BIOGAS POWER PLANT
Market Development & Technology Overview

USAID ICED II
Belitung, 26 October 2016
Presentation Outline

1. Definition and Project Type
2. Market Potential and Development
3. Typical Design of Biogas Power Project
4. Project Development
1. Definition and Project Type

1.1 What is Biogas?
1.2 Anaerobic Digestion
1.3 Gas Composition
1.4 Feedstock of Biogas
1.4 Type of Biogas System
Popular Terminology on Bioenergy Projects

- **Biomass** (as a fuel)
- **Biogas** (as a fuel)
- **Biofuel** (*Bahan Bakar Nabati / BBN*): Bioethanol and Biodiesel
- **Energy Plantation** (dedicated plantation / crop as a biomass fuel)
- **MSW-solid combustible / Refuse Derived Fuel** (as a fuel)
- **Landfill Gas** (produce from MSW-wet organic)

Note: only **Biogas power project** discuss during this session.
Route of Energy Conversion System

Thermochemical conversion
- Combustion
- Gasification
- Pyrolysis Liquefaction HTU

Biochemical conversion
- Digestion
- Fermentation
- Extraction (oilseeds)

Conversion pathways:
- Steam → Gas turbine combined cycle, engine
- Gas → Methanol/hydrocarbon/hydrogen synthesis
- Charcoal → Upgrading → Diesel
- Biogas → Gas engine
- Distillation → Ethanol
- Esterification → Bio-diesel
- Purification → PPO

Products:
- Heat
- Electricity
- Fuels
BIOGAS

- Biogas is gas produced by anaerobic digestion of biodegradable materials by microorganism especially bacteria. The biodegradable material are typically biomass, manure, sewage, municipal waste, and crops waste.

- Anaerobic Digestion (AD) as metabolism process in the absence of oxygen is more effective on producing high yield of methane (biogas), pre-tread waste water rich in nutrients (Nitrogen and Phosphorus) and minimize the sludge production.
Anaerobic Digestion Process & Biogas Composition

### Biogas Composition

<table>
<thead>
<tr>
<th>Elements</th>
<th>Formula</th>
<th>Concentration (Vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>50 - 75</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>CO₂</td>
<td>25 - 45</td>
</tr>
<tr>
<td>Water Vapor</td>
<td>H₂O</td>
<td>2 - 7</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>Hydrogen Sulphide</td>
<td>H₂S</td>
<td>&lt; 2</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH₃</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>

### Biogas Composition of Landfill Gas, Biogas, and Natural Gas

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Landfill Gas</th>
<th>Biogas</th>
<th>Natural Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kandungan Methane</td>
<td>vol-%</td>
<td>35 - 60</td>
<td>53 - 70</td>
<td>81 - 87</td>
</tr>
<tr>
<td>Kandungan Karbondioksida</td>
<td>vol-%</td>
<td>15 - 50</td>
<td>30 - 47</td>
<td>-</td>
</tr>
<tr>
<td>Heating Value (LHV)</td>
<td>MJ/m³</td>
<td>16</td>
<td>21 - 23</td>
<td>30 - 40</td>
</tr>
<tr>
<td>Densitas</td>
<td>kg/m³</td>
<td>1,3</td>
<td>1,2</td>
<td>0,8</td>
</tr>
</tbody>
</table>

Sumber: nachwachsende-rohstoffe.de & EIA Bioenergy 2006
Most Common Biogas Feedstock

In Southeast Asia and Indonesia:

1. Palm Oil Mill Effluent (POME)
2. Cassava-Starch Mill Effluent
3. Bioethanol Mill Effluent
4. Cow Farm Manure

In Europa and America:

Feedstock Mixed: Crops Waste (Wheat Straw, Corn Stover) & Livestock (dairy or swine Manure).
Potential Biogas Yield from Several Organic Materials

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Biogas yield (m³/t fresh mass)</th>
<th>CH₄ content (vol. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle Slurry</td>
<td>20 – 30</td>
<td>60</td>
</tr>
<tr>
<td>Pig Slurry</td>
<td>20 - 35</td>
<td>60 - 70</td>
</tr>
<tr>
<td>Cattle Manure (Dung)</td>
<td>40 - 50</td>
<td>60</td>
</tr>
<tr>
<td>Pig Manure</td>
<td>55 - 65</td>
<td>60</td>
</tr>
<tr>
<td>Chicken Manure</td>
<td>70 - 90</td>
<td>60</td>
</tr>
<tr>
<td>Maize Silage</td>
<td>170 - 200</td>
<td>50 - 55</td>
</tr>
<tr>
<td>Rye Whole-Crop Silage</td>
<td>170 - 220</td>
<td>55</td>
</tr>
<tr>
<td>Organic Waste</td>
<td>80 - 120</td>
<td>58 - 65</td>
</tr>
<tr>
<td>Grass Cuttings</td>
<td>150 - 200</td>
<td>55 - 65</td>
</tr>
<tr>
<td>POME</td>
<td>40 - 50</td>
<td>60</td>
</tr>
<tr>
<td>EFB</td>
<td>200 - 250</td>
<td>60</td>
</tr>
</tbody>
</table>
Mass Balance in Palm Oil Mill

Produk Utama

Sisa Perkebunan
PELEPAH (Frond)
Yield 8,4 ton/ha/thn

Sisa Tanam Ulang
BATANG (Trunk)
Yield 65 ton/ha

TANDAN BUAH SEGAR
100%

MINYAK SAWIT (CPO)
21 - 23%

MINYAK BIJI SAWIT
(PKO)

Produk Samping

SERAT (Fiber)
11 - 12%

CANGKANG
5 - 7%

TANDAN KOSONG
20 - 23%

LIMBAH CAIR (POME)
50 - 60%
<table>
<thead>
<tr>
<th>Parameter Standard</th>
<th>Untreated POME</th>
<th>Environmental Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Discharge to Water Body*</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>15,100 – 65,000</td>
<td>350</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>8,200 – 40,000</td>
<td>100</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>1,330 – 50,700</td>
<td>250</td>
</tr>
<tr>
<td>pH</td>
<td>3.3 – 4.6</td>
<td>6 - 9</td>
</tr>
<tr>
<td>Total-N</td>
<td>12 – 126</td>
<td>50</td>
</tr>
<tr>
<td>Oil &amp; Fat</td>
<td>190 – 14,720</td>
<td>25</td>
</tr>
<tr>
<td>Max. Flow (m³/ton)</td>
<td>2.5</td>
<td>-</td>
</tr>
</tbody>
</table>

*Keputusan Manteri Negara Lingkungan Hidup No.: KEP-51/MENLH/10/1995 tentang Baku Mutu Limbah Cair Bagi Kegiatan Industri, Lampiran B.IV

Biogas Production Rate

![Graph showing Biogas Production Rate](image)

- **Accumulated Biogas Yield (m³/kg)**
- **Specific Gas Production Rate (m³/m³ *d)**

**X-axis:** Average Hydraulic Retention Time (HRT), in days

**Y-axis:** Gas Production Rate or Biogas Yield
Type of Biogas System

1. Domestic or Household Biogas System
Mainly the feedstock is from livestock-dung and use in household for cooking purpose.

2. Utility Scale Biogas System
Agro-industries that have large number of potential feedstock. In Indonesia Palm Oil Mill industry is the main potential resources.
Domestic / Household Biogas System
Fixed Dome Digester 4 m³ – 12 m³

Aplikasi Kompor
Aplikasi Lampu Gas

Sumber: Program Biru Hivos, 2008
**Domestic / Household Biogas System**

**Typical Digester Design, Gas Production & Cost Estimation**

<table>
<thead>
<tr>
<th>Ukuran (m³)</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumlah sapi (ekor)</td>
<td>3</td>
<td>4-5</td>
<td>6</td>
<td>7-8</td>
<td>9</td>
</tr>
<tr>
<td>Jumlah kg kotoran/hari</td>
<td>30</td>
<td>45</td>
<td>60</td>
<td>75</td>
<td>90</td>
</tr>
<tr>
<td>Gas yang dihasilkan (m³)</td>
<td>1</td>
<td>1,5</td>
<td>2</td>
<td>2,5</td>
<td>3</td>
</tr>
<tr>
<td>Lama penggunaan untuk kompor (jam)</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Biaya konstruksi</td>
<td>5,7 juta</td>
<td>6,3 juta</td>
<td>7 juta</td>
<td>8 juta</td>
<td>8,8 juta</td>
</tr>
</tbody>
</table>

*Sumber: Program Biru Hivos, 2008*
Utility Scale Biogas System

Covered Anaerobic Lagoon (CAL)  Completely Stirred Tank Reactor (CSTR)
Utility Scale Biogas System
Typical Mill Capacity and Power Plant Design

**Palm Oil Mill Effluent (POME)**
- Mill Capacity of 60 ton/hour (Biogas production 20,500 Nm³/day)
- Power Plant Design Capacity = 1.5 - 2 MW

**Cassava-Starch Mill Effluent**
- Mill Capacity of 200 ton/day (Biogas production 26,700 Nm³/day)
- Power Plant Design Capacity = 2 - 2.5 MW

**Cow-Feedlot Farm Effluent**
- Feedlot Capacity of 18,000 cows (Biogas production 6,500 m³/day)
- Power Plant Design Capacity = 0.6 - 1 MW

*Source: Ecossecurities 2006 dan PDD Lampung Bekri Feedlot*
2. Market Potential & Development

2.1 Technology Maturity
2.2 Global Biogas Development
2.3 Development Status in Indonesia
2.4 Market Potential & Project Sizing in Indonesia
Technology Maturity

Source: EPRI, 2010
Global Biogas Development

- Germany remains Europe’s largest producers of bio-power of 7.1 GW in 2015.
- Germany installed about 5,000 unit of biogas plants with total capacity of 4.8 GW.
- In Southeast Asia, Malaysia and Thailand are leading on the biogas project development.

Total Bio-power capacity 106 GW

Source: REN21, 2016
Development Status in Indonesia
Project Scheme & Utilization

1. **Independent Power Producer (IPP) Scheme**
   Sell the whole electricity production to the grid.

2. **Internal Use and Excess Power Scheme**
   Use for the internal mill utilization and sell the surplus of electricity to the grid.

3. **Captive Power Scheme** (Power Plant & Co-Firing)
   Use for the internal mill power (electricity or heat) utilization.

4. **Rural Electrification Off-Grid Scheme**
   Sell the whole electricity production to the isolated grid for rural electrification.
1. Independent Power Producer (IPP) Scheme

- Biogas PP capacity 1 MWe in Belitung, On-grid system
- Using Covered Anaerobic Lagoon
- Feedstock POME: 150,000 m³

The first IPP Biogas Power Plant in Indonesia.

Sources: AANE 2013
2. Captive Power Plant BOT Scheme

- Biogas PP capacity 1 MWe in Riau
- Electricity for internal use to replace the diesel generating power
- Using Covered Anaerobic Lagoon, 24,400 m³, HRT 30-40 day
- Feedstock: 140,000 m³ POME (Palm Oil Mill Effluent/wastewater)
3. Captive Power Plant (Substitute Diesel Plant)

- Biogas Power Plant 1 MW di Lampung (Starch Processing Mill)
- System UASB (Up-flow Anaerobic Sludge Blanket)
- Feedstock 550,000 m³ Starch Mill Effluent

Sources: Illustration UASB
4. Captive Power for Co-firing in Boiler System

- Biogas Plant in Bengkulu and biogas co-firing in boiler system to replace the biomass-shell fuel.
- Using CSTR (Continuous Stirred Tank Reactor) 6,400 m$^3$, HRT 10 day
- Feedstock: 150,000 m$^3$ POME (Palm Oil Mill Effluent/wastewater)
Market Potential & Project Sizing in Indonesia Palm Oil Mill Industry in Indonesia (Status 2010)

With total POM capacity of 34,280 TPH, the potential generated power is about 1,195 MWe (about 600 unit Biogas Power Plant).

Assumption POME 0.65 m3/ton and COD 60,000 mg/l.

Number of Mills 608 units
Total Capacity 34,280 TPH
EFB Production 21.13 million ton
## New Biogas Feed-in Tariff in Indonesia

### Harga Pembelian Tenaga Listrik Dari PLTbg

**Oleh PT Perusahaan Listrik Negara (Persero)**

<table>
<thead>
<tr>
<th>No.</th>
<th>Lokasi/Wilayah PLTbg</th>
<th>Harga Pembelian (sen USD/kWh)</th>
<th>Faktor F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Kapasitas s.d 20 MW</td>
<td>20 MW &lt; Kapasitas ≤ 50 MW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tegangan Rendah</td>
<td>Tegangan Menengah atau Tinggi</td>
</tr>
<tr>
<td>1.</td>
<td>Pulau Jawa</td>
<td>13,14 x F</td>
<td>10,64 x F</td>
</tr>
<tr>
<td>2.</td>
<td>Pulau Sumatera</td>
<td>13,14 x F</td>
<td>10,64 x F</td>
</tr>
<tr>
<td>3.</td>
<td>Pulau Sulawesi</td>
<td>13,14 x F</td>
<td>10,64 x F</td>
</tr>
<tr>
<td>4.</td>
<td>Pulau Kalimantan</td>
<td>13,14 x F</td>
<td>10,64 x F</td>
</tr>
<tr>
<td>5.</td>
<td>Pulau Bali, Pulau Bangka Belitung, dan Pulau Lombok</td>
<td>13,14 x F</td>
<td>10,64 x F</td>
</tr>
<tr>
<td>6.</td>
<td>Kepulauan Riau, Nusa Tenggara, dan Pulau Lainnya</td>
<td>13,14 x F</td>
<td>10,64 x F</td>
</tr>
<tr>
<td>7.</td>
<td>Pulau Maluku dan Pulau Papua</td>
<td>13,14 x F</td>
<td>10,64 x F</td>
</tr>
</tbody>
</table>
Evolving of Biogas Feed-in Tariff in Indonesia in Rp/kWh

<table>
<thead>
<tr>
<th>Year</th>
<th>Region</th>
<th>FIT (Rp/kWh)</th>
<th>Tariff (c$/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>Sumatra</td>
<td>1,591</td>
<td>12.2</td>
</tr>
<tr>
<td></td>
<td>Kalimantan</td>
<td>1,798</td>
<td>13.8</td>
</tr>
<tr>
<td></td>
<td>Babel</td>
<td>2,067</td>
<td>15.9</td>
</tr>
<tr>
<td>2014</td>
<td>Sumatra</td>
<td>1,208</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kalimantan</td>
<td>1,365</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>Sumatra</td>
<td>787</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kalimantan</td>
<td>853</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td></td>
<td>80% x HPP PLN</td>
</tr>
<tr>
<td>2002</td>
<td></td>
<td></td>
<td>Capacity Maximum 1 MW</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>80% x HPP PLN</td>
</tr>
</tbody>
</table>
3. Typical Design of Biogas Power Plant

3.1 Type of System & Layout Diagram
3.2 Technology Selection & Characteristic
3.3 Mass and Energy Balance
3.4 Project Design Characteristic
Type of Biogas Industrial Digester System

1. **Covered Anaerobic Lagoon (CAL)**

   Anaerobic lagoons are essentially covered ponds equipped with mixing mechanisms. This design normally handles a solids content of less than 2%, and operates in the mesophilic temperature range.

2. **Completely Stirred Tank Reactor (CSTR)**

   CSTRs are typically concrete or metal cylinders with low height-to-diameter ratios. They can operate at mesophilic or thermophilic temperatures, with mechanical, hydraulic, or gas-injection mixing.
Example of CAL System

PLTBg 1 MW in Belitung
Feedstock: 150,000 m³ POME

PLTBg 1 MW in Riau
Feedstock: 140,000 m³ POME

Sources: AANE and KME
Layout System Design of CAL System

Sumber: KME
Example of CSTR System in Indonesia

Biogas Plant, Co-firing in Boiler System, located in Mukomuko, Bengkulu
Digester volume 6,400 m$^3$, HRT (Hydraulic Retention Time) 10 days
Feedstock: 150,000 m$^3$ POME
Example of CSTR System in Germany
Layout of CSTR System

- Digester
- Post Digester
- Storage Biomassa solid
- Unit Gas Cleaning
- Pra-Tangki
- Pompa
- Unit Pembangkit CHP
- Tangki Penyimpanan

Sumber: AnnexPower 2010
Layout System Design of CSTR System


## CAL System Vs CSTR System

<table>
<thead>
<tr>
<th>Technology</th>
<th>CAL System</th>
<th>CSTR System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid Content</td>
<td>Thin Liquid ( &lt; 3% )</td>
<td>Liquid &amp; Solid ( 3 – 10% )</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>Mesophilic range 24 – 40°C</td>
<td>Thermophilic range 50 – 60°C</td>
</tr>
<tr>
<td>HRT (Hydraulic Retention Time)</td>
<td>Approximately 30 – 60 days</td>
<td>Approximately 10 – 30 days</td>
</tr>
<tr>
<td>Methane Yield</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>Low - Medium</td>
<td>High</td>
</tr>
<tr>
<td>Operating Complexity</td>
<td>Low - Medium</td>
<td>Medium - High</td>
</tr>
</tbody>
</table>
## Conversion System of POME to MW Capacity

<table>
<thead>
<tr>
<th>Feedstock Parameters</th>
<th>Unit</th>
<th>Palm Oil Mill Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mill Capacity</strong></td>
<td>TPH</td>
<td>30</td>
</tr>
<tr>
<td>Supply FFB</td>
<td>ton/year</td>
<td>150,000</td>
</tr>
<tr>
<td>Factor of Wastewater volume generated</td>
<td>m3 POME/t FFB</td>
<td>0.65</td>
</tr>
<tr>
<td>Effluent quantity</td>
<td>m3/year</td>
<td>97,500</td>
</tr>
<tr>
<td>COD of POME entering the digester</td>
<td>mg/L</td>
<td>60,000</td>
</tr>
<tr>
<td>Methane fraction in Biogas</td>
<td>m3 CH4/m3 Biogas</td>
<td>0.600</td>
</tr>
<tr>
<td>Digester efficiency</td>
<td>%</td>
<td>80%</td>
</tr>
<tr>
<td>Gas engine efficiency</td>
<td>%</td>
<td>38%</td>
</tr>
<tr>
<td>Potential Biogas generation</td>
<td>m3 biogas/year</td>
<td>2,723,464</td>
</tr>
<tr>
<td>Methane content in Biogas</td>
<td>m3 CH4/year</td>
<td>1,634,078</td>
</tr>
<tr>
<td>Potential gross total electricity generated</td>
<td>kWh/year</td>
<td>6,188,950</td>
</tr>
<tr>
<td>Operational hours</td>
<td>hours/year</td>
<td>7,008</td>
</tr>
<tr>
<td>Average Generated Capacity</td>
<td>kWhe</td>
<td>883</td>
</tr>
<tr>
<td><strong>Installed Capacity</strong></td>
<td>MWe</td>
<td>1.0</td>
</tr>
<tr>
<td>Gas Engine Configuration</td>
<td>MWe</td>
<td>1 + 5</td>
</tr>
<tr>
<td></td>
<td>2 x 1</td>
<td></td>
</tr>
</tbody>
</table>
Power Output Simulation
During High/Low Crop Session

Palm Oil Mill 45 TPH (POME supply 150,000 ton/year)
TANDAN BUAH SEGAR
100%
Yield 17 ton/ha/thn
MINYAK SAWIT (CPO)
23%
MINYAK BIJI SAWIT (PKO)
2,3%
SERAT (Fiber)
12%
CANGKANG
6%
TANDAN KOSONG
21%
LIMBAH CAIR (POME)
50%

Sisal Perkebunan
PELEPAH (Frond)
Yield 8,4 ton/ha/thn
Sisa Tanam Ulang
BATAK (Trunk)
Yield 65 ton/ha

PKS 60 TPH

Sistem Kogenerasi
Boiler 80 tph, 67 bar
Steam Turbine 12 MW

Listrik ± 1 – 2 MW
Steam 0,5 ton/ton TBS

Listrik ± 10 MW

Grid PLN

Recent Development - Integrated Concept
Biomass-Biogas Power Plant in Palm Oil Mill

Listrik 1 - 2 MW

Sistem Methane Capture
dan Gas Engine

± 10 MW

Steam 0,5 ton/ton TBS

± 1 – 2 MW

Steam 0,5 ton/ton TBS

± 1 – 2 MW
Piloting Development – Biogas Power Plant with Mixed-Feedstock of POME & EFB in Palm Oil Mill

- **PKS 60 TPH**
  - Sisa Perkebunan PELEPAH (Frond)
    - Yield 8,4 ton/ha/thn
  - Sisa Tanam Ulang BATANG (Trunk)
    - Yield 65 ton/ha

- **TANDAN BUAH SEGAR**
  - Yield 17 ton/ha/thn

- **MINYAK SAWIT (CPO)**
  - 23%

- **MINYAK BIJI SAWIT (PKO)**
  - 2,3%

- **SERAT (Fiber)**
  - 12%

- **CANGKANG**
  - 6%

- **TANDAN KOSONG**
  - 21%

- **LIMBAH CAIR (POME)**
  - 50%

- **Digester CSTR Sistem & Gas Engine**

- **Listrik ± 1 – 2 MW Steam 0,5 ton/ton TBS**

- **Grid PLN**

- **Sistem Kogenerasi**
  - Boiler 2 x 20 tph, 20 bar
  - Steam Turbine 1 - 2 MW

**Production Breakdown**

- **TANDAN BUAH SEGAR**
  - 100% Yield

- **MINYAK SAWIT**
  - 23%

- **MINYAK BIJI SAWIT**
  - 2,3%

- **SERAT**
  - 12%

- **CANGKANG**
  - 6%

- **TANDAN KOSONG**
  - 21%

- **LIMBAH CAIR**
  - 50%

- **Listrik ± 1 – 2 MW Steam 0,5 ton/ton TBS**

**Additional Components**

- **Listrik 5 - 10 MW**

**System Components**

- **Digester CSTR Sistem & Gas Engine**
- **Listrik ± 1 – 2 MW Steam 0,5 ton/ton TBS**
- **Grid PLN**
- **Sistem Kogenerasi**
  - Boiler 2 x 20 tph, 20 bar
  - Steam Turbine 1 - 2 MW

**Piloting Development**

- Biogas Power Plant with Mixed-Feedstock of POME & EFB in Palm Oil Mill

**Additional Notes**

- **Piloting Development**
  - Biogas Power Plant with Mixed-Feedstock of POME & EFB in Palm Oil Mill
Key Factor Maintaining Biogas Production

- Volume of Effluent (Stable Fluctuation)
- Temperature (Stable range as operating design Mesophilic or Thermophilic)
- pH and Alkalinity (Maintaining at 6.5 – 7.5)
- COD – BOD (Maintaining higher value is better)
- Volatile Matter & Total Suspended Solids (More Volatile is better)
- Nutrients (Ratio C : N = 25 : 1 dan Ratio C : P = 20 : 1)
- Retention Days (Make sure the bacteria is not wash out)
- Toxicity
4. Project Development

4.1 Project Management
4.2 Project Construction
4.3 Project Cost
Project Development Flow

1. Pre-FS and Interconnection Study
2. Raise Seed Equity
3. Feasibility Study
4. Obtain Local Permits
5. Feedstock Supply Agreement (FSA)
6. Power Purchase Agreement (PPA) with PLN
7. EPC Contract & O&M Contract
8. Land Acquisition
9. Obtain balance of permits & License
10. Raise balance of equity
11. Obtain debt financing
12. Financial Closure
13. Implement construction work
14. Test Run and COD
15. Operation Stage
16. Project Transfer
17. Decommissioning / Rebuild
Main Component of Biogas Power Plant

1. **Upstream:**
   - Cooling Pond and Mixing Pond
   - Covered Anaerobic Lagoon (CAL) System

2. **Downstream:**
   - Gas Cleaning System (*Deshulphuration Unit & Dehumidity Unit*)
   - Gas Engine and Generator
   - Biogas Flaring System

3. **Control & Monitoring:**
   Safety-valve, pumps, POME flow meter, COD & BOD analyzer, gas flow & temperature meter, pressure gauge, gas analyzer, flare temperature detector, and kWh meter

4. **Interkoneksi System to Grid**
Project Construction

I. Land Clearing

Sources: Biogas Tandun PTPN V
Project Construction
2. Piping Installation

Sources: Biogas Tandun PTPN V
Project Construction
3. Membrane Covered & Gas Collection Installation

Sources: Biogas Tandun PTPN V
Project Construction
4. Control System, Feeding & Gas Distribution System

Sources: Biogas Tandun PTPN V
Project Construction
5. Gas Cleaning System (Scrubber and Dryer)

Sources: Biogas Tandun PTPN V
Project Construction
6. Gas Engine and Distribution Line

Sources: Biogas Tandun PTPN V
Project Construction
7. Test Run and Commissioning

Sources: Biogas Tandun PTPN V
Typical Project Cost Component

**CAPEX:**

Project Development Cost: Permits, Overhead Cost, Study and Engineering Cost (Feasibility Study, Interconnection Study, Feedstock Lab Test, Soil Test, UKL-UPL, Basic Engineering Design)

EPC Cost:
- Site Preparation & Civil Work
- Digester System, Piping & Flaring
- Gas Cleaning & Pumps System
- Gas-Engines & Generator
- Controller & Electrical System
- Balance of Plants
- Grid Interconnection System
- Other Cost (IDC & Insurance)

Financing Cost: Interest, Equity Return

Other Cost: Insurance, Tax, CSR, etc

**OPEX:**

Operating Labor
General Administration & Others
Insurance
Digester Service & Maintenance
Gas Engine Service & Maintenance
# Project Cost Reference (Value in 2008)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas 500 kW</td>
<td>20</td>
<td>85</td>
<td>425</td>
<td>300-360</td>
<td>1950-2200</td>
<td>350-400</td>
<td>550-700</td>
<td>300-330</td>
<td>3550-3990</td>
</tr>
<tr>
<td>Biogas 1 MW</td>
<td>20</td>
<td>85</td>
<td>850</td>
<td>200-250</td>
<td>1750-1950</td>
<td>200-250</td>
<td>450-550</td>
<td>250-300</td>
<td>2850-3330</td>
</tr>
<tr>
<td>Biogas 2 MW</td>
<td>20</td>
<td>85</td>
<td>1700</td>
<td>130-150</td>
<td>1600-1750</td>
<td>150-175</td>
<td>230-300</td>
<td>170-200</td>
<td>2300-2572</td>
</tr>
</tbody>
</table>

**Notes:**
- Equipment and material costs depend on technology providers (each brand/type can be significantly cheaper or more expensive than the others).
- Civil cost is subject to the location of the project (this cost is usually more expensive in remote areas).

**Sources:** World Bank, 2008
**Project Cost Reference of Biogas Power Plant**

<table>
<thead>
<tr>
<th>Digestor System</th>
<th>CAPEX / MW (USD Million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAL System</td>
<td>1.5 – 3</td>
</tr>
<tr>
<td>CSTR System</td>
<td>2.5 – 3.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Install Capacity</th>
<th>CAL System Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MW</td>
<td>2,000,000</td>
</tr>
<tr>
<td>1.5 MW</td>
<td>2,500,000</td>
</tr>
<tr>
<td>2 MW</td>
<td>3,500,000</td>
</tr>
</tbody>
</table>

**Cost Composition CAL System**

<table>
<thead>
<tr>
<th>Capital Expenditures:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Development Cost</td>
<td>2%</td>
</tr>
<tr>
<td>Site Preparation &amp; Civil Work</td>
<td>5%</td>
</tr>
<tr>
<td>Digester System, Piping &amp; Flaring</td>
<td>34%</td>
</tr>
<tr>
<td>Gas Cleaning &amp; Pumps System</td>
<td>11%</td>
</tr>
<tr>
<td>Gas-Engines &amp; Generator</td>
<td>17%</td>
</tr>
<tr>
<td>Controller &amp; Electrical System</td>
<td>10%</td>
</tr>
<tr>
<td>Balance of Plants</td>
<td>11%</td>
</tr>
<tr>
<td>Grid Interconnection System</td>
<td>4%</td>
</tr>
<tr>
<td>Other Cost (IDC &amp; Insurance)</td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

**Operational Expenditures:**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Labour</td>
<td>25%</td>
</tr>
<tr>
<td>General Administration &amp; Others</td>
<td>14%</td>
</tr>
<tr>
<td>Insurance</td>
<td>5%</td>
</tr>
<tr>
<td>Digester Service &amp; Maintenance</td>
<td>17%</td>
</tr>
<tr>
<td>Gas Engine Service &amp; Maintenance</td>
<td>39%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>
Challenges and Risks

Main Challenges:
1. Securing feedstock supply (FSA with Mill Owner)
2. Distance to the electricity grid and grid absorption
3. Obtaining an acceptable Power Purchase Agreement
4. Obtaining project financing

Other Less Challenges:
1. Securing the necessary permits
2. Identifying suitable technical solutions for the feedstock
3. Social acceptance
Thank You

Bayuaji Kencana
bayuaji.kencana@iced.or.id

USAID ICED – Indonesia Clean Energy Development II

Implemented by

Tetra Tech | Complex World, Clear Solutions™

Menara Jamsostek, North Tower 14th Floor | Jl. Gatot Subroto No. 38 | Jakarta 12710 INDONESIA
Main: +62 21 5296 2325 | Fax: +62 21 5296 2326

www.iced.or.id