Biogas Upgrading and Bottling Technology Developed for Vehicular Applications

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BIOGAS

- Energy source produced from biodegradable /organic wastes by anaerobic digestion process
- Possible feedstock material: All good biodegradable organic materials

✓ Digester sludge

✓ Manure (liquid & solid)

✓ Organic waste (Household waste, restaurant waste, food industry

✓ waste, etc.)

✓ Energy crops (silage of maize, grass, corn, etc.)

- Additional benefit of 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, density and Wobbe Index are almost similar to natural gas
- Biogas can be adapted to the quality of natural gas

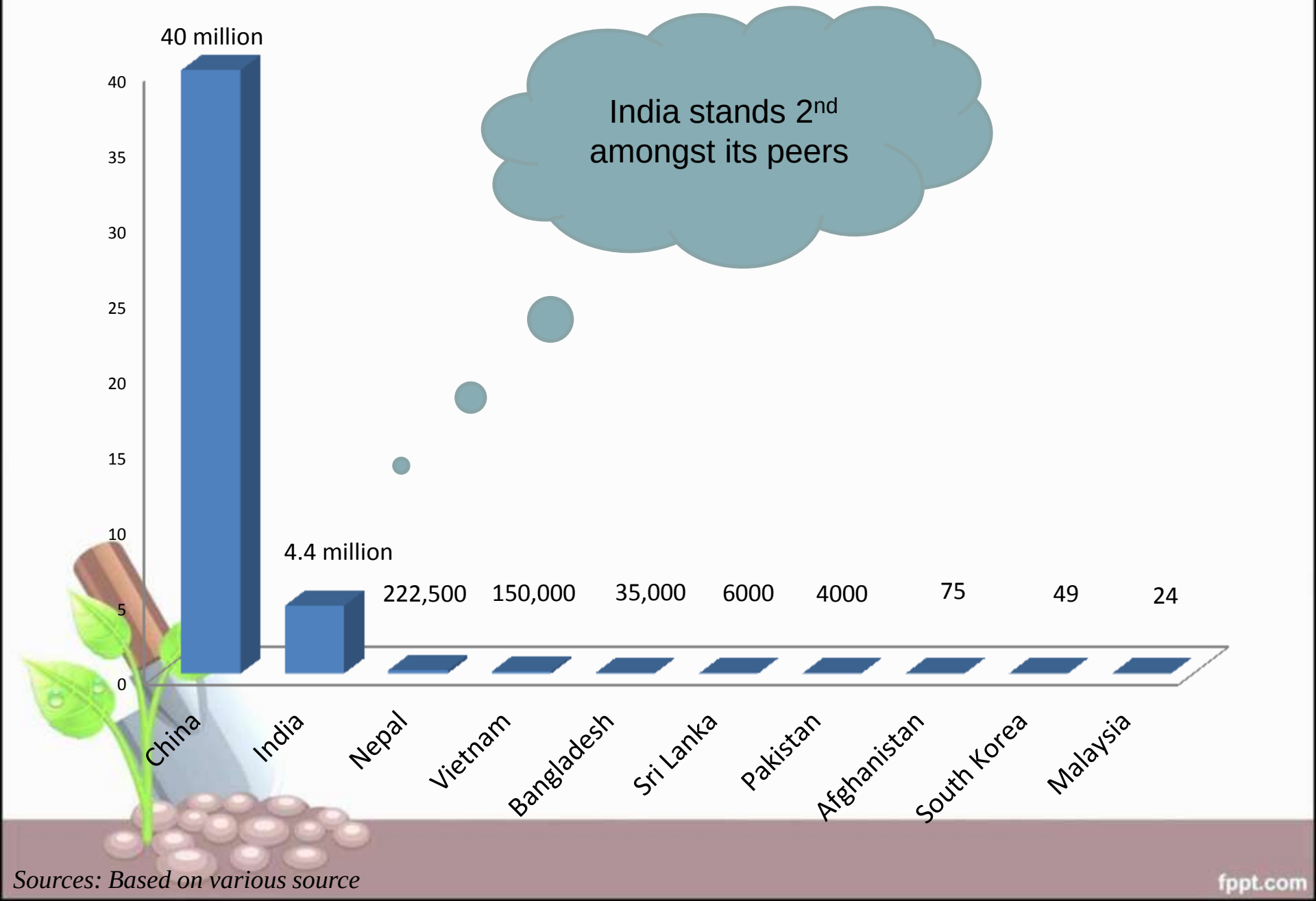
Biogas in INDIA

- An estimate indicates that India has a potential of generating 6.38 X 10^{10} m^3 of biogas from 980 million tones of cattle dung produced annually from **300 million cattle population**.

- The heat value of this gas amounts to 1.3 X 10^{12} MJ. In addition, 350 million tones of manure would also produce along with biogas.

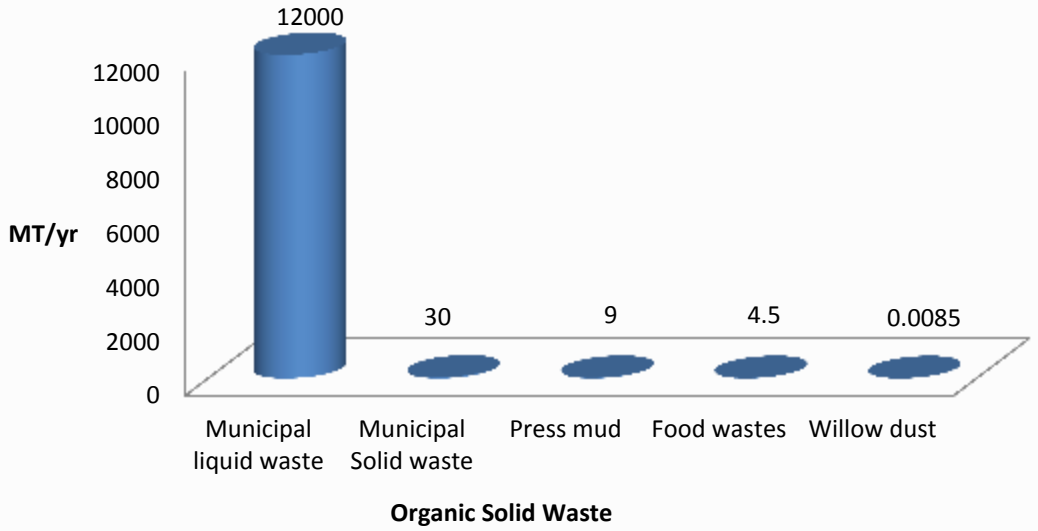
- Apart from the **4.5 million domestic biogas plants installed in India against the potential of 12 million**, there is a huge potential of installation of medium and large scale biogas plants installation in India in small scale industries, animal rearing farms, poultry farms, distilleries, tanneries, hotels, restaurants, military barracks etc.

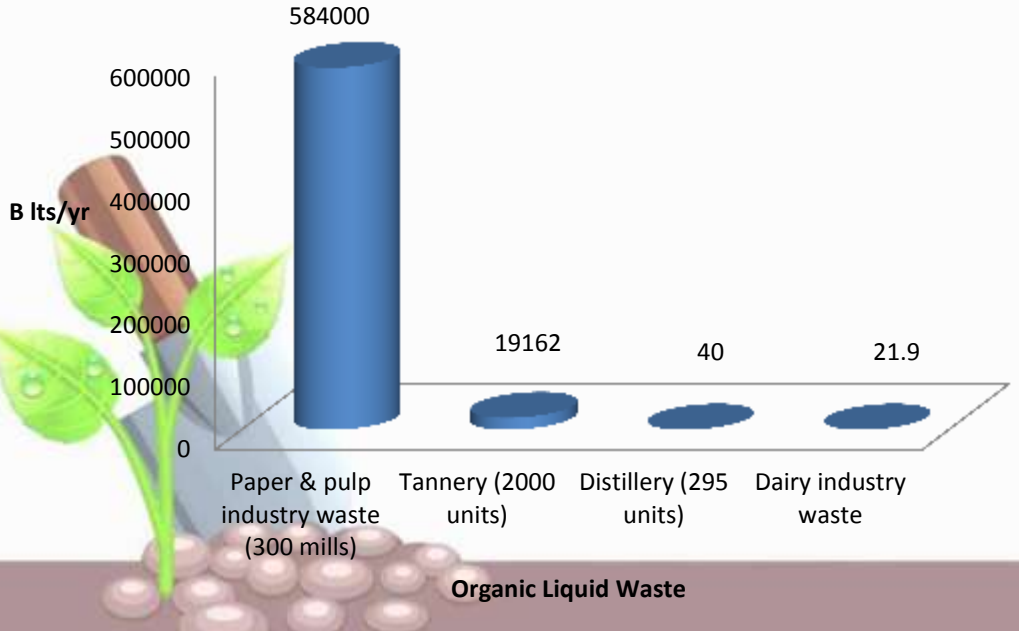
Domestics Size Biogas Plants installed upto 2010 in some developing countries



Sources: Based on various source

Biogas Production Potential From Organic Wastes in India





Potential

There are around 300 distilleries throughout India which collectively have a potential of producing 1200 million Nm^3 biogas, and 2000 tannery units capable of producing 787,500 Nm^3 of biogas . The increasing number of poultry farms can also add to biogas productivity as with a current population of 649 million birds, another 2173 million Nm^3 of biogas can be generated.

Source: MNES Report, Renewable Energy in India and business opportunities, MNES. Govt. of India, New Delhi

Composition of raw biogas

Compound	Chem %
Methane CH_4	55–65
Carbon dioxide CO_2	35–45
Nitrogen N_2	0–10
Hydrogen H_2	0–1
Hydrogen Sulfide H_2S	0–3
Moisture	Saturated

Average calorific value of biogas is 20 MJ/m^3 (4713 $kcal/m^3$).

Unlike conventional natural gas which is composed mostly of hydrocarbons — 70% or more methane (CH_4) plus propane and butane — raw biogas generally contains somewhat less methane, a significant amount of carbon dioxide (CO_2), and lesser amounts of nitrogen, hydrogen, carbon monoxide and a variety of contaminants.

Raw Biogas ⟶ Upgraded Biogas

- **A low Grade fuel** (CH_4 55-65 % & CO_2 35-45 %) with lower percentage of methane.
- **Mode of utilisation**
  - The presence of CO_2 besides being non combustible, restrains its compressibility there by making biogas difficult to be stored in containers.

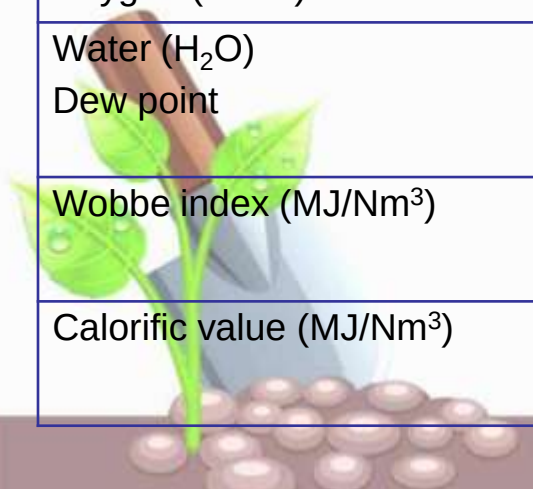
- **A high grade fuel** (CH4 > 90 % and < 10 % other gases) with high percentage of methane.
- **Mode of utilisation**
  - Remote applications
  - Methane burns faster hence yields a higher specific output and thermal efficiency compared to raw biogas when used as engine fuel.
  - Upgrading , compression and bottling facilitates easy storage and transportation as a vehicle fuel

Characteristic Comparison of Natural gas, Upgraded Biogas and Raw Biogas

Properties	Compressed Natural Gas	Upgraded Biogas	Raw Biogas
Composition % (v/v)	CH_4 – 89.14% CO_2 – 4.38% H_2 – .01% N_2 – .11% C_2H_6 – 4.05% C_3H_8 – 0.83% Iso-C_4H_{10} – 0.28% Neo-C_4H_{10} – 0.66% Iso-C_5H_{12} – 0.09% Neo-C_5H_{12} – 0.28% C_6H_{14} -0.17%	CH_4 – 93% CO_2 – 4% H_2 – .06% N_2 – 2.94 % H_2S – 20 ppm	CH_4 – 55- 65% CO_2 – 35-45% H_2 – .02% N_2 – 1.98% H_2S – 500 ppm
Lower Heating Value	44.39 MJ/kg	42.62 MJ/kg	20.5 MJ/kg
Relative Density	0.765	0.714	1.014
Flame speed (cm/sec)	34	–	25
Stoichiometric A/F (kg of Air/ kg of Fuel)	17.03	17.16	17.16
Auto-ignition Temperature (^0C)	540	–	650

Biogas standards requirements for grid injection for utilization as vehicle fuel in Europe

Countries / Specification	France	Sweden	Netherlands	Germany	Austria	Switzerland
Methane (% vol)	96	>97	-	-	96	> 96
Carbon Dioxide (CO_2) (% mol)	<2.5	< 4	< 6	< 6	< 3	< 6
Hydrogen Sulphide (H_2S) (mgS/Nm^3)	<5	<15	< 5	< 5	< 5	< 5
Hydrogen (H_2) (% vol)	<6	-	< 12	< 5	< 4	< 4
Mercaptans (mgS/Nm^3)	<6	-	< 10	< 16	< 6	<5
Total Sulphur (mgS/Nm^3)	< 30	< 23	< 45	< 30	< 10	< 30
Oxygen (% vol)	< 1	< 1	< 0.5	< 0.5	< 0.5	< 0.5
Water (H_2O) Dew point	< -5^0 C	< -9^0 C @ 200 bar	< -10 °C @ 8 bar	at ground temperature	<-8°C @40bar	< -8 °C at MOP
Wobbe index (MJ/Nm^3)	48.24-56.52	44.7-47.3	43.46-44.41	46.1-56.5	47.7-56.5	47.9-56.5
Calorific value (MJ/Nm^3)	38.52-46.08	-	31.6-38.7	30.2-47.2	38.5-46.0	38.5-47.2



Source : IEA BIOENERGY, December 2006

Standards for Upgraded Biogas in India

The first 'Indian Standard IS 16087: 2013 entitled Biogas (Biomethane) – Specifications' has been released by BIS. This standard covers biogas (biomethane) applications in stationary engines, automotive and thermal applications and supply through piped network. It will help in increasing confidence of investors, infusing more finances and expanding business in biogas sector manifold. Upgraded biogas delivered to any vehicle, stationary engine or piped network shall comply to the following standards

No.	Biogas Component	Percentage
1	**Methane (CH_4)**	**≥ 90 %**
2	**Carbon Dioxide (CO_2)**	**≤ 4 %**
3	**Hydrogen Sulphide (H_2S)**	**≤ 20 ppm**
4	**Moisture**	**≤ 0.02 g m^{-3}**

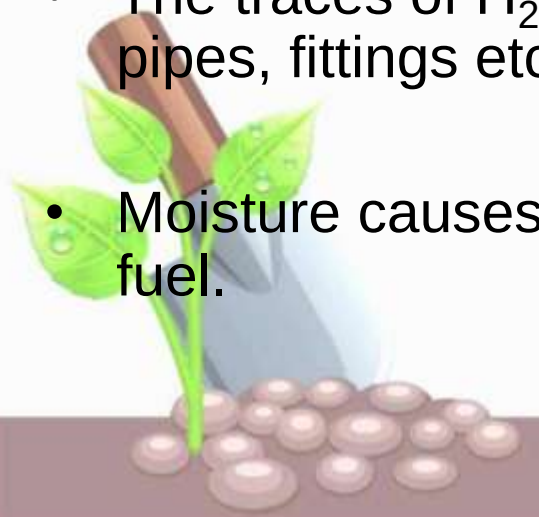
Biogas Upgrading

The use of a biogas upgrading or purification process in which the raw biogas stream like CO_2, H_2S and moisture are absorbed or scrubbed off, leaving above 90% methane per unit volume of gas.

- Presence of CO_2 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 H_2S produces H_2SO_4 which corrode the internals of pipes, fittings etc.

- Moisture causes corrosion and decreases heating value of the fuel.



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.

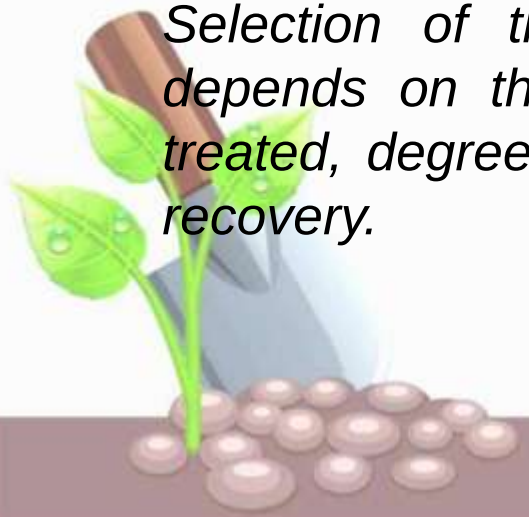
- Compression can eliminate the mismatch of pressures and guarantee the efficient operation of the equipment.

Removal of CO_2 from Biogas

The feasible processes of biogas purification are:

- Absorption into liquid (Physical / Chemical)
- Adsorption on solid surface
- Membrane separation
- Cryogenic separation

Selection of the appropriate process for a particular application depends on the scale of operation, composition of the gas to be treated, degree of purity required, capital cost and the need for CO_2 recovery.



Biogas upgrading using water scrubbing method at IIT Delhi

Water Scrubbing Method

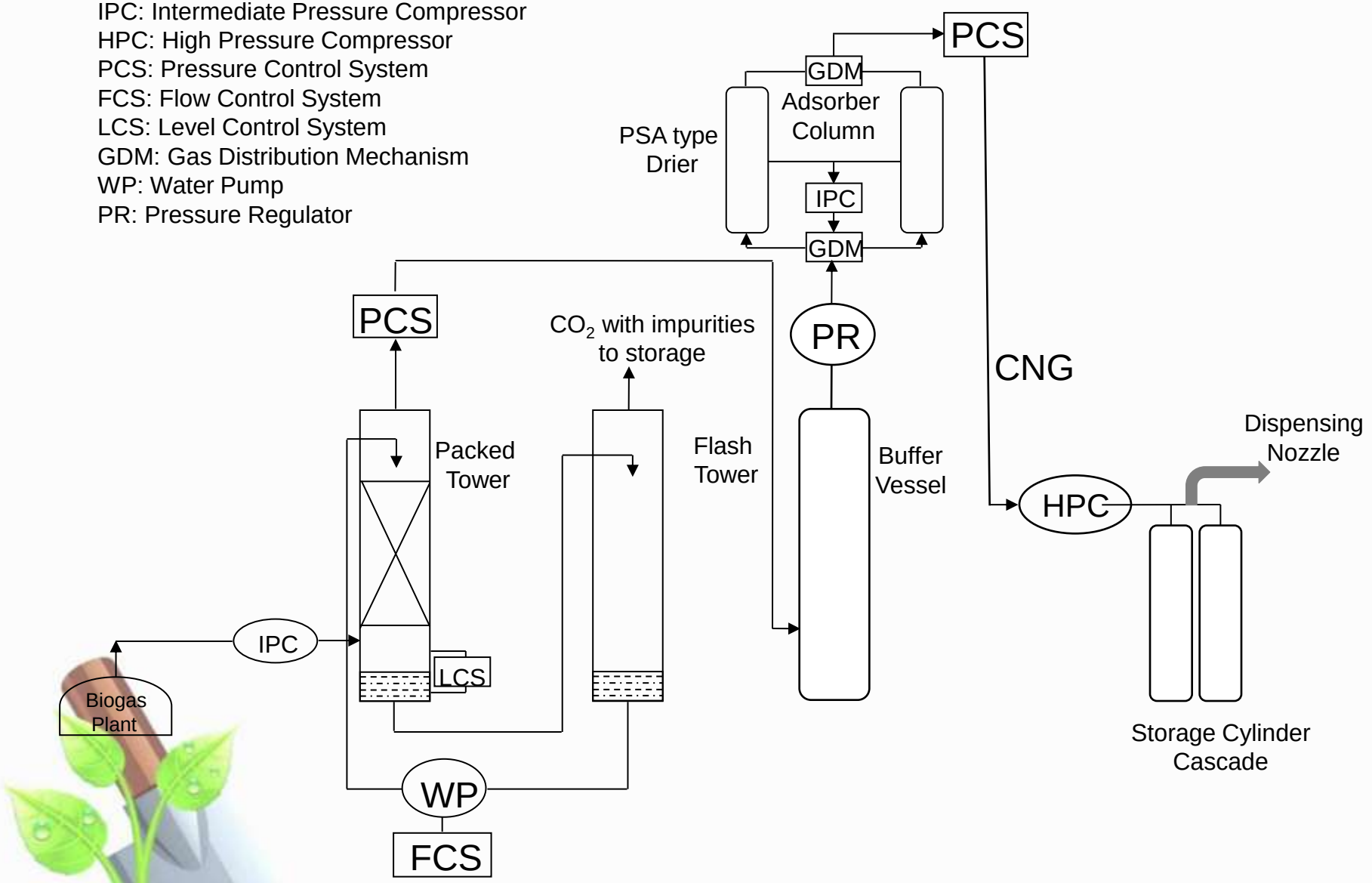
- Involves the physical absorption of CO_2 and H_2S in water at high pressures and regeneration by a release in pressure with very little change in temperature.

- 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_2S in water are collected at the bottom of the tower.

Biogas enrichment and bottling system wit
vehicle at IIT Delhi, India

IPC: Intermediate Pressure Compressor
HPC: High Pressure Compressor
PCS: Pressure Control System
FCS: Flow Control System
LCS: Level Control System
GDM: Gas Distribution Mechanism
WP: Water Pump
PR: Pressure Regulator



Block Diagram of Biogas Purification & Bottling Plant

Water Redistributors

Water Pump

Pneumatic Valve

PID Controllers

Compressor

High Pressure Compressor

Gas Storage Vessel

Biogas Cylinders

PSA

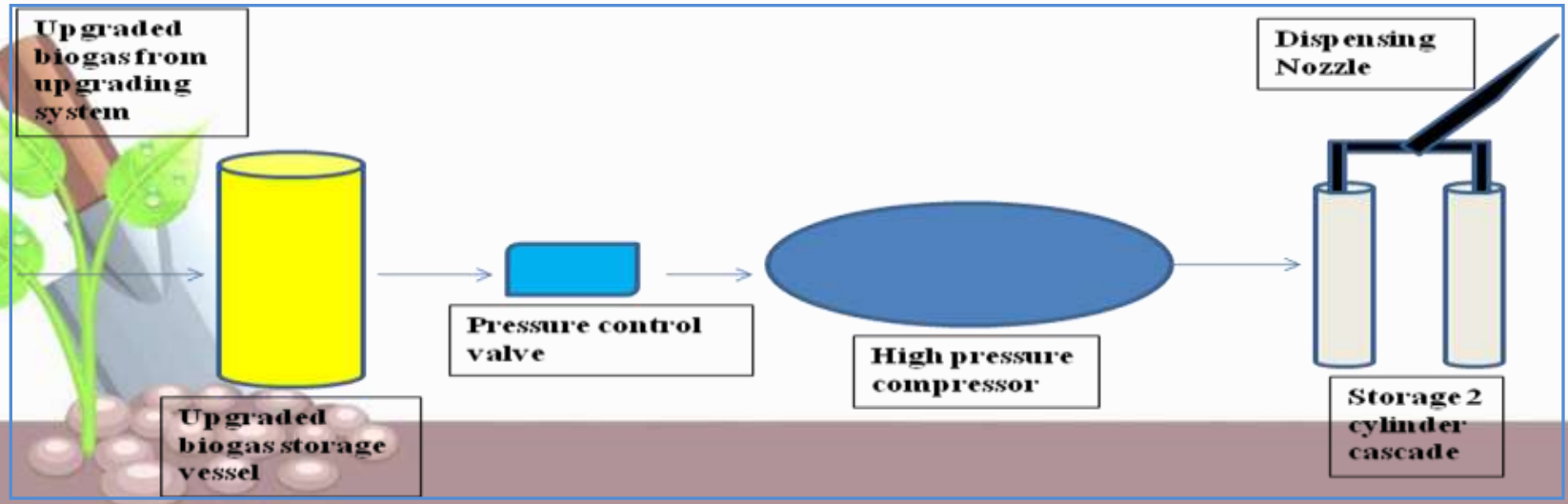
Biogas Vehicle

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

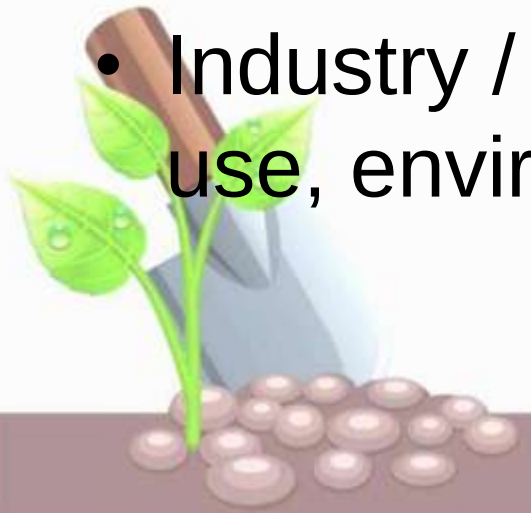

BioGas


Biogas
vehicle

Video

Issues for discussion

- Technology for dissemination – scale, suppliers,
- Government support – subsidy, incentives
- Policy and regulations – use in vehicles,LPG replacement, PESO, BIS
- Industry / Green Industry – licensing/land use, environmental certificates etc



THANK YOU