A life cycle analysis on Bio-DME synthesis system considering biomass materials

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1. Objective

This study focuses on Bio-DME (Biomass Di-methyl Ether) which is BTL (Biomass To Liquid). We executed process design of the Bio-DME production system. Especially, in order to estimate the variation of wood materials, seventeen species in Japan and Papua New Guinea (PNG) are selected.

- To investigate the differences of specific CO_2 emissions with variation of the materials, their moisture content, and transportation distances.
- To estimate energy intensities and specific CO_2 emissions, due to Bio-DME production performances and CO_2 inventories based on LCA methodology.

2. Wood Materials

JAPAN	PNG
P. densiflora	A. mangium
C. japanica	C. equisetifolia
P. bambusoides	C. oligodon
Q. serrata	E. deglupta
C. obtusa	E. grandis
Phragmites	L. leucocephala
Scrap	P. falcataria
Driftwood	P. aduncum
	E. robusta

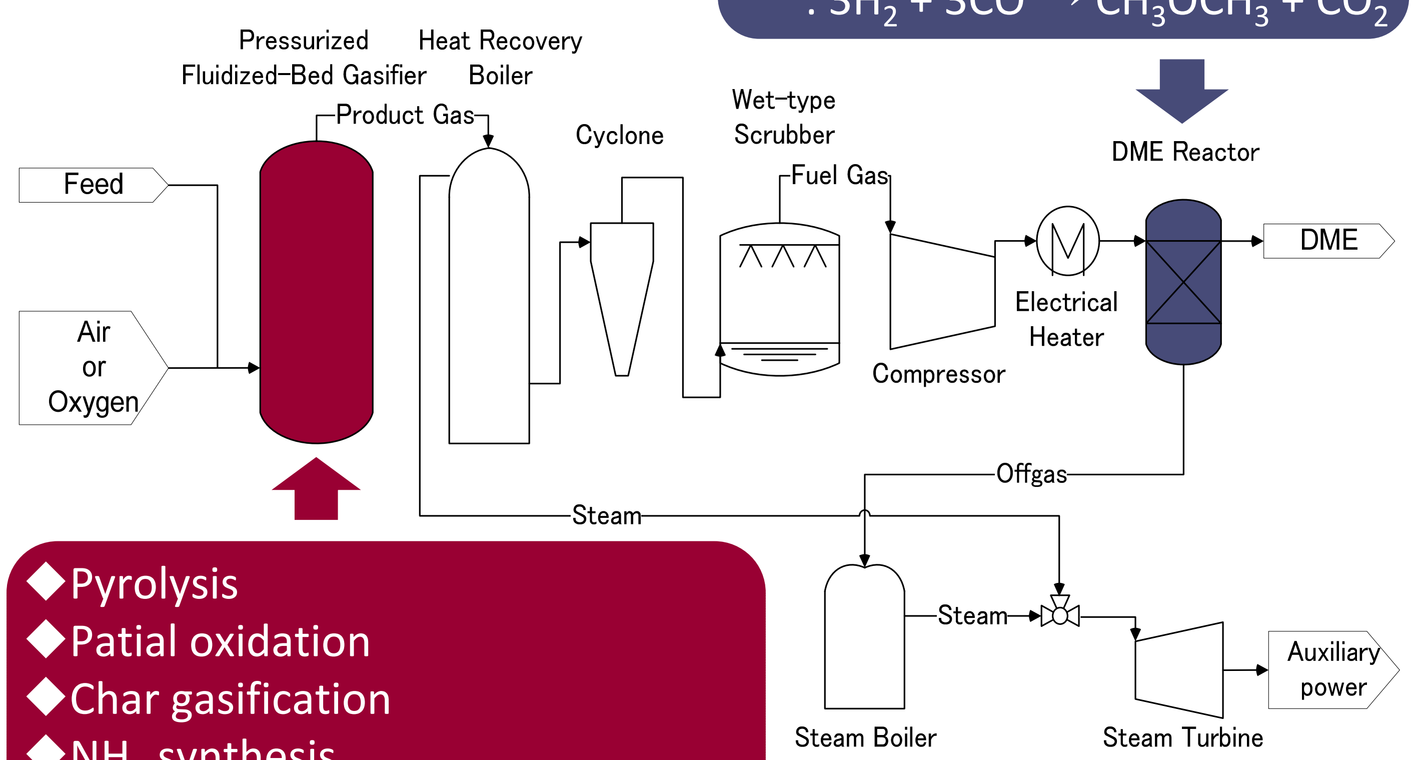
Basic Experiments

- Ultimate analyses
- Gaseous yields in pyrolysis
- Reaction rate of char gasification

$$C + H_2O \rightarrow CO + H_2$$
$$C + CO_2 \rightarrow 2CO$$

3. Process Design

Direct synthesis process (theoretical equilibrium condition)
Chemical equation
: $3H_2 + 3CO \rightarrow CH_3OCH_3 + CO_2$



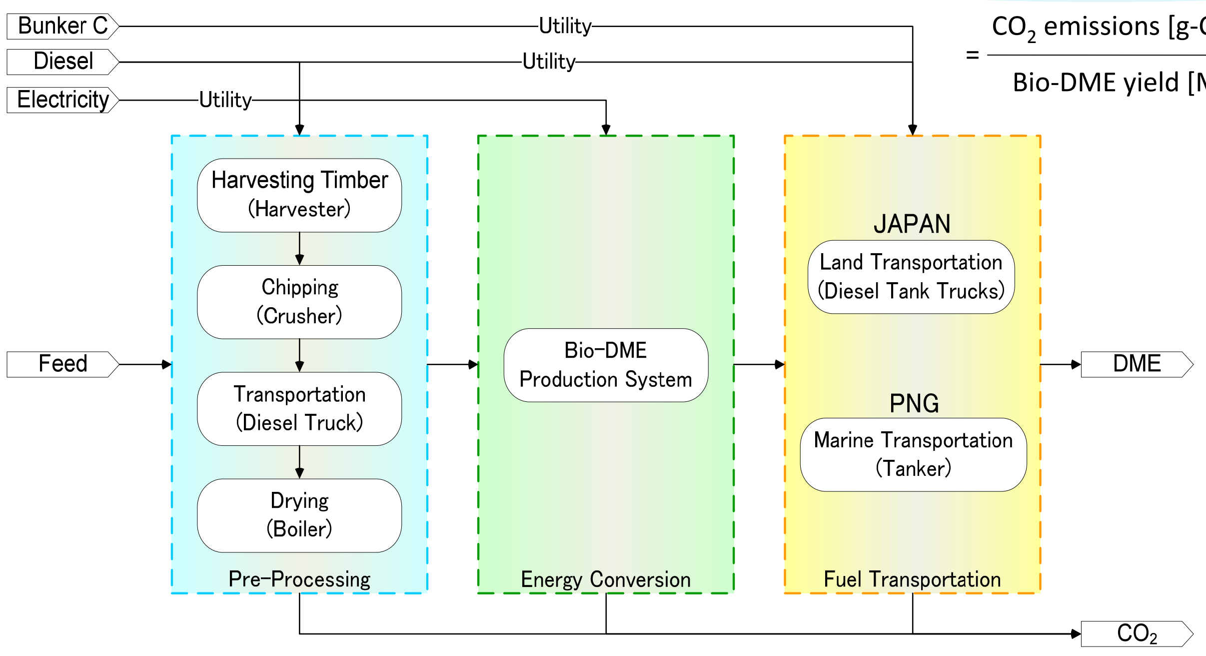
- Pyrolysis
- Patial oxidation
- Char gasification
- NH_3 synthesis
- Steam reforming with CO and CH_4

Schematic design of Bio-DME production system

4. Bio-DME LCA

Functional Unit [g-CO_2/MJ]

$$= \frac{CO_2 \text{ emissions [g-}CO_2\text{/yr]}}{\text{Bio-DME yield [MJ/yr]}}$$



System boundary of Bio-DME production system

Pre-Processing Process
- Transportation process
  Transportation distance
  JAPAN : 5~150km, PNG : 0~2.5km
- Drying process
  Initial moisture content : 20~50%

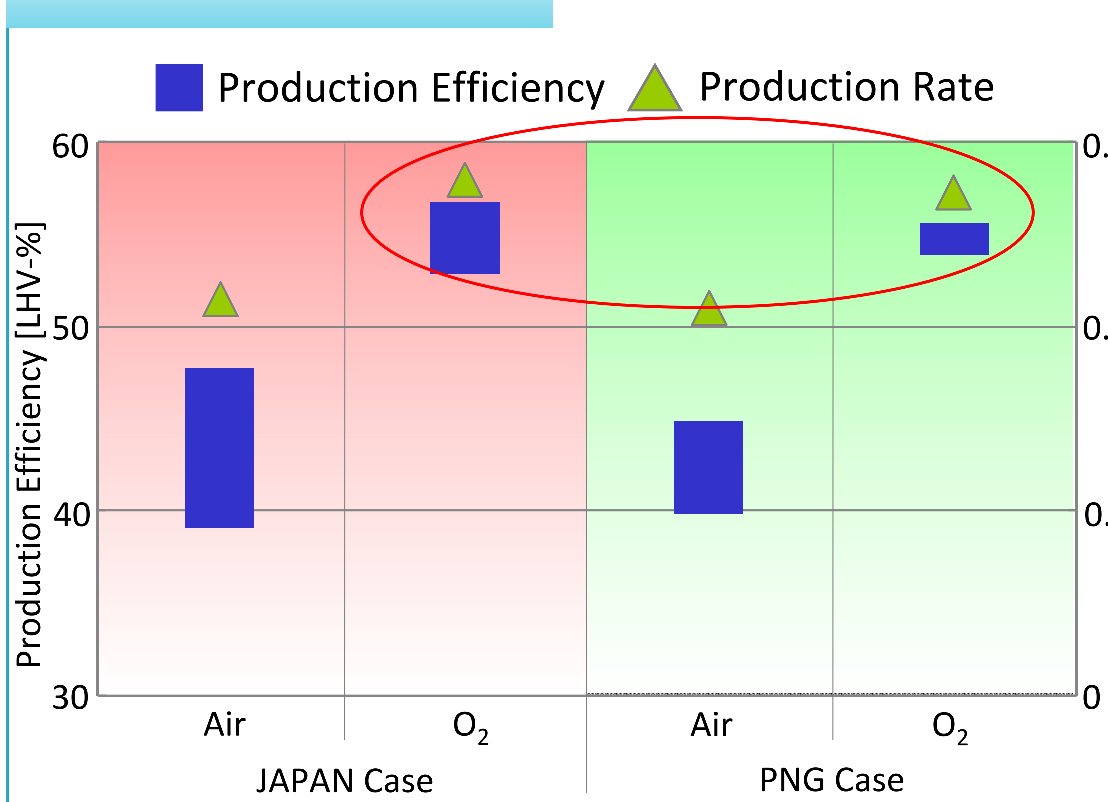
Uncertainties
- Transportation distance (feed collection)
- Materials condition (moisture contents)

•Monte Carlo methodology
- Iteration count : 10,000 times
- Significant level : 95%

Energy Conversion Process
- Gasification process
  Oxydation agent : Air, Oxygen
  Plant scale : 50 t/d (dry-base), operating time : 7200h/yr
- Liquefaction process
  Synthesis condition : 240 °C, 3MPa

Fuel Transportation Process
Fuel transportation distance → JAPAN ; 100km, PNG : 4,765km (one-way trip)

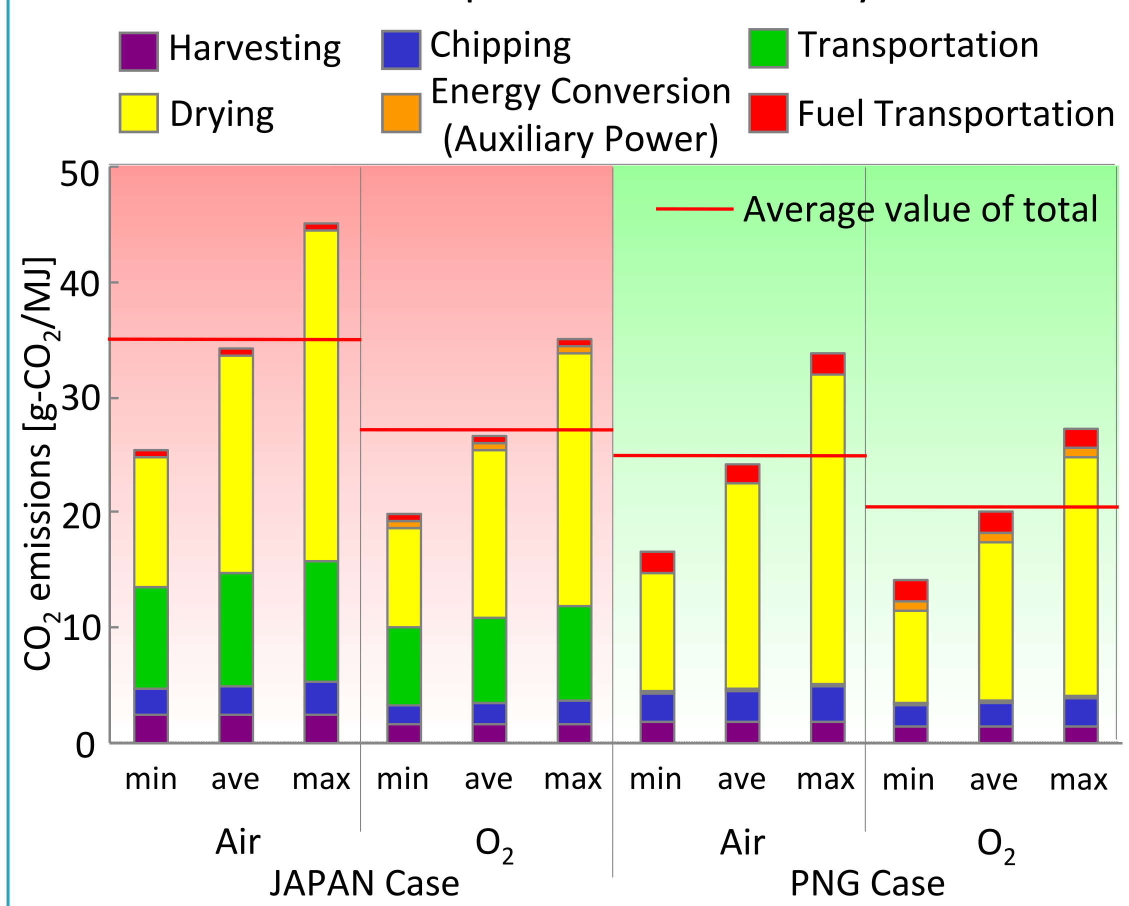
5. Results



Bio-DME production Efficiency

Case
- Country: •JAPAN •PNG
- Agent: •Air •O_2

Production Efficiency
- Air Blown Type (JAPAN:39~48%, PNG:40~45%)
- O_2 Blown Type (JAPAN:53~57%, PNG:54~56%)



CO_2 emissions of LCA methodology

CO_2 emissions
- JAPAN Case (17.8~50.5g-CO_2/MJ)
- PNG Case (12.2~36.7g-CO_2/MJ)

Uncertainty effect
- Transportation distance (feed collection)
- Materials condition (moisture content)

* min, ave and max mean the maximum value, the mean one and minimum one in the Monte Carlo simulation

6. Discussions

It is important to propose the appropriate materials for CO_2 emissions mitigation, and for Bio-DME production yield.

the regression equations on the specific CO_2 emission and the production yield of Bio-DME were estimated, base on analysis results.

JAPAN Case

- Air Blown Type
  $Y_{DME} = 0.017Mat_{lhv} - 3.30Cont_{H_2} + 0.19$ (r^2 = 0.915)
  CO_2 = -142.27Y_{DME} – 17.7Mat_{den} + 72.1 (r^2 = 0.900)
- O_2 Brown Type
  $Y_{DME} = 0.020Mat_{lhv} - 1.23Cont_{H_2} + 0.06$ (r^2 = 0.950)
  $CO_2 = 94.83Y_{DME}$ (r^2 = 0.845)

PNG Case

- Air Blown Type
  $Y_{DME} = 0.021Mat_{lhv} - 1.33Cont_{H_2}$ (r^2 = 0.856)
  CO_2 = -105.76Y_{DME} – 4.73Mat_{den} + 50.2 (r^2 = 0.987)
- O_2 Brown Type
  $Y_{DME} = 0.022Mat_{lhv} - 0.48Cont_{H_2} - 0.02$ (r^2 = 0.988)
  $CO_2 = 73.09Y_{DME}$ (r^2 = 0.864)

Y_{DME} : Bio-DME production yield [kg/kg-feed], Mat_{lhv} : Lower heating value [MJ/kg]
CO_2 : CO_2 emissions [g-CO_2/MJ], Mat_{den} : Bulk density [t/m³], $Cont_{H_2}$: Hydrogen content [wt.%]

7. Conclusions

- We analyzed the differences of the seventeen species for their performances and the specific CO_2 emissions in the Bio-DME production system.
- If the heating value, the hydrogen contents and the bulk densities of feeds are provided, the Bio-DME production yields and the CO_2 emissions would be able to be predicted.