Use of Syngas from Waste and Biomass Gasification to SOFC System

2008. 4. 24.

Yongseung Yun, Seung Jong Lee, Soo Hyun Kim
Plant Engineering Center, Institute for Advanced Engineering
Korea
(Homepage) http://w3eps.iae.re.kr
http://www.coal.or.kr

IAE

Background

- Recent concerns regarding the fossil energy shortage and climate change ignited the search for the maximum utilization of renewable energy that would eventually replace CO_2-producing fossil fuels.
- Ultimate replacement to renewable energy might take more than 30 years without a really stringent carbon tax, which is not possible within few years.
- Many specialists predict that, at least, most countries need to start real reduction in CO_2 amount from 2013 as a result of international agreement at Bali on CO_2 in 2007.
- During the interim period before the full renewable energy society, maximizing the utilization of unconventional energy source such as wastes and biomass should be the first step. Next important step is in developing the electricity producing system of high efficiency like a fuel cell that can use a less CO_2-dependent unconventional energy source.

IAE

Typical Municipal Solid Waste
(S city, Gyunggi Province, Korea)

Examples of Biomass Feedstock

Moisture 5.4%
Volatile matter 74.0%
Ash 0.6%
Fixed Carbon 20.0%

C 50.6%
H 6.2%
N 0.04%
S 0.04%
O 42.5%
Ash 0.6%

(unit: cm)

Moisture 15.0%
Volatile matter 67.2%
Ash 0.04%
Fixed Carbon 17.8%

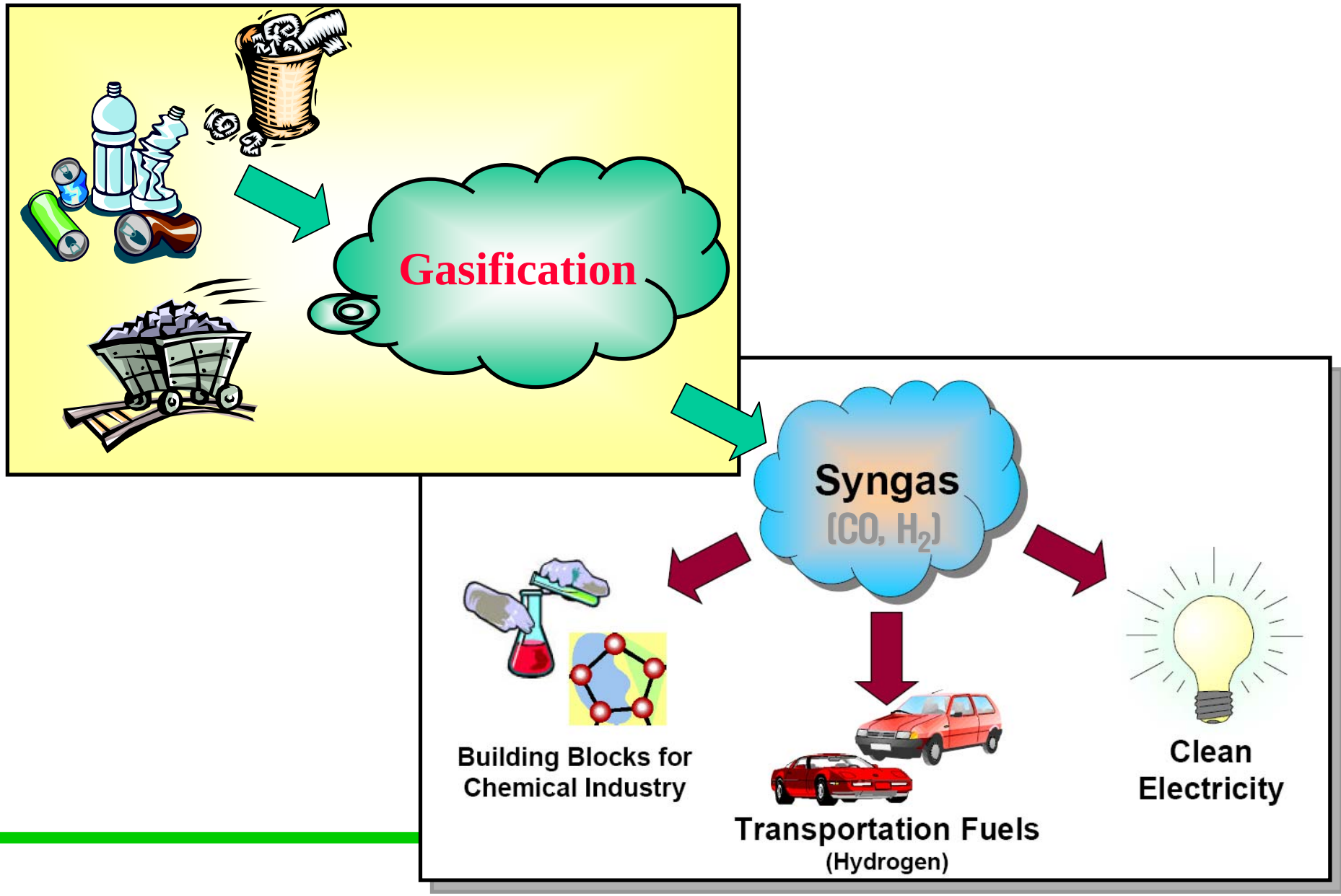
C 50.4%
H 6.2%
N 0.27%
S 0.08%
O 43.0%
Ash 0.05%

Trend of Heating Value in Korean MSW

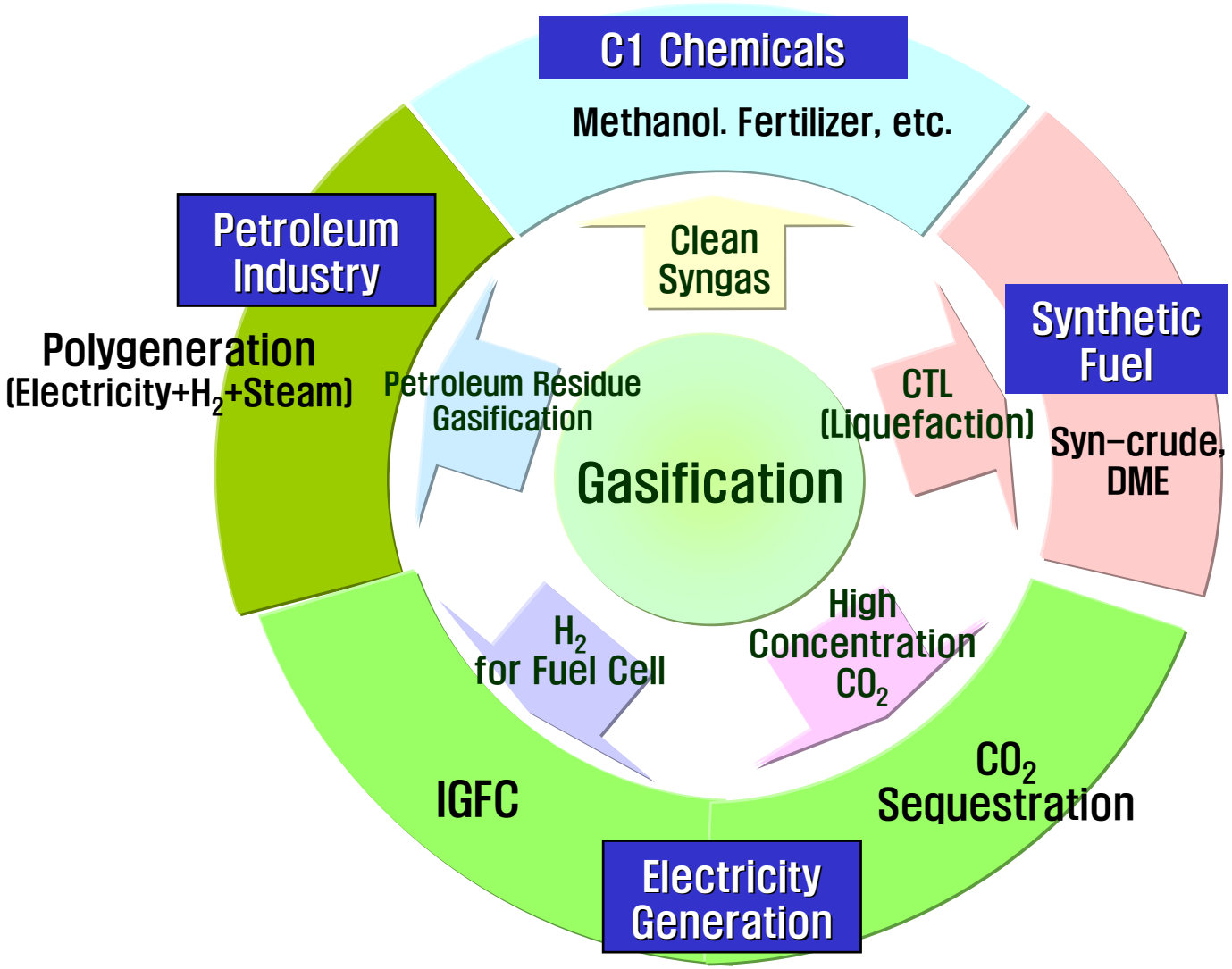
Year	Heating Value (kcal/kg)		Composition (wt%)			No. of plant sites for data collection
	Average	Maximum	Moisture	Combustibles	Ash	
1997	1,496	2,001	54	35	11	10
1999	1,511	2,019	53	36	11	15
2001	1,578	2,981	50	40	10	27
2002	1,945	3,403	47	43	10	29
2003	2,243	3,892	42	46	12	33
2004	2,302	3,340	41	49	10	32
2005	2,541	3,611	38	52	10	33

- Clear trend in moisture, combustibles
- Mainly due to :
  - Lower moisture, food wastes
  - Higher content of vinyls, plastics, papers, woods/leaves, textiles

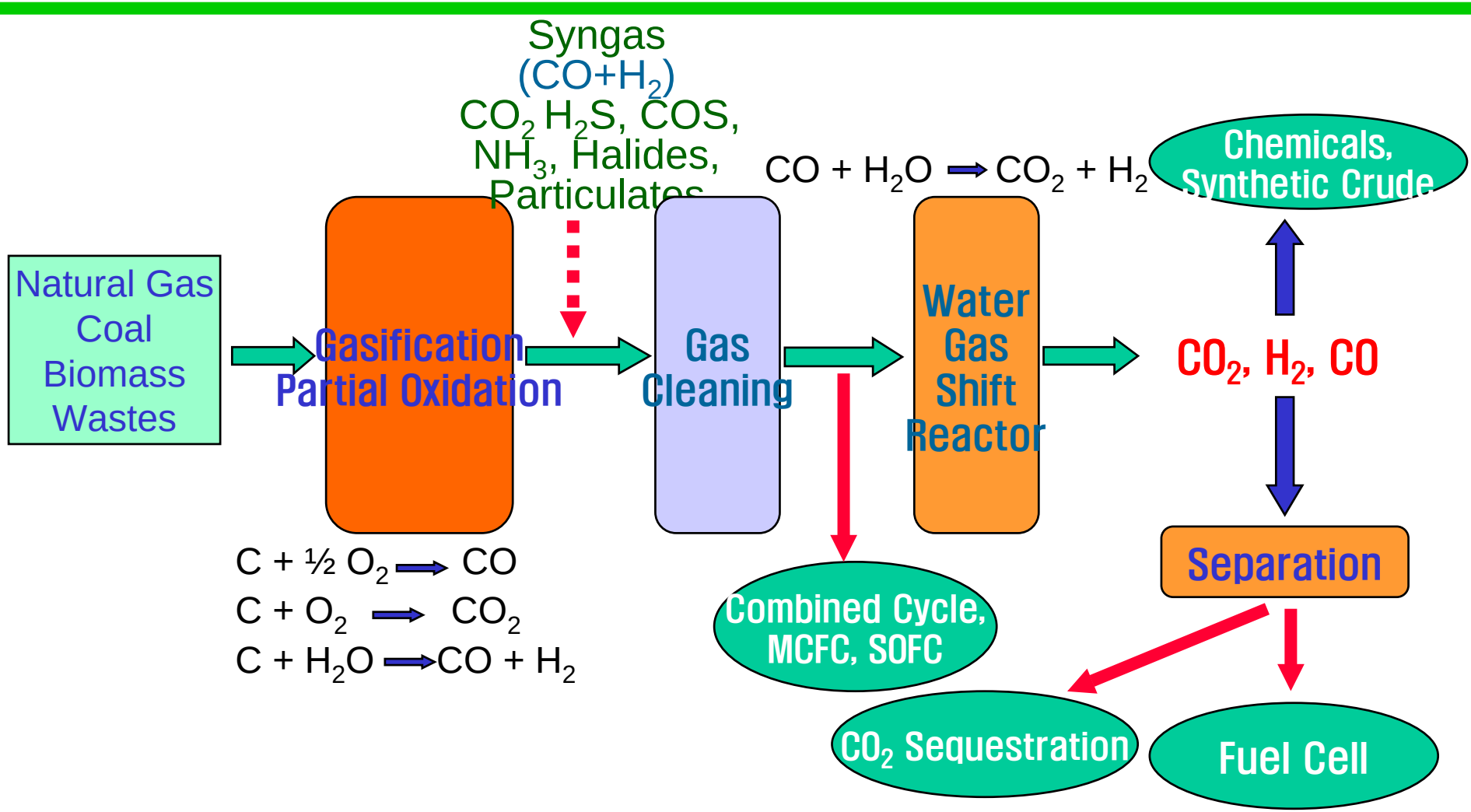
Gasification ?



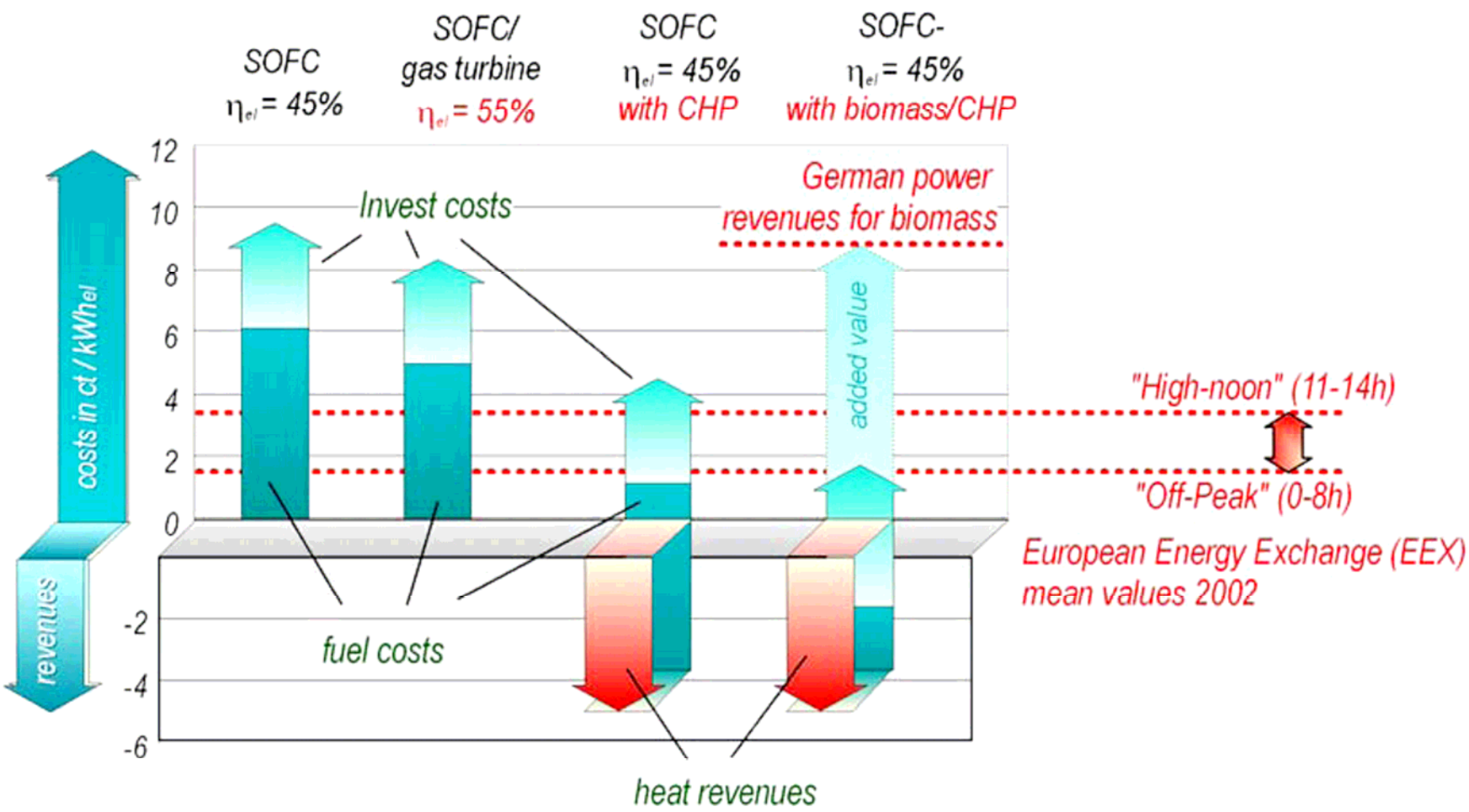
Syngas Application Route



Typical Process Configuration of Gasification



Electricity Production Costs for SOFC Concepts



Ref.: J. Karl, S. Karellas, Highly efficient SOFC systems with indirect gasification, Proc. 6th Eur. Solid Oxide Fuel Cell Forum, Lucerne, 2004, Vol. 2, S. 534-545.

Typical Syngas Compositions by Gasification

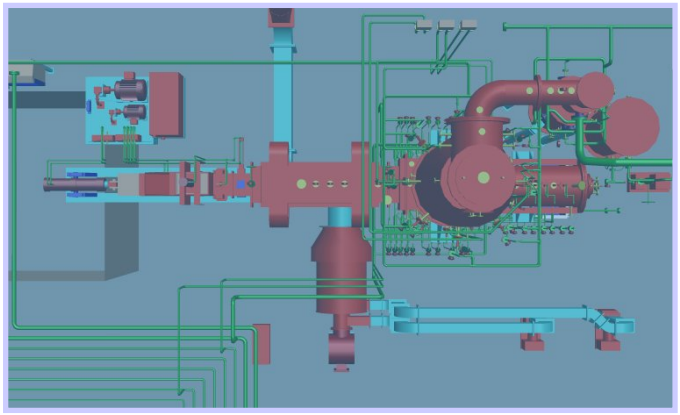
	Project								
	NG Reforming	Tampa IGCC	El Dorado IGCC	Shell IGCC	Sierra Pacific IGCC	Pyromaat	Schwarze Pumpe Gasification	IAE Coal Gasification	IAE Waste Gasification
Country		USA	USA	Netherlands	USA	Netherlands	Germany	Korea	Korea
Fuel	Natural Gas	Coal	Pet coke/Waste oil	Vacuum residue	Coal	Biomass (willow)	Lignite/oil slurry, RDF, waste plastics	Coal	Wastes
Syngas Composition				(dry-basis)		(dry-basis)	(dry-basis)		
H_2	50.0	27.0	35.4	34.4	14.5	33.2	61.9	22	28
CO	9.2	35.6	45.0	35.1	23.5	31.1	26.2	45	32
CH_4	0.5	0.1	0.	0.3	1.3	0.1	6.9	0	2
CO_2	6.1	12.6	17.1	30.0	5.6	34.8	2.8	9	30
N_2+Air	0.01	6.8	2.1	0.2	49.3	–	1.8	24	8
H_2O	34.1	18.7	0.4	–	5.7	–	–	–	–
Oxidant	O_2	O_2	O_2	O_2	Air	O_2	O_2	O_2	O_2

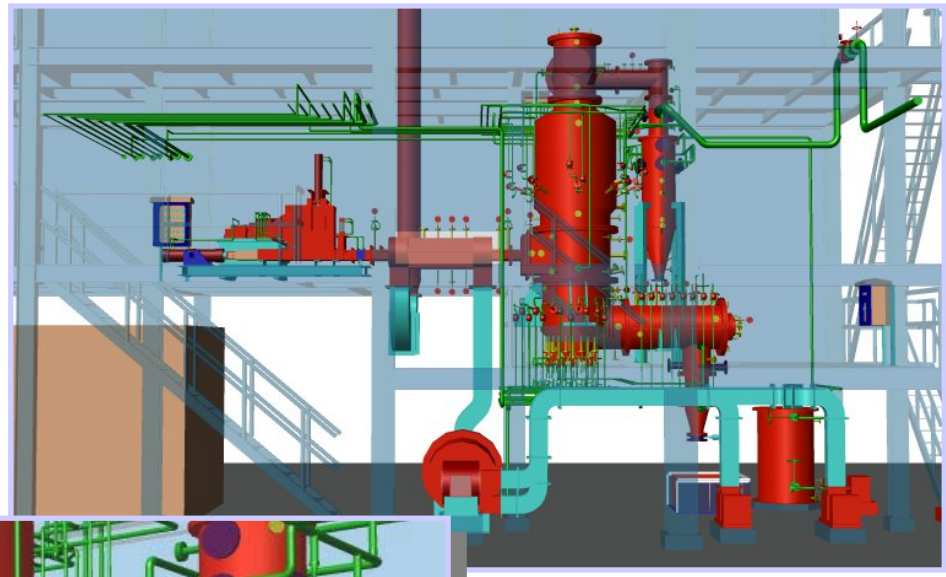
Syngas Cleaning Requirements

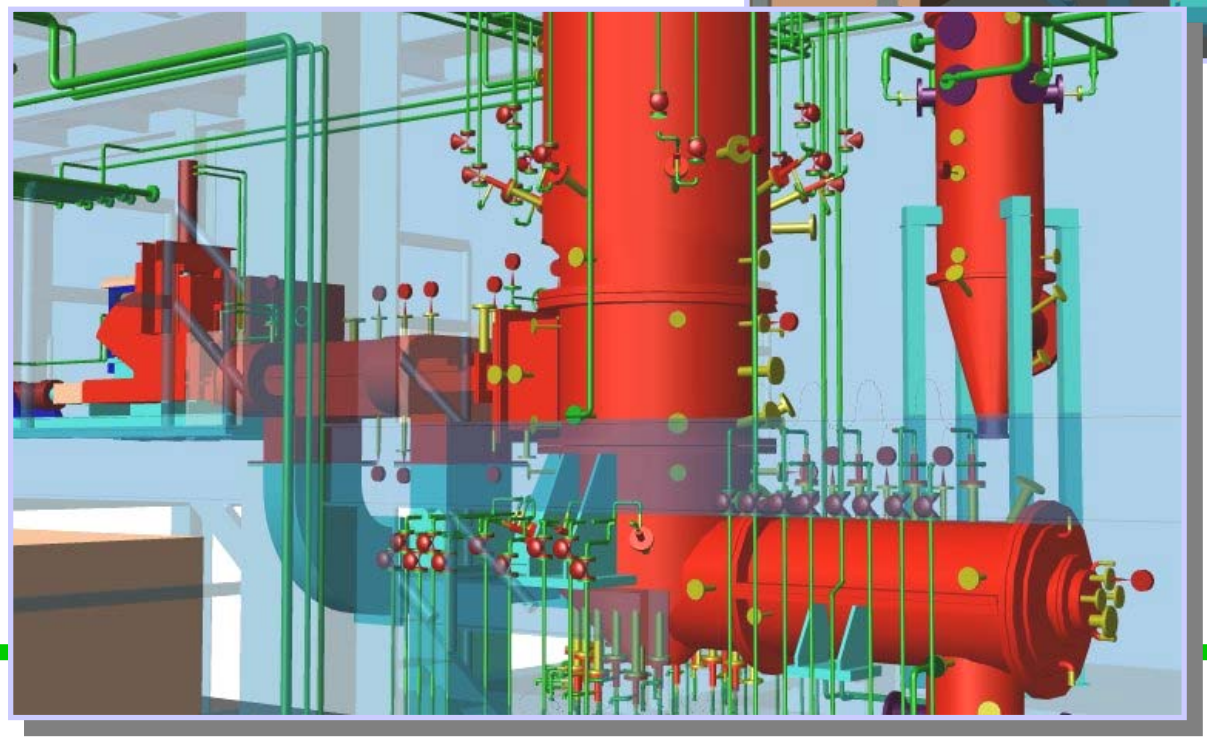
Application	Cleaning Requirements
Gas Turbine	- Alkali 0.1 – 0.5 ppmv - Halides 0.6 – 3.0 ppmv - Vanadium 0.05 – 0.2 ppbv - Sulfur-compounds < 10-15 ppmv
MCFC	- H_2S / COS < 0.5 ppmv - HCl < 0.5 ppmv - NH_3 < 1 vol% - Hg < 35 ppmv
SOFC	- H_2S / COS < 1 ppmv (or < 0.1 ppmv) - HCl < 1 ppmv - NH_3 < 0.5 vol%
Chemicals, Syn-crude	- Total S < 60 ppbv - Total Halides < 10 ppbv - Acetylene < 10 ppbv - NH_3 < 10 ppbv - NOx < 100 ppbv - HCN < 10 ppbv

IAE

MSW Gasification Melting Pilot Plant (3 ton/day) at IAE





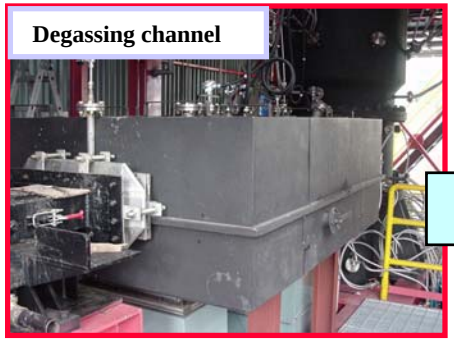


- Based on Thermoselect® process, modified for Korean MSW

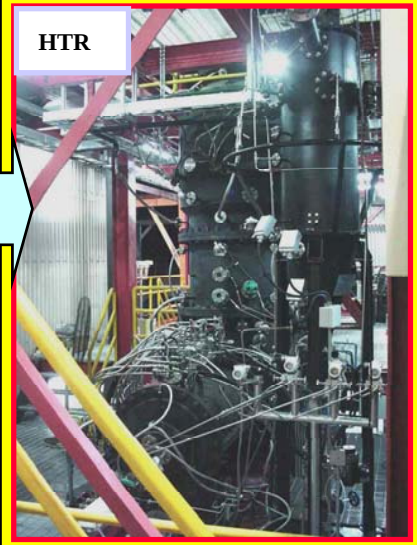
IAE

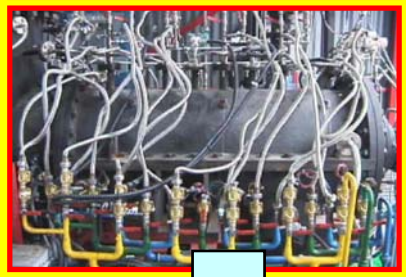
3 Ton/Day MSW Gasification Pilot Plant at IAE

Degassing channel



HTR



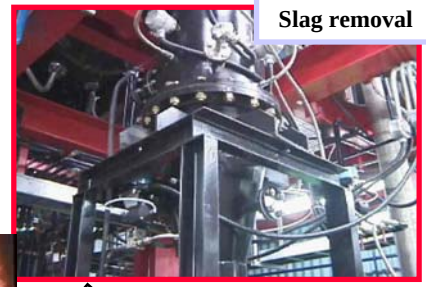


Shocking cooling and gas cleaning

Press

Combustor

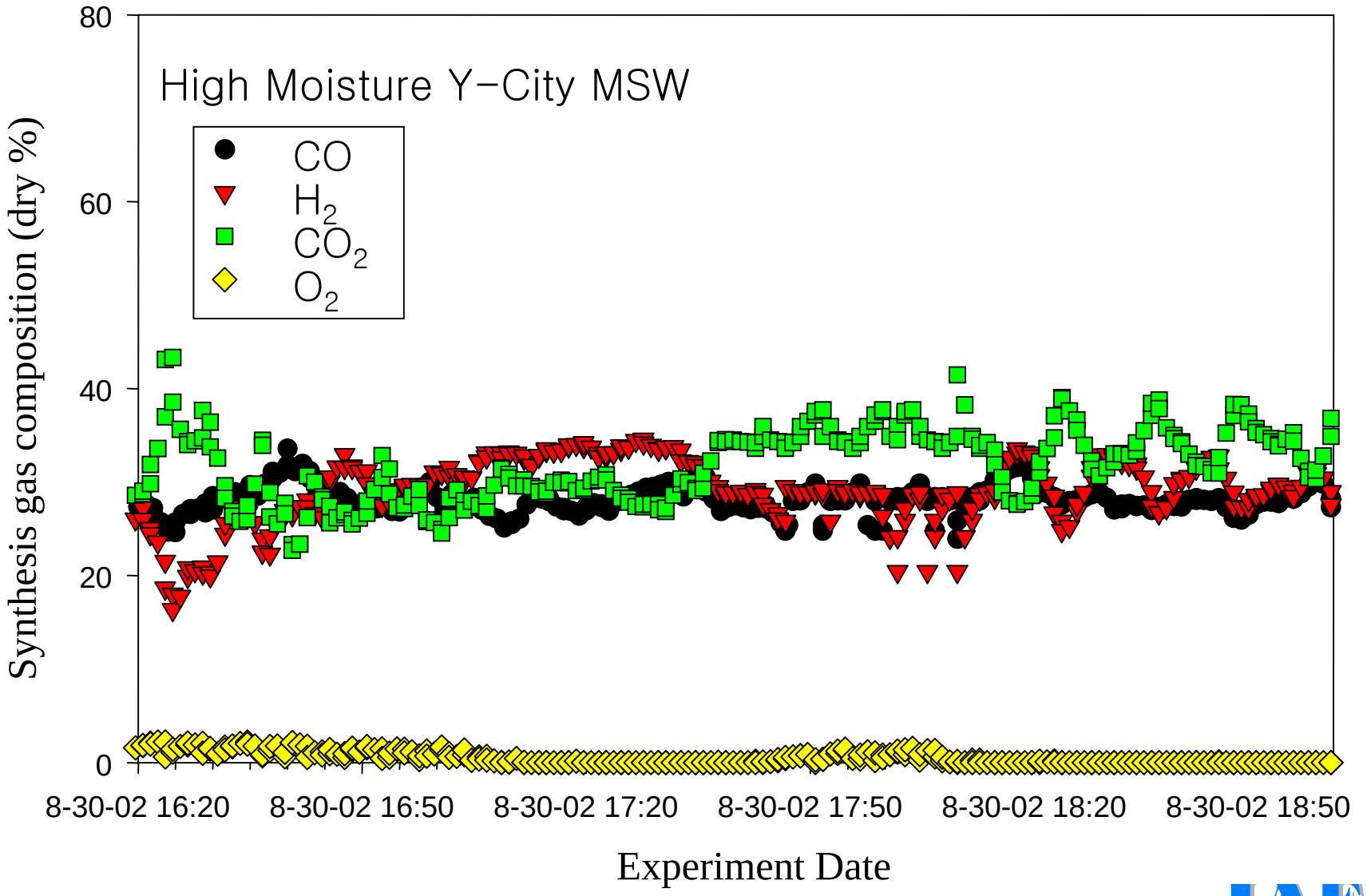
Slag removal



Control room

IAE

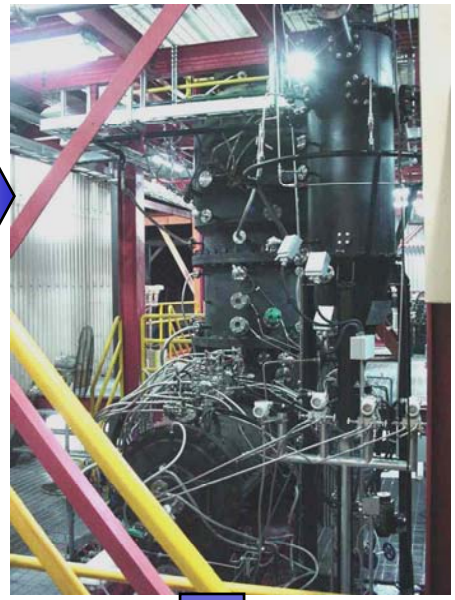
Syngas Composition from Pyrolysis-Gasification (55.8 wt% Moisture MSW, Y-City, Korea)



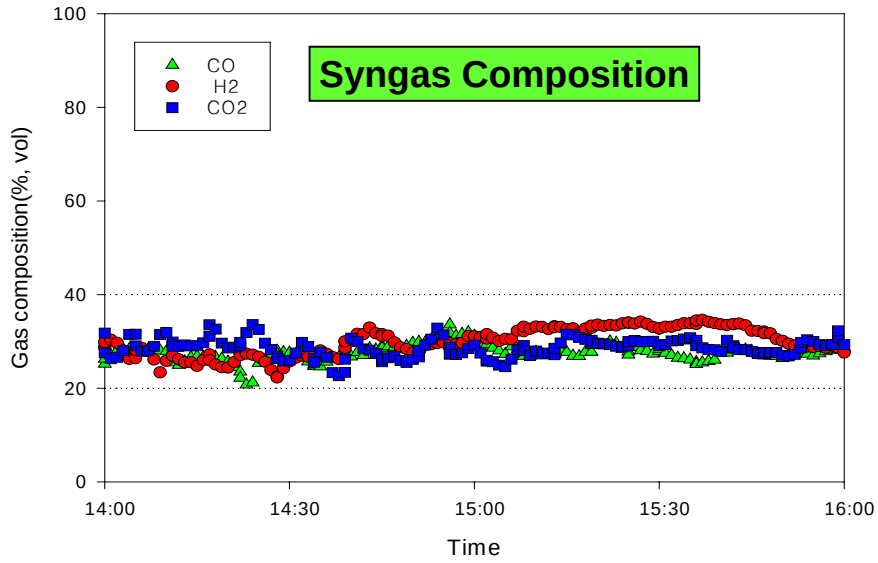
Gasification of Industrial Wastes

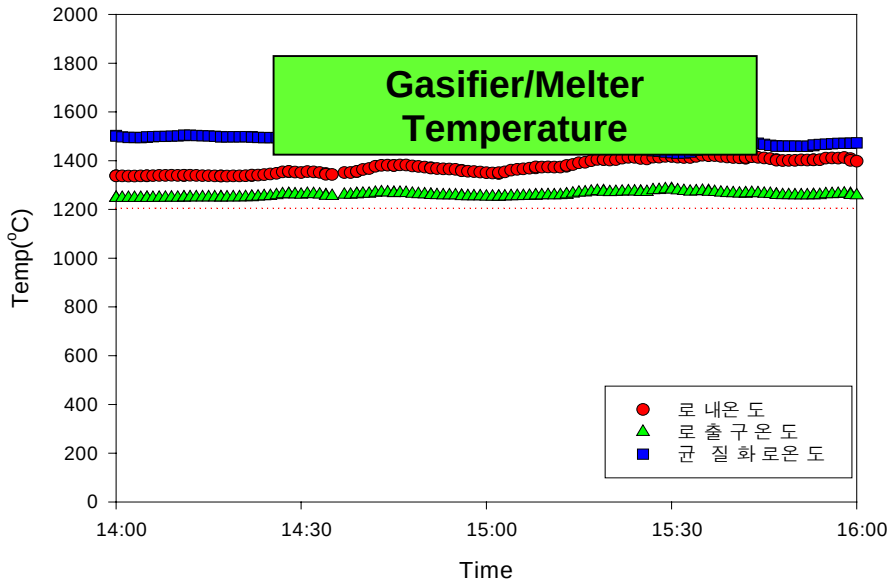
Waste

Gasifier



Slag





Gasifier / Syngas Cleaning System

Gasifier (high pressure)

Metal Filters

Desulfurization/Regeneration

IAE

Design Conditions for Syngas Cleaning

Inlet	
Temp.	400 ℃
Pressure	20 kg/cm^2
Flow	120 Nm^3/hr
Particulates	2000 mg/Nm^3

Particulates Removal

Outlet	
Temp.	400 ℃
Pressure	20 kg/cm^2
Flow	120 Nm^3/hr
Particulates	10 mg/Nm^3

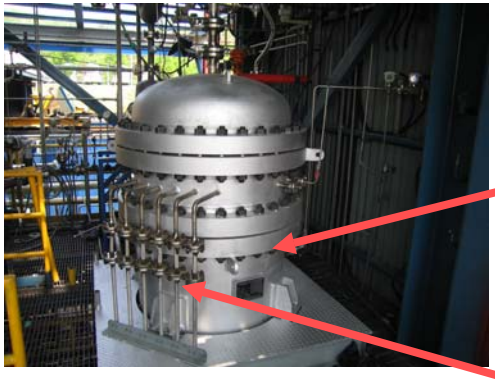
Inlet	
Temp.	30 ℃
Pressure	20 kg/cm^2
Flow	120 Nm^3/hr
H_2S	1000 ppm

Desulfurization

Outlet	
Temp.	40 ℃
Pressure	20 kg/cm^2
Flow	120 Nm^3/hr
H_2S	0.5 ppm

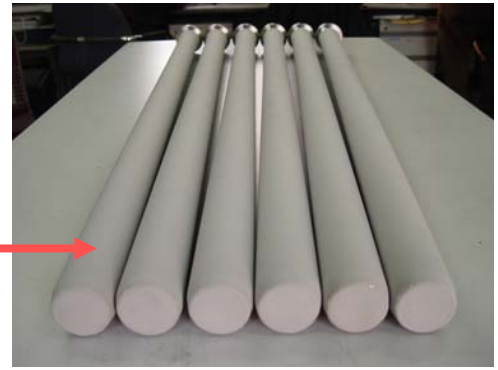
IAE

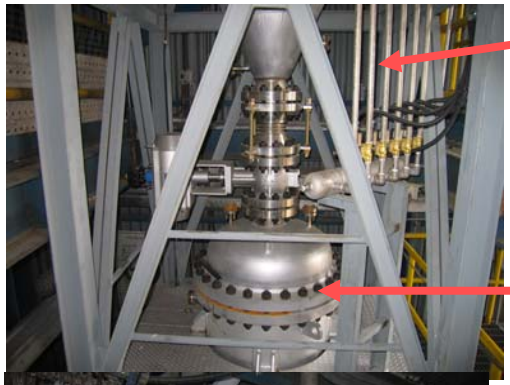
High Temperature Filtering System



Filtering Vessel

Filters
(Sintered Metal)

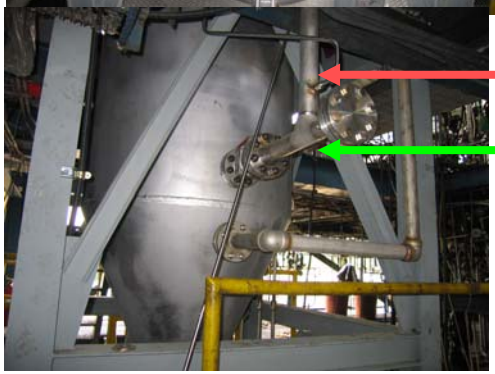




N_2 Back-pulsing pipes

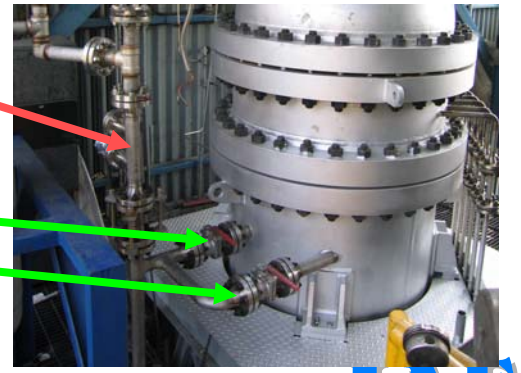
Control panel

Ash storage hopper

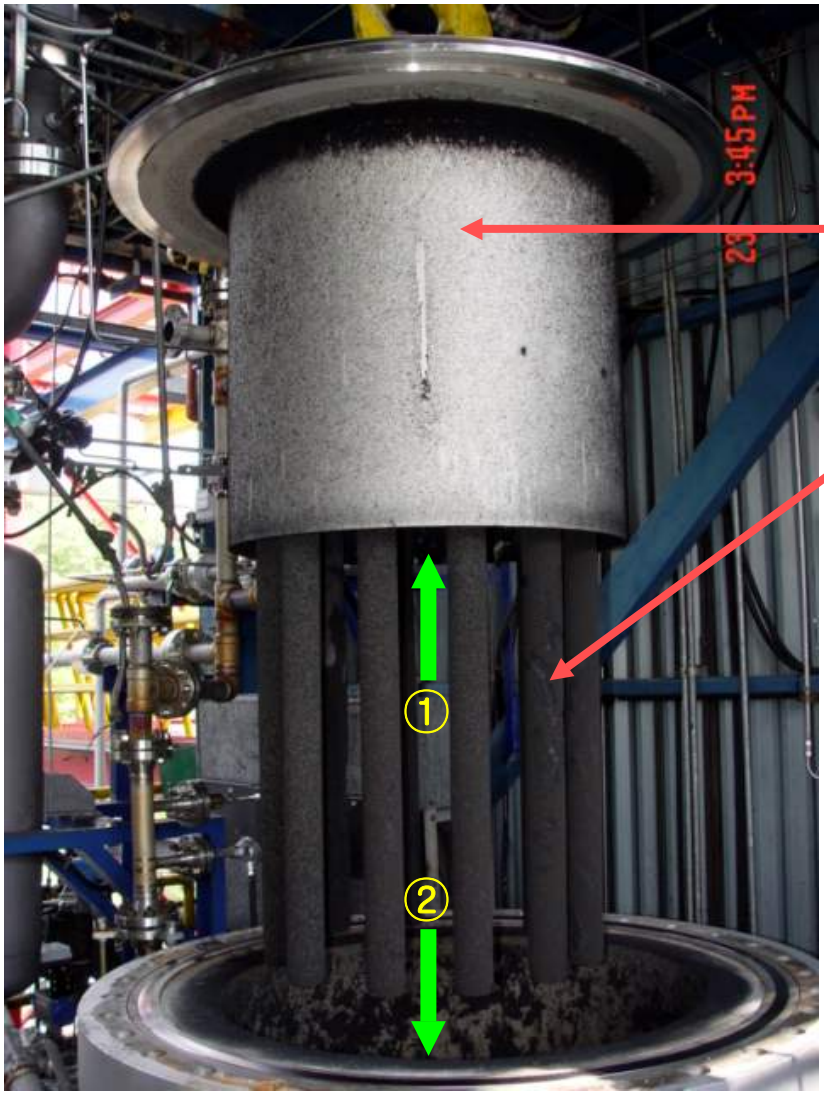


Syngas inlet

1) Lower part
2) Front upper part
3) Front side part

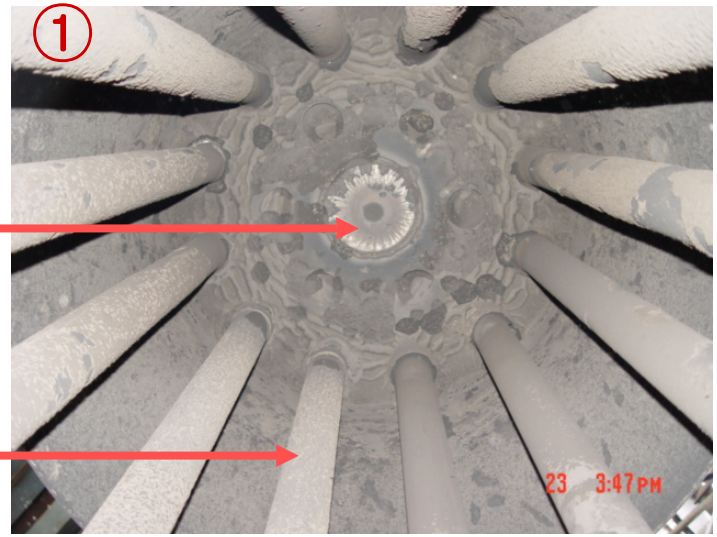


Filters inside Particluates Removal Vessel



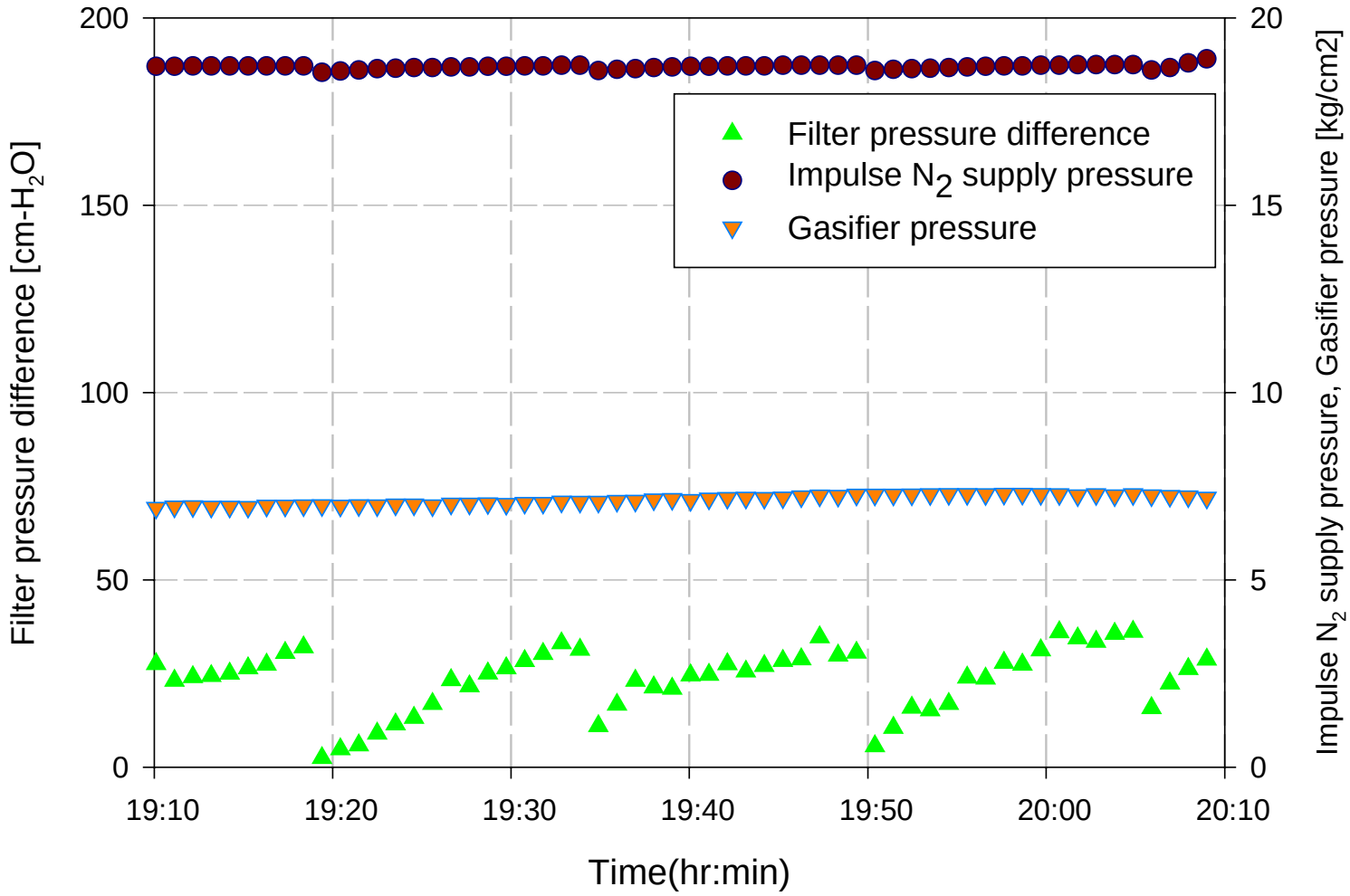
Baffle

Metal Filters

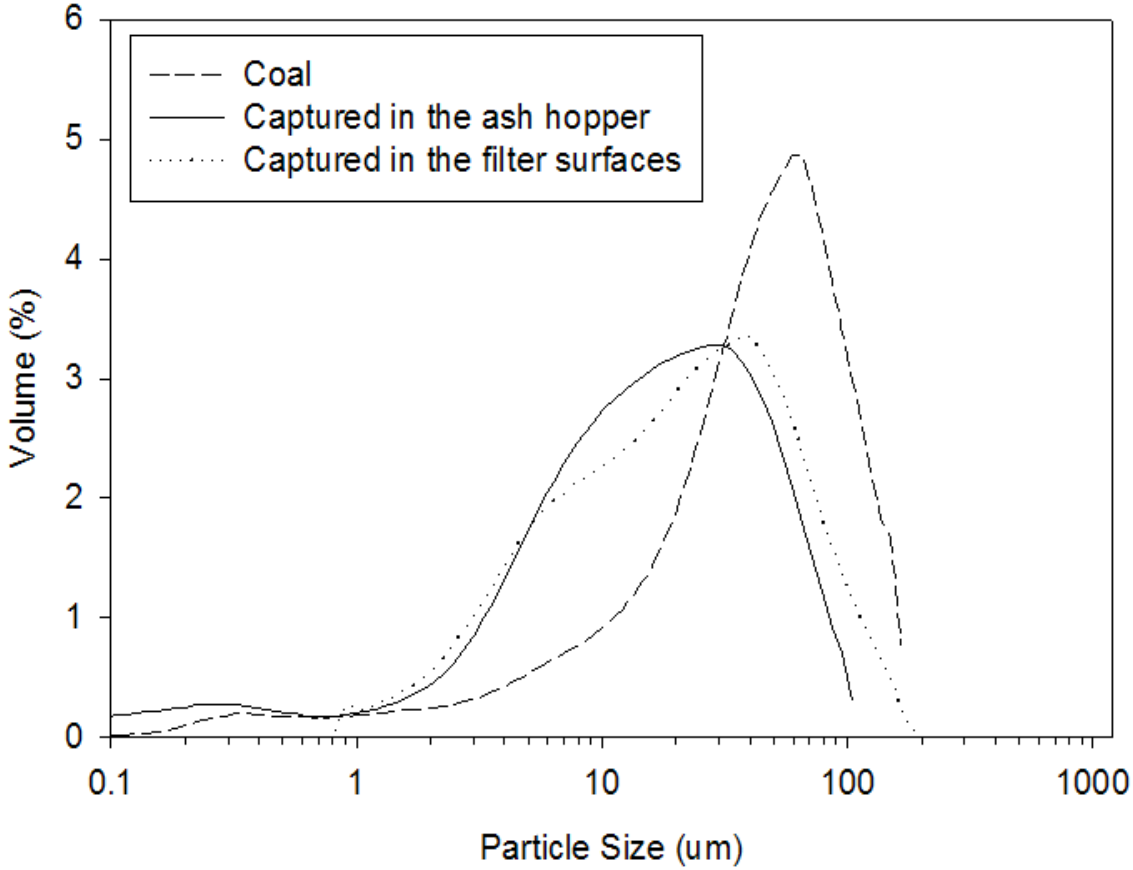


Syngas inlet pipe

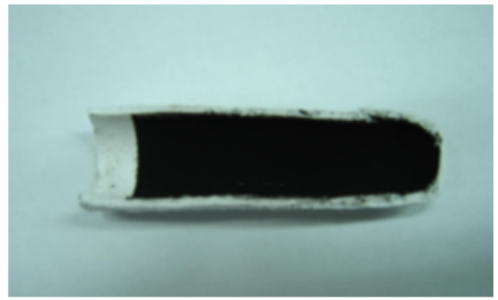
High Temperature Particulates Removal



Captured Particulates



Particle size 측정 결과



집진 전 분진 측정 결과
(5000-7000 mg/m^3)

집진 후 분진 측정 결과
(5-6 mg/m^3)

집진 효율: **99.8%**

Low-Temperature Desulfurization System for Syngas

Ventury

Spray Nozzle

H_2S Absorber

Demister

Reagent Regenerator

Control Panel

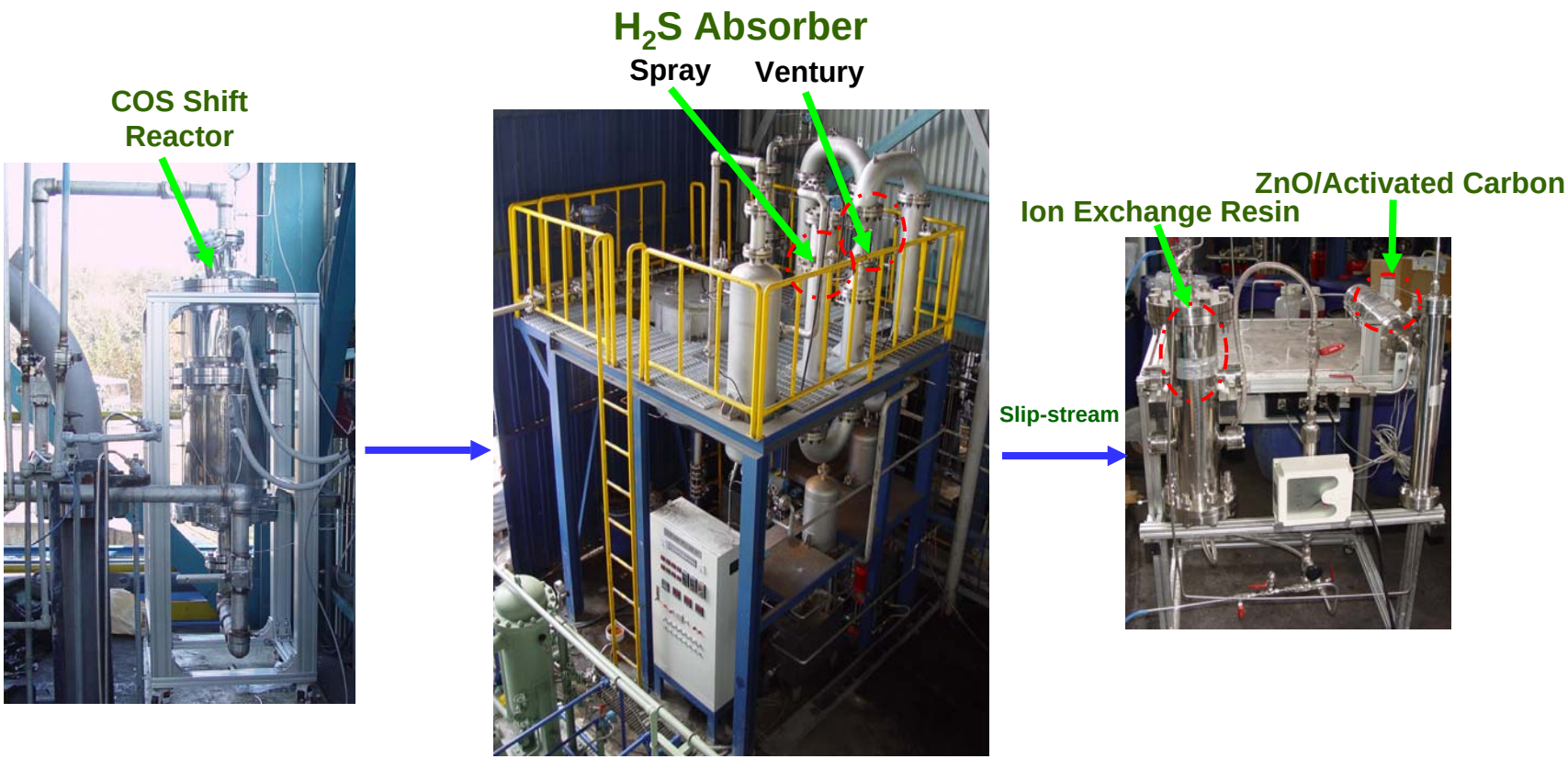
1. $H_2S + 2NaOH \Leftrightarrow Na_2S + 2H_2O$

2. $H_2S + 2Fe^{+++} = S + 2Fe^{++} + 2H^+$

$2Fe^{++} + 2H^+ + 1/2O_2 = H_2O + 2Fe^{+++}$

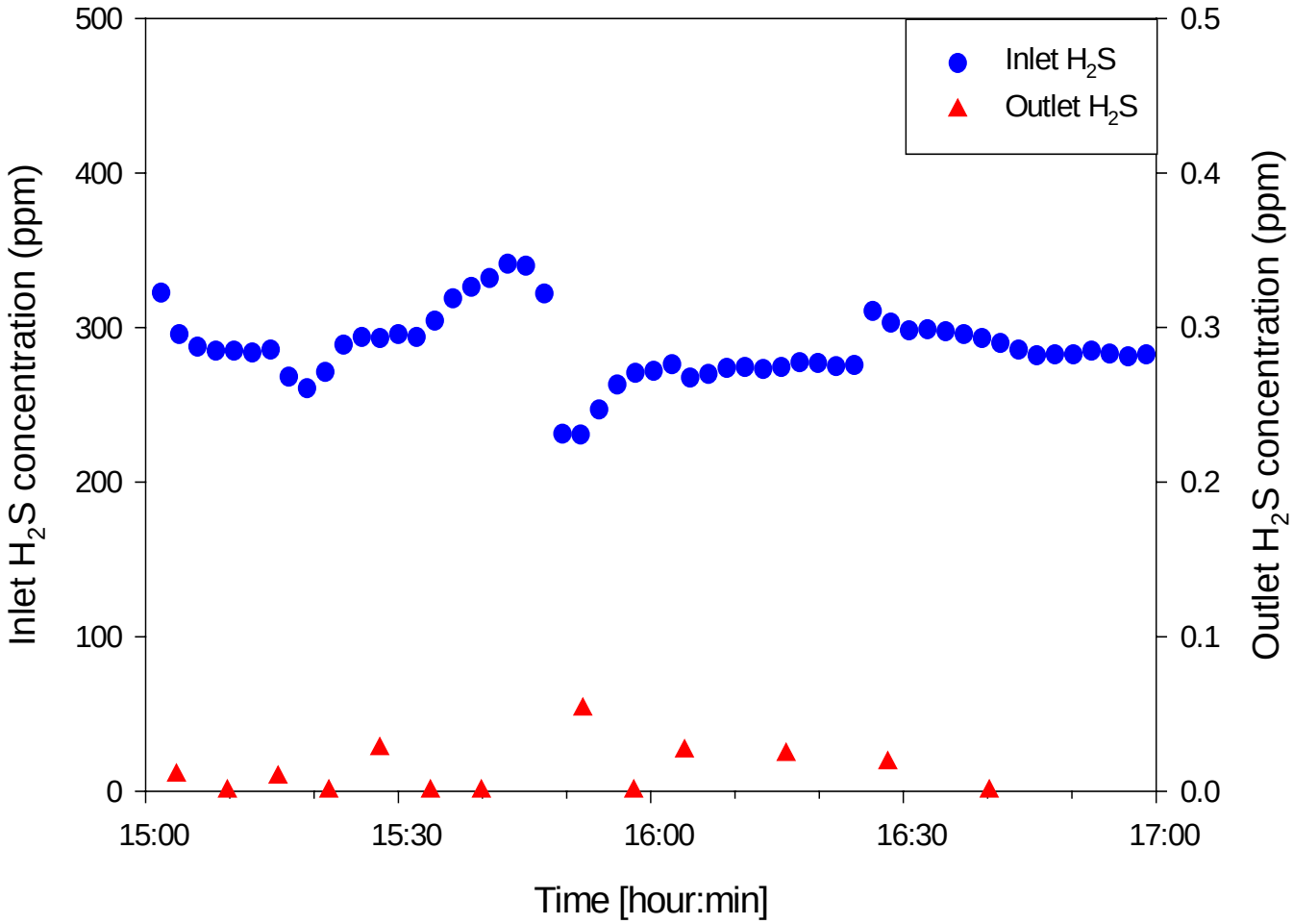
IAE

Low-Temperature Desulfurization System (COS Removal)



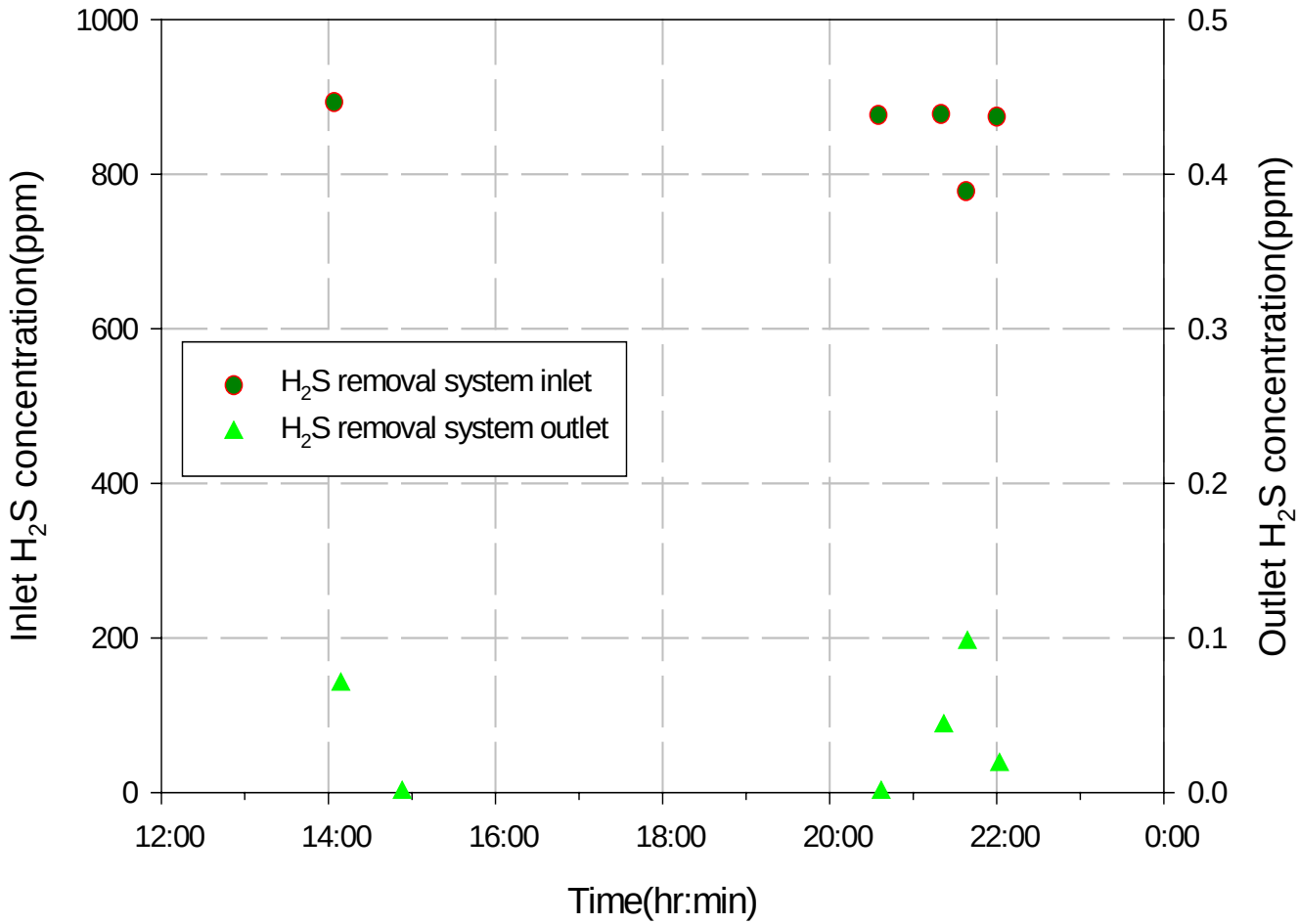
COS Shift Reactor | **H_2S Removal Facility** | **COS Removal (Adsorbing)**

H_2S Desulfurization

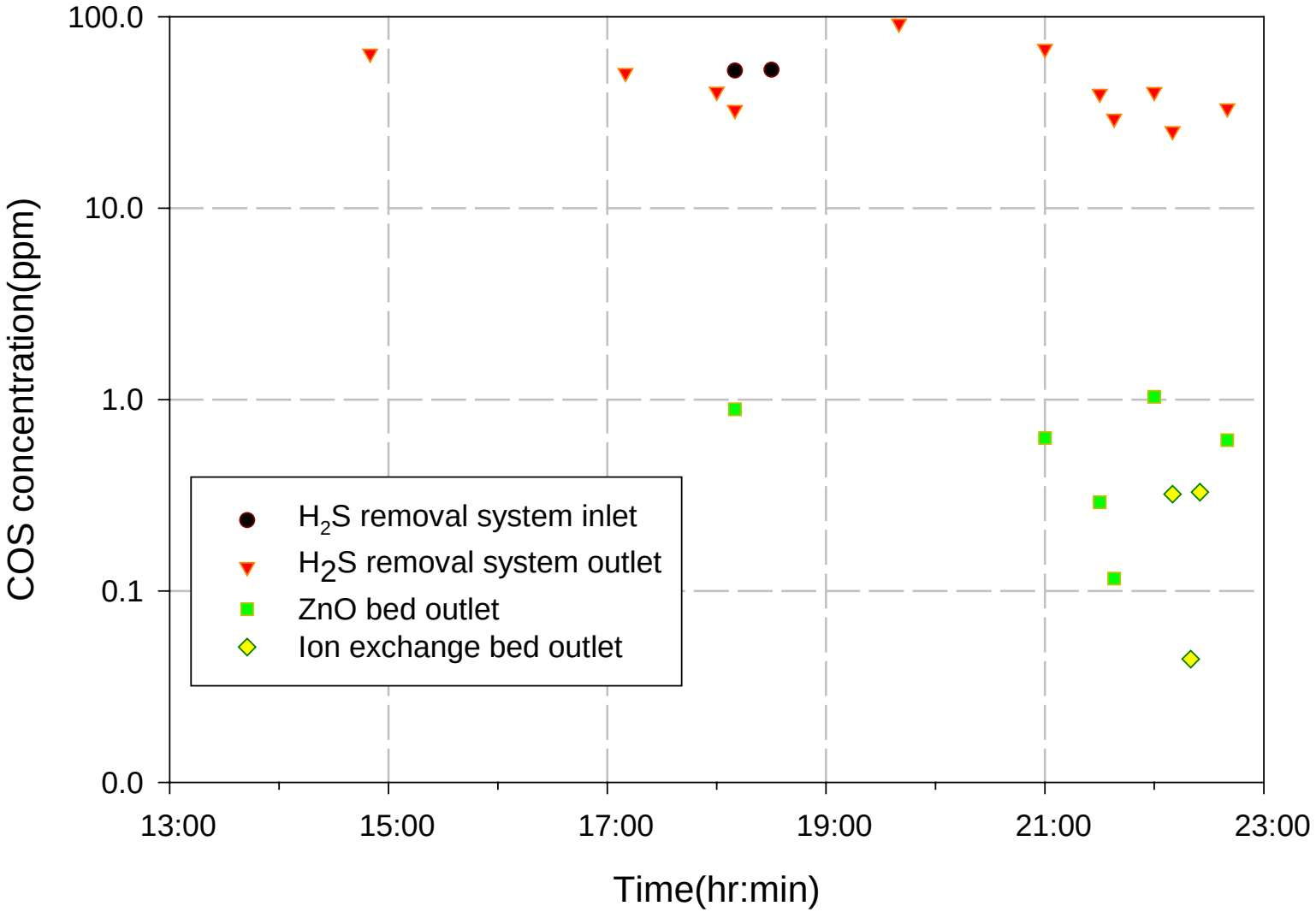


- Syngas from Indonesian Roto Subbituminous Coal (CO 37-45%, H_2 15-20%, CO_2 4-7%)

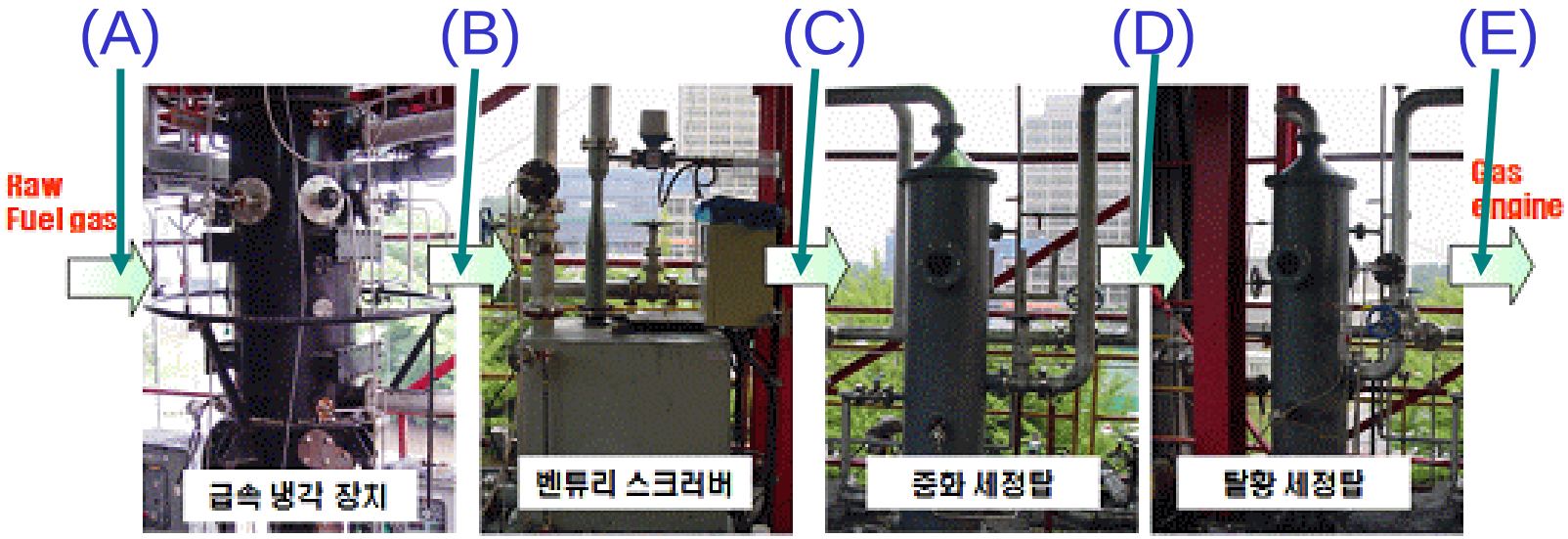
H_2S Desulfurization for Coal Syngas



COS Removal


100.0
10.0
1.0
0.1
0.0
COS concentration(ppm)
13:00
15:00
17:00
19:00
21:00
23:00
Time(hr:min)
H2S removal system inlet
H2S removal system outlet
ZnO bed outlet
Ion exchange bed outlet

Low-Temperature, Atmospheric Syngas Cleaning System



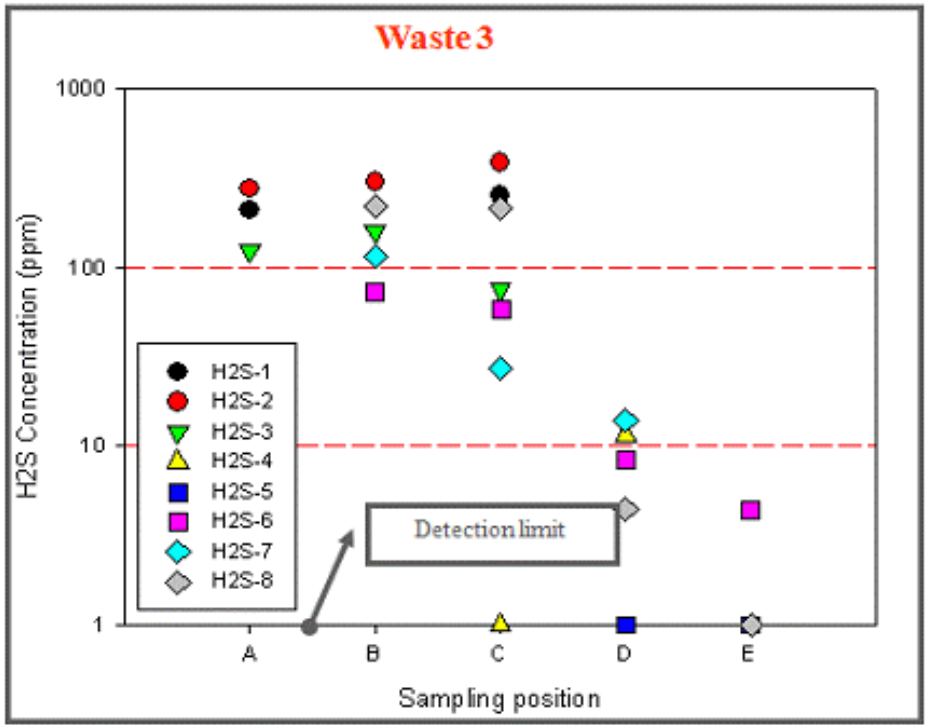
Minimize dioxin recombination

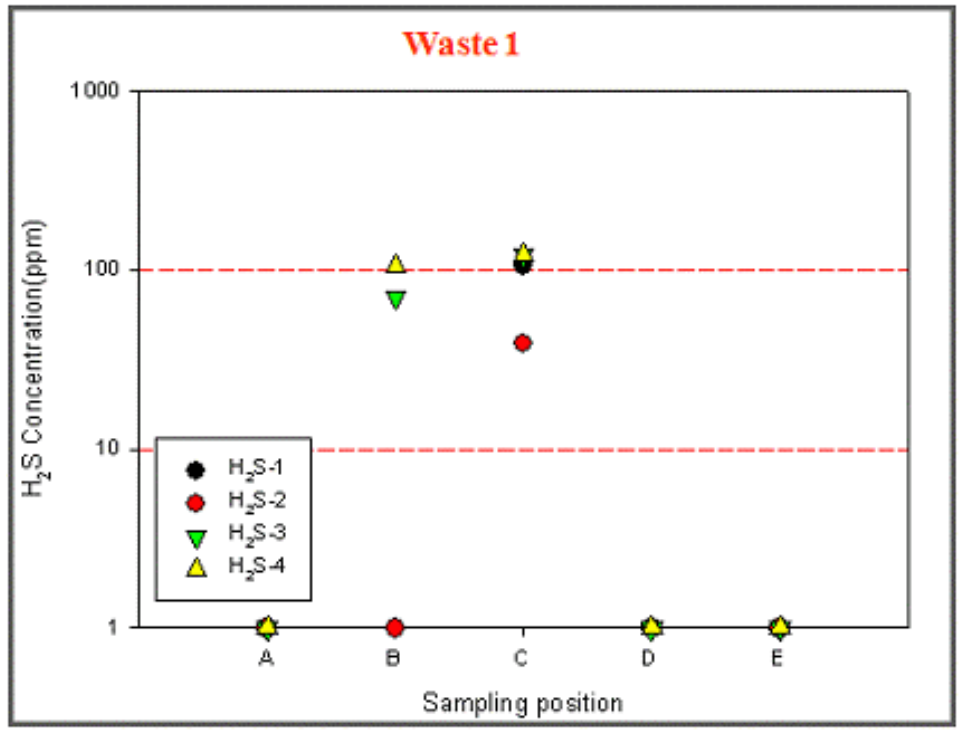
De-dusting

HCl removal

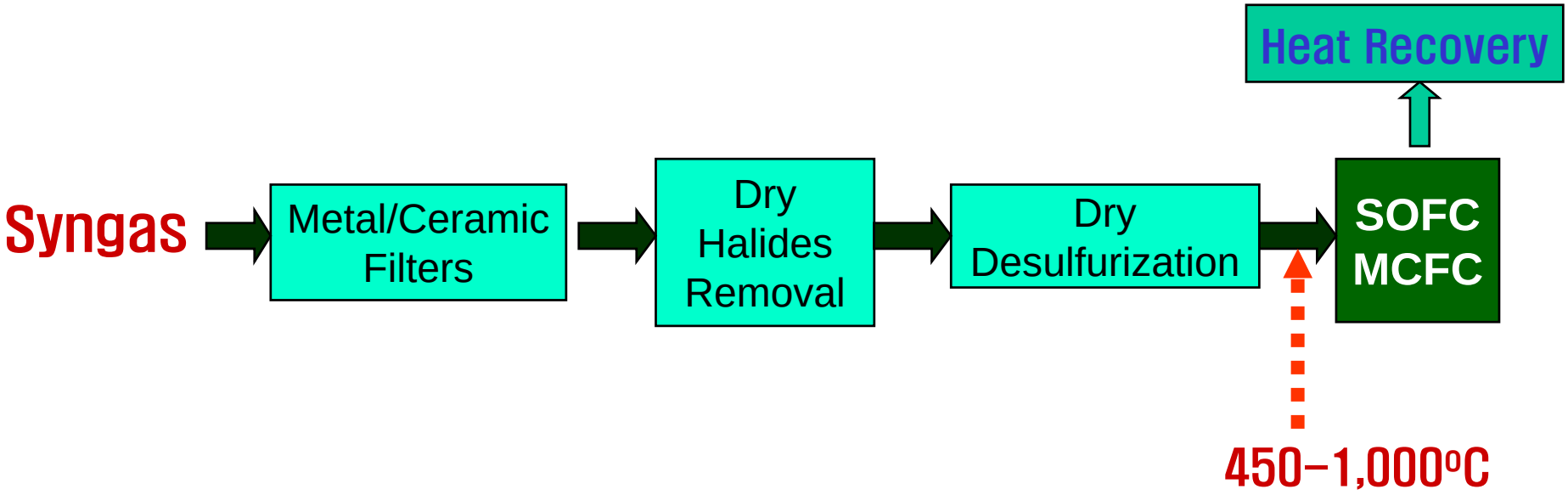
Desulfurization

H_2S Removal in Syngas from Waste Gasification





Dry Syngas Cleaning for Better Efficiency



- Low-temperature desulfurization : needs more complicated heat exchanging design to increase the temperature of cleaned syngas
- Problem of dry-type cleaning : only pilot-scale, few-month operation is possible. Commercially not proven.

Summary

- Use of renewable energy source like biomass and wastes to generate electricity at high efficiency requires to solve technical challenges in gas cleaning and durable fuel cells.
- SOFC should remain as a most promising candidate for utilizing the gasification syngas with a high efficiency.
- Pilot-scale tests demonstrated that simpler and cheaper methods are feasible in syngas cleaning to the level of less than 1 ppm.
- For higher energy efficiency, high temperature and dry-type syngas cleaning system is necessary. But, it's only at the pilot scale level.