A System Analysis of Bio-ethanol Produced from Cassava and Sugarcane in Northern Thailand

Silver Poster Award

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Introduction

Thailand

- Saving fossil fuels
- Increase of farm income opportunities
- Sustainable recycling of biomass waste feedstock

The government's bio-fuel policy
E10(~2011) ->E20
Raw materials: sugarcane, cassava (See Fig.1)

Japan

- 25% Reduction in GHG by 2020 (COP15)
- Need to Gain CER By the scheme of CDM (Clean Development Mechanism)

The biomass gasification system :Blue Tower (BT) system

Under the CDM scheme, we optimized the biomass utilization system to increase recycle rate and to mitigate CO_2 emission (See Fig.2).

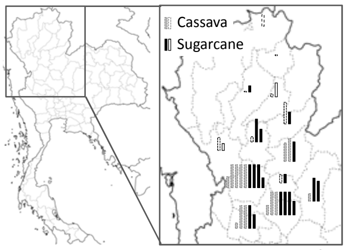


Fig.1: Target area and cultivation of sugarcane and cassava

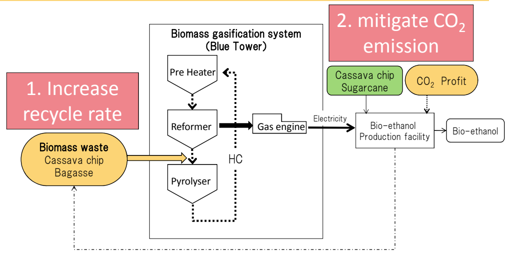


Fig.2: combination of Blue Tower process and bio-ethanol plant

Methodology

We estimated by "Biomass Utilization Model" …

i. the optimal routes of cultivation site to ethanol plant and ethanol plant to BT plant.
ii. the available material weight (0~15%-> Monte Carlo simulation) in each site for the existing bio-ethanol plant.
iii. the locations of bio-ethanol plant and BT gasification plant (scale: 30 t/d) based on a site investigation.
iv. CO_2 intensity is based on LCA methodology (see Fig.3)

We optimized the combination of bio-ethanol plants with BT plants by solving non-linear mixed integer program written in GAMS ver.23.0.

1. Cultivation

Indirect emissions :Fertilizers(N, P_2O_5, K_2O) and Herbicides
Direct emissions: Diesel oil

2. Transportation

	truck	Load ratio(λ)	a [g-CO_2/km]	b [g-CO_2/km]
Cassava	10ton	100%	669.96	476.35
Sugarcane	15ton	167%	1004.95	543.34

The fuel consumption rate : $f_{FC}(\lambda)=a\lambda+2b$

The road distance between each province is used as the shortest pathway.

3. Ethanol production

Ethanol conversion ratio>>
Cassava: 137L-ethanol/t
Sugarcane: 10.17L-ethanol/t
Direct emissions: Electricity, Coal and Diesel

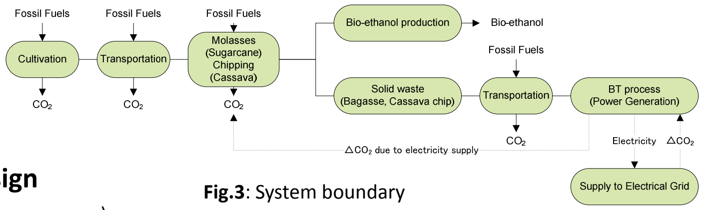
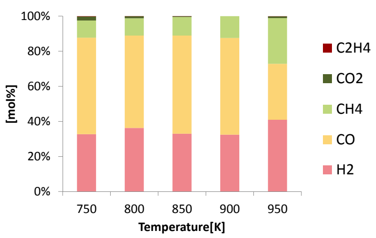


Fig.3: System boundary

4. Blue Tower process design

a. Result of reforming experiment (e.g. cassava)



b. Material balance (e.g. cassava)
(S/C=1.7, M.C.=10.21wt.%, 950 deg.C).

$$C_{27.9}H_{51.6}O_{31.4}N_{0.56} + 40.83H_2O \longrightarrow 6.39CH_4 + 7.83CO + 10.06H_2 + 9.35CO_2 + 49.24H_2O + 0.26N_2 + \text{Others (Char etc.)}$$

Based on the simulator , we estimated the energy efficiencies.
-> **Power efficiency: Cassava 16.8%, Sugarcane 17.6%**

5. Simulation by using Biomass Utilization Model

Objective function

$$Min.: Net\_CO_2 = EtOH\_CO_2 - CO_2\_BT$$

$EtOH\_CO_2$: Cultivation + Transportation + Ethanol production
CO_2_BT : BT process – Transportation to BT

6. Economical Efficiency Evaluation

BT plant: 2,250 million yen/unit(durable time:15 years)
One administrator and 8 workers for one BT plant
Salary for worker :350,000THB/person/year
Transportation cost : 10.32 THB/km/t

Results

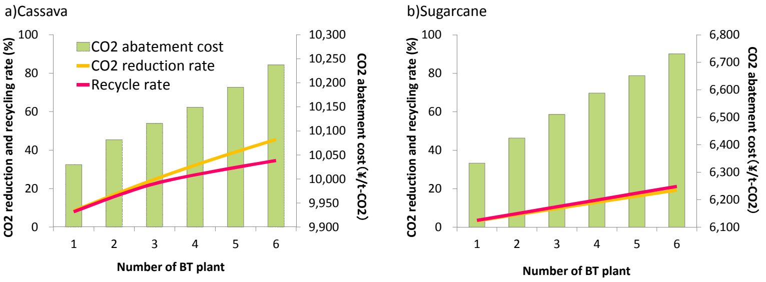


Fig.4 CO_2 reduction rate, abatement cost and recycling rate

Number of BT plant	Less	→	Lot
CO_2 reduction rate	Low	◀	High
Recycling rate	Low	◀	High
CO_2 abatement cost	Low	▶	High

$$CO_2reduction\_Rate = \frac{EtOH\_CO_2 - Net\_CO_2}{EtOH\_CO_2} \times 100$$

$$Recycling\_Rate = \frac{Used\_Amount\_BT}{EtOH\_Waste} \times 100$$

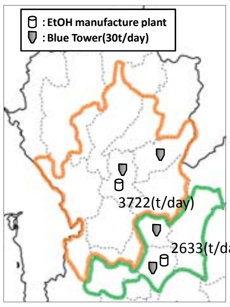


Fig.5 Optimal allocation of EtOH synthesis plant and BT plant (sugarcane)

Conclusion

Table1 CO_2 abatement cost in comparison with another renewable options

	CO_2 Abatement Cost (¥/CO_2-t)	Unit price for power production (¥/kWh)
BT (Cassava)	10,134	16.8
BT (Sugarcane)	6,540	14.4
Solar PV	8,419～84,955	40～90
Wind Energy	-9,950 ～ 9,950	7～20

There are possibility of CO_2 abatement and profitability of the project operation in our system.

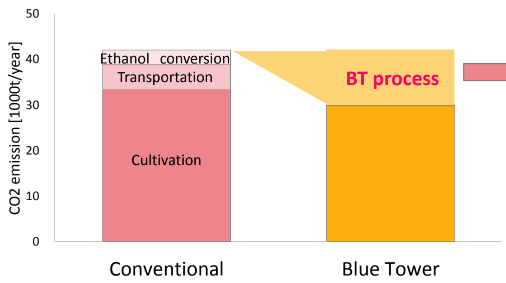


Fig.6 CO_2 emission of conventional case and Blue Tower case (cassava)

Additional Reduction of CO_2 emission

Surplus electricity would be supplied to the general grid -> reduction of CO_2 emission

1. BT system has great potential to gain CER (Certified Emission Reduction) efficiently .
2. Using biomass waste feedstock efficiently, the eco-energy, and the job opportunities for farmers would be created.