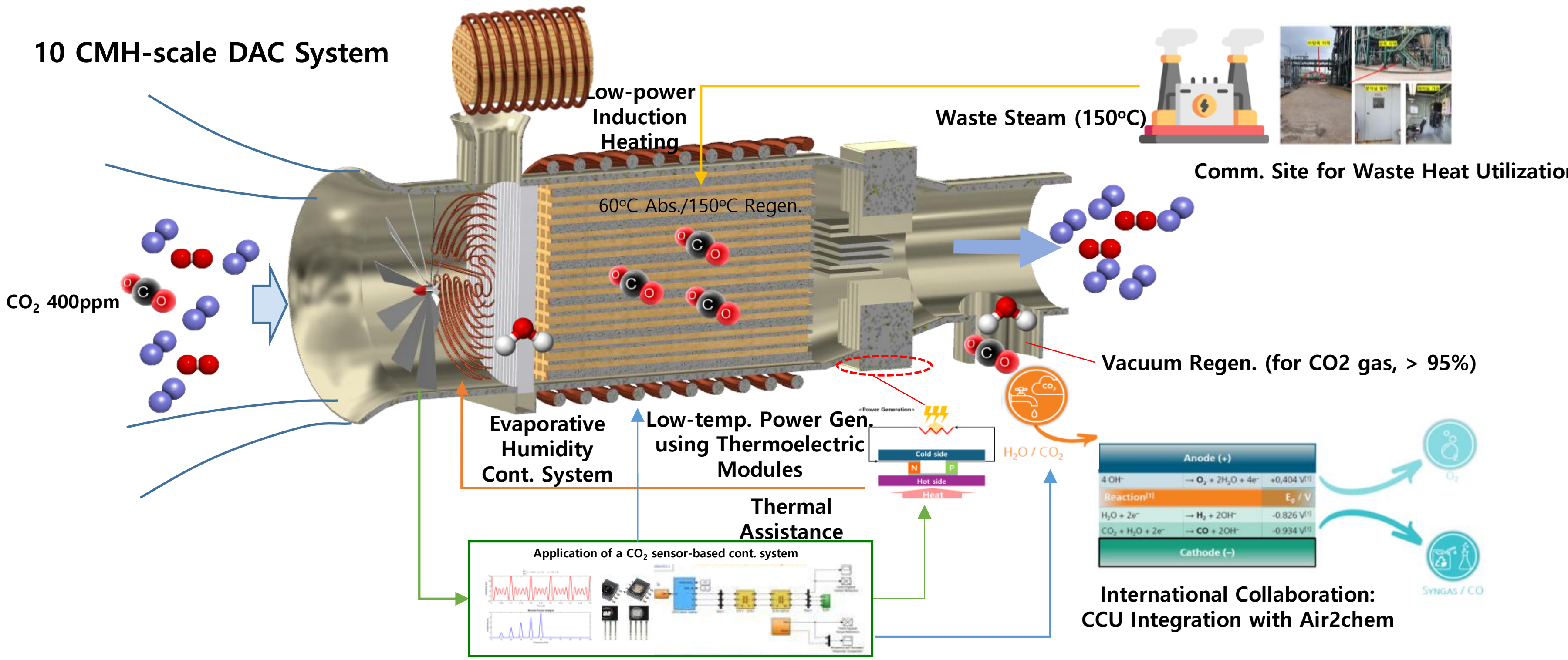
Comparison of Monthly Energy Costs for Wet CO_2 capture using Renewable Energy(LP Steam) and for Compression Including Nitrogen



Approximately 6% reduction in operating costs compared to the conventional process.

Expected GHG reduction and cost saving through Bio-CH_4(renewable energy) supply.

DAC-CCU



PLC(Data Collection) & OPC-UA(Data Transmission) & DB(Storage & Management)

Comb. & Opti. of core tech. = Dry Sorbent + System Cont. + Regen. + Waste Heat + CCU Integration

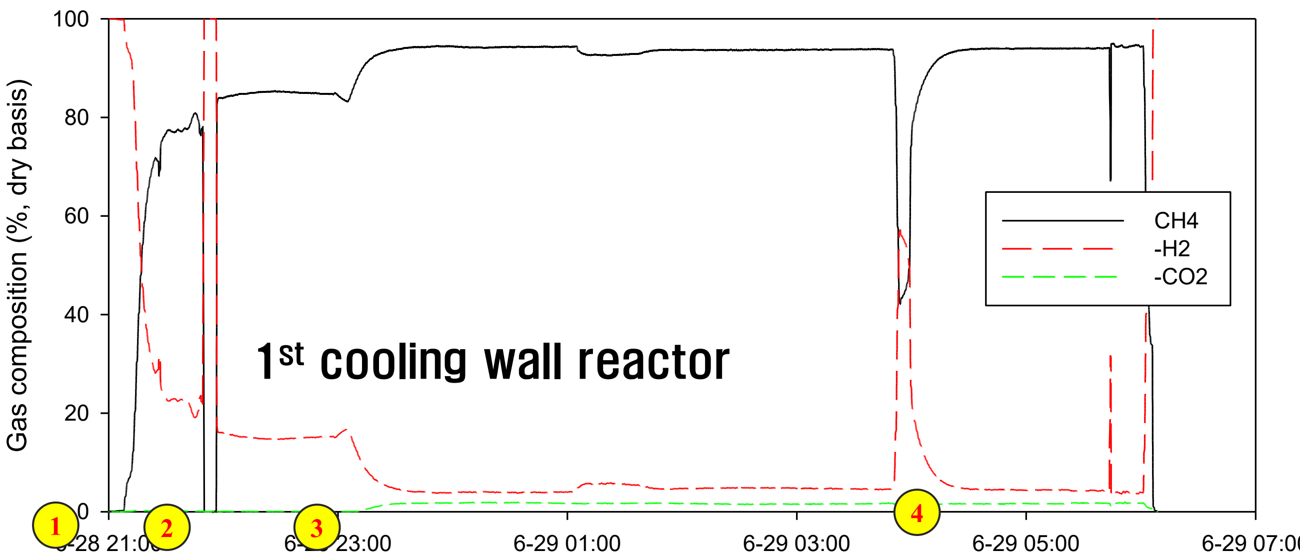
Domestic DAC Regen. Energy Consumption (A) = Sorbent Regen. + System = **7.2GJ/CO_2 ton(A)**

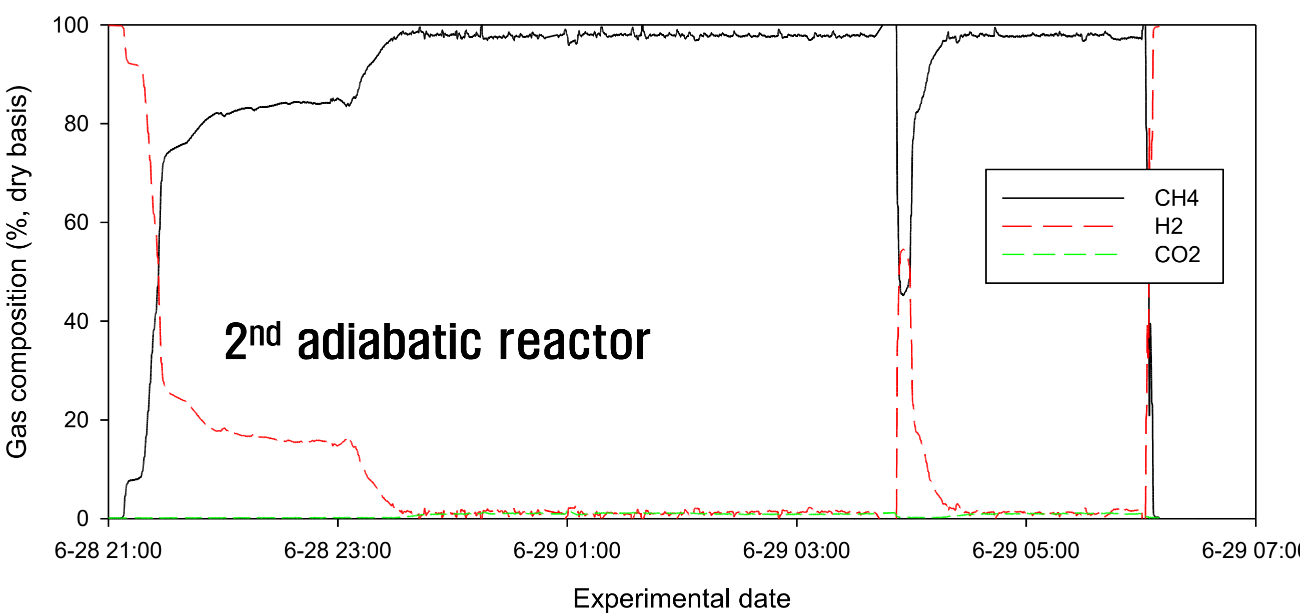
Regen. Energy ★Reduction★	
	Waste-Heat Integration (Design of DAC body using tower and materials) Energy Savings = **1.53GJ/CO_2 ton (B)**
	Low-power induction heating with thermoelectric materials, vacuum regen. System, Energy Savings = **1.7GJ /CO_2 ton(C)**

Regen. Energy of DAC system = **A-B-C = 3.97GJ/CO_2 ton**

About 45%Reduction

2 Nm^3/h-scale Cooling Wall & Adiabatic Reactor System

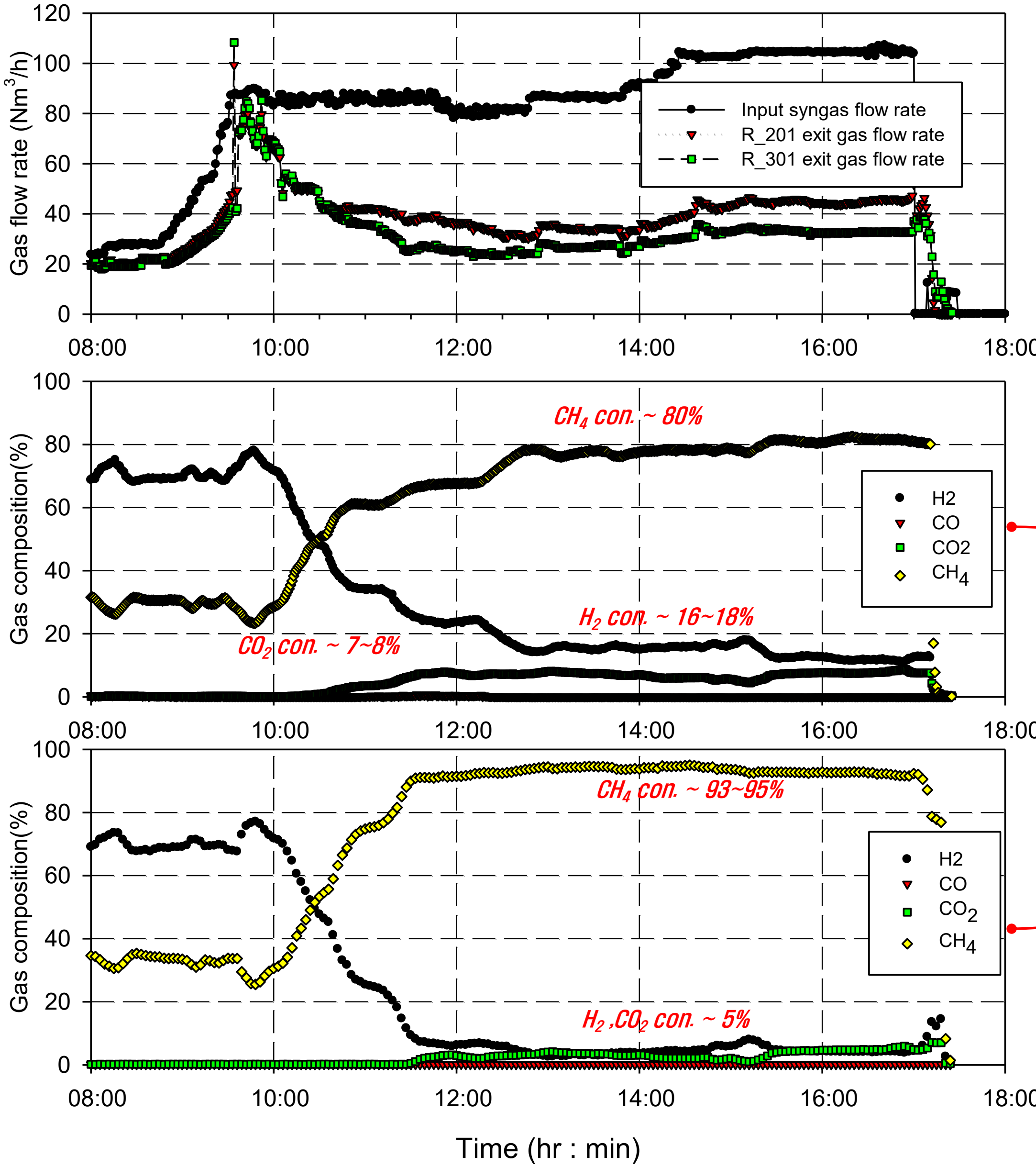


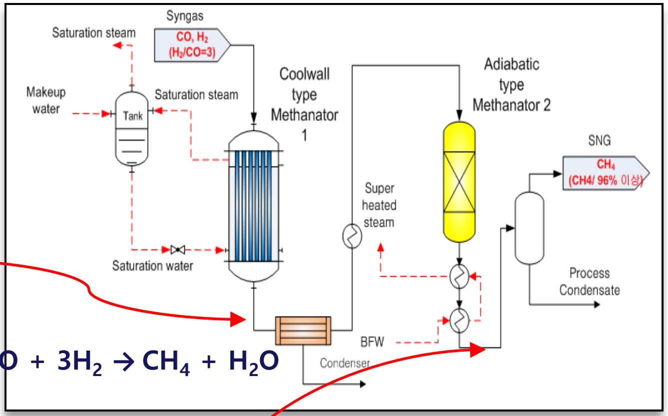


2 Nm^3/h
H_2/CO=2.97

① Introduction of CO from a 20 bar hydrogen saturator (feeding rate: 1 Nm^3/h)
② Analyzer malfunction occurred
③ Syngas (H_2/CO) flow increased to 2 Nm^3/h.
④ During CO cylinder replacement, no CO was supplied.

100 Nm^3/h-scale Cooling Wall & Adiabatic Reactor System

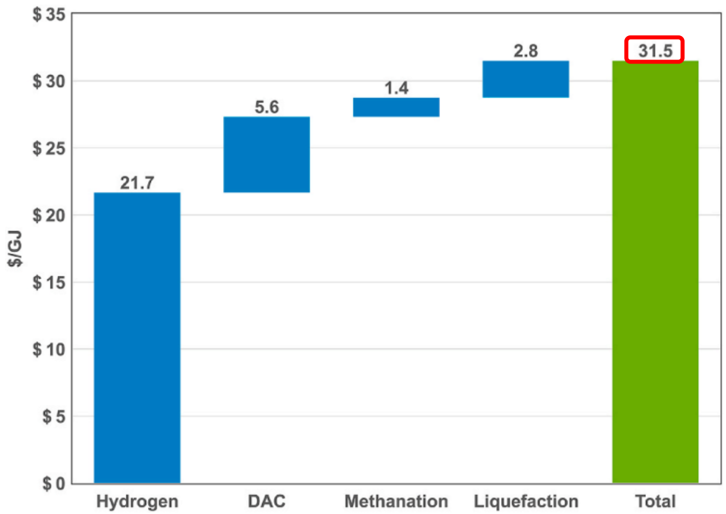




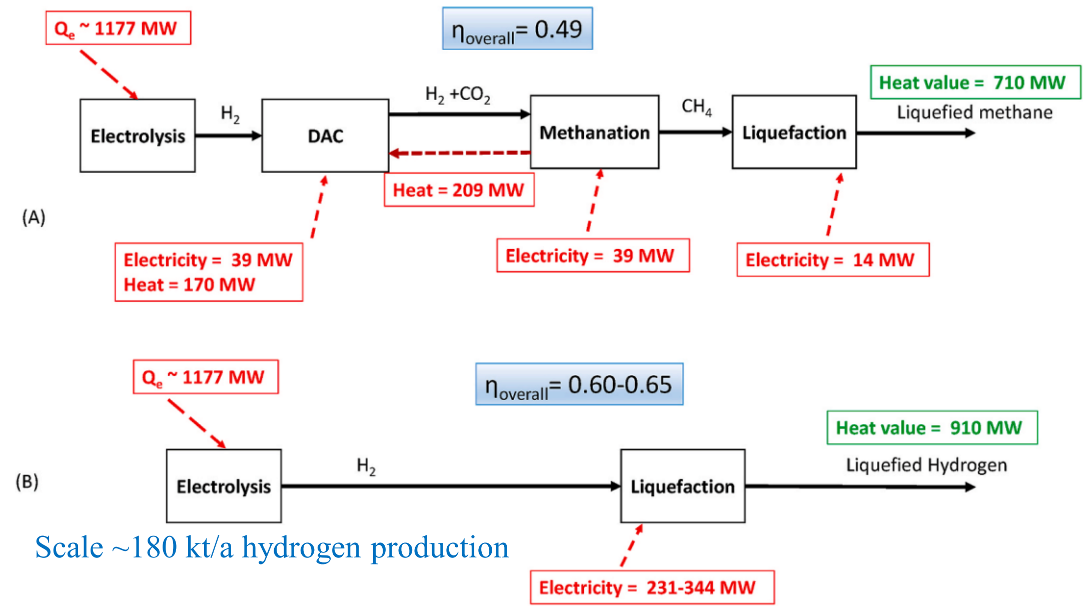
$CO + 3H_2 \rightarrow CH_4 + H_2O$

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

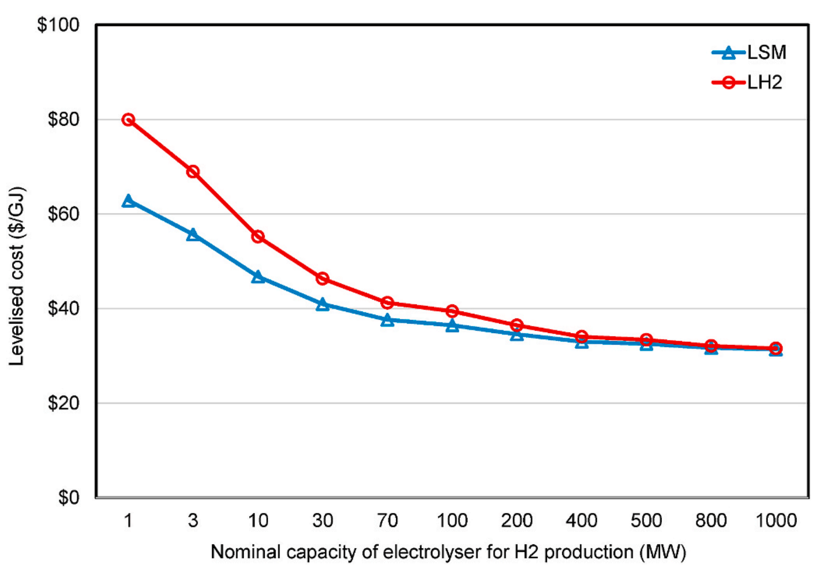
DAC-based LSM vs. LH_2



Liquefied synthetic methane : 360 kt/a
DAC



Scale ~180 kt/a hydrogen production

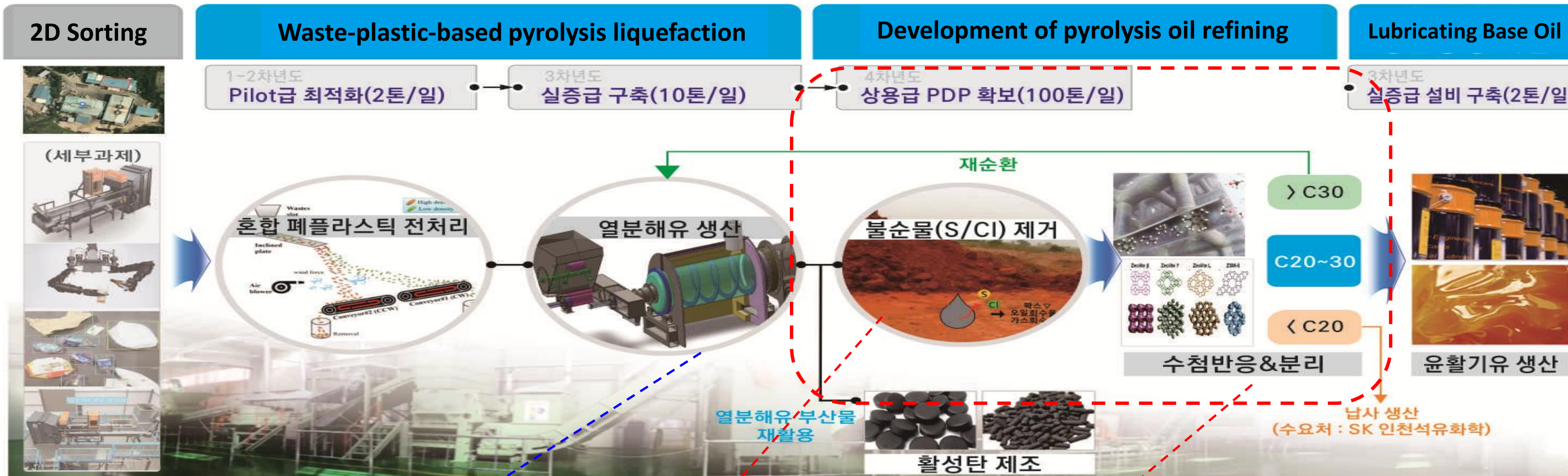


Costs of LSM and LH_2 per unit

Electrolysers efficiency ~80%

Source : Journal of Natural Gas Science and Engineering 94 (2021)

Recycled Fuel Oil Production using Waste Plastics



Removal of Dust, Moisture, and High-Viscosity Wax Components

Removal of Impurities (Cl)

Provision of Adsorbent Design Conditions

Mass Production of Adsorbents and Design/Construction/Operation of the Adsorption

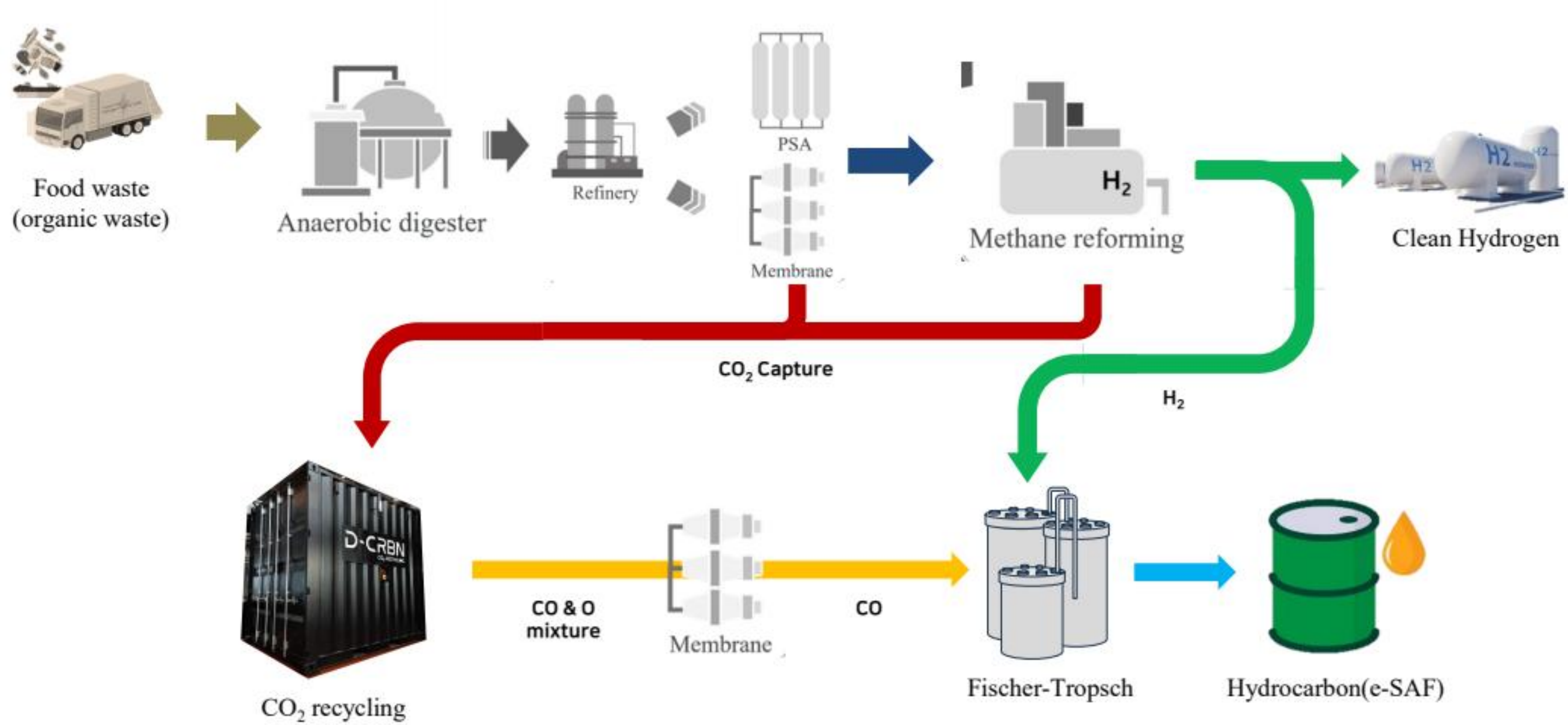
Development of Hydrotreating and Separation

Provision of Catalyst Design

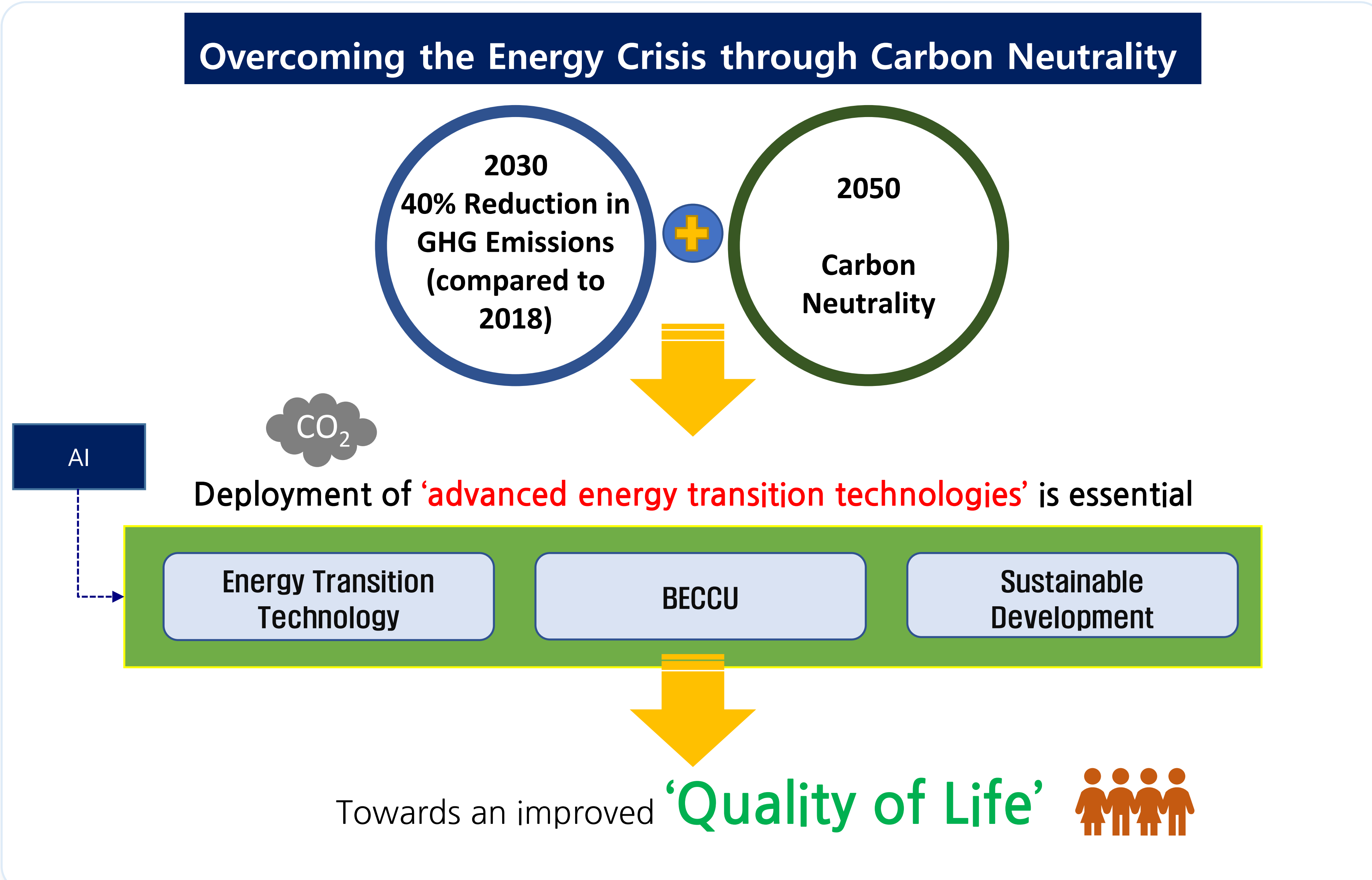
Mass Production of Catalyst and Design/Construction/Operation of the Hydrotreating

Control of T. P

Concept of Co-production Process for Clean H_2 & e-SAF from Biogas



Conclusion


Overcoming the Energy Crisis through Carbon Neutrality
2030
40% Reduction in GHG Emissions (compared to 2018)
2050
Carbon Neutrality
CO_2
AI
Deployment of 'advanced energy transition technologies' is essential
Energy Transition Technology
BECCU
Sustainable Development
Towards an improved 'Quality of Life'

Thank you