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Comparison of Gasification Technologies for Coal and Wastes

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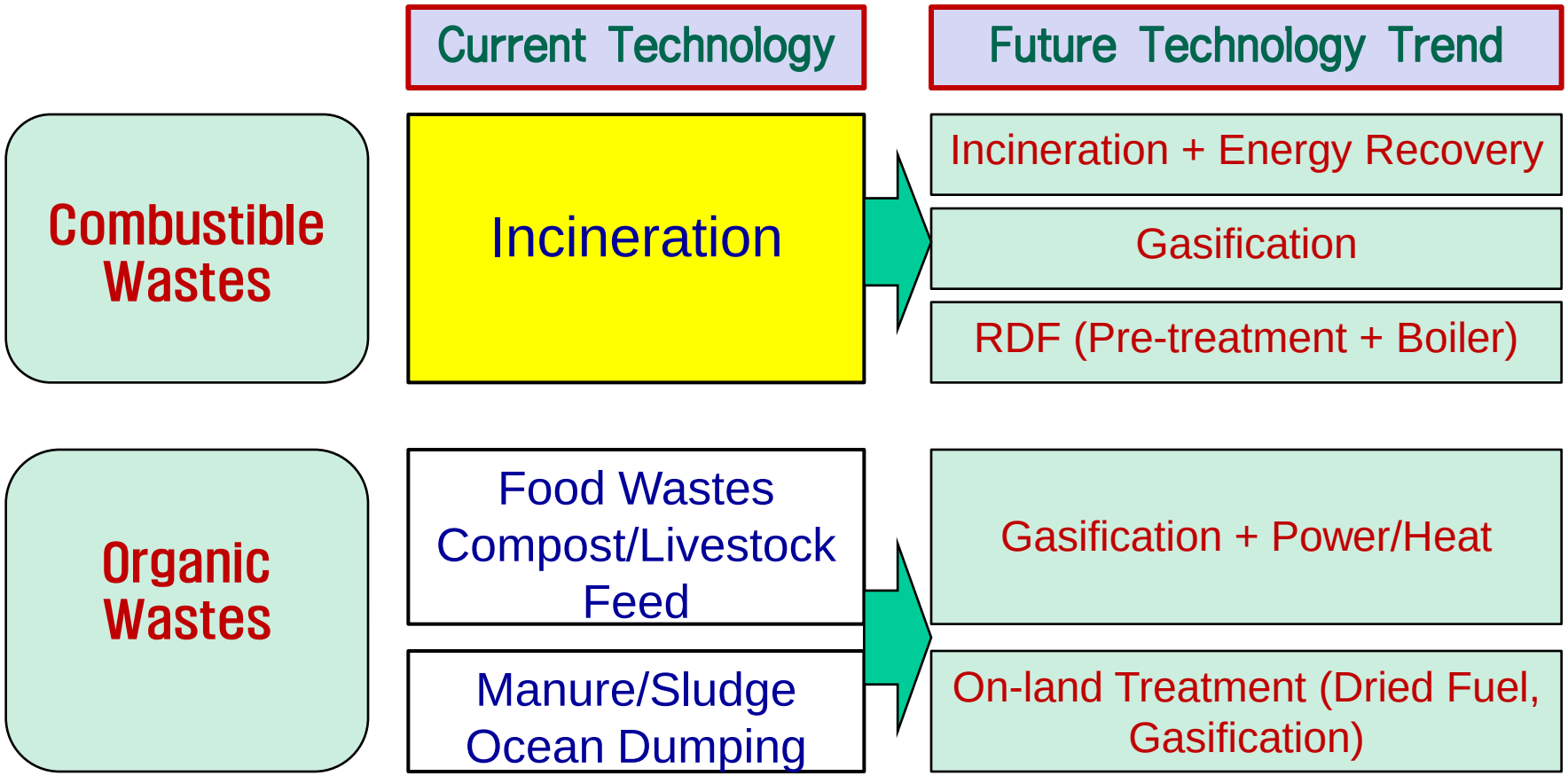
Background

- Many aspects in coal gasification have not yet applied to waste area. It is clear that a short-medium term goal in waste gasification is to catch up the already-achieved performance in coal gasification.
- When the waste amount is limited in supply, a better economical performance in waste gasification can be realized,
  - by higher efficiency gas engine, gas turbine
  - by converting syngas to more profitable chemical by-products (methanol, DME, etc.)
- Pyrolysis/gasification route for WTE requires a high capital investment while providing the valuable syngas of carbon monoxide and hydrogen that is the basic ingredient for petrochemical industry. With high capital cost per unit wastes, at least 50-100 ton/day scale plant should be constructed to ensure the economic competitiveness. Syngas can go to gas engine, gas turbine, or fuel cell after gas cleaning. If enough waste amount can be gathered and guaranteed, even investment for converting to synthetic diesel or DME(di-methyl ether), methanol can be rationalized at the time of peak oil.

Background

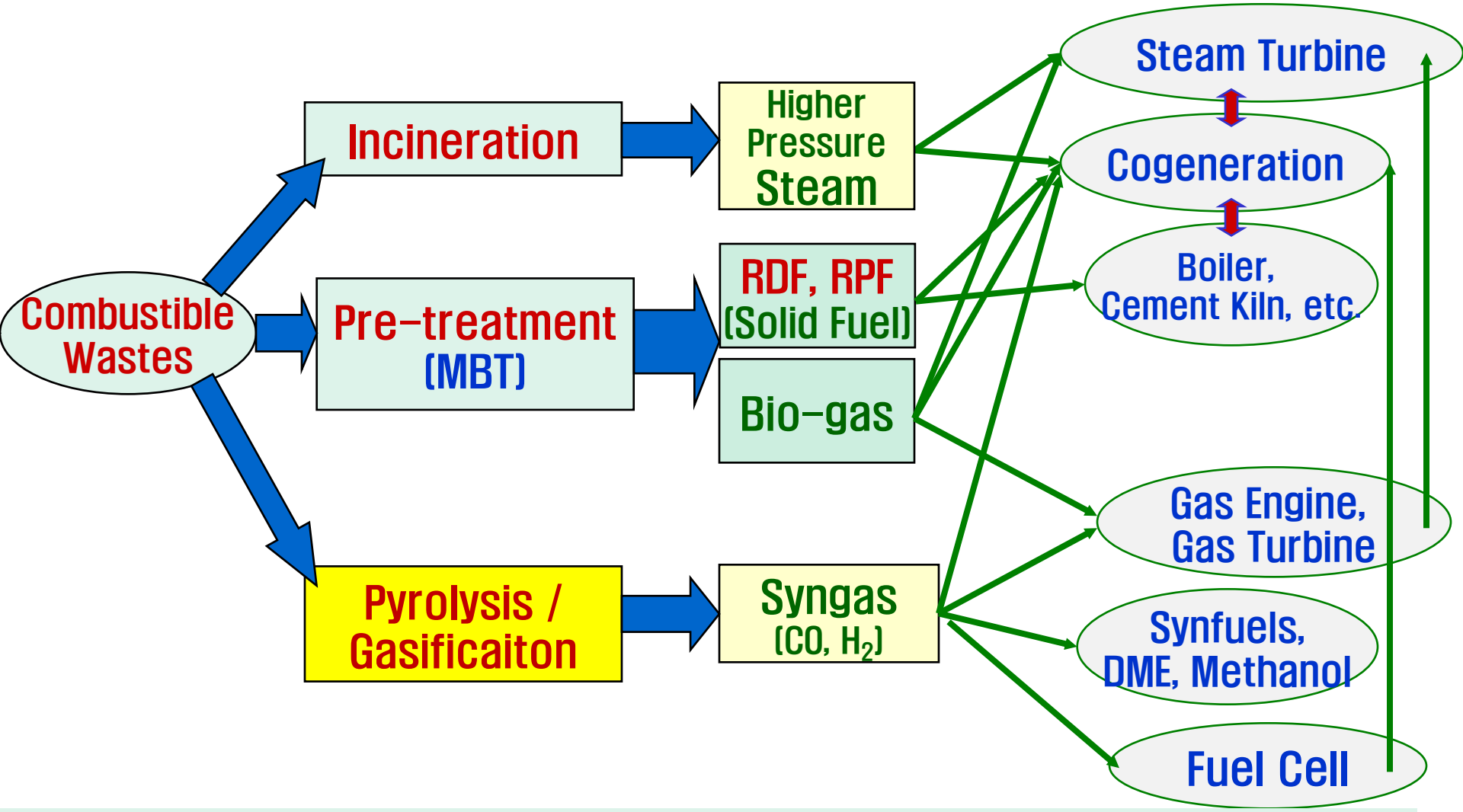
- In Korea, nine waste gasification facilities (30-150 TPDx2) were introduced to offset the NIMBY for waste incinerators during the 2003-2007 period. But, high operation cost causes delay of further installations.
- IAE has operated gasification pilot plants more than 20 years. Experiences in IAE on coal and wastes gasification might provide a useful guideline in future developments on wastes gasification.

Technology Trend for WTE



(Modified from MOE, KEITI presentation table)

Recent Trend in Key Technologies for WTE



- Recent trend in Korea is treating the wastes through pre-treatment in order to maximize the reuse of combustible and bio-digestible wastes similar to the policy that has been popular in Europe.

- MBT: Mechanical Biological Treatment, DME : Di-methyl Ether

Wastes Pyrolysis/Gasification Plants : Korea's Case

Location	Capacity (ton/day)	Feed Wasts	Constuction Co.	Technology Licenser	Type	Constructed Year
Koyang	150 × 2 ea	MSW	POSCO E&C	Nippon Steel (Japan)	Shaft	2006 (2010.2)
Hwasung	150 × 2 ea	MSW	GS + Hyosung Ebara	Ebara (Japan)	Fluidized	2007 (2010.10)
Yangsan	100 × 2 ea	MSW	POSCO E&C	Nippon Steel (Japan)	Shaft	2003 (2008.3)
Yangjoo	100 × 2 ea	MSW	Dongbu	Mitsui (Japan)	Rotary Kiln	2005 (2009.12)
Pankyo	45 × 2 ea	MSW	Halla	Kobelco (Japan)	Fluidized	2006 (2009)
Daegu	70	MSW	Hyosung Ebara	Ebara (Japan)	Fluidized	(2010)
Eunpyung, Seoul	48	MSW	GS + Hyosung Ebara		Fluidized	2006 (2008.10)
Pajoo	48	MSW	Halla + Daewoo	Kobelco (Japan)	Fluidized	(2011.2)
Yangyang	30	MSW	Daewoo + Halla	KIMM (Korea)	Fixed	(2008.6)
Kaeryong	25	MSW	Young Eng.	Young Eng. (Korea)	Plasma	(2006.7)
Chungsong	10 (Pilot)	MSW	GS Platec	GS Platec (Korea)	Plasma	2008

25-150 ton/day capacity

Issues

- **Complexity by syngas → Expensive :**
  - Since syngas contains a harmful gas composition like CO, and explosive gas like hydrogen, plants involving the gasification process show much higher construction and operating costs.
  - It means, in general, that a bigger scale plant in gasification should be economical simply because syngas requires more complex design, control, and safety facilities.
- **Competing technologies :**
  - Competing technologies based on combustion and incineration have attained an optimized mature technology level after several decades of upgrading.
- **Market :**
  - Many cases, first-of-the-kind plant → Trial errors
  - Gasification-based plants should show a clear advantage in certain points to be chosen as a waste-to-energy technology option.

Issues

- **Feed Availability → Plant Size (Economies of Scale) :**
  - Most prominent issue in developing waste-to-energy plants resides in securing enough feed material that can sustain the operation.
  - Coal is more readily available in quantity.
  - Coal gasification plant could employ high pressure gas turbines which is only economical when the plant capacity is well over 1,000 ton/day.
  - Typical waste gasification has a capacity of 30-250 ton/day, mainly because of available wastes amount.
- **Gas turbine vs. Gas engine :**
  - Due to the bigger plant size in coal applications, expensive gas turbine can be applied → higher efficiency by combined cycle in power generation.
  - Gas turbine requires a high pressure feed inlet and thus a pressurized gasifier is usually applied.
  - Gas engine is typically used in waste gasification, simply because the plant size cannot accommodate the expensive gas turbine system.
  - Earlier expectation for the cheap and reliable micro gas turbine has resulted in failure to the anticipated market.

Typical Electrical Generation Tool Using Syngas

Energy conversion device	Net electrical efficiency of gasification plant	Main advantages	Main disadvantages
Steam turbine	15–24%	High electrical efficiency. Turbine components are isolated from combustion products. Long maintenance intervals, high availability. High specific work (kJ/kg yielded for working fluid)	Expensive. Partial load decreases efficiency significantly. Plants is extremely large due to space requirements for the condenser and the heat recovery steam generator (HRSG)
Gas turbine	20–30%	High electrical efficiency. Compact assembly. Long maintenance intervals, high availability. Ideal for cogeneration plants (CHP) due to high exhaust temperatures	Turbine components are exposed to combustion products. Partial load decreases efficiency significantly. Moderately expensive
Gas engine	14–26%	High electrical efficiency. Relatively inexpensive. Durable and reliable. Partial load effects efficiency only marginally	Engine components are exposed to combustion products.Short and expensive maintenance intervals, low availability

Coal vs. Waste Gasification : Technical Aspects

Item	Coal Gasification	Waste Gasification
Gasifier Type	Fixed, Fluidized bed, Entrained	Fixed, Fluidized bed, Entrained, Plasma, Rotary Kiln
Gasifier Pressure (typical, bar)	22~42	1~10
Gasifier Size (typical, Ton/Day)	600~3,000	30~250
Heat Recovery	**Radiant**, Convective	Convective
Electricity Generation Tool	Gas turbine+Steam turbine (Combined Cycle)	Gas engine, (Future) Micro gas turbine
Electricity Generation Efficiency	38~42%	15~30%
Oxidant (typical)	O_2	Air
Feed Availability	Relatively Good	Mostly Limited
Competing Technologies	Ultra-supercritical(USC) power generation	Incineration, MBT + Energy recovery

*MBT : Mechanical Biological Treatment

Coal vs. Waste Gasification : Economic/Social Aspects

Item	Coal Gasification	Waste Gasification
NIMBY	Yes	Yes
CO_2 Issue	Big, Current	Limited
New/Renewables Applicability (Incentives)	No (New Energy in Korea)	Yes (only applicable to bio-degradables in European Union)
Market Players	Oligopoly by major big companies	Mid-size companies + Some major companies
Recent Market Direction	Poly-generation (Electricity/ SNG/DME/Chemicals)	Combined Heat & Power
Key Technical/ Economic Limitations	- Plant availability less than 80 % in IGCC - Expensive construction/ operating cost	- Difficulty in securing >1,000 TPD plant - Feed separation - Severe environmental regulations than coal case

*IGCC : Integrated Gasification Combined Cycle, SNG : Synthetic Natural Gas, DME : Di-Methyl Ether

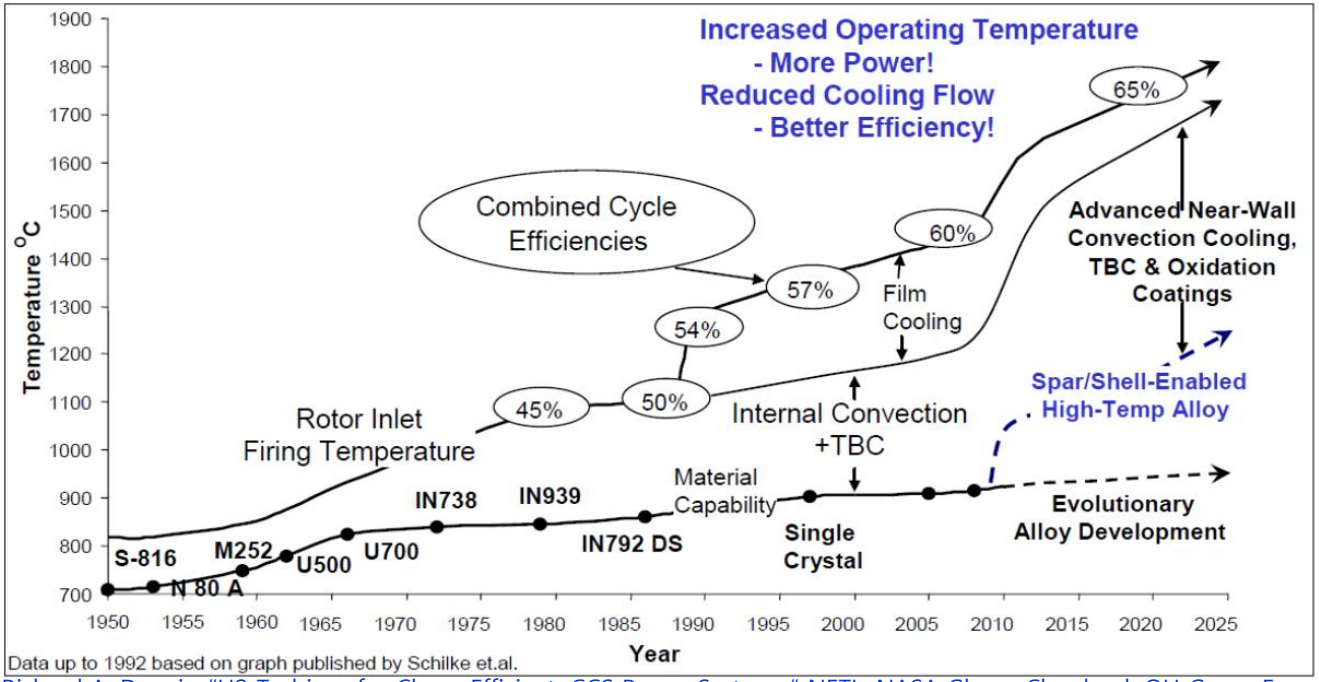
Background for Applying Gasification for Coal Power Plants

Key Words :

- **High Efficiency**: Due to increase in Gas Turbine efficiency
- **Poly-generation**: Power + Synthetic fuel + Hydrogen + Chemicals
- **CO_2**: Favorable in capture
- **Low-rank coal**: Large reserve, Low price
- **Disadvantages**: High captital cost, Low availability

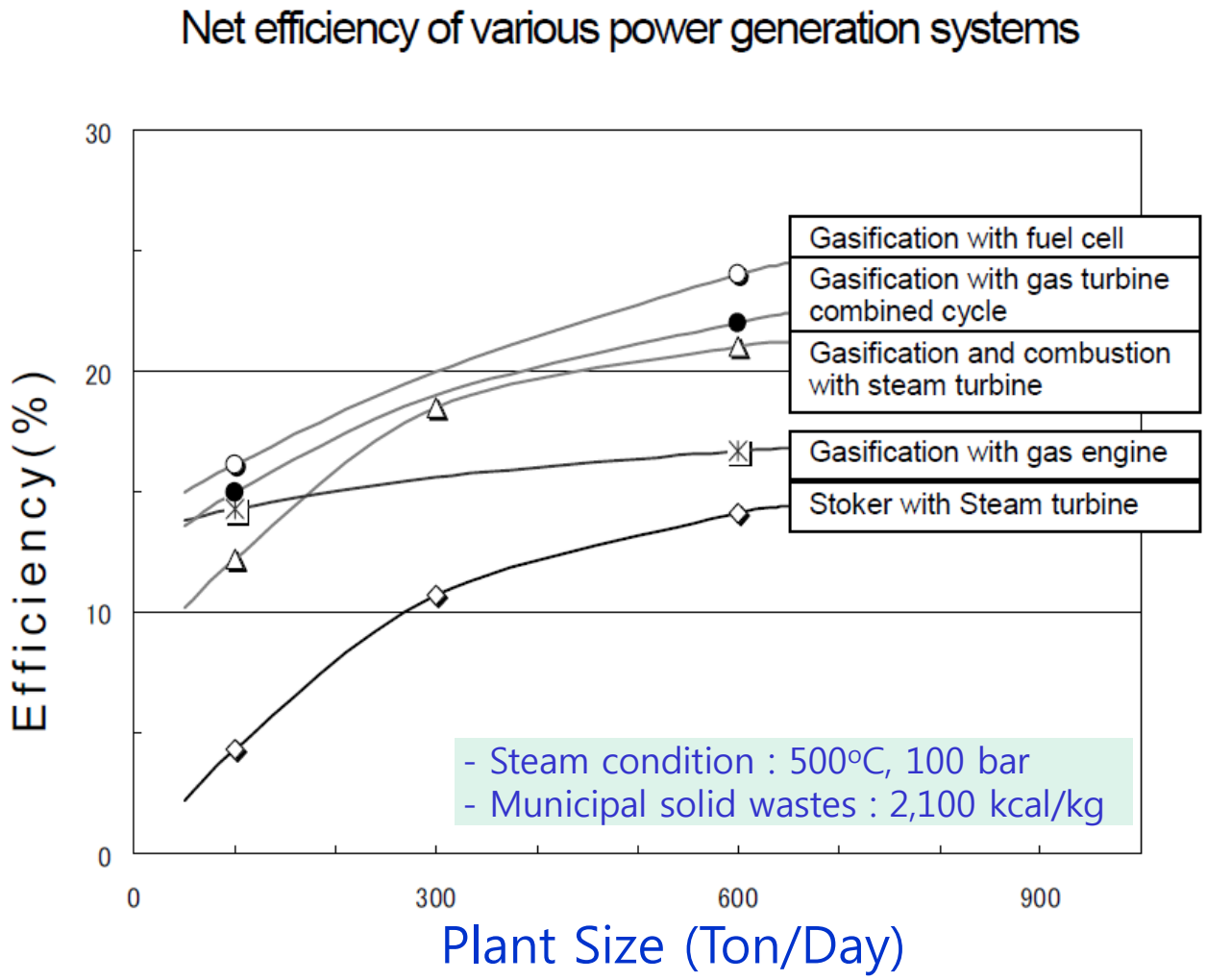
Increase in Gas Turbine Efficiency :

- **IGCC** : Combined Cycle (Gs Turbine + Steam Turbine)
- **Conventional Coal Power Plants** : Only Steam turbine



Source: Richard A. Dennis, "H2 Turbines for Clean, Efficient, CCS Power Systems," NETL, NASA Glenn, Cleveland, OH Green Forum, 2009/9/22.

Net Efficiency Comparison with Treatment Options



Source: Satoshi Atoji, et.al., "A Total System Optimization Study of Waste Pyrolysis and Gasification Process for Electric Power Generation," 14th International Conference on the Properties of Water and Steam in Kyoto, 2004.

Definition of New & Renewable Energy in Korea

	Energy Source		IEA	EU	USA	JAPAN	CHINA	KOREA	AUSTRALIA	FRANCE	S. AFRICA	UK
Renewable Energy	Hydro	Large Hydro	○	×	○	×	○	○	○	○	○	○
		Small Hydro	○	○	○	○	○	○	○	○	○	○
		Pumped Storage Power Generation	×	×	×			×				
	Geothermal	Power Generation	○	○	○	×	○	○	○	○		
		Heat Pump	×	×	×	○						
	Solar Energy	Photovoltaic	○	○	○	◎	◎	◎	○	○	○	○
		Solar Heating	○	○	○	○	○	○		○		
		Solar Heat Electricity Generation	○	○	○		○	○	○		○	
		Passive Solar	×	○	×	○	○	×				
	Sea Power		○	○	○	×	○	○	○		○	○
	Wind Power		○	◎	○	○	◎	◎	○		○	○
	Biomass	Solid Biomass	○	○	○	○	○	○	○	○	○	○
		Biomass Gas	○	○	○	○	○	○	○	○	○	○
		Liquid Biomass	○	○	○		○	○		○		
		Black Liquor				○		×	○			
	Wastes	Renewable Municipal Wastes	○	○	○	○		○	○	○	○	○
		Non-renewable Municipal Wastes	×	×	×	○		○				○
		Industrial Wastes	×	×		○		○				○
		Non-specific Combustible Renewables	×	×		○		○				○
		Waste Heat from Wastes	×	×		○		○				○
		Food Wastes				○		×	○			
	Temperature Difference Energy		○	○	×	○		×				
New Energy	Fuel Cell							◎				
	Gasification/Liquefaction of Coal							○				
	Hydrogen				○			○				

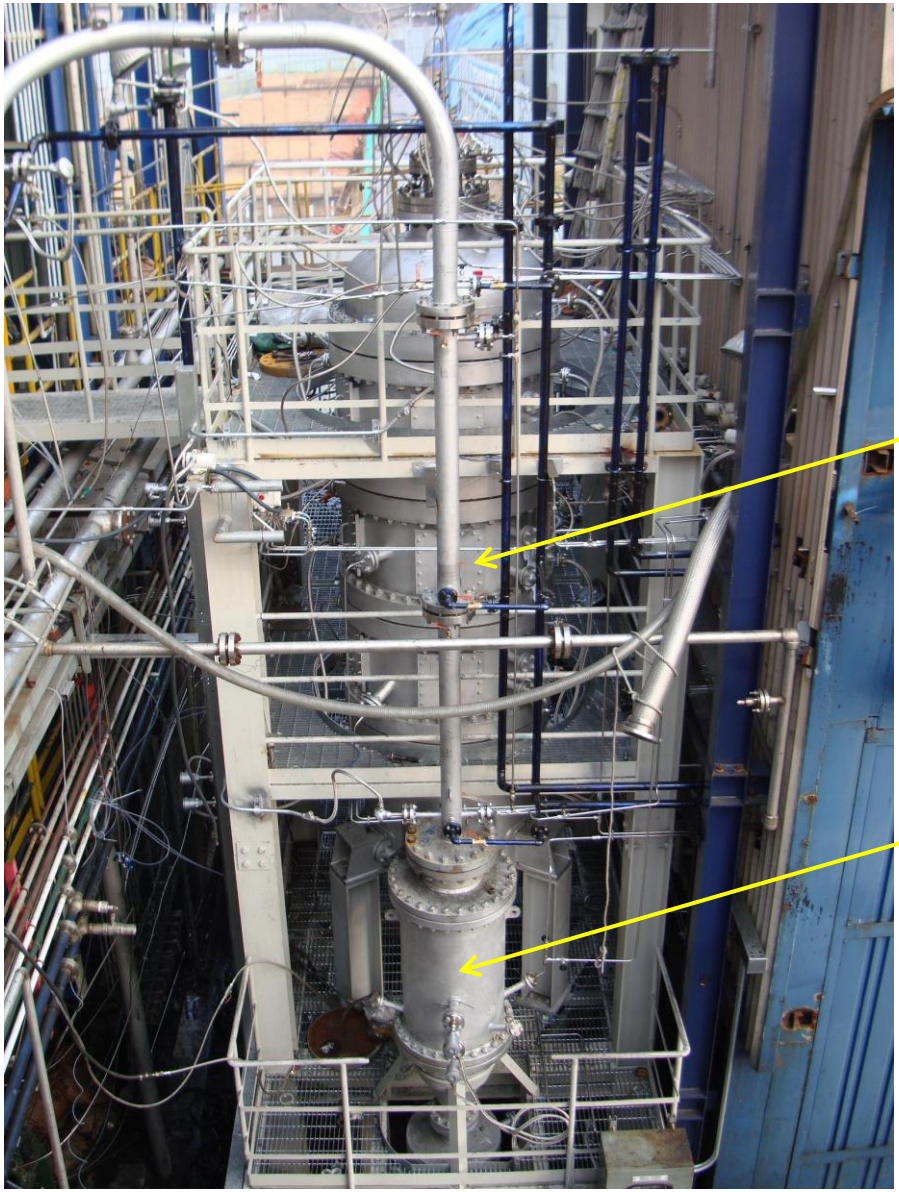
Coal Gasification Facility in IAE (3 Ton/Day)
(Entraind-bed, Slagging)

Operated from 1995
(Max. Pressure: 28 bar,
Max. Temperature: 1550°C)

Coal Gasification Facility in IAE (2 Ton/Day)
(Entrained-bed, Non-slagging)

Hot Syngas Metal Filtering

Syngas to High Temp. Metal Filter



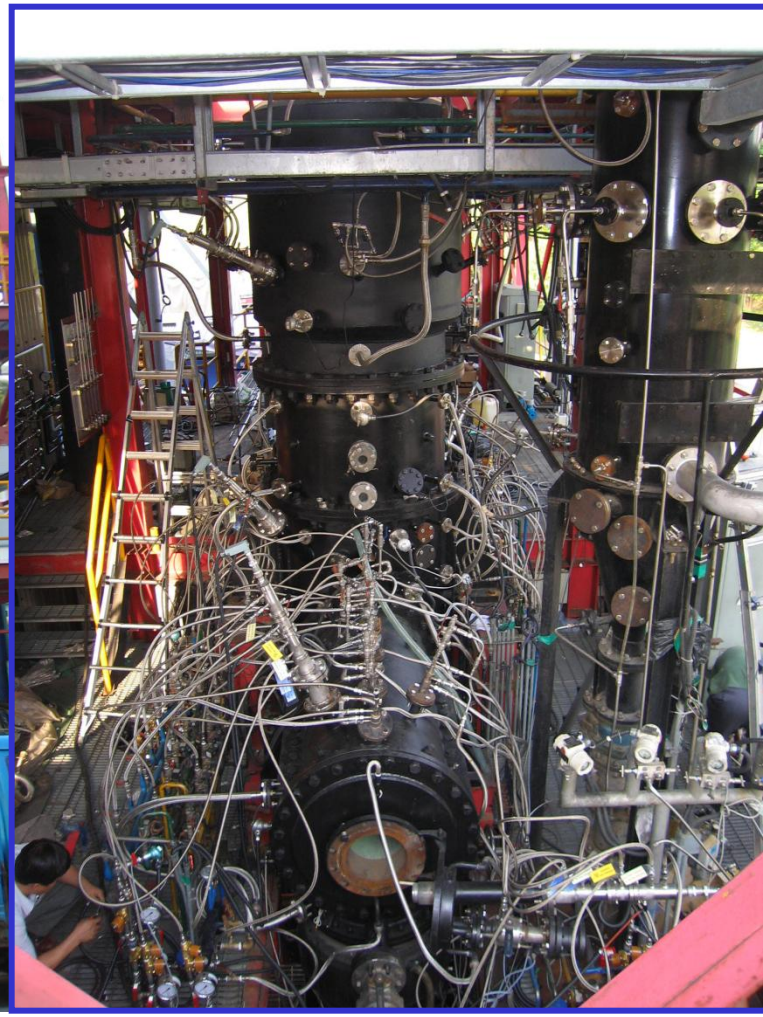
Gasifier

Cyclone

Waste Gasification Facility in IAE (1 Ton/Day)
(Entrained-bed, Slagging)

Capacity : Waste-oil 1 ton/day, Max. 10 bar operation

Waste Gasification Facility in IAE (5 Ton/Day)
(Fixed-bed, Slagging)



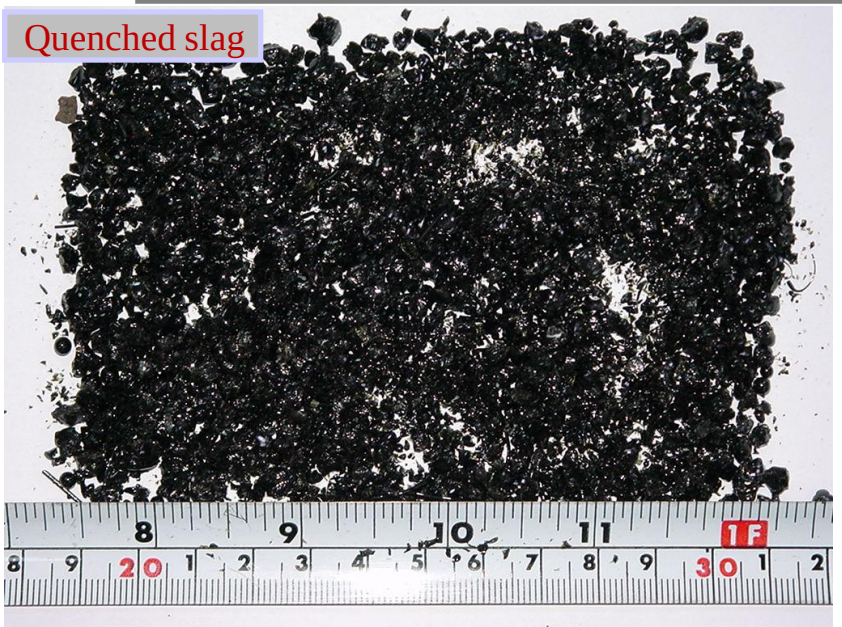
Coal Gasification : Slag, Syngas flame

Produced slags after the gasification
(5-10 bar, 1450-1500°C)

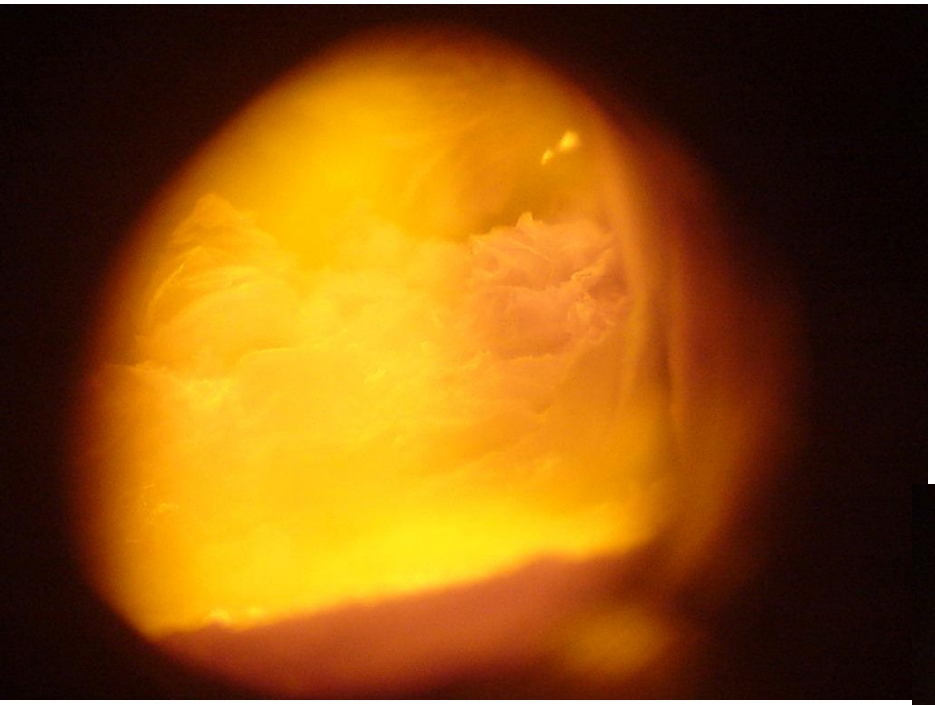
(Unit: cm)

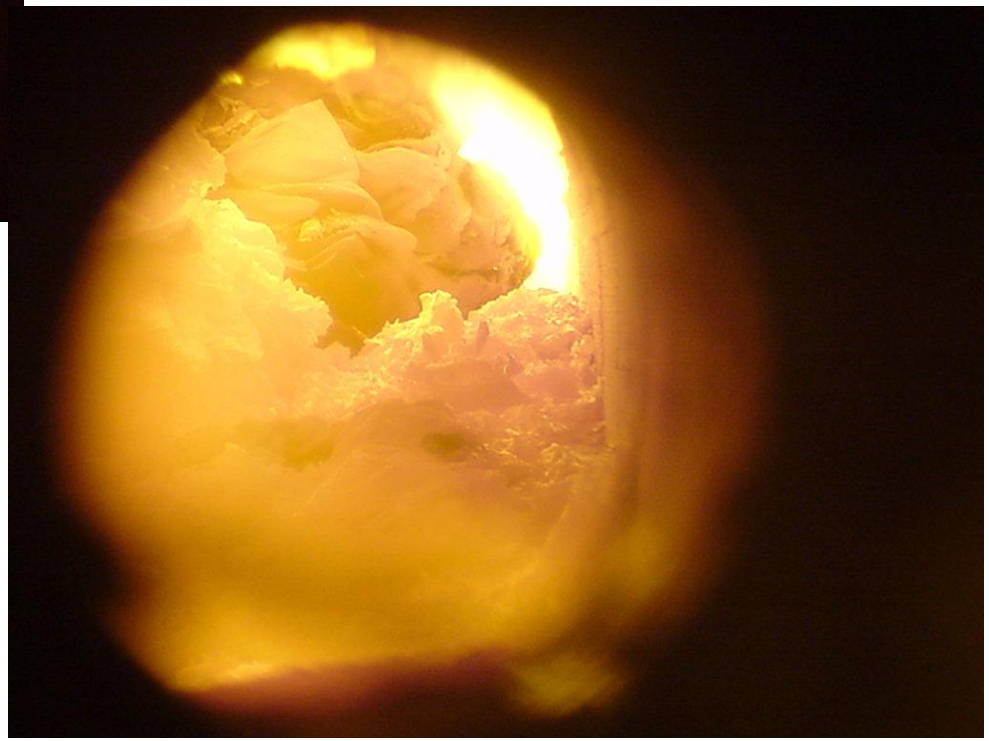
Combustion flame of syngas

Waste Gasification : Slag from 30-50 wt% Moisture MSW

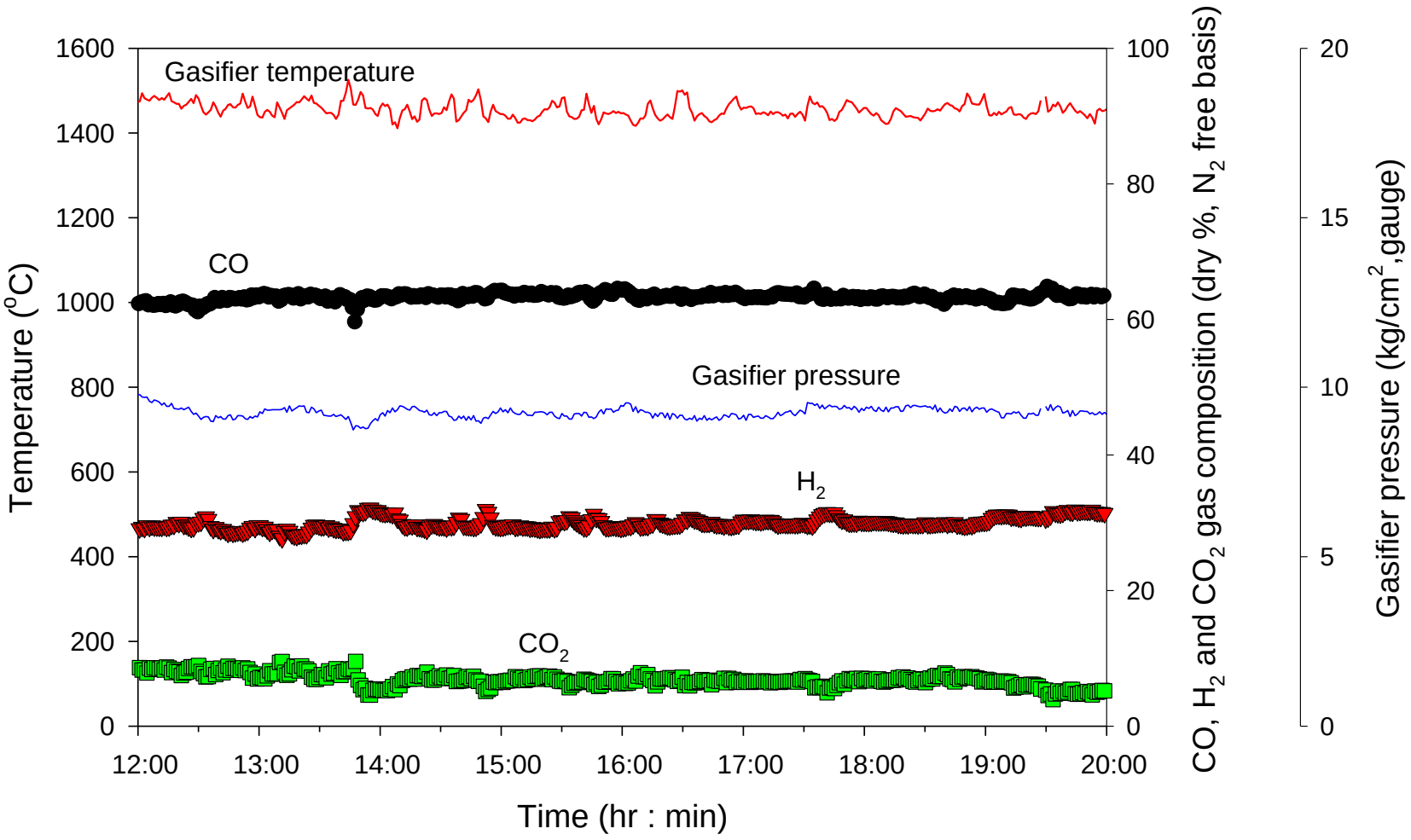


View of Waste Gasification/Melting Main Section



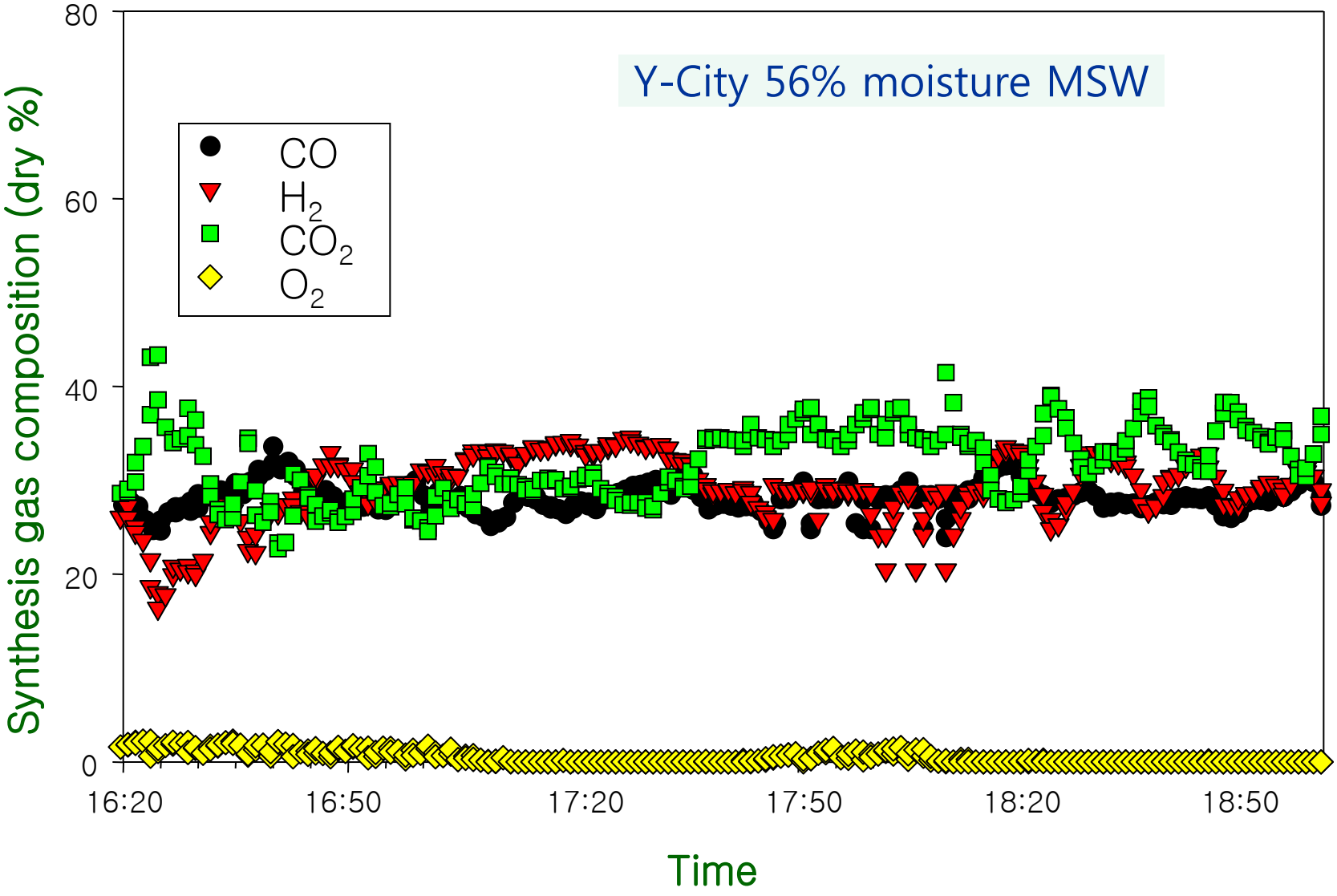


Coal Gasification : Typical Operation Profiles



(Indonesian Adaro coal)

Waste Gasification : Typical Syngas composition



Conclusions

- Waste gasification has not yet attained fully matured technical status, and needs to learn much from coal gasification advances.
- Coal gasification has its own problems in high construction/ operation costs. Similarly, waste gasification should sought a cheaper version of next generation equipments (relative to stokers).
- Without the cheaper and easy-to-operate gasification technology for wastes, it's difficult to compete with already-matured technologies like incinerators. Sometimes, subsidy like RPS will help.
- High moisture-containing MSW actually provides suitable syngas for DME manufacturing.
- Realizing higher plant availability and lower cost are key factors, and need to improve manufacturing capability in nearby areas to lower the cost.


Discussion