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

**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)

Under the CDM scheme, we optimized the biomass utilization system to increase recycle rate and to mitigate CO2 emission (See Fig.2).

**Methodology**

We estimated by "Biomass Utilization Model"...  
1. **Cultivation**  
   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. CO2 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.

2. **Transportation**  
   i. truck load ratio [kg CO2 per km] [kg biomass per km]
   - Cassava: 10 ton 100% 669.96 476.35
   - Sugarcane: 15 ton 167% 1004.95 543.34

The fuel consumption rate: \( f_t = a + b \)  
The road distance between each province is used as the shortest pathway.

3. **Ethanol production**  
   - Conversion ratio >> Cassava: 137L ethanol/t  
   - Sugarcane: 10.17L ethanol/t
   - Direct emissions: Electricity, Coal, and Diesel

4. **Blue Tower process design**
   a. Result of reforming experiment (e.g. cassava)

5. Simulation by using Biomass Utilization Model

Objective function

\[
\begin{align*}
\text{Min}: & \quad \text{Net CO}_2 = \text{EtOH} - \text{CO}_2 - \text{CO}_2 - \text{BT} \\
& \quad \text{EtOH} - \text{CO}_2 : \quad \text{Cultivation + Transportation + Ethanol production} \\
& \quad \text{CO}_2 - \text{BT} : \quad \text{BT process} - \text{Transportation to BT}
\end{align*}
\]

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 CO2 reduction rate, abatement cost and recycling rate

**Conclusion**

**Table 1 CO2 abatement cost in comparison with another renewable options**

<table>
<thead>
<tr>
<th></th>
<th>CO2 Abatement Cost (X/CO2 t)</th>
<th>Unit price for power production (X/kW/H)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BT (Cassava)</td>
<td>10,134</td>
<td>16.8</td>
</tr>
<tr>
<td>BT (Sugarcane)</td>
<td>6,540</td>
<td>14.4</td>
</tr>
<tr>
<td>Solar PV</td>
<td>8,419~8,955</td>
<td>40~90</td>
</tr>
<tr>
<td>Wind Energy</td>
<td>-9,950 ~ 9,950</td>
<td>7~20</td>
</tr>
</tbody>
</table>

There are possibility of CO2 abatement and profitability of the project operation in our system.

**Additional Reduction of CO2 emission**

Surplus electricity would be supplied to the general grid → reduction of CO2 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.