Feasibility Studies with the Aim of Developing a Bilateral Offset Credit Mechanism FY2011

Studies for Project Exploration and Planning

FEASIBILITY STUDY ON
INSTALLATION OF HYBRID POWER GENERATION SYSTEM IN THE REPUBLIC OF MOZAMBIQUE UNDER THE BILATERAL CARBON OFFSETTING MECHANISM (BOCM)

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Nippon Biodiesel Fuel Co.,Ltd.
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1. BACKGROUND OF THE STUDY

- **Situation of Mozambique**
  - National electrification rate → 17%
  - Rural electrification rate → 1.4%

- **Policy of the GOM** (five-year government programme 2010/14)
  “Promotion of electrification is a **key to the development of the country.** The Challenge is to **improve access to sustainable energy** to contribute to fight against poverty, well-being of Mozambicans, and socio-economic development”

This project attempts to...

**Accelerate electrification of Mozambican rural community with Japan’s low-carbon, sustainable technology.**
2. Overview of the Project (1)

Main ideas:

1. **Electrification of remote villages** with locally available renewable energy source
   - Jatropha
   - Locally produced RE source
   - Income generation
   - Japanese technology
   - Low-carbon technology
   - Sustainable energy
   - Accessible energy

2. **GHG reduction** by substituting carbon-intensive electrification
   - Develop methodologies for measurement of GHG emission reduction (MRV)
   - Carbon-intensive electricity
   - Low-carbon & sustainable electricity
   - Carbon credit under BOCM
2. Overview of the Project (2)

Solar panel (20kW) → Power conditioner → Hybrid control system

Sunlight (5.2~6.0kWh/m²/day)

Jatropha Seeds

Processing → Degummed oil → Jatropha oil Power Generation (50kW)

Renewable Energy Source
Jatropha produced by local farmers’ club & solar power

Electricity production
Electricity produced with Jatropha & solar hybrid system. Total capacity is 50kw

Hybrid control system

Mini-grid

Distribution
Distributed with mini-grid

Residences • Hospitals/clinics • Schools

Electrification
Remote communities will be electrified with RE
3. Implementation Plan (1)

The Project activities involve the followings

- **Electricity generation and distribution:**

- **Jatropha Procurement:**
  purchase from farmers’ group (approx. 100 farmers) and pay with cash or tickets. Ticket can be used for payment of bills

- **Sub business:**
  - Ice production: produce ice and sell to local fishermen
  - Solid fuel: produce solid fuel from Jatropha residue
  - Purchase: purchase rice and other agriculture products
3. IMPLEMENTATION PLAN (2)

- Business Framework

**Local Company**

<table>
<thead>
<tr>
<th>Sub businesses</th>
<th>Customer services</th>
<th>Plant operation</th>
<th>Procurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice production/sales Rice purchase</td>
<td>Billing/ Collect fees</td>
<td>Oil processing Power generation</td>
<td>Purchase of Jatropha seed</td>
</tr>
</tbody>
</table>

- Residents, farmers, Fishermen
- Public / commercial facilities, industries
- Farmers’ club (100 farmers)
- Production of Jatorropha seed
- Payment with cash, ticket or seed
- Electricity
- Ticket or cash
- Jatropha seed

Village ( >500 households)
4. OVERVIEW OF THE HYBRID SYSTEM (1)

Choice of technology & design concept

- What is sustainably available energy supply system for Mozambique?

Combination of maximum use of renewable Energy (Solar, Wind Power etc) & stable energy source is the best

Choice of Renewable Energy
- Solar Power: Less sensitive to locational condition, maintenance is easy
- Wind Power: Sensitive to wind condition, maintenance is important
- Other RE: locational condition is determinant

Choice of Stable energy supply
- Time-proven, easy operation, durable and easy-maintenance generator
- Small scale and quick response to load change
- No locational limitations

Select Solar Power

Select Diesel Generator

Maximum use of RE

- Select high-efficiency PV module supplied by Japanese producers
- Maximum use with Japan’s power conditioner

Procurement of fossil fuel is unstable, non-sustainable

- Choose Jatropha (widely producible in Mozambique) as the raw material of fuel
- Employ Japan’s oil processing technology & DG

Select high efficiency modules

Select biodiesel generator

Easy and Quick installation at sites

Hybrid system of Biodiesel generator and Solar Power. Employ Japanese technology and design the system based on 20ft. containers for easy installation
## 4. Overview of the Hybrid System (2)

### System Composition of the Hybrid System

4 patterns of composition are designed to be selected depending on the conditions (load, availability of Jatropha etc) of the locations.

<table>
<thead>
<tr>
<th>Supply pattern</th>
<th>50kW / 14 hrs</th>
<th>50kW/ 24hrs</th>
<th>100kW / 14 hrs</th>
<th>100kW/ 24hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Generator</td>
<td>50kW*1</td>
<td></td>
<td>50kW*2</td>
<td></td>
</tr>
<tr>
<td>PV array</td>
<td>10kW*2</td>
<td></td>
<td>10kW*3</td>
<td></td>
</tr>
<tr>
<td>Jatropha processing</td>
<td>50kg/h</td>
<td></td>
<td>100kg/h</td>
<td></td>
</tr>
<tr>
<td>Ice Production</td>
<td>100 kg /24h</td>
<td></td>
<td>200 kg /24h</td>
<td></td>
</tr>
<tr>
<td>Input Jatropha</td>
<td>500 kg</td>
<td>800 kg</td>
<td>1,000 kg</td>
<td>1,600 kg</td>
</tr>
<tr>
<td>Output fuel oil</td>
<td>125 L</td>
<td>200 L</td>
<td>250 L</td>
<td>400 L</td>
</tr>
<tr>
<td>Output solid fuel</td>
<td>375 kg</td>
<td>600 kg</td>
<td>750 kg</td>
<td>1,200 kg</td>
</tr>
<tr>
<td>Input water</td>
<td>300 L</td>
<td>600L</td>
<td>300 L</td>
<td>600 L</td>
</tr>
<tr>
<td>Output ice</td>
<td>50 kg</td>
<td>500 kg</td>
<td>250 kg</td>
<td>500 kg</td>
</tr>
</tbody>
</table>

Selected for this F/S
4. **Overview of the Hybrid System (3)**

- **50kW/ 14 hrs system (selected for F/S)**

<table>
<thead>
<tr>
<th>DG Container [50kW]</th>
<th>PV Container [10kW]</th>
<th>PCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG 50kW</td>
<td>PV 10kW</td>
<td>PV 10kW</td>
</tr>
</tbody>
</table>

**A system configuration diagram**

<table>
<thead>
<tr>
<th>Transmission Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>400</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Production volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Input (kg/h)</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>Max 100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diesel Generator Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>200</td>
</tr>
</tbody>
</table>
5. MRV (1)

- **MRV design policy:**
  
  - Widely applicable but simple & conservative methodology
  
  - Designed based on the following approved small scale CDM methodologies:

    AMS-I-F (Renewable electricity generation for captive use and mini-grid) and,

    AMS-I-H (Biodiesel production and use for energy generation in stationary applications)
5. MRV (2)

AMS-I-F & AMS-I-H was modified to make sure the MRV can be properly adopted by Mozambican local operators (including farmers).

- **Features of the MRV:**
  - Reference emissions are identified by the amount of electricity supplied to the grid (not by the amount of biofuel used in the power generation plants)
  - Nationally appropriate land eligibility applied
  - Default factor of emissions from cultivation process of biofuel crops (in the case of no fertilizer, no pesticide, default emission is 0 (zero))
5. MRV (3)

Eligibility (key points)

- **Eligible countries**: LDCs & Sub-Saharan African countries.
- **Installation capacity**: 5 MW or lower.
- **Area**: Non-electrified areas with no official plans for grid connection.
- **Electricity supply source**: local grid using power generated by a renewable energy source (PV, wind & biodiesel power generation)
- **Biofuel**: Inedible vegetable fat or oil with a similar performance to biodiesel
- **Land**: Land should be justified by host country as suitable land for biofuel crop cultivation (no conditions may apply when the cultivation land is used as hedges for private houses)
- **Claimer of emission reduction**: Owner of power generation system
- **Exclusions**: Mixed combustion of biodiesel and solid fuel, biodiesel produced under the project must not be exported abroad.
5. MRV (4)

- **Project boundary:**
  Power consumers, generators, and other Physical & geographical area connected to the grid

- **Additionality:**
  No need for proof of additionality as the eligibility for the MRV exclude project more than 5MW capacity

- **Reference scenario:**
  Power will be supplied from a carbon intensive mini-grid electricity, if there is no official plan of the central government or local government concerning the construction of transmission and distribution.
5. MRV (5)

<M: Measurement>
Calculation of GHG Emission reduction

\[ ER = ER_i + ER_{BD} \]

- **Reference emission**
  \[ RE_i = (EG_i: \text{Power substituted with RE}) \times (EF_{CO2,y}: \text{Emission Factor of local grid}) \]

- **Project emission**
  \[ PE = (PE_i: \text{Emission from RE}) + (PE_{BD}: \text{Emission from DG}) \]

- **Leakage**
  \[ L = 0 \]

- **Emission Reduction**
  \[ ER = (RE_i: \text{Emission reduction with RE}) + (ER_{BD}: \text{Emission reduction with DG}) \]
5. MRV (6)

<R: Reporting>

Monitoring and Reporting

- Eligibility
  - Cultivation site of raw crops for biodiesel
  - Weight of produced and consumed biodiesel (t)
  - Total installed capacity of power generation facilities using renewable energies (≤5MW) and means of power generation

- Monitoring of Activities/Parameters
  - Electric energy transmitted by renewable energy source ($EG_i$, kWh)
  - Emission coefficient for the local grid in the reference scenario ($EF_{CO2,y}$, kg-CO$_2$/kWh)
5. MRV (7)

<V: Validation / Verification>

○ Validation
  • Whether or not the project meets the eligibility criteria for MRV
  • The LDC criteria and reference scenario criteria in the host country are confirmed when the host country is approved for project implementation.
  • Whether or not the equations to calculate the reference emission, project emission and project reduction are properly defined
  • Whether or not the data and parameters to be used for the calculation of the GHG reduction can be measured in the project
  • Whether or not QA/QC is properly planned

○ Verification
  • Reconfirmation of the eligibility criteria for the project (excluding the LDC criteria and reference scenario criteria of the target country) at the time of project commencement
  • Confirmation of proper calculations using activities data and parameters
  • Whether or not the GHG reduction is properly calculated
  • Whether or not QA/QC is properly implemented.
### 6. Selection of Candidate Sites and Project Plan (1)

#### Selection of the Project sites

<table>
<thead>
<tr>
<th>Selected Location(s)</th>
<th>Cabo-delgado</th>
<th>24 PAs /48 villages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Criteria</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>low electrification rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>size &amp; density of rural population</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existing Jatropha production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suitable climate for Jatropha production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No existence of grid connection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No existence of DG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low probability of grid connection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population size &gt;500 h/h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Existence of Jatropha production &amp; possibility of procurement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PA Quiterajo, Macomia Dist**

- No electricity used
- Existing Jatropha production near the village
- Main industries: agriculture + fisheries
6. **SELECTION OF CANDIDATE SITES AND PROJECT PLAN (2)**

- **Business Plan in Quiterajo**
  - Supply electricity to 600 households
    - 500 h/h with 1 light bulb btw 6 - 10 pm
    - 90 h/h with 2 light bulbs btw 6 - 10 pm
    - 10 h/h with 3 light bulbs + TV + mobile phone charge btw 8 am - 10 pm
  - Produce 250 kg/d of ice & sell @25 MT/kg
  - Procure solid fuel & sell @ 3 MT/kg

![Load pattern for 50kw/14hrs supply](image)
7. **Calculation of GHG Emission Reduction**

- **Project emission**
  
  \[ PE = (PE_i: \text{Emission from RE}) + (PE_{BD}: \text{Emission form DG}) \]
  
  \[ = 0 + 1,850 \ell/y \times 0.9 \text{kg/\ell} \times 43.0 \text{MJ/kg} \times 0.0741 \text{t-CO2/MJ} \]
  
  \[ = 5.3 \text{ t-CO2/y} \]

- **Emission Reduction**
  
  \[ RE_i = (EG_i: \text{Power substituted with RE}) \times (EF_{CO2,y}: \text{Emission Factor of local grid}) \]
  
  \[ = (20kW \times 8,760h/y \times 17.7\%) \times (1.0\text{kg-CO2/kwh}) \]
  
  \[ = 31.0 \text{ t-CO2/y} \]

  \[ RE_{BD} = (PE_{FF}: \text{Project Emission from Fossil Fuel}) \]
  
  \[ = 47,250 \ell/y \times 0.9 \text{kg/\ell} \times 39.6 \text{MJ/kg} / 3.6 \text{MJ/kWh} \times 33.67\% \times 1.0\text{kg-CO2/kWh} \]
  
  \[ = 75.0 \text{ t-CO2/y} \]

- **Emission Reduction**
  
  \[ ER = (RE_i: \text{Emission reduction with RE}) + (ER_{BD}: \text{Emission reduction with DG}) - PE \]
  
  \[ = 31.0 \text{ t-CO2/y} + 75.0 \text{ t-CO2/y} - 5.3 \text{ t-CO2/y} \]
  
  \[ = 101 \text{ t-CO2/y} \]
8. Financial Analysis for Candidate Site (1)

- **Power generation & supply facility (cost)**
  - 50 kW diesel generator | MT 510,000
  - 20 kW PV power generation | MT 330,000
  - Hybrid control panel | MT 150,000
  - Unitisation cost | MT 150,000
  - Mini-grid | MT 150,000
  - Import/export and transportation cost | MT 150,000
  - Local installation cost | MT 100,000

- **Oil processing facility (cost)**
  - Hopper | MT 10,000
  - Heater | MT 20,000
  - Oil mill | MT 70,000
  - Filtering device | MT 50,000
  - Degumming device | MT 10,000
  - Briquetting machine | MT 50,000

- **Tariff (revenue)**
  - Power supply contract for 1 light bulb | 400 households | MT 300/month
  - Power supply contract for 2 light bulbs | 90 households | MT 550/month
  - Power supply contract for TV, mobile phone battery charger and 3 light bulbs | 10 households | MT 2,200/month

- **Solid fuel (revenue)**
  - Residual of Jatropha oil pressing (briquettes) | MT 1.5/kg | 375 kg/day
8. Financial Analysis for Candidate Site (2)

- **Emission Reduction**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RE</td>
<td>31.0 t-CO2/y + 75.0 t-CO2/y = 106.0 t-CO2/y</td>
<td></td>
</tr>
<tr>
<td>REi (20 kW PV)</td>
<td>20 kWs × 8,760h/y × 17.7% × 1.0 kg-CO2/kWh = 31.0 t-CO2/y</td>
<td></td>
</tr>
<tr>
<td>REBD (50 kW DEG)</td>
<td>47,250ℓ/y × 0.9 kg/ℓ × 39.6 MJ/kg /3.6 MJ/kWh × 33.67% × 1.0 kg-CO2/kWh = 75.0 t-CO2/y</td>
<td></td>
</tr>
<tr>
<td>PE</td>
<td>5.3 t-CO2/y + 0 t-CO2/y = 5.3 t-CO2/y</td>
<td></td>
</tr>
<tr>
<td>PEFF</td>
<td>1,850ℓ/y × 0.9 kg/ℓ × 43.0 MJ/ kg × 0.0741 t-CO2/MJ = 5.3 t-CO2/y</td>
<td></td>
</tr>
<tr>
<td>Emission other than PEFF</td>
<td>0 t-CO2/y</td>
<td></td>
</tr>
</tbody>
</table>

- **IRR 10yrs (depreciation 5yrs, credit@ JPY1,200/kg-CO2)**

<table>
<thead>
<tr>
<th></th>
<th>Ratio of self finance</th>
<th>Fiscal benefit (specific)</th>
<th>Cost of distribution network</th>
<th>IRR 10yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Without credit</td>
</tr>
<tr>
<td>Case 1</td>
<td>100%</td>
<td>Y</td>
<td>included</td>
<td>14.2%</td>
</tr>
<tr>
<td>Case 2</td>
<td>100%</td>
<td>Y</td>
<td>not included</td>
<td>19.8%</td>
</tr>
</tbody>
</table>

- Improvement of financial viability with conditions of; sub-business(additional revenue), reduction of overhead cost, lower capital cost, fiscal benefit, subsidiary for distribution network, and good price for carbon credit
9. Future Plan and Conclusions (1)

- **Expansion to 3,000 locations in Mozambique**
  - GHG Emission Reduction: 300 ~ 1,820 kt-CO2/y

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (DG + PV)</td>
<td>50kW (50 + 20)</td>
<td>100kW (100 + 30)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation hrs/d</td>
<td>14hrs</td>
<td>24hrs</td>
<td>14hrs</td>
<td>24hrs</td>
</tr>
<tr>
<td>GHG reduction/ location</td>
<td>101t-CO2</td>
<td>321t-CO2</td>
<td>202t-CO2</td>
<td>642t-CO2</td>
</tr>
<tr>
<td>Load / household</td>
<td>100w</td>
<td></td>
<td>200w</td>
<td></td>
</tr>
<tr>
<td>GHG reduction/ 3,000 locations</td>
<td>300kt-CO2</td>
<td>960kt-CO2</td>
<td>610kt-CO2</td>
<td>1,820kt-CO2</td>
</tr>
</tbody>
</table>

- Improve access to medical services
- Improve access to education, information
- Expand income generation opportunities
- Mitigate deforestation by Reduced dependency on forestry resource

⇒ **Appropriate as Mozambique’s NAMAs**
9. Future Plan and Conclusions (2)

- Incorporation in Apr. 2012
- Start sales of oil in May/June 2012 & establish supply chains
- Continue with potential survey for electricity supply business & start actual operation in 2013

<table>
<thead>
<tr>
<th>2012/ Apr</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorporation</td>
<td>★</td>
</tr>
<tr>
<td>Jatropha cultivation</td>
<td></td>
</tr>
<tr>
<td>Sales of oil</td>
<td></td>
</tr>
<tr>
<td>Est. supply chain</td>
<td></td>
</tr>
<tr>
<td>Potential survey</td>
<td></td>
</tr>
<tr>
<td>Electricity supply</td>
<td></td>
</tr>
</tbody>
</table>
10. NECESSARY CONDITIONS FOR IMPLEMENTATION

- **Project proponents**
  - Prepare profit-adding sub-business (ice production,)
  - Identify potential un-electrified areas
  - Find appropriate financial source

- **Government of Mozambique**
  - Prepare statistical data of un-electrified villages
  - Measures on investment promotion under BOCM

- **Government of Japan**
  - Packaged assistance such as financial assistance + capacity building etc., for project implementation under BOCM
  - Assistance on NAMAs and MRV development