Proposals of the agricultural products cultivation system due to Blue Tower gasification combined-cycle systems to reduce CO_2 emission

Tokyo University of Science

Kiyoshi DOWAKI

E-mail: dowaki@rs.noda.tus.ac.jp

Energy I: LCM in the Energy Sector I 31/Aug/2011: 2:00pm-4:00pm

1. Background

CO$_2$ emission abatement

Biomass resources are **carbon neutral**. ⇒ Contribution to the Global warming protection.

Cost barrier

The installation cost is **relatively high**. ⇒ Creation of the newly effective system.

Fukuoka Blue Tower project

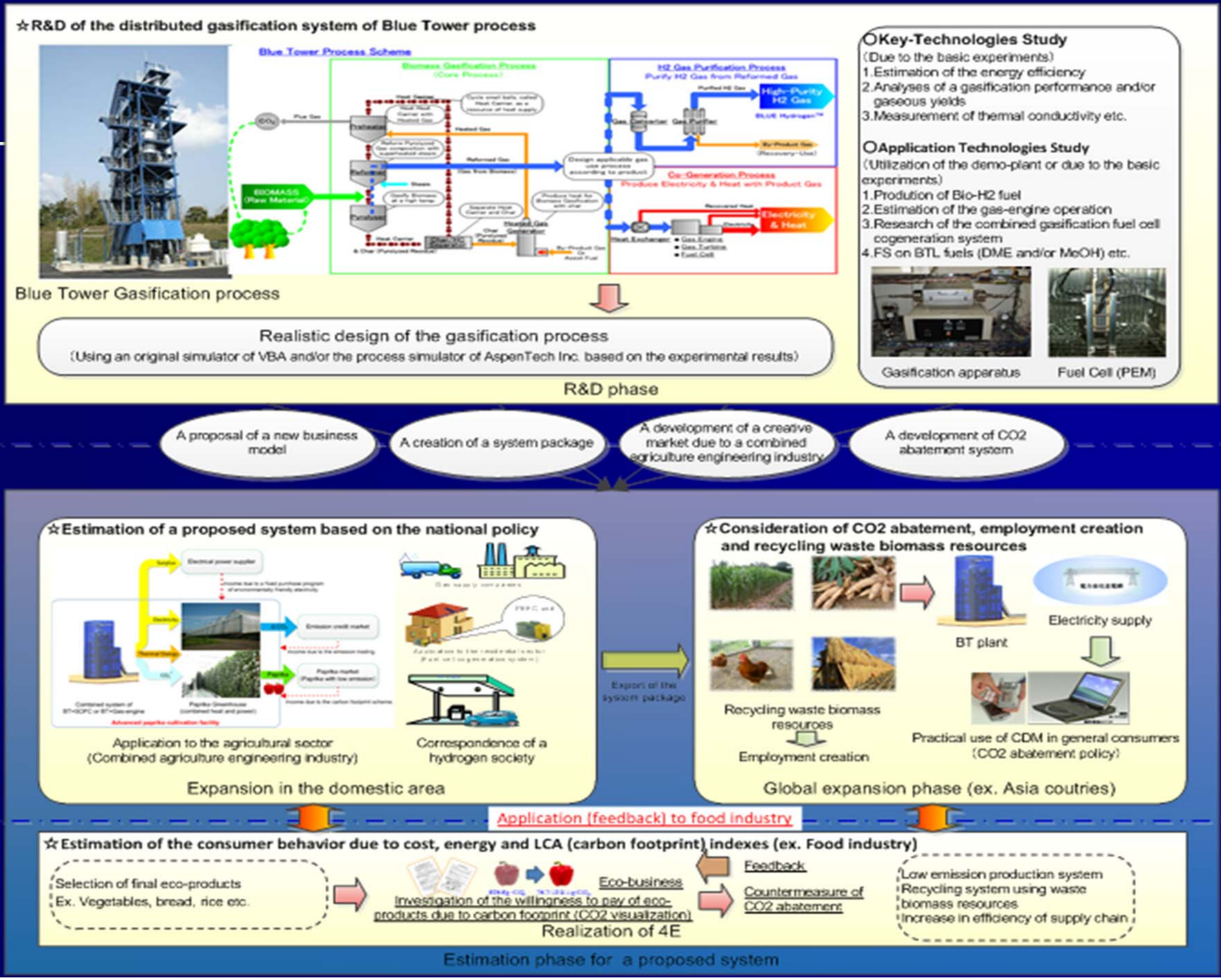
Installation of Bio-H$_2$ production system through biomass gasification process.

Due to a good business model in consideration of an environmental aspect and/or a solution for cost barrier, the eco-friendly system would be promoted.

Plant scale: 15 t/d
Product: H$_2$ gas (300Nm^3/h)
Location: Fukuoka, Japan

Provided by IDEX, Japan

2. Comprehensive whole system



3. In the previous studies

So far, we executed the following research contents;

a. We checked the performance through the demo-plant.
b. The process design was executed based on the lab-scale experimental data. We also estimated the consistency between the plant data and the simulated one.
c. We investigated the effect of CO_2 abatement in consideration of energy consumption in end-users.

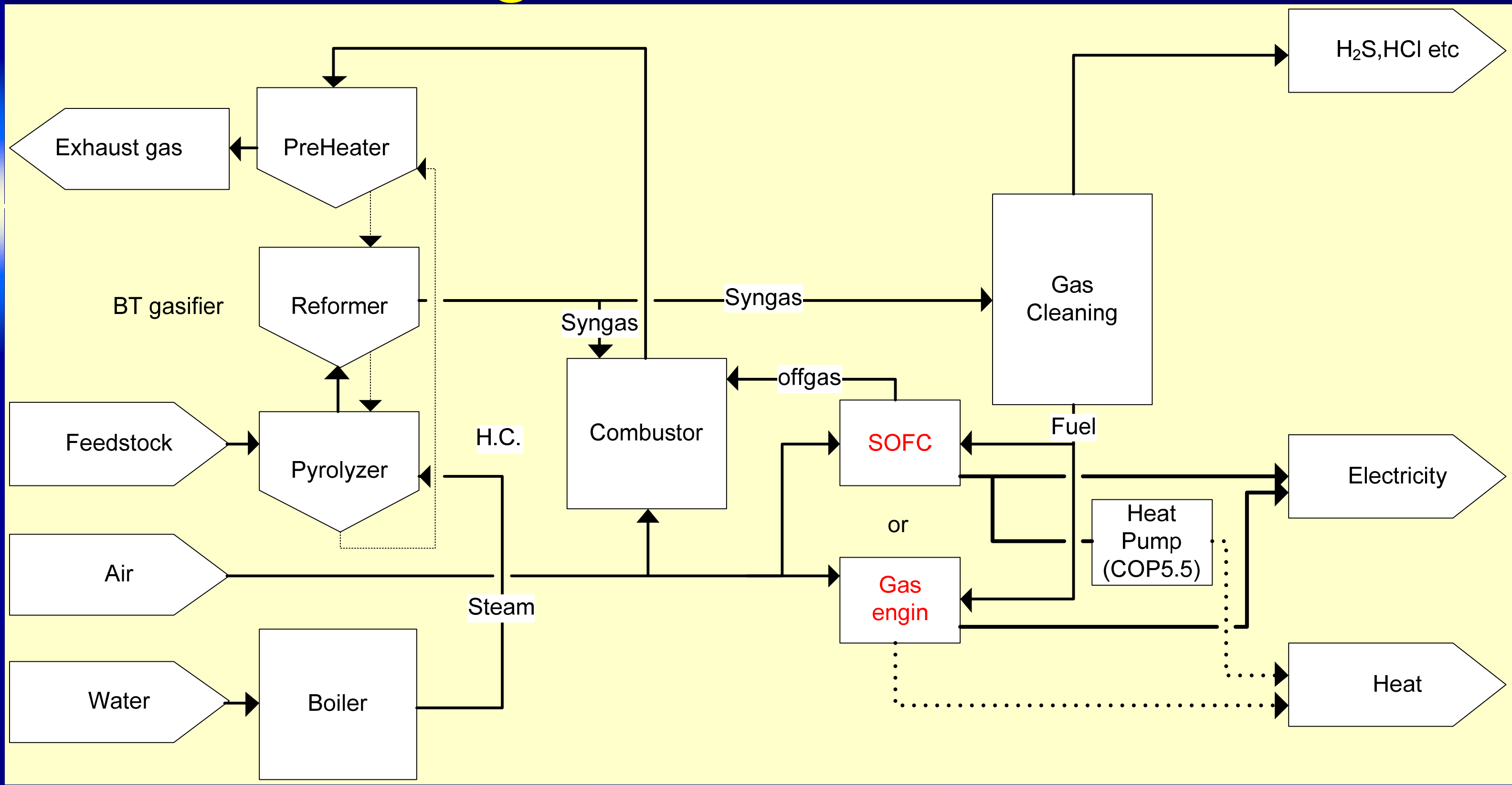
4. Objectives in this study

For the paprika greenhouse facility,

a. Based on the previous studies, we proposed the BT-SOFC and/or the BT-GE for the paprika greenhouse facility.
b. We estimated the energy efficiency and/or the energy cost in consideration of excess energy supply.
c. Based on LCA methodology, we estimated the CO_2 intensity of a paprika. This time, we compared two cases.
d. Using the result of questionnaire for the consumers, we analyzed the willingness to pay (WTP) for CO_2 abatement.
e. We compared the energy cost based on the effects of FIT and/or WTP of CFP.

Proposal of the advanced energy system for the paprika green house facility due to the contribution of CO_2 abatement and the reduction of cost barrier.

5. Schematic design of BT-SOFC/BT-GE



<u>Basic specification of BT</u>

1. Blue Tower Gasification Plant（Scale:15t-dry/d)
2. Additional feedstock is necessary in BT-GE case.
3. Gaseous components (at 550 ºC in the pyrolyzer and at 950 ºC in the reformer, and at S/C=1.0)

$$C_{33.9}H_{46.8}O_{20.3}N_{0.3} + 33.9H_2O \rightarrow$$
$$3.34CH_4 + 12.9CO + 34.8H_2 + 12.7CO_2 + 45.0H_2O$$
$$+ 0.15N_2 + \text{Others}(\text{Char etc.})$$

➡ <u>H_2 conc. >50 Vol.%(Dry-basis)</u>

→Paprika Greenhouse Facility (1.2ha)

6. Performance of BT-SOFC

*The performance data of BT reactor is based on the design of Fukuoka project.

Table 1 Data of the specification of SOFC unit

Item	Unit	Data
Unit Scale	[kW]	200
Number of unit	[-]	4
Operating Temperature	[deg.C]	900
Current density J	[mA/cm^2]	612
Stoichiometric ratio	[-]	1.25
Tafel slope b	[mV/dec.]	2.2
Resistance R	[ohm]	0.52
Open Circuit Voltage U_0	[mV]	950
DC/AC converter Eff.	[%]	95

Table 2 Performance of BT-SOFC system

Item	Unit	Data
Feedstock	[kg/h]	764.5
Cold gas efficiency	[%-LHV]	87.3
Auxiliary Power	[kW]	113.9
Partial load ratio (SOFC)	[%]	81.7
Net Power eff. vs. Feedstock	[%-LHV]	19.2
Net power scale	[kW]	540

Definition of each performance data

1. Cold gas efficiency(LHV-basis)…

$$\eta_{cold} = \frac{\text{Syngas}\,[\text{MJ/h}]}{\text{Feedstock}\,[\text{MJ/h}]} \qquad (1)$$

2. I-V equation …

$$U = U_0 - RJ - b\ln(J) \qquad (2)$$

Note: J. Kim et al. (1995): Journal of. Electrochemical Society, 142(8), 2670-2674

7. Performance of BT-GE

*The performance data of BT reactor is based on the design of Fukuoka project.

Table 3 Data of the specification of gas-engine unit

Item	Unit	Data
Unit Scale	[kW]	215
Number of unit	[-]	3
Engine output	[PS]	318
Revolution per minite	[rpm]	1,500
Compression ratio (design)	[-]	10.0

Table 4 Performance of BT-GE system

Item	Unit	Data
Feedstock	[kg/h]	764.5
Cold gas efficiency	[%-LHV]	71.4
Auxiliary Power	[kW]	111.1
Partial load ratio (Gas-engine)	[%]	88.4
Net Power eff. vs. Feedstock	[%-LHV]	16.3
Net power scale	[kW]	459
Net Heat recovery eff.	[%-LHV]	28.6
Net heat supply	[MJ/h]	2,895

<Important suggestion>

In this case, the additional feedstock is necessary in order to satisfy the condition of reaction sensible heat in reactor.

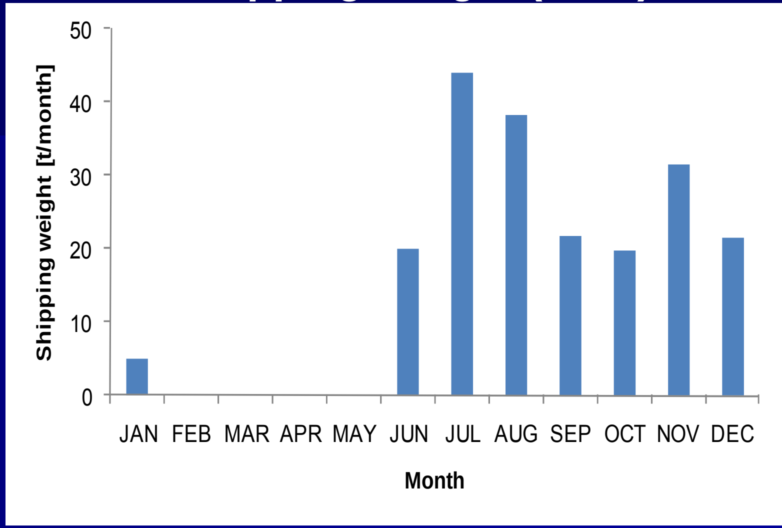
➡ 139.5 kg/h (Main feedstock: 625.0 kg/h)

Total feeding weight (764.5 kg/h) is same in both cases.

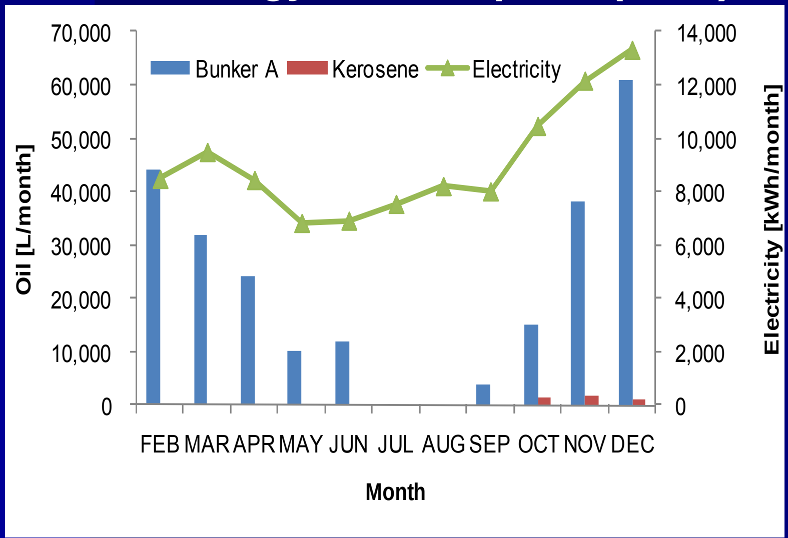
8. Energy / CO_2 Demand

Paprika Greenhouse (Miyagi, Japan)

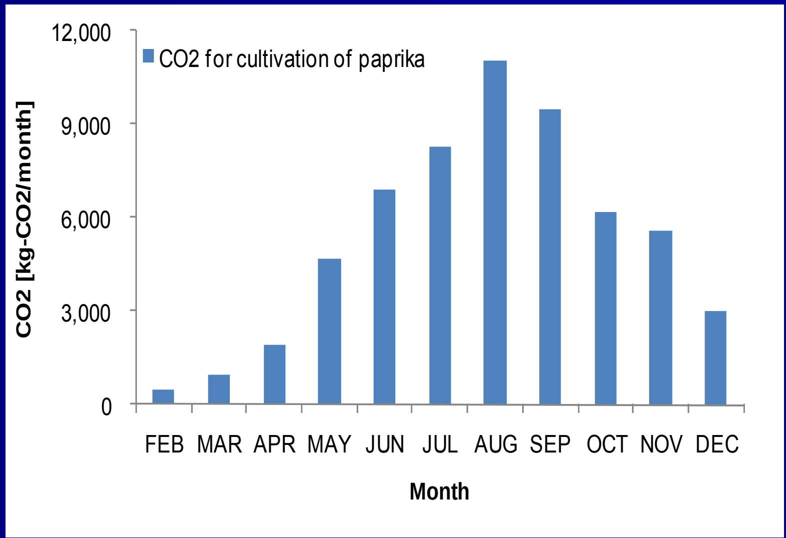
Annual Shipping Weight (2008)



Annual Energy Consumption (2008)

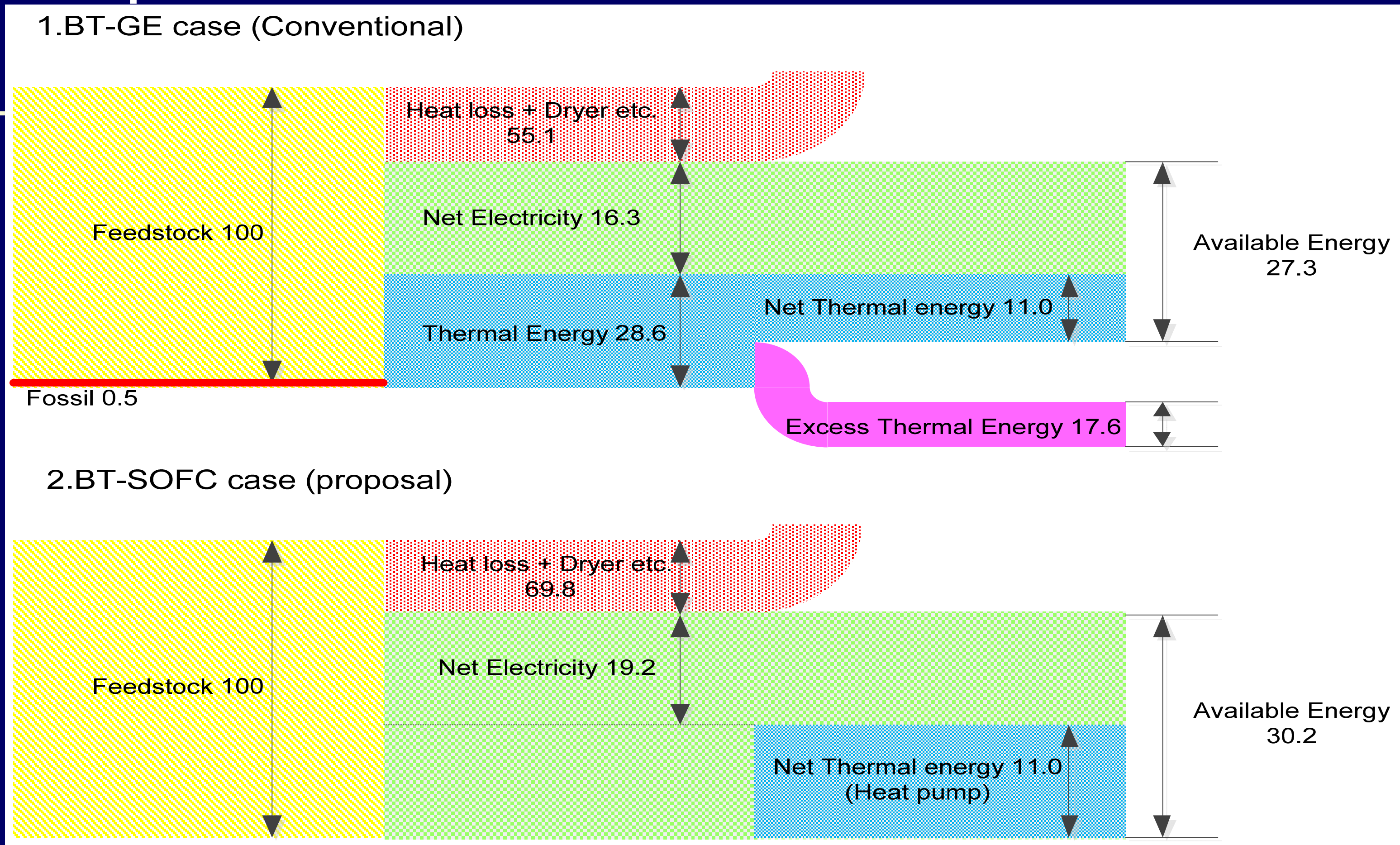


Annual CO_2 gas for growth agent (2008)



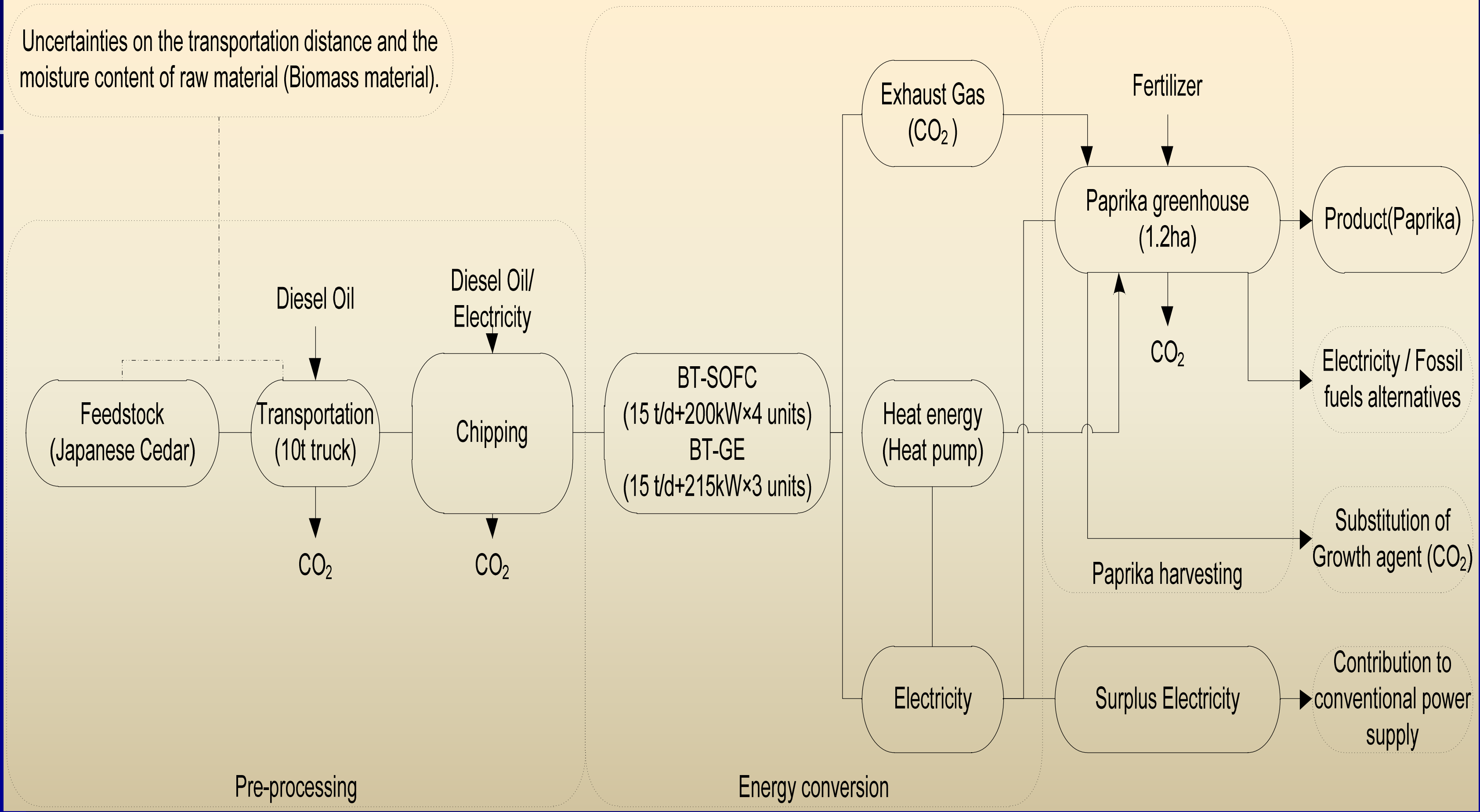
9. Analysis of exergy

*Comparison of BT-SOFC to BT-GE



1. **Due to the excess thermal energy, the exergy efficiency of gas-engine case would be worse (3 point disadvantages.)**
2. **The excess energy would be generated by the discrepancy between supply and demand.**

10. System boundary



Note:

In the LCI of "WtT (Well to Tank)" phase, the uncertainties on the transportation distance and the moisture of feedstock were considered.

11. Specific CO_2 emission

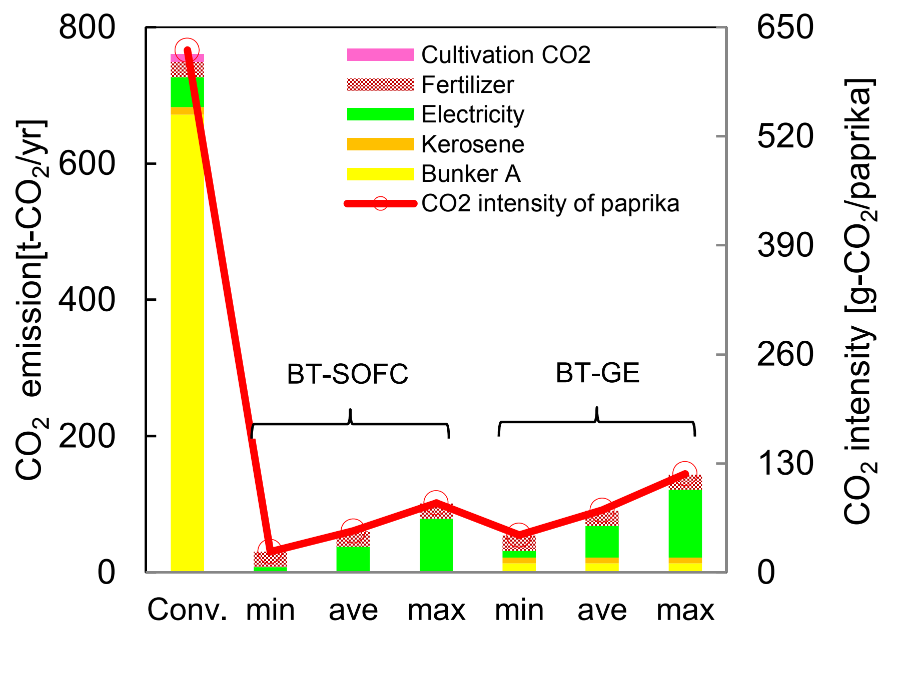


Fig. 1 Specific CO_2 emission of paprika cultivation

<Emission>

1. Conv. case: 622.6 g-CO_2/paprika
2. BT-SOFC: 25.0 -82.8 g-CO_2/paprika
3. BT-GE: 44.5 -117.7 g-CO_2/paprika

*Note that the uncertainties on the transportation distance and/or the moisture content of feedstock are included in the result.

**The paprika in the greenhouse is assumed to absorb 80 % of CO_2 gas which is synthesized artificially.

Table 5 Data of specific CO_2 emission

Item	Specific CO_2 emission	Note
Feedstock	0.0 g-CO_2/MJ-Fuel	at 20 wt.% (moisture content), Japanese Cedar, HV:13.23 MJ/kg
Diesel	74.4 g-CO_2/MJ-Fuel	Chipping, Transportation, HV: 35.50 MJ/L
Bunker A	76.9 g-CO_2/MJ-Fuel	Paprika production (Boiler)
Kerosene	73.6 g-CO_2/MJ-Fuel	Paprika production (Boiler)
Electricity	123.1 g-CO_2/MJ-Fuel	Paprika production (Ventilation and lightning)
Fertilizer (N)	5.67 kg-CO_2/kg	Indirect CO_2 emission
Fertilizer (P_2O_5)	0.88 kg-CO_2/kg	Indirect CO_2 emission
Fertilizer (K_2O)	1.85 kg-CO_2/kg	Indirect CO_2 emission

12. Expected operating cost

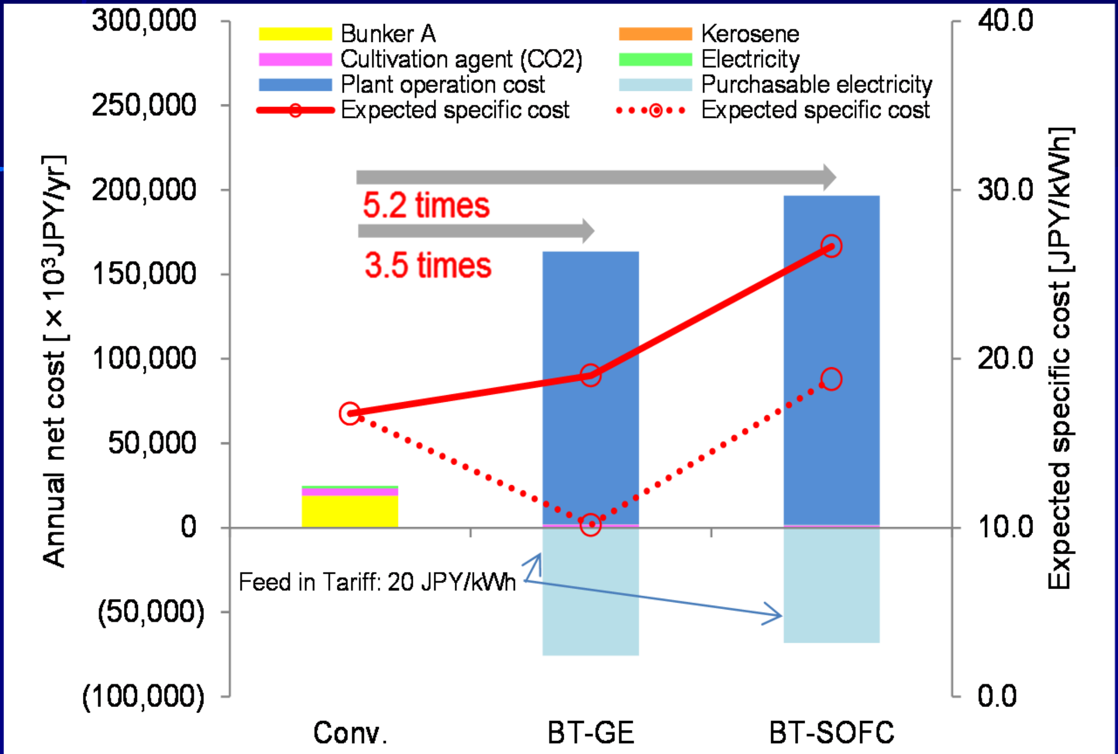


Fig. 2 Expected operating cost

<Condition>

1. BT plant: 1 billion JPY
2. SOFC:
   1 million JPY/kW as of 2015

   GE: 0.24 million JPY/kW

*Note that the subsidy (1/2 rates) was considered in the both cases. Also, the FIT of 20 JPY/kWh was considered.

Based on the questionnaire (Oct. 1 to 15,2010/ Respondents: 249) on the willingness to pay of paprika with CFP,

$$CO_2 \text{ benefit [JPY/yr]} = \frac{82.9\text{[JPY/paprika]} \times CO_2 \text{ abatement [\%]}}{3.05^{***}} \times \text{Annual products} \quad (3)$$

was obtained (Dot lines are indicated in consideration of WTP of CFP.).

**Annual products: 1.22 $\times 10^6$ pieces/1.2 ha

***JOHN A. LIST and CRAIG A. GALLET

13.Conclusion Remarks

- On the promotion of biomass gasification system, the greenhouse is one of the promising candidates.
- From the viewpoint of the energy efficiency, the energy supply due to BT-SOFC is better in comparison to BT-GE. This is due to the excess energy supply.
- CO_2 abatement of BT-system would be obtained to much extent.
- The energy cost is still high in comparison to the conventional one.
- However, using the FIT and/or the CFP scheme, the cost reduction can be achieved.

Thank you for your attention.