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Bio-DME production using Modular Slurry Phase DME Synthesis Process

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RenFuD Corporation

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Contents

Introduction of RenFuD Corporation

- RenFuD: Renewable Fuel Development

  Technical consulting company established in 2009.

- DME related conceptual studies conducted on;

  DME production from Renewable hydrogen

  DME production from Biomass

  DME production from Oxygen blast furnace gas

  DME production from Brown coal with Renewable Hydrogen

  Comparative study of Hydrogen carriers

- Experimental study of DME synthesis from Bio-derived gas

- RenFuD has taken over the global right of Process licensing and proprietary catalyst supply of Slurry phase DME synthesis process in 2016.

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DME Production Technology

- **Two step process (Methanol synthesis +Dehydration)**

(1) Methanol synthesis: $4H_2+2CO \rightarrow 2CH_3OH$

(2) Dehydration of Methanol: $2CH_3OH \rightarrow CH_3OCH_3+H_2O$

- **One step process (Slurry Phase DME Synthesis)**

In addition to the above reactions (1) and (2), (3)Water gas shift reaction is promoted in One Single reactor.

(3) Water gas Shift reaction: $H_2O+CO \rightarrow H_2+CO_2$

(4) DME synthesis: $3H_2+3CO \rightarrow CH_3OCH_3+CO_2$

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Characteristics of DME Direct synthesis process

[1]Catalyst system for DME synthesis reaction

・3 function (Methanol synthesis +Dehydration +Shift) catalyst system realizes DME synthesis reaction with high equilibrium conversion from syngas of $H_2/CO=1$. This ratio is adequate for carbon rich resources

・Proprietary catalyst with high conversion and selectivity in slurry phase

[2]Slurry phase reactor

・Effective heat conductivity of slurry is high, homogeneous temperature distribution is realized without hot spot

・Heat transfer coefficient is so high that heat removal from reactor is easy

・Catalyst exchangeable during the operation

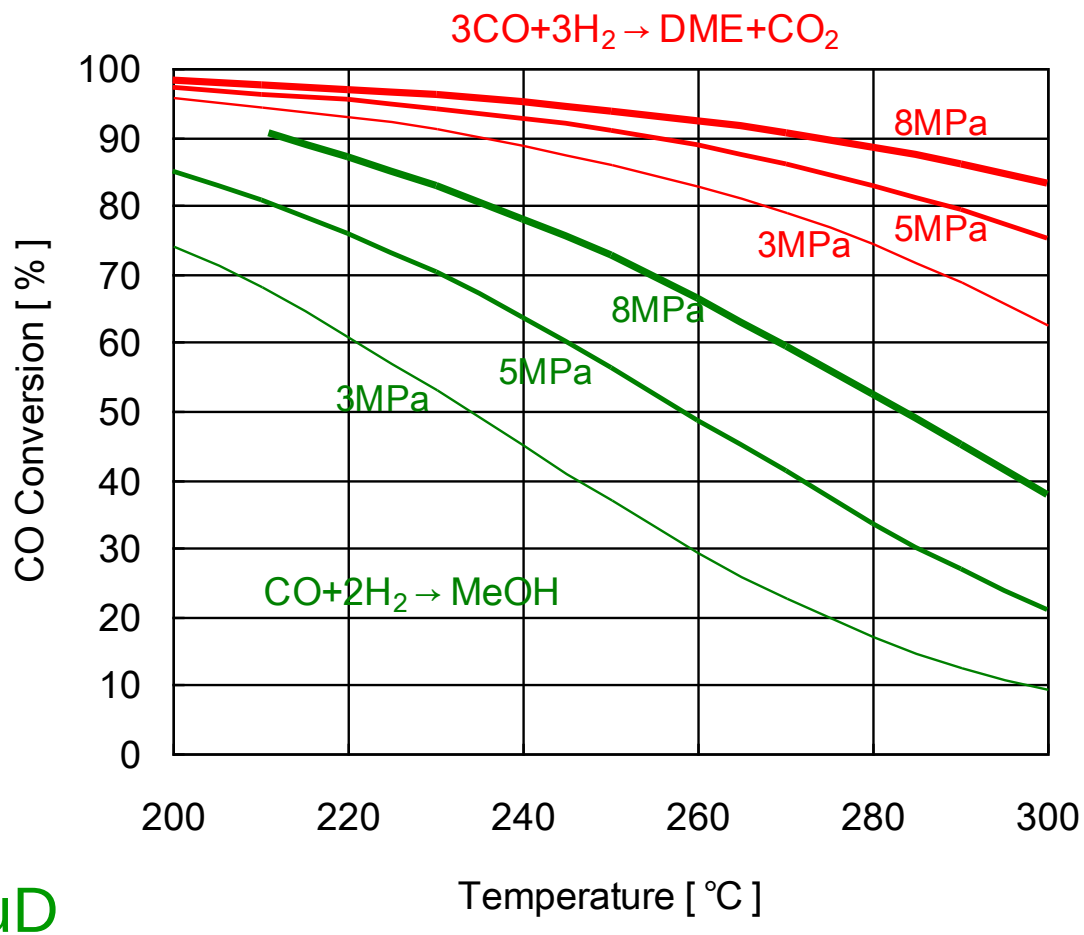
[3]Separation of produced DME

・Little water by-production enables DME separation at chilled temperature

・ CO_2 is separated by being absorbed in DME

Equilibrium CO conversion

- DME synthesis has higher equilibrium conversion than Methanol synthesis at lower pressure.



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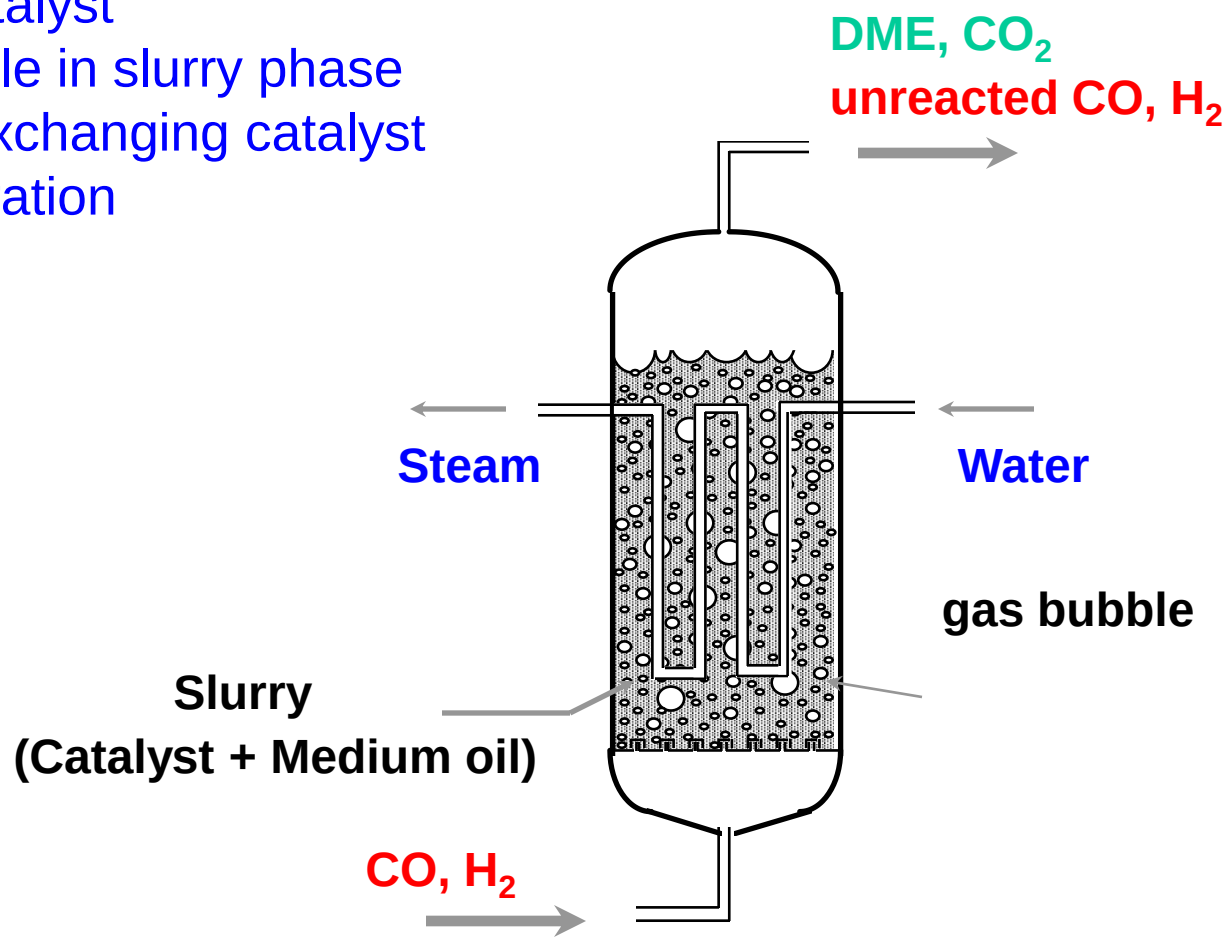
Slurry Phase Reactor for DME Synthesis

- Homogeneous temperature distribution to be controlled easily, adequate for highly exothermic reaction
- Proprietary Catalyst
  active and stable in slurry phase
- Possibility of exchanging catalyst during the operation



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Technology Development and Transfer to RenFuD

• Slurry phase DME synthesis process had been developed by NKK (now JFE), stepwise starting from beaker scale, through bench scale, to 5 ton/day pilot plant with its own proprietary catalyst since 1989.

• From 2001 to 2007, 100 ton/day demonstration plant project was successfully conducted by DME Development Corp. funded by 10 companies. The process performance, catalyst life and long-term stable operation have been demonstrated for a commercial scale technology.
With this technical success, feasibility studies of commercial scale DME production from natural gas or coal were conducted.

• With change of JFE's management policies, four companies (Total, JAPEX, INPEX, Toyota Tsusho) succeeded the technology in 2010.

• In 2016, those four companies have transferred the technology patents to RenFuD Corporation.

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DME 5ton/day Pilot plant

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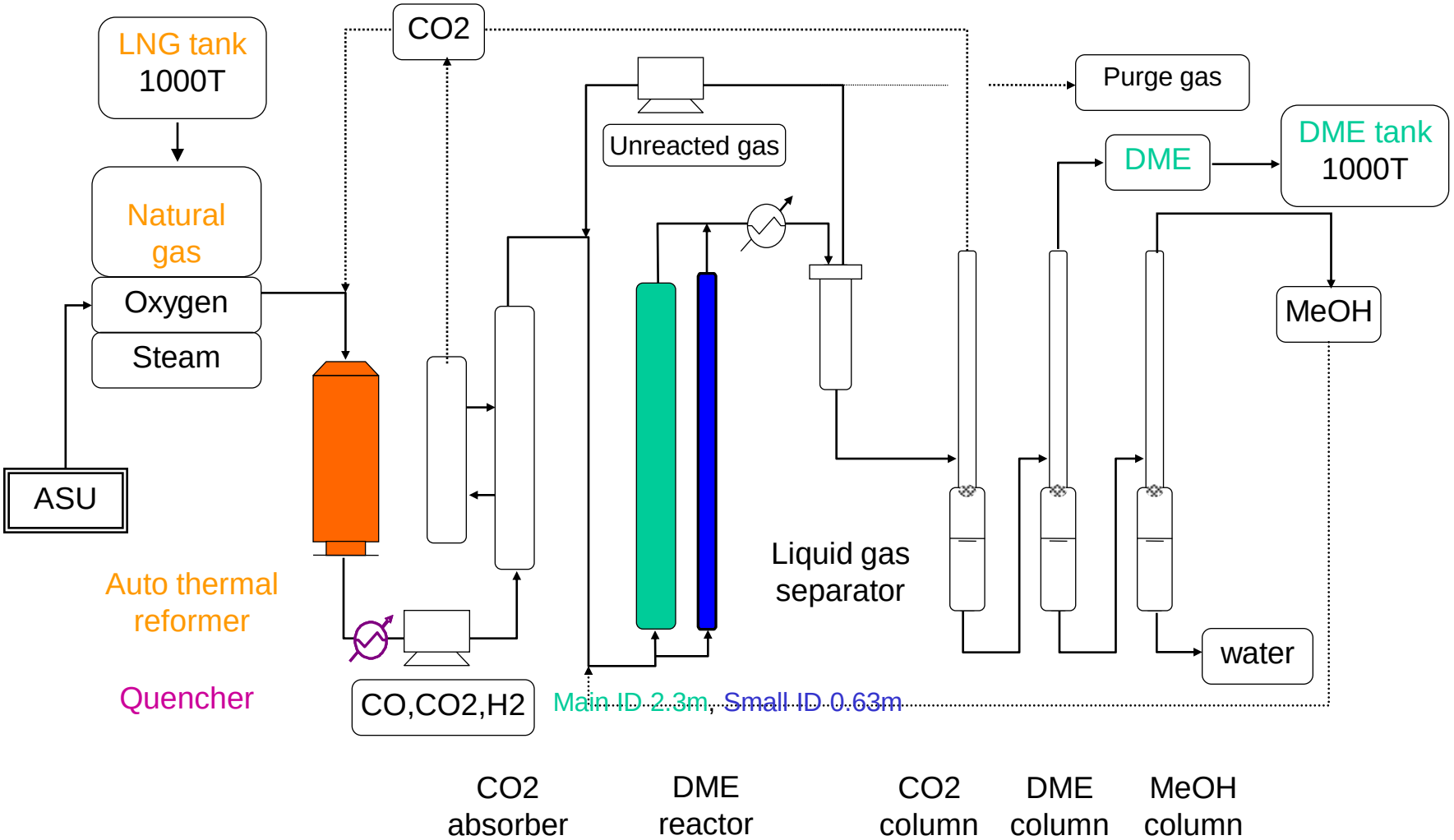
DME 100 ton/day Demonstration Plant

Process Flow Diagram of 100 ton/day DME Synthesis Plant



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Results of Test Operation

- Stable operation was realized and operation procedure for a commercial scale plant has been confirmed.
- Targeted values of the process performance were achieved.

Total conversion: 96%. Selectivity of DME(DME/(DME+MeOH): 94%. Maximum production:109 ton/day. DME purity: 99.8%. Continuous operation : 5 months.

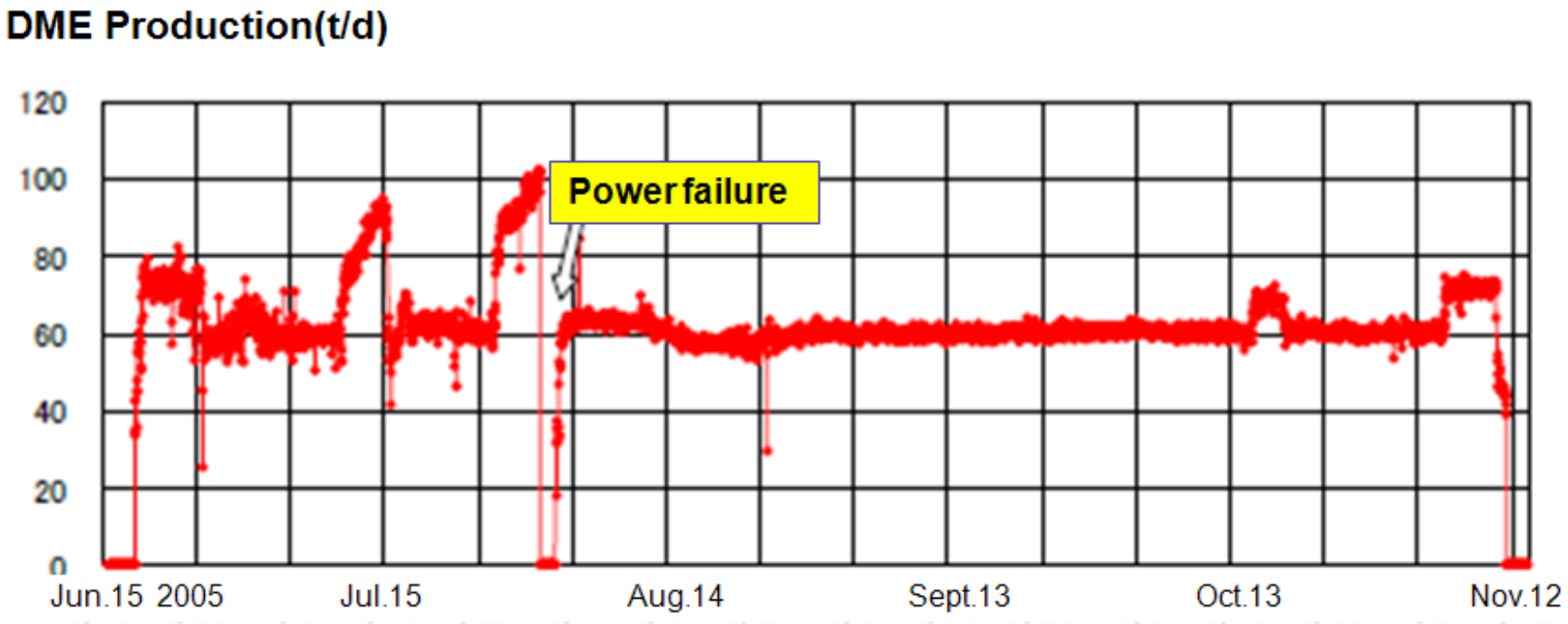
- Engineering data were obtained and scale-up technology has been established.

Operation time and production

RUN NO.	Period	Duration (day)	DME production(t)
RUN100	2003/12/12-2004/1/26	43	1,240
RUN200	2004/6/20-7/31	39	2,500
RUN300	2004/10/6-12/16	72	4,230
RUN400/500	2005/6/15-11/13	152	9,070
RUN600	2006/4/3-5/12	40	2,480
(Total)		346	19,520

DME production for 5 months operation

- DME production plant was operated very smoothly for 5 months following operation plan.
- Despite of unplanned shut down caused by power failure during thunderstorm, DME production was restarted and recovered for short time.



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DME Shipment from 100 ton/day plant

Business requirement for Bio-DME production

• With CO_2 problem growing after the Paris Agreement in 2015, DME production from renewable resources, especially from biomass is expected to be a promising option.

• There is a limit to the collection of biomass as raw materials. The use of biomass is inevitably made by a small to medium-sized plant. Compared to large-scale plants, DME production cost is so high that the business model of local production for local consumption is suitable.

• Food waste and sewage sludge collected in the environment business of local governments as well as wood waste in the wood industries are expected practical because the supply cost of these materials is low.

(Typical gas composition from Biomass)
- Biogas from fermentation of organic waste: CH_4 60%, CO_2 40%
- Gasification gas of wood waste with O_2/Steam:
H_2 43%, CO 43%, CO_2 14%

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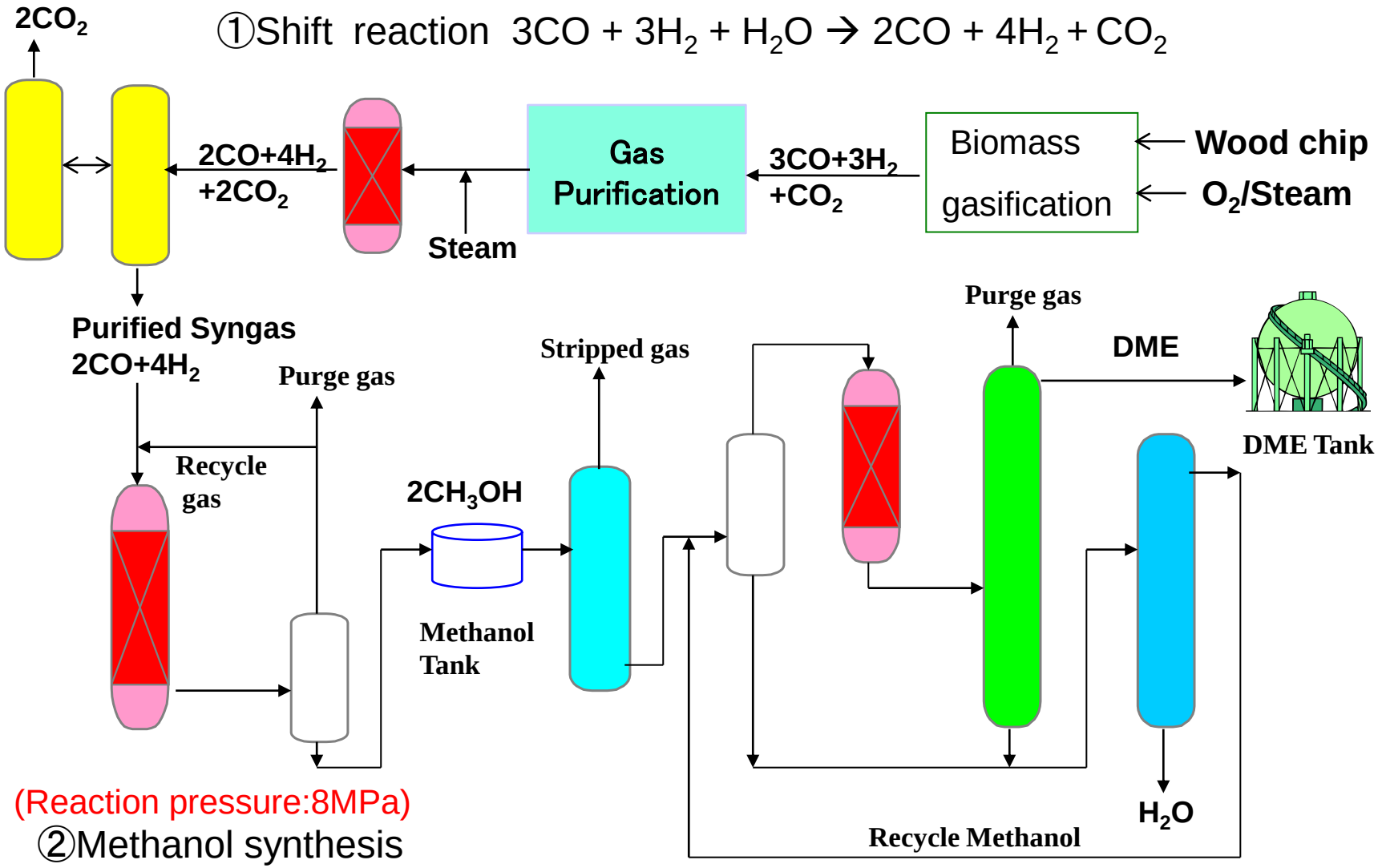
DME production by Two step process

①Shift reaction $3CO + 3H_2 + H_2O \rightarrow 2CO + 4H_2 + CO_2$



(Reaction pressure:8MPa)

②Methanol synthesis

$2CO + 4H_2 \rightarrow 2CH_3OH$

③Dehydration $2CH_3OH \rightarrow CH_3OCH_3 + H_2O$

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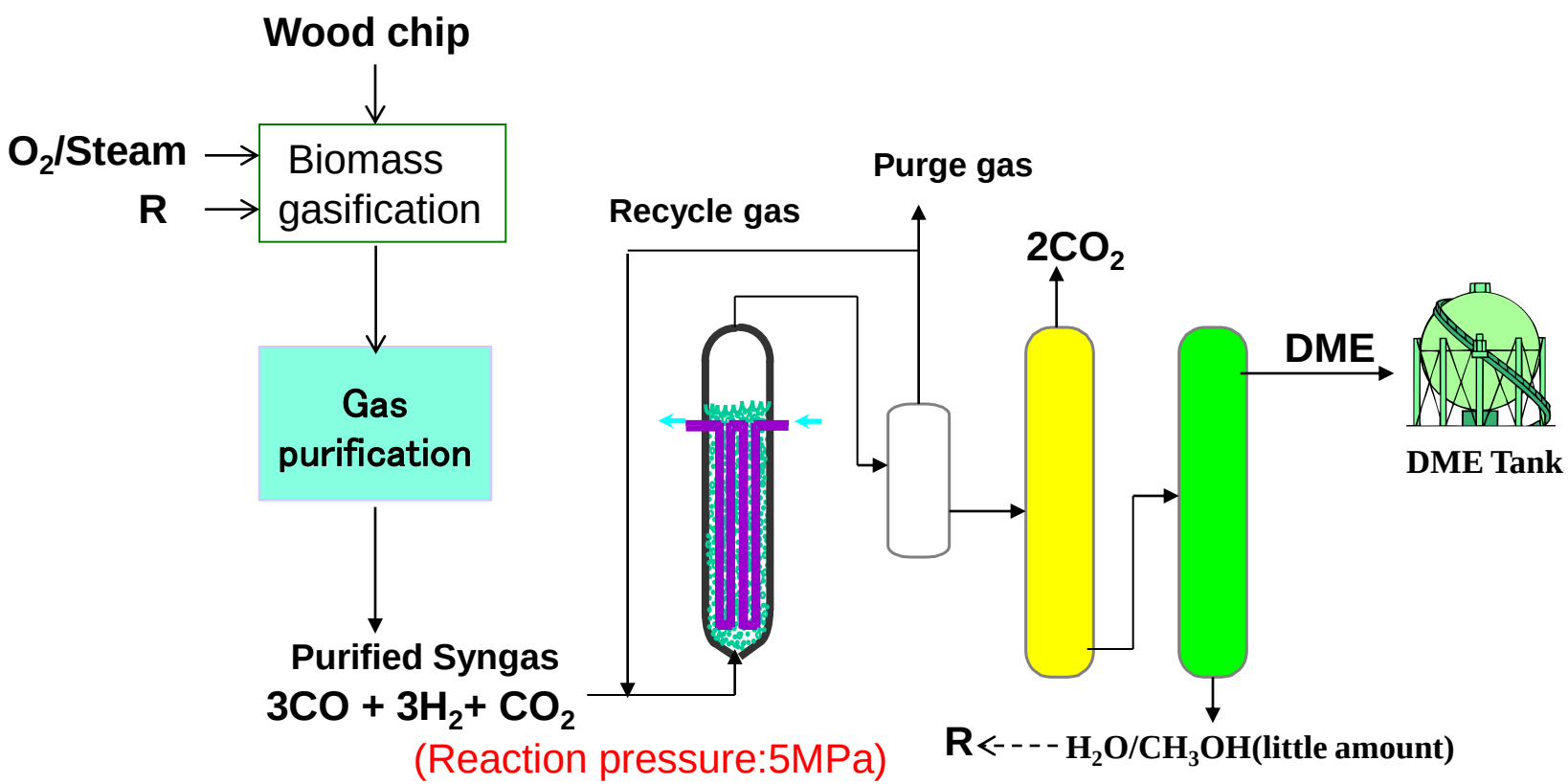
DME production by One step process

- Number of equipment is less and process configuration is simpler, reaction pressure is lower compared to the indirect DME synthesis via methanol.



DME synthesis $3CO + 3H_2 \rightarrow CH_3OCH_3 + CO_2$

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Biogas from Methane fermentation of waste

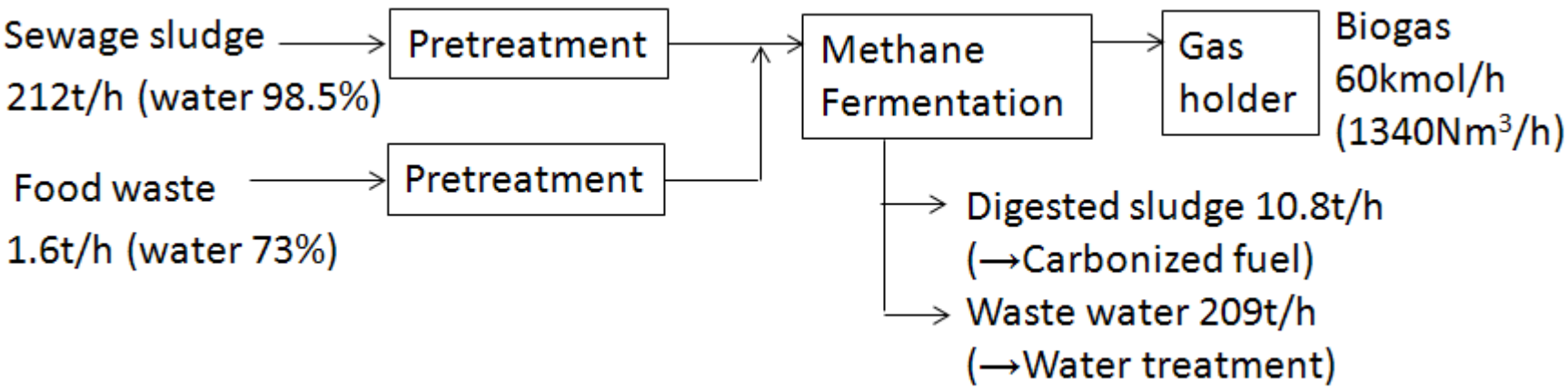
- In case of a city with population of 250thousand peoples,

  they discharge Sewage sludge: 212t/h (water content 98.5%)

  Food waste: 1.6t/h (water content 73%)

- Methane fermentation of these wastes produces

  Biogas (CH_4 60%,CO_2 40%): 1340Nm^3/h(60kmol/h)



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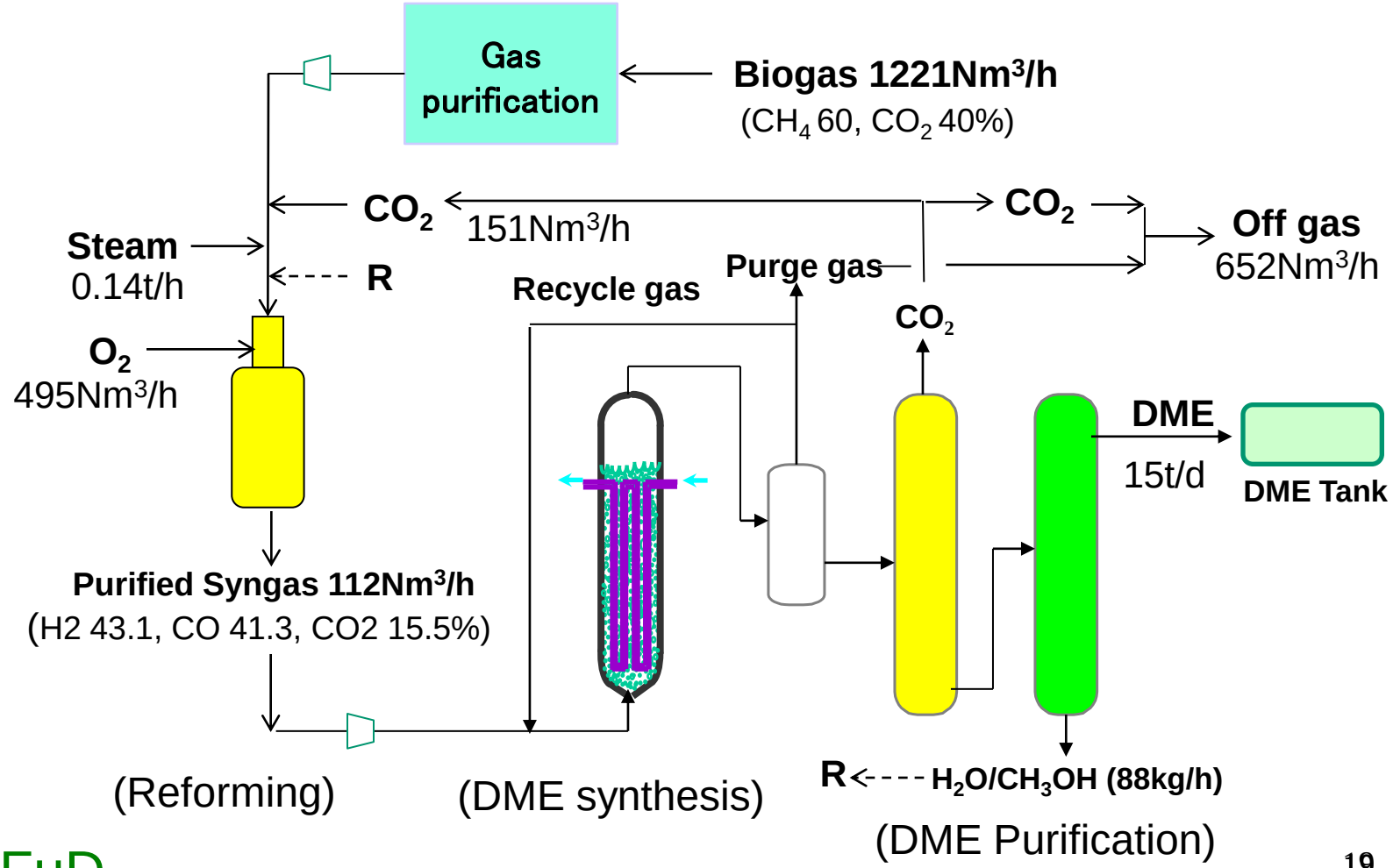
DME production process flow from Biogas

- 15ton/day of DME is produced from 1221Nm^3/h (54.5kmol/h) of Biogas. Cold gas efficiency of DME production is 68.7%.



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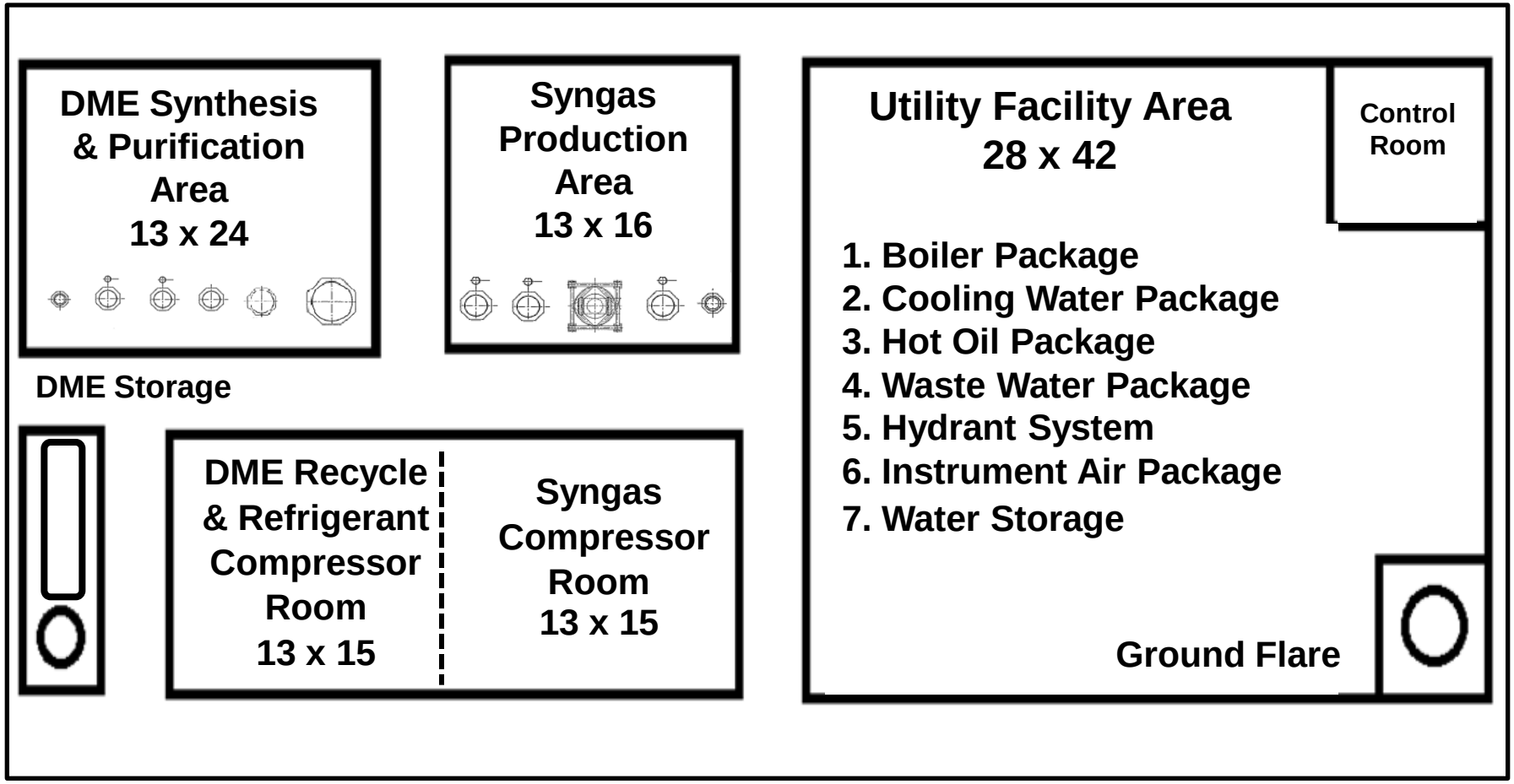
Typical Plot plan of Modular DME 15ton/day Plant

- Total Plant Area: 70m x 35m



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3D-View of Main process part

- Feedstock: Biogas from methane fermentation
- Plant capacity: 15ton/day (5000ton/year)
- Each unit module is smaller than 12m high, 2.6m x 2.4m section for land transportation

[Syngas production unit] [DME synthesis & Purification unit]

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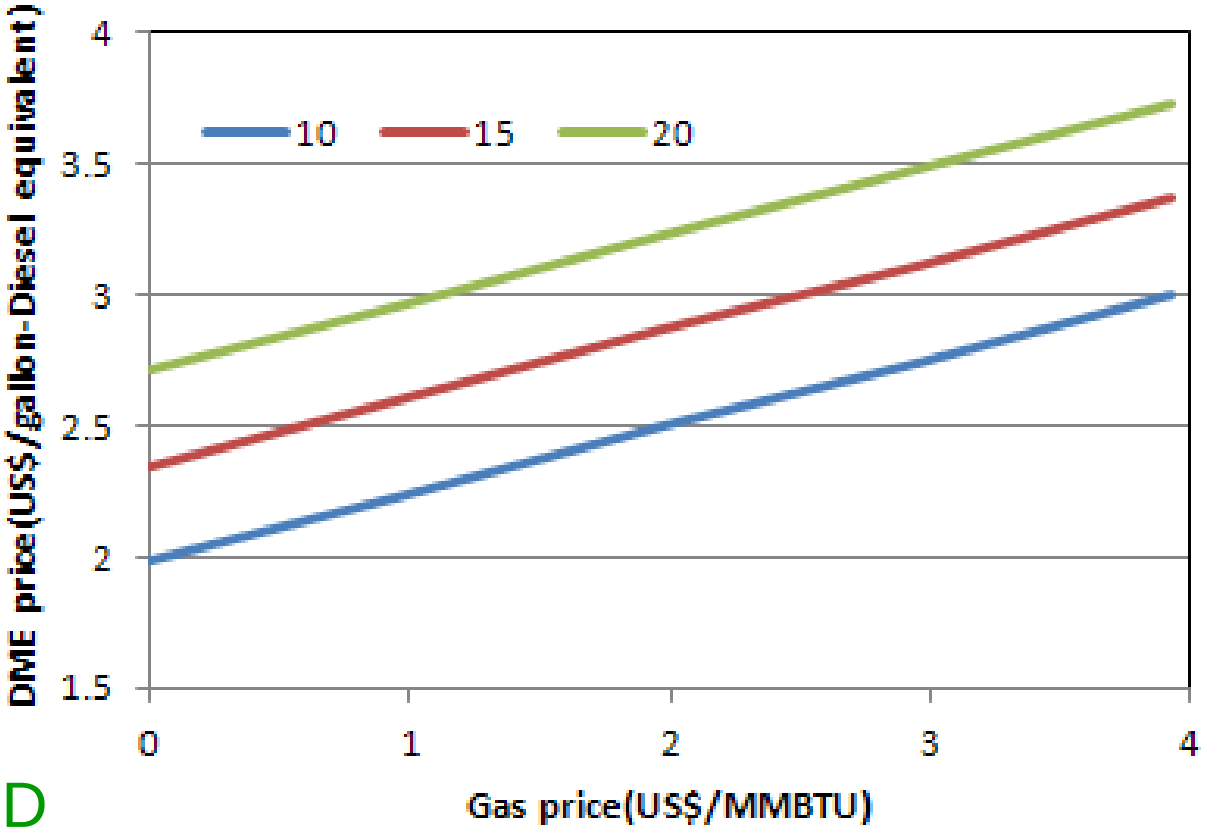
Economics of DME production from Biogas

- Plant capacity: 15ton-DME/day
- Plant cost: 15MMUS$(±30%)
- Depreciation: straight-line for 20years
- Biogas price: 0-4US$/MMBTU
- Profit rate: 20% of DME price



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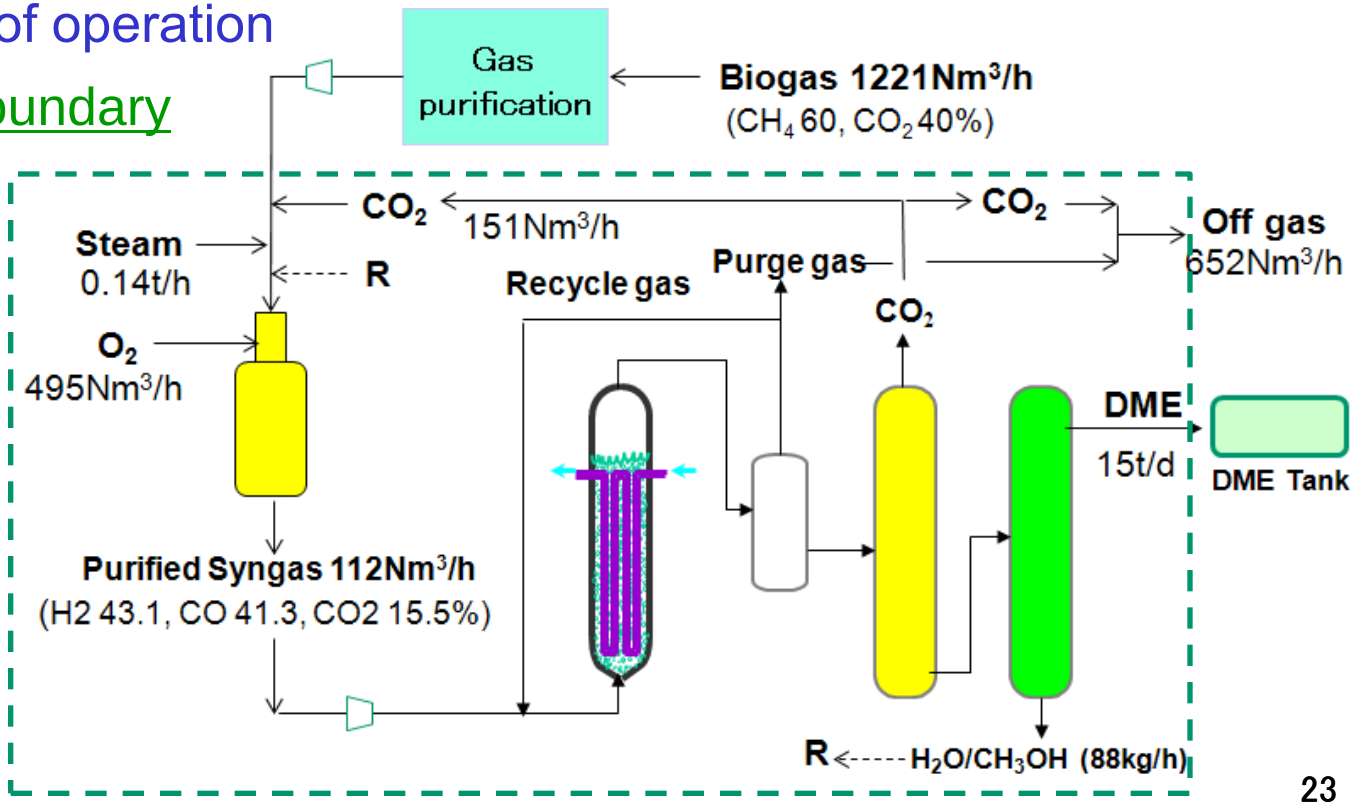
Process Licensing policies

- Pre-FS with customers
- License agreement in cooperation with owner and EPC company
- Deliverables: Basic design package, Operation manual, Guarantee figures
- Proprietary catalyst supply
- Supervise of operation
- Process boundary



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Conclusion

- Slurry phase DME synthesis technology has been confirmed by long term operation of 100 ton/day demonstration plant. Catalyst performance in slurry phase reactor was stable.
- Slurry phase DME synthesis process is suitable for the synthesis gas derived from biomass, because it synthesizes directly DME from synthesis gas of $H_2/CO=1$.
- Number of equipment is less and process configuration is simpler, reaction pressure is lower compared to the indirect DME synthesis via methanol. Lower equipment cost and operating cost are expected.
- Modular type plant is easy to be relocated responding to changes in raw material supply situation.
- RenFud **is ready for process licensing and catalyst supply.**

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