Prospects & Developments of Small Scale Biogas Upgrading & Bottling in India

Prof. Virendra K. Vijay
Centre for Rural Development & Technology
IIT Delhi
Email: vkvijay@rdat.iitd.ernet.in
011 26596351
BIOGAS

- Energy source produced from biodegradable /organic wastes by anaerobic digestion process
- Possible feedstock material: All good biodegradable organic materials
  ✓ Manure (liquid & solid)
  ✓ Organic waste (Household waste, restaurant waste, food industry waste, etc.)
  ✓ Energy crops (silage of maize, grass, corn, etc.)
- Digested slurry - can be dried and sold as high quality compost.
- Biogas belongs to the same gas-family as natural gas
- After upgrading biogas, calorific value and density are almost similar to natural gas
- Biogas can be adapted to the quality of natural gas
## Composition of Raw Biogas

<table>
<thead>
<tr>
<th>Compound</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane CH(_4)</td>
<td>55–65</td>
</tr>
<tr>
<td>Carbon dioxide CO(_2)</td>
<td>35–45</td>
</tr>
<tr>
<td>Nitrogen N(_2)</td>
<td>0–10</td>
</tr>
<tr>
<td>Hydrogen H(_2)</td>
<td>0–1</td>
</tr>
<tr>
<td>Hydrogen Sulfide H(_2)S</td>
<td>0–3</td>
</tr>
<tr>
<td>Moisture</td>
<td>Saturated</td>
</tr>
</tbody>
</table>

Average calorific value of biogas is 20 MJ/m\(^3\) (4713 kcal/m\(^3\))
VERSATILITY OF BIOGAS USE

Raw Biogas
- Injection into natural gas grid
- Electricity production by using 100% biogas engines
  - In remote areas
- Upgraded Biogas
  - If available in large quantities
  - Transportation fuel for vehicles
- Bottled Biogas
  - Cooking by using biogas cook stoves
    - Commercial Cooking is economical

Upgrading widens the scope of utilization
Resource Availability for Small Scale Biogas Upgrading in India

- Medium and small size biogas plants can be built due to the availability of widespread organic waste.

- Animal / agro waste, human waste, wastes from agro-based industries (paper and pulp production, sugarcane processing, distilleries, and other food and food-processing industries).
<table>
<thead>
<tr>
<th>Medium size biogas plants</th>
<th>biogas plants in urban localities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dairies, cattle sheds, poultry farms, piggery farms and animal rearing farms, fruit and vegetable market waste, water borne biomass such as water hyacinth, algae and variety of such agro wastes.</td>
<td>Biogas Plants intended to recycle the biodegradable MSW, sewage waste water, food waste etc of communities and centralised human habitats as hostels, restaurants, military barracks, hotels, community toilets, etc.</td>
</tr>
</tbody>
</table>
Feedstock Availability and potential of medium – community scale biogas plants in *Rural Areas*

**DECENTRALISED Biogas Production**

- **Cattle Waste** - From about 304 million cattle till 2012 - an estimated potential of about 18,240 M m³ of biogas annually.

- **Poultry Waste** - There are large number of poultry farms and about 10 major poultry processing plants and can generate 2173 M m³ biogas annually with 649 million numbers of birds.

- **Crop/ agricultural residue** – Some is used as fodder to feed animals or fire wood. The remaining biomass may be available for bioenergy generation and is estimated as 278.71 million tonnes annually. The biogas potential for the crop residue and agricultural waste is estimated as 45.8 million cubic meter of biogas generation annually.
Feedstock Availability and potential of medium – community scale biogas plants in Urban Areas

- **Vegetable Market Waste** (Mandi waste)
- **Food waste/ Canteen Waste**
- **Human Waste/ Community Toilets**
- **Municipal Waste** (Housing Societies)
### Potential for Small-Scale Upgraded Biogas Storage, Bottling & Distribution in Developing Economies

<table>
<thead>
<tr>
<th>Type of Biogas Plants</th>
<th>Range of Biogas Plant Capacity/Size (Assumption)</th>
<th>Viability of Biogas Upgrading and Bottling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium size biogas plants</td>
<td>85 - 600 Nm$^3$ day$^{-1}$ for dairies, vegetable markets, poultry farms etc.</td>
<td>• On-site small-scale biogas upgrading and bottling and hence captive utilisation of biogas as vehicle fuel.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Collection and transportation in pressurised tankers to centralised upgrading and bottling station.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Distribution of bottled gas to far off places or filling stations for vehicle fuel applications.</td>
</tr>
<tr>
<td>Community size biogas</td>
<td>85 - 600 Nm$^3$ day$^{-1}$ Hostels, restaurants, military barracks, hotels, community toilets.</td>
<td>• On-site small-scale biogas upgrading and bottling and hence captive utilisation of biogas as vehicle fuel.</td>
</tr>
<tr>
<td>plants</td>
<td></td>
<td>• Commercial selling of bottle biogas for cooking or transport.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Collection and transportation in pressurised tankers to centralised upgrading and bottling station.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Distribution of bottled gas to far off places or filling stations for vehicle fuel applications.</td>
</tr>
</tbody>
</table>
**Raw Biogas**  

- **A low Grade fuel** (CH$_4$ 55-65 % & CO$_2$ 35-45 %) with lower percentage of methane.

- **Mode of utilisation**
  - On site or nearby
  - Cooking and for electricity production.
  - The presence of CO$_2$ besides being non combustible, restrains its compressibility thereby making biogas difficult to be stored in containers.
  - For utilisation at far off places it must be stored in biogas balloons and taken to the site of utilisation or it can be transported by pipelines.

- **Upgraded Biogas**

- **A high grade fuel** (CH$_4$ > 90 % and < 10 % other gases) with high percentage of methane.

- **Mode of utilisation**
  - Remote applications
  - Methane burns faster hence yields a higher specific output and thermal efficiency compared to raw biogas when used as engine fuel.
  - Upgrading, compression and bottling facilitates easy storage and transportation as
    - As a vehicle fuel
    - As a cooking fuel
    - For electricity production
Utilization of Raw Biogas

Pipeline for raw biogas use as a cooking fuel

Raw biogas cookstove

Biogas lamp

Biogas Engine for electricity production
Prospects of Biogas Bottling in India

- Commercial Cooking as a replacement of LPG
- Electricity / Power production-in remote areas through biogas engines
- Upgraded –Bottled Biogas for vehicular use - BioCNG
Utilization of Upgraded Biogas

- Upgraded and bottled biogas for use as a cooking fuel
- Cascades of Upgraded biogas being transported
- Biogas Motorcycle in Thailand
- Biogas car in Sweden
- Biogas Train in Sweden
- Biogas Car in India
### Characteristic Comparison of Natural gas, Upgraded Biogas and Raw Biogas

<table>
<thead>
<tr>
<th>Properties</th>
<th>Compressed Natural Gas</th>
<th>Upgraded Biogas</th>
<th>Raw Biogas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Composition % (v/v)</strong></td>
<td>CH$_4$ – 89.14%</td>
<td>CH$_4$ – 93%</td>
<td>CH$_4$ – 55- 65%</td>
</tr>
<tr>
<td></td>
<td>CO$_2$ – 4.38%</td>
<td>CO$_2$ – 4%</td>
<td>CO$_2$ – 35-45%</td>
</tr>
<tr>
<td></td>
<td>H$_2$ – .01%</td>
<td>H$_2$ – .06%</td>
<td>H$_2$ – .02%</td>
</tr>
<tr>
<td></td>
<td>N$_2$ – .11%</td>
<td>N$_2$ – 2.94 %</td>
<td>N$_2$ – 1.98%</td>
</tr>
<tr>
<td></td>
<td>C$_2$H$_6$ – 4.05%</td>
<td>H$_2$S – 20 ppm</td>
<td>H$_2$S – 500 ppm</td>
</tr>
<tr>
<td></td>
<td>C$_3$H$_8$ – 0.83%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iso-C$<em>4$H$</em>{10}$ – 0.28%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neo-C$<em>4$H$</em>{10}$ – 0.66%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iso-C$<em>5$H$</em>{12}$ – 0.09%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neo-C$<em>5$H$</em>{12}$ – 0.28%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C$<em>6$H$</em>{14}$ -0.17%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Lower Heating Value</strong></td>
<td>44.39 MJ/kg</td>
<td>42.62 MJ/kg</td>
<td>20.5 MJ/kg</td>
</tr>
<tr>
<td><strong>Relative Density</strong></td>
<td>0.765</td>
<td>0.714</td>
<td>1.014</td>
</tr>
<tr>
<td><strong>Flame speed (cm/sec)</strong></td>
<td>34</td>
<td>–</td>
<td>25</td>
</tr>
<tr>
<td><strong>Stoichiometric A/F</strong> (kg of Air/ kg of Fuel)</td>
<td>17.03</td>
<td>17.16</td>
<td>17.16</td>
</tr>
<tr>
<td><strong>Auto-ignition Temperature (°C)</strong></td>
<td>540</td>
<td>–</td>
<td>650</td>
</tr>
</tbody>
</table>
Adaptability Scenario of Bottled Biogas in Natural Gas Infrastructure & Network in India

Availability of

- Natural Gas Vehicles
- Natural Gas Grid Availability in some urban areas
- CNG conversion kits availability
- Interchangeability/ use of Technologies/ equipments available for CNG
  - Upgrading Units
  - High Pressure Compressors
  - Gas Storage and Distribution Units (CNG Cylinders/Dispensing Units etc)
Feasible Scenarios for the Adoption of Bottled Biogas in India

Captive/ In-house Use

• Biogas upgrading and bottling in rural areas (Cattle sheds)
• Biogas upgrading and bottling in communities like hostels, fruit and vegetable market, marriage halls, community toilets.
• Biogas upgrading and bottling in urban areas serving housing societies/ housing clusters (WWTP, Sewage Treatment Plants, medium scale biogas production)
Selling of Bottled Biogas as a Fuel

- Biogas upgrading and bottling at far off location from the site of production of waste (collection of waste from different locations and transportation to a centralised site of biogas production and upgrading)

- Mobile upgrading and bottling system

- In urban areas – in housing societies, clusters of households
Centralised Waste Collection, Biogas Production, Upgrading & Bottling

- Centralized Waste Collection
- Agricultural Waste
- Food Waste
- Cow Dung
- Waste as Feedstock
- Community Biogas Plants
- Raw Biogas
- Water scrubbing
- Purified Biogas
- Biogas engine
- Electricity Production
- Cooking Fuel
- Transport Fuel
- PSA
- Purified Cylinder Cascade
Mobile Biogas upgrading and bottling system
Biogas Upgrading

The use of a biogas upgrading or purification process in which the raw biogas stream like CO₂, H₂S and moisture are absorbed or scrubbed off, leaving above 90% methane per unit volume of gas.

• Presence of CO₂ in biogas poses following problems:
  – It lowers the power output from the engine;
  – It takes up space when biogas is compressed and stored in cylinder;
  – It can cause freezing problems at valves and metering points where the compressed gas undergoes expansion during engine running.

• The traces of H₂S produces H₂SO₄ which corrode the internals of pipes, fittings etc.

• Moisture causes corrosion and decreases heating value of the fuel.
Technologies for Conversion of Raw to Upgraded Biogas

- Water scrubbing
- Chemical absorption
- Pressure swing absorption
- Membrane
- Cryogenic
Comparison between selected parameters for common upgrading processes

<table>
<thead>
<tr>
<th>Methods</th>
<th>High pressure water scrubbing</th>
<th>Chemical absorption</th>
<th>Pressure swing absorption</th>
<th>Membrane separation</th>
<th>Cryogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Pre Cleaning Requirement</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Working Pressure</td>
<td>9-10 Bar</td>
<td>1 Bar</td>
<td>4 – 7 bar</td>
<td>4-7 bar</td>
<td>40 bar</td>
</tr>
<tr>
<td>Methane Loss</td>
<td>1– 2 %</td>
<td>1-2 %</td>
<td>1-9 %</td>
<td>10 - 15 %</td>
<td>1-2%</td>
</tr>
<tr>
<td>% purity attained of upgraded Biogas</td>
<td>95-98 %</td>
<td>Upto 99 %</td>
<td>95 - 99 %</td>
<td>Upto 90 %</td>
<td>Upto 99 %</td>
</tr>
<tr>
<td>Heat requirement</td>
<td>-</td>
<td>Required</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Initial Cost</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Process Handling</td>
<td>Easy</td>
<td>Complex</td>
<td>Easy</td>
<td>Easy</td>
<td>Complex</td>
</tr>
</tbody>
</table>
Compression of Biogas

• The energy density of upgraded biogas is comparatively low at ambient pressure and as a result it must be compressed at high pressures (e.g. 200-250 bar) to allow its sufficient storage in bottles/cylinders.

• Compressing biogas
  • reduces storage space requirements,
  • concentrates energy content and
  • increases pressure to the level needed to overcome resistance to gas flow.

• Compression can eliminate the mismatch of pressures and guarantee the efficient operation of the equipment.
Biogas upgrading using water scrubbing method at IIT Delhi
Water Scrubbing Method

- Involves the physical absorption of CO$_2$ and H$_2$S in water at high pressures and regeneration by a release in pressure with very little change in temperature.

- Easiest and cheapest method involving use of pressurized water as an absorbent.

- The absorption process is, thus a counter-current one. The dissolved CO$_2$ and H$_2$S in water are collected at the bottom of the tower.
Bhilwara goshala (common cowshed)

Biogas Purification and Bottling plant
Bhilwara, Rajasthan
A Biogas Bottling plant

Consists of
- High Pressure compressor,
- Cascade of storage cylinders and
- A dispensing nozzle for filling the compressed purified gas in the vehicles.

Dried and purified gas goes into the suction of High Pressure Compressor, where it compress the gas to desired working pressure (~200 Bar) and fill into the storage cylinder cascade. A CNG dispensing cable along with nozzle is used for filling of gas in the vehicles.
Upgraded Biogas Dispensing System at IIT Delhi

High Pressure Compressor

Two cylinder cascade for bottling of upgraded biogas

Dispensing Nozzle - NZ type
BIOGAS ENRICHMENT AND BOTTLING PLANT - IIT DELHI
Biogas Programmes for Upgrading and Bottling

New Initiative for Technology Demonstration:

• Demonstration of Integrated Technology Package on Biogas-Fertilizer Plants (BGFP) for Generation, Purification/Enrichment, Bottling and Piped Distribution of Biogas.

• Establishment of Business Model for Demonstration of an Integrated Technology Package for creation of smokeless villages using biogas/bio-energy systems and meeting ‘Life-line Energy’ envisaged in ‘Integrated Energy Policy’
Main Components of Biogas-Fertilizer Plants (BGFPs)

- Slurry/ Feed-stock preparation systems.
- BGFP Digester.
- Biogas Purification/ Enrichment and Safety Systems.
- Biogas bottling and piped distribution for various applications.
- CO$_2$ bottling and utilization.
- Slurry processing/ for recycling of water.
- Vermi-composting and slurry management system.
- Bio-fertilizer upgradation and packaging.
- Marketing and supply management of Bio-fertilizers.
# Financial Support for BGFP Projects

Proposed financial support:

<table>
<thead>
<tr>
<th>Organization</th>
<th>Percentage of Project Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>MNRE support:</td>
<td>50%</td>
</tr>
<tr>
<td>IREDA/ Bank Loan:</td>
<td>30%</td>
</tr>
<tr>
<td>Promoter/ user agency contribution:</td>
<td>20%</td>
</tr>
</tbody>
</table>
## Indian Standard on Biogas (Biomethane)- specification
### IS 16087 : 2013

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Characteristic</th>
<th>Requirements</th>
<th>Method of Test, Ref to.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CH$_4$, Percent, <em>Min</em></td>
<td>90</td>
<td>IS 15130(Part 3): 2002</td>
</tr>
<tr>
<td>2</td>
<td>Moisture, mg/m$^3$ <em>Max</em></td>
<td>16</td>
<td>IS15641 (Part 2): 2006</td>
</tr>
<tr>
<td>3</td>
<td>H$_2$S, mg/m$^3$ <em>Max</em></td>
<td>30.3</td>
<td>ISO 6326-3: 1989</td>
</tr>
<tr>
<td>4</td>
<td>CO$_2$+N$_2$+O$_2$, Percent, <em>Max (v/v)</em></td>
<td>10</td>
<td>IS15130 (Part 3): 2002</td>
</tr>
<tr>
<td>5</td>
<td>CO$_2$, Percent, <em>Max (v/v)</em>, <em>(When intended for filling in cylinders)</em></td>
<td>4</td>
<td>IS15130 (Part 3): 2002</td>
</tr>
<tr>
<td>6</td>
<td>O$_2$, Percent, <em>Max (v/v)</em></td>
<td>0.5</td>
<td>IS15130 (Part 3): 2002</td>
</tr>
</tbody>
</table>
Pilot Scale Technology Demonstration and Biogas Upgrading Plants in India

1. Rajasthan Go Seva Sangh Plant, Jaipur (1st pilot model)
2. MGVAS Bhilwara Plant (2nd pilot Plant)
3. Biogas upgradation and bottling plant at Nasik, Maharashtra - BGFP
Water Scrubbing and PSA system at Nasik

Cylinder Cascade for bottled biogas

High Pressure Compressor at Nasik plant
4. Biogas Upgrading and Bottling Plant at Abhohar, Mukatsar, Punjab 1st Technology demonstration plant BGFP project
Biogas Based Entrepreneurial Avenue Options in India
In rural areas of developing economies many entrepreneurial avenues in the biogas sector are available in:

1) Goshalas (common cow-shed),
2) Poultry Farms
3) Dairy farms
4) Cluster of biogas plants in villages
5) Mobile Biogas Upgrading & Bottling Units
Is It The Future
Suggestions for the successful development of the small scale biogas bottling industry

• Appropriate grants should be made available to support the initiation of this industry.
• Special allowances and incentives for the promotion of biogas bottling projects should be made.
• Bank loans and central subsidies should be provided for the promotion of biogas upgrading and bottling plants.
• By 2017, in India will have a natural gas pipeline grid of 30,000-km. Currently, country wide network of 12,000 km of gas pipeline and another 12,000 km of pipelines are under construction. Hence, financial support, standards and allowance for the use of natural gas infrastructure should be provided for upgraded biogas.
• Central Financial Support (CFA) should be provided to support biogas bottling.

• Training, workshops and dissemination activities for users, manufacturers and entrepreneurs.

• It has also been suggested that norms for small-scale biogas bottling systems should be eased for small-scale biogas bottling systems,

• Subsidies should be provided for application of biogas bottling systems in rural areas.

• Development of a system for manure management.

• Government should make biogas projects eligible for funding for efficient rural development.

• Introduction of green certificates should be encouraged for the producers of bottled biogas. The project developers should receive a certificate for converting waste to energy efficient fuel called bioCNG / biomethane
OR IS THIS THE FUTURE
THANK YOU