

WATER SCRUBBING BASED BIOGAS ENRICHMENT TECHNOLOGY BY IIT DELHI

***A FIT OPTION FOR LOW COST SMALL SCALE
APPLICATIONS***

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The NEED.....

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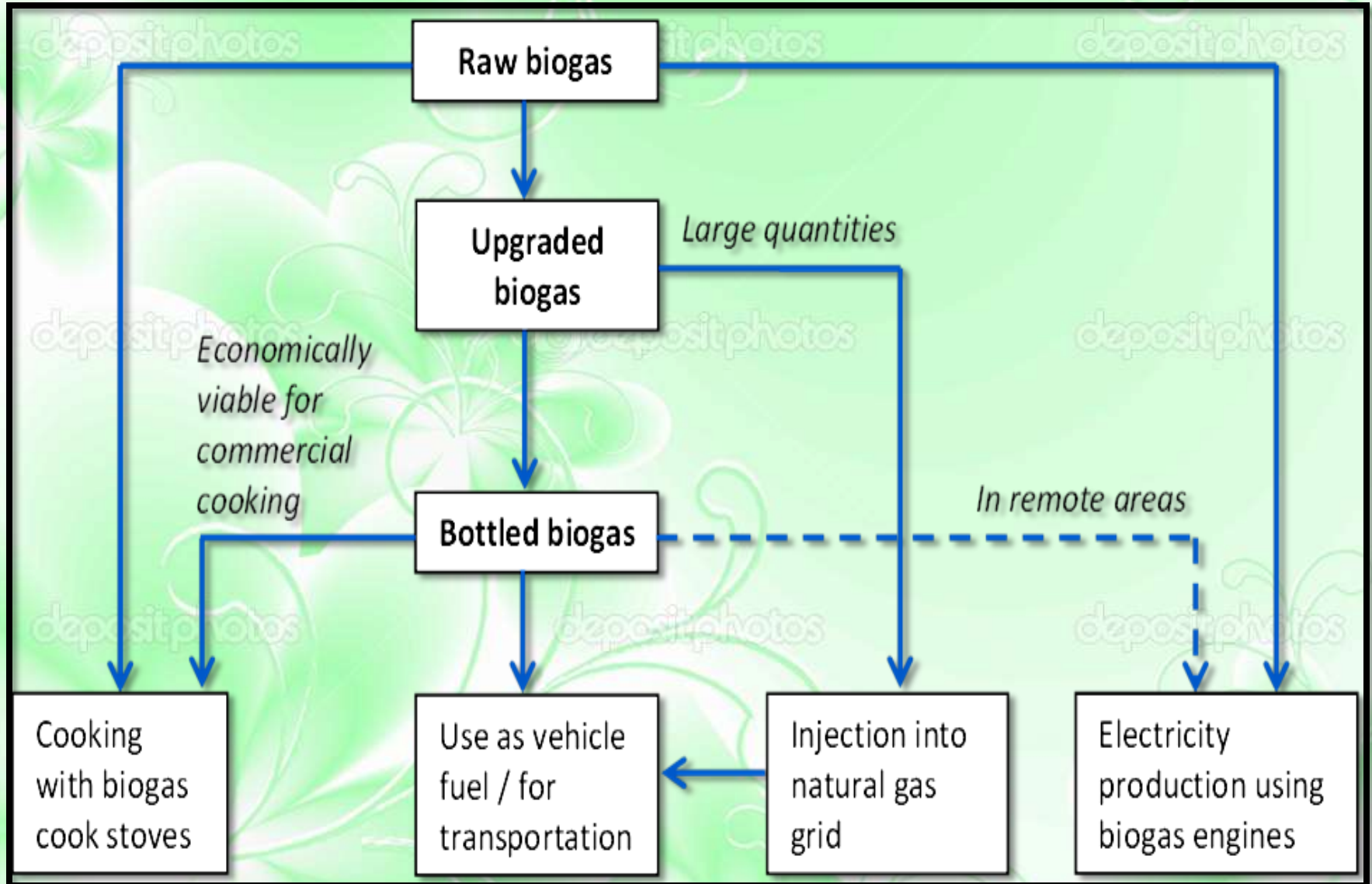
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Raw Biogas Upgraded Biogas

- **A low Grade fuel** (CH_4 55-65 % & CO_2 35-45 %) with lower percentage of methane.
- **Mode of utilisation**
 - On site itself or nearby for cooking and for electricity production. The presence of CO_2 besides being non combustible, restrains its compressibility there by 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.
- **A high grade fuel** (CH_4 > 90 % and < 10 % other gases) with high percentage of methane.
- **Mode of utilisation**
 - 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

VERSATILITY OF BIOGAS USE

Upgrading widens the scope of utilization



Utilization of Raw Biogas



Pipeline for raw biogas use as a cooking fuel



Raw biogas cookstove



Raw biogas for use as a cooking fuel



Biogas Engine for electricity production

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

The Solution.....

.....**Low Cost biogas Upgrading**

Biogas Enrichment

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 CO₂ from Biogas

The feasible processes of biogas purification are:

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

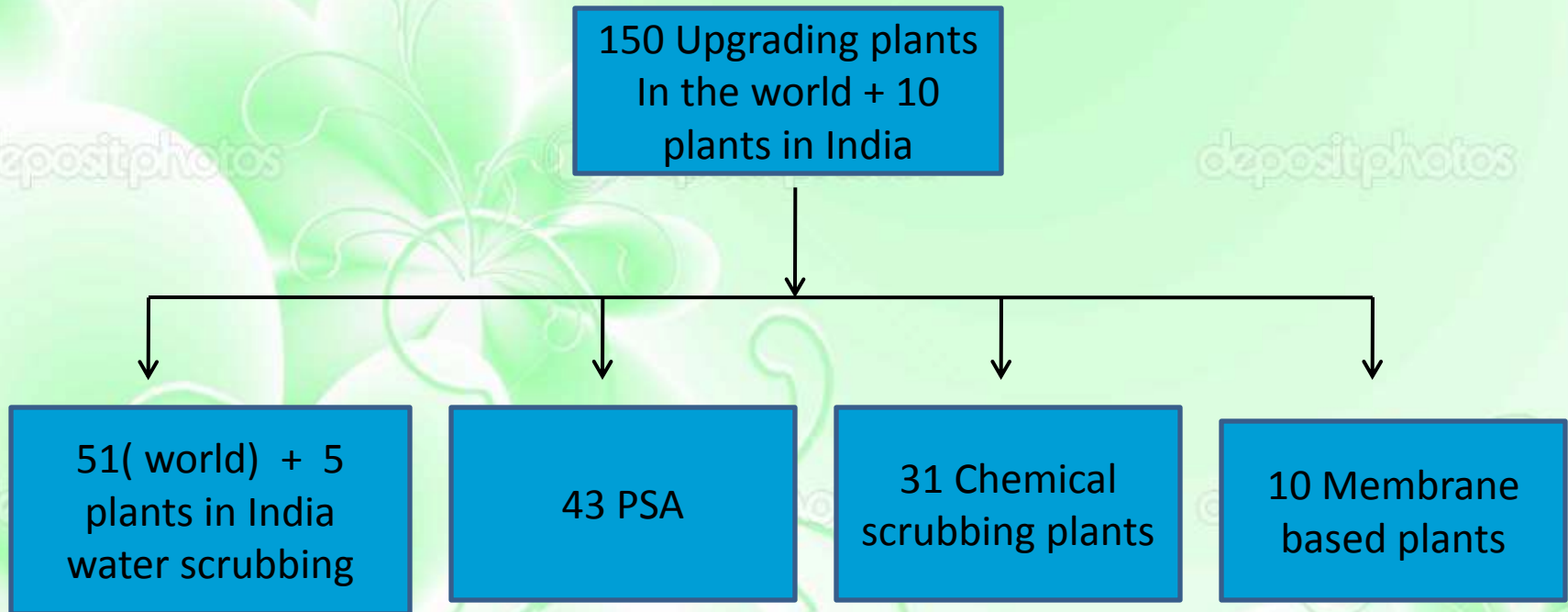
Selection of the appropriate process for a particular application depends on the scale of operation, composition of the gas to be treated, degree of purity required, capital cost and the need for CO₂ recovery.

Comparison between selected parameters for common upgrading processes

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

•The most widely used technologies for biogas upgrading are water scrubbing, PSA, membrane and chemical scrubbing. Out of these technologies, water scrubbing and PSA are considered to be most appropriate at a small scale due to low cost and easy maintenance.

•Till 2011, the number of biogas upgrading plants in the world were 150 at the commercial level. In India there are 5 biogas upgrading plants.





DESIGN OF WATER SCRUBBING SYSTEM

Water Scrubbing Method

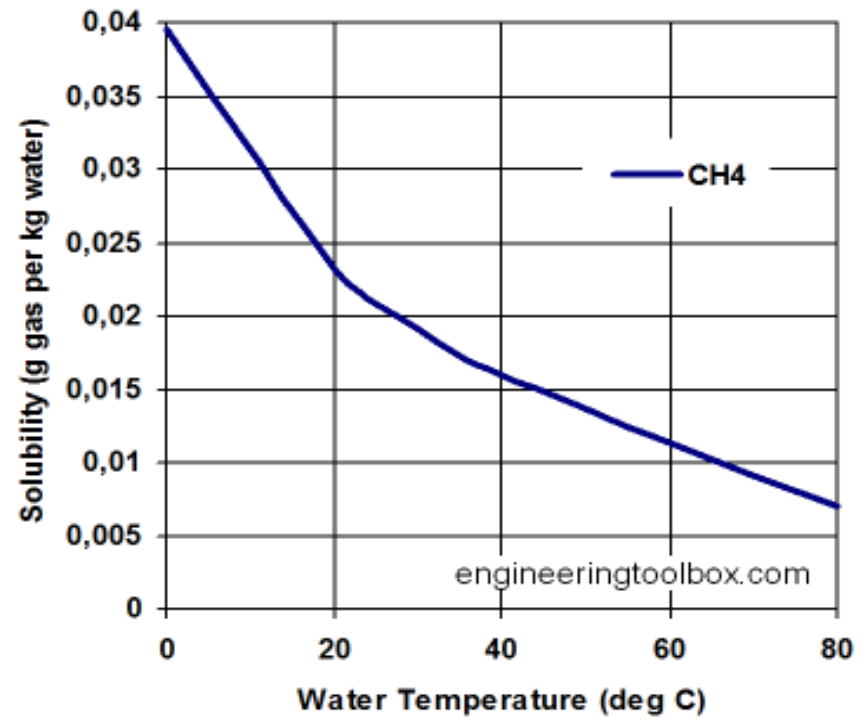
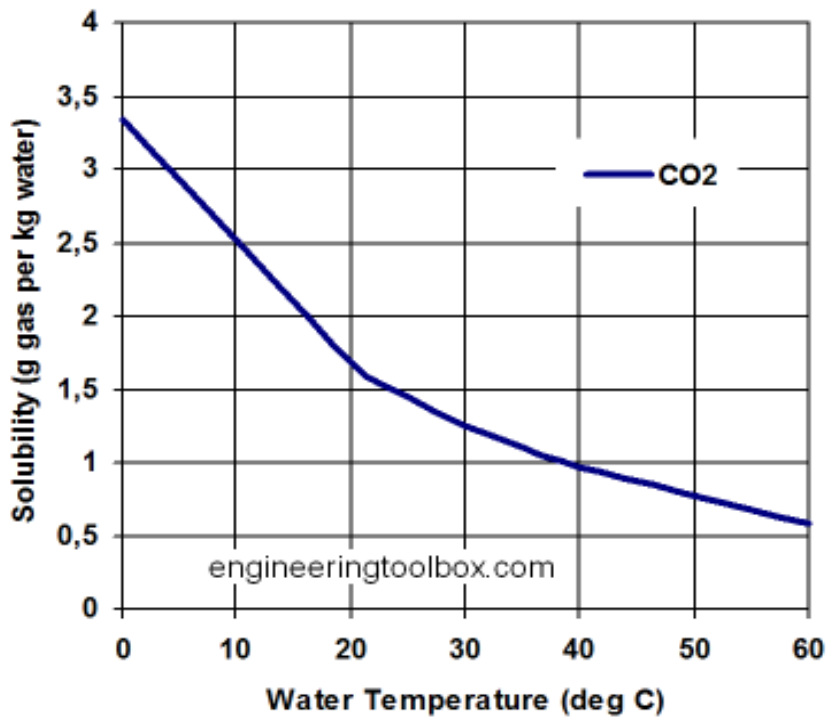
- Involves the physical absorption of CO_2 and H_2S in water at high pressures and regeneration by a release in pressure with very little change in temperature.
- Easiest and cheapest method involving use of pressurized water as an absorbent.
- The absorption process is, thus a counter-current one. The dissolved CO_2 and H_2S in water are collected at the bottom of the tower.

Absorption of CO₂ in water

The amount of CO₂ being dissolved in water is determined by

- 1) **The time of contact between biogas and with water** - To increase the contact time of the gas with water, counter current mechanism is followed by making water to flow from the top to bottom and raw biogas from bottom to top.
- 2) **the pressure** of the raw biogas and water .

Solubility of CO₂ and CH₄ in Water

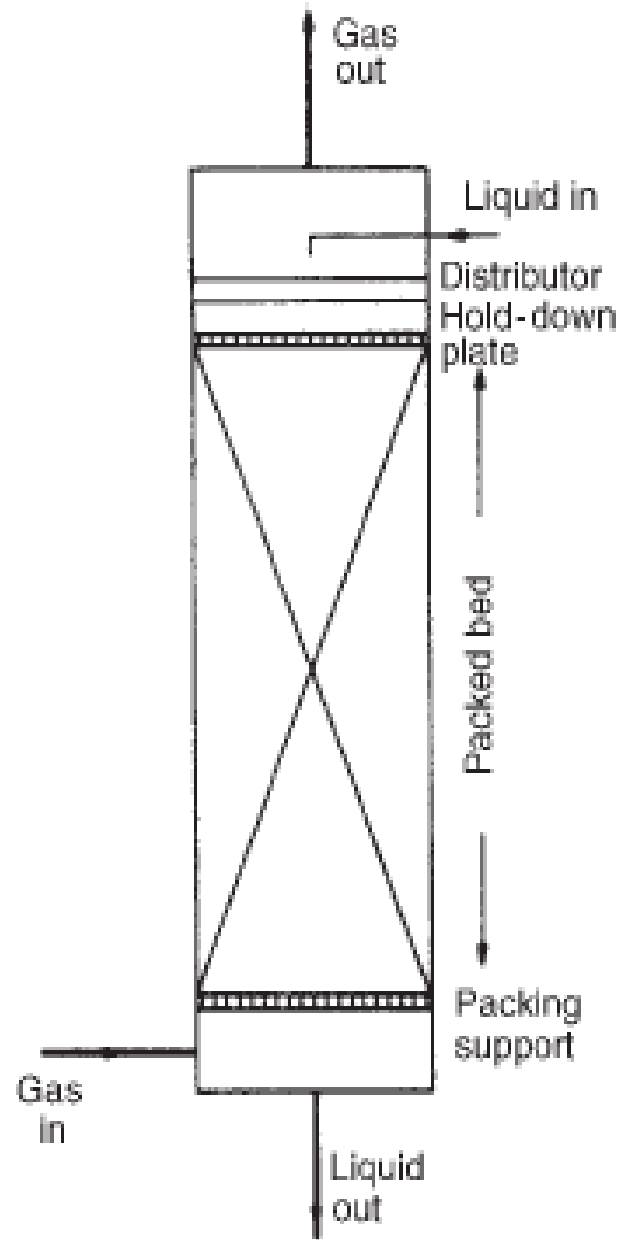


Approximate Solubility of CO₂ in Water

Pressure (atm)	Solubility, in kg of CO ₂ per kg of water at different temperatures.			
	0° C	10° C	20° C	30° C
1	0.40	0.25	0.15	0.10
20	3.15	2.15	1.30	0.90
50	7.70	6.95	6.00	4.80

Packed Bed Scrubber

- Packed bed scrubbers are used for distillation and gas absorption.
- Consists of
 - a cylindrical column, equipped with a gas inlet and distributing space at bottom,
 - a liquid inlet and distributor at top,
 - liquid and gas outlets at bottom and top respectively and
 - a supported mass of inert solid shapes.
- The solid shapes are called column packing or filling.
- The packing provides a larger area of contact between the liquid and gas and encourages intimate contact between the phases.



A Typical Packed Bed Tower

Main parameters calculated for the packed bed for a particular capacity are—

- Working Pressure
- Tower Packing
- Diameter of Packed Bed
- Height of Packed Bed

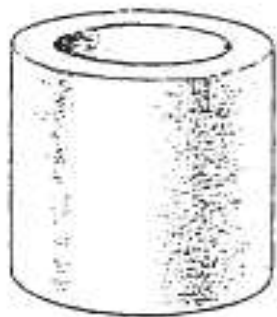
Working Pressure of the Packed Bed Tower

- The solubility of CO_2 & CH_4 in water is directly proportional to pressure. As the pressure increases, requirement of water and volume of packed column decreases for a fixed flow rate of biogas.
- Higher working pressure poses the problem of difficult fabrication of tower, difficulty in finding control equipments (sensor, valves etc.) and higher electricity consumption for compression of gas.
- Very low pressure results in excess water requirement and much bigger size of columns.
- Therefore, an intermediate value working pressure of 10 bar (absolute) is chosen in IIT Delhi WS system case.

Tower Packing

- Packing provides the large interface area for the contact of liquid and gas phase inside the packed tower.
- Has an open structure: low resistance to gas flow.
- Promote uniform liquid distribution on the packing surface.
- Promote uniform vapor gas flow across the column cross-section.

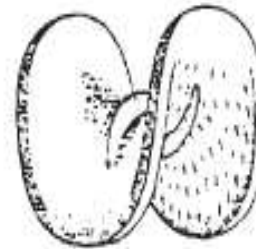
Types of packing (a) Raschig rings (b) Pall rings (c) Berl saddle ceramic (d) Intalox saddle ceramic (e) Metal Hypac (f) Ceramic, super Intalox



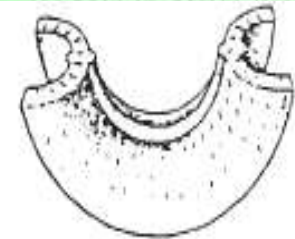
Ceramic



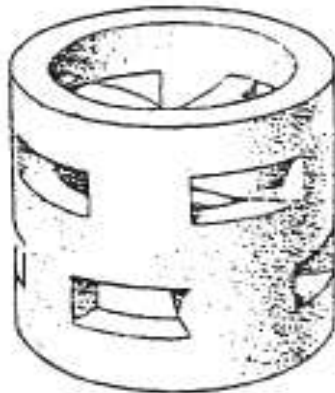
Metal



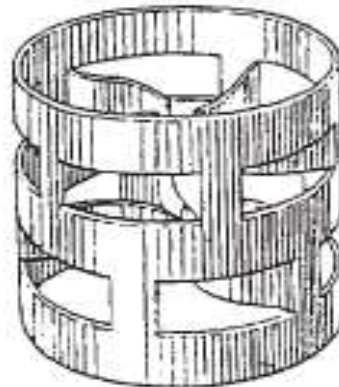
(c)



(d)



Ceramic



Metal



(e)



(f)

(a)

(b)


Determination of Diameter (D) and Height (H) of the Packed Bed Column

- The capacity of a packed bed absorption column is depended on its cross-sectional area.
- The column will be designed to operate at the highest economical pressure drop, to ensure good liquid and gas distribution.
- There is no entirely satisfactory method for predicting the height of a transfer unit. In practice the value for a particular packing will depend not only on the physical properties and flow-rates of the gas and liquid, but also on the uniformity of the liquid distribution throughout the column, which is dependent on the column height and diameter.

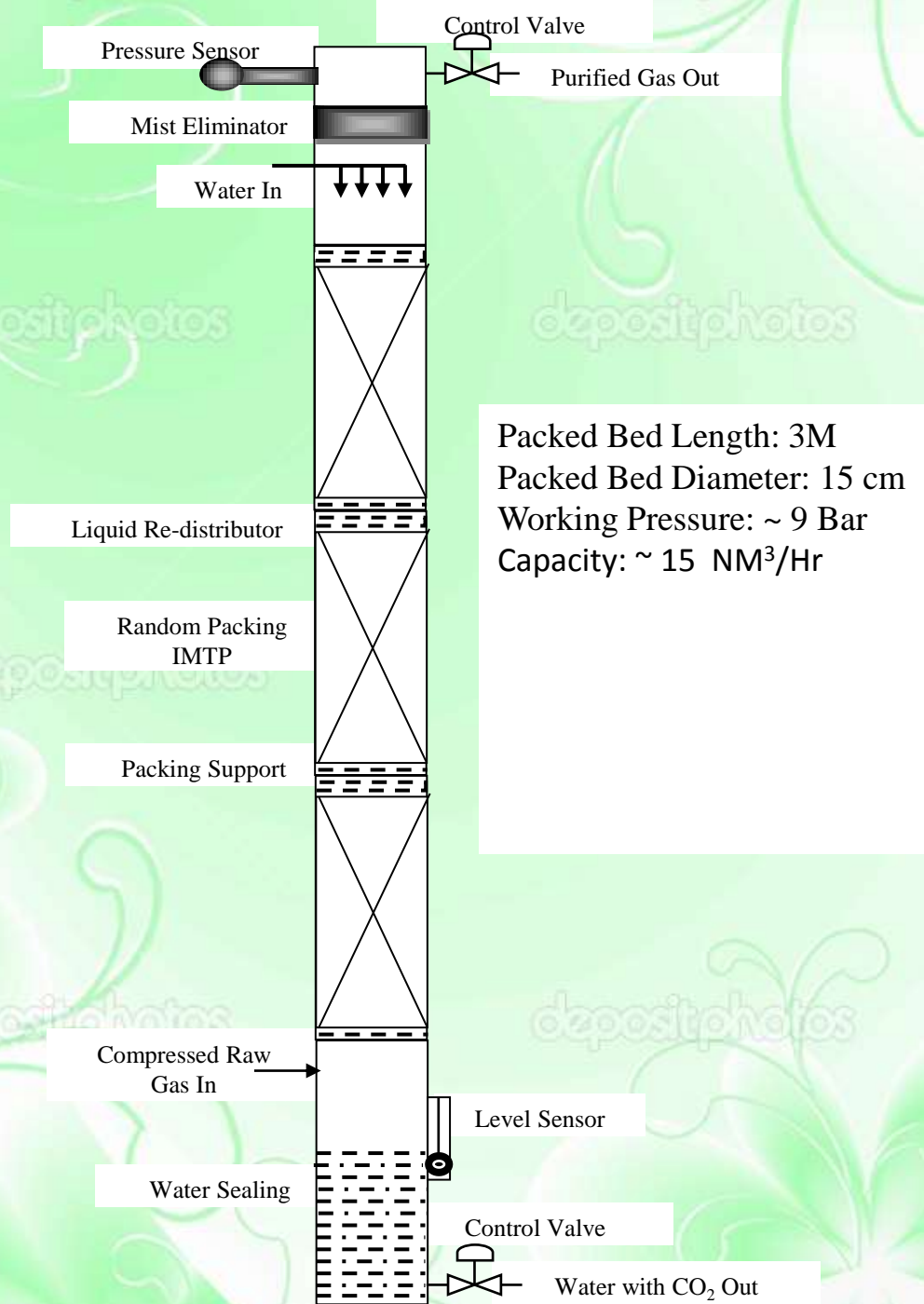
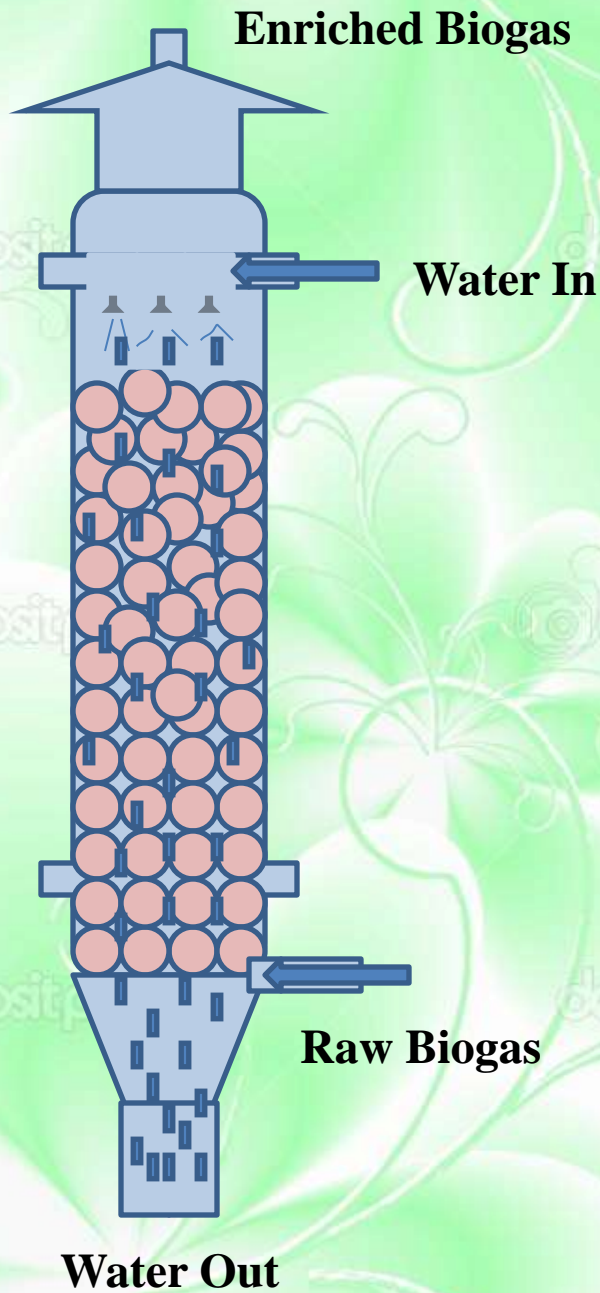
Hence based upon the above calculations and selections the following input parameters are decided

Biogas Enrichment Plant Parameters

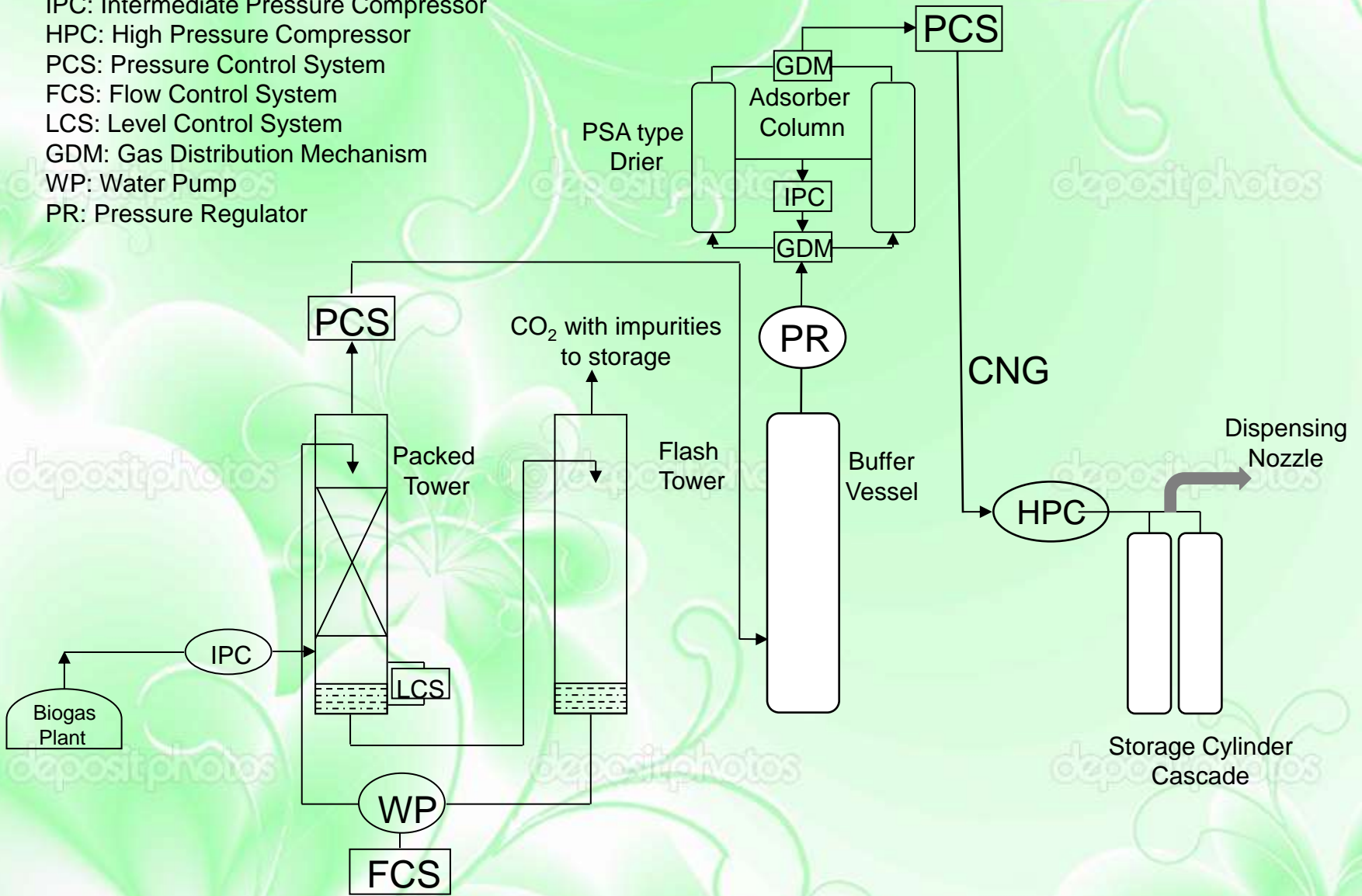
Raw Biogas Flow Rate	20Nm³/Hr
Vapour phase	Biogas (63% CH₄, 34% CO₂)
Liquid Phase	Water
Working Pressure	~10 Bar
Working Temperature	Ambient
Packing Material	IMTP
Diameter of Packed Bed	15cm
Height of Packed Bed	3.0 m
Water flow rate	4 Nm³/hr



Water Scrubbing System for Biogas Enrichment at IIT Delhi



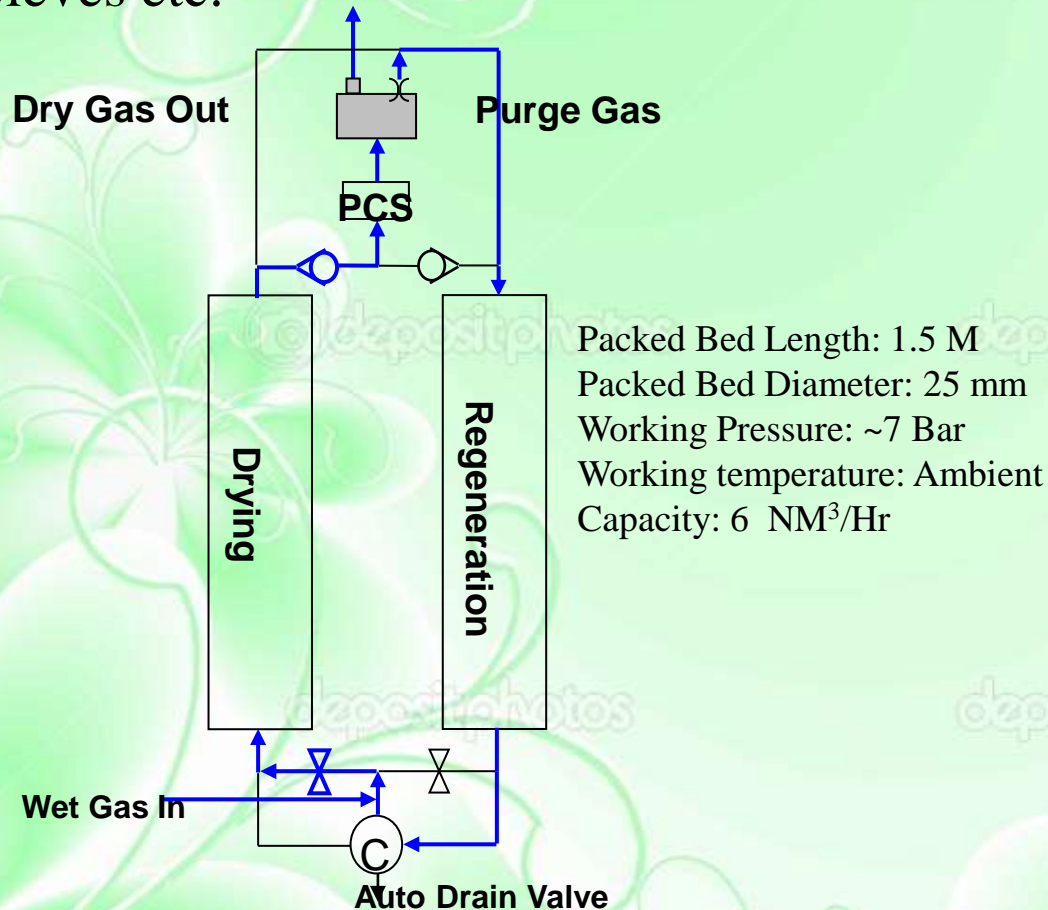
IPC: Intermediate Pressure Compressor
 HPC: High Pressure Compressor
 PCS: Pressure Control System
 FCS: Flow Control System
 LCS: Level Control System
 GDM: Gas Distribution Mechanism
 WP: Water Pump
 PR: Pressure Regulator



Block Diagram of Biogas Purification & Bottling Plant

Moisture Removal Setup

PSA type drier is employed for the removal of moisture. Based on the concept of selective adsorption of moisture at the outer surface of adsorbents such as Silica Gel, Activated Alumina, Zeolite Molecular Sieves etc.



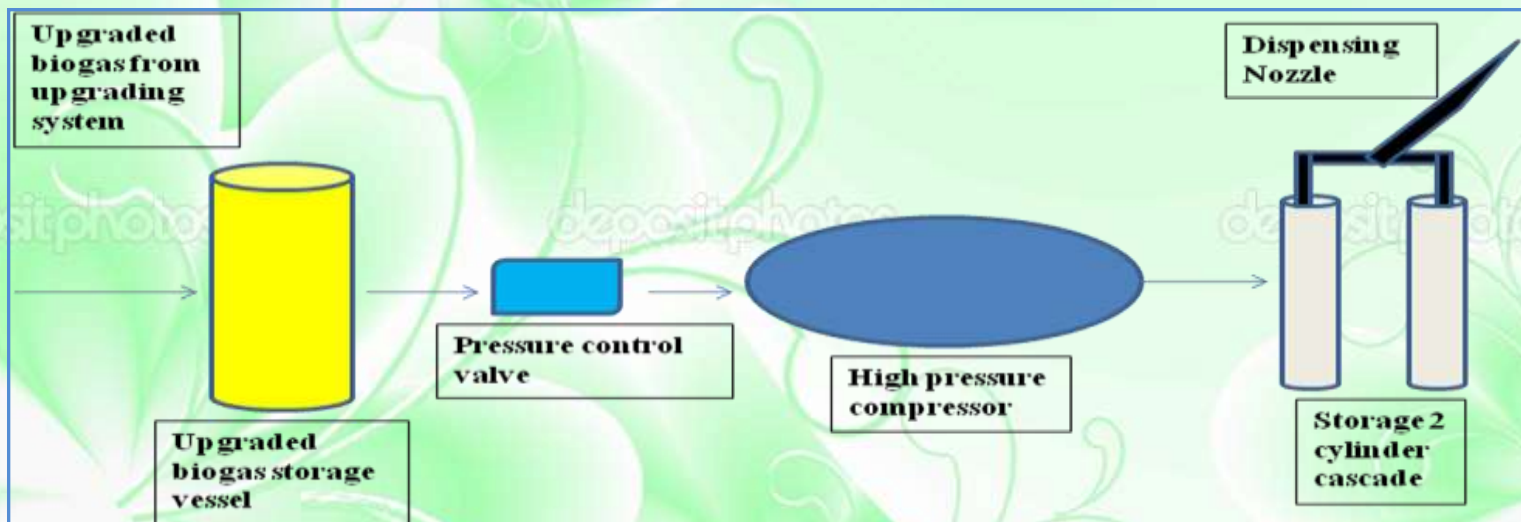
PSA type Drier for Moisture Removal

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 compresses the gas to desired working pressure (~200 Bar) and fills into the storage cylinder cascade. A CNG dispensing cable along with nozzle is used for filling of gas in the vehicles.



Control System

Is used for maintaining the desired working parameters in the plant. There are mainly three control systems in the plant—

- Water flow rate control
- Gas pressure Control
- Water level control

Power Consumption in the Upgrading Plant:

- For a 20 Nm³/hr capacity plant, the power requirement in upgrading is —
- Raw Biogas Compressor: 3 KW
- Water Pump: 2 KW
- Control Valves & Sensors etc.: 0.25KW
- Total: 5.25 KW
- 0.26 kWhr/Nm³ of raw biogas.

Power Consumption in the Bottling System :

- Energy Required for Compression And Bottling: 3 kW
- Total energy required for upgrading and bottling of 20m³/hr of raw biogas = 2 + 3 + 3 + 0.25 = 8.25 kW
- Power requirement per Nm³ raw biogas = 0.4125 kWh
- System energy requirement as a percentage of raw biogas = 6.88 % of raw biogas energy



Biogas Plant at IIT Delhi



New Modified Water Scrubbing Tower at IIT Delhi

Liquid Redistribution unit in the new modified water scrubbing tower at IIT Delhi



Water pump



Rotameter



High Pressure compressor



Raw and upgraded biogas storage vessels



Two cylinder cascade for bottling of upgraded biogas

Upgraded Biogas Dispensing System at IIT Delhi



Dispensing upgraded biogas in vehicle



Enriched Biogas Operated Three Wheeler Luggage Carrier

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Biogas Dispenser

BIOGAS OPERATED VEHICLE



Demonstration and Performance Evaluation
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Results

- A fully automatic plant of 20 Nm³/Hr capacity has been developed successfully at IIT Delhi.
- Desired composition of purified gas (CH₄: 95% (min), H₂S: 20 ppm (max), Moisture: 20 ppm (max) is achieved with a consistent gas quality.
- Our system is automatically controlled with consistent quality of enriched gas and a methane loss of about 2%.

Some pilot plants for biogas upgradation

- Rajasthan Go Sewa Sangh Jaipur since 2007
- Madhav Govigyan Sansthan Bhilwara 2008
- Muni Sewa Asharam near Vadodra since 2008
- Community level Biogas plant for piped distribution of gas near Valsad (Guj) sine 2008
- Shri Krishna Goshala , Ghaziabad since 2009

Biogas upgradation and bottling plant at Nasik, Maharashtra

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Water Scrubbing and PSA system at Nasik



Cylinder Cascade for bottled biogas



High Pressure Compressor at Nasik plant



Biogas Upgrading and Bottling Plant at Abhojar, Mukatsar, Punjab 1st Technology demonstration plant BGFP project





Biogas Based Entrepreneurial Avenue Options in India

**In developing economies many
entrepreneurial avenues in the biogas sector
are available in :**

- 1) Goshalas,
- 2) Poultry Farms
- 3) Dairy farms
- 4) Cluster of households in villages

In the developing countries the following biogas enterprenurial options are possible

Consider : Cluster of households in villages

Centralized waste collection system

Rural people put all their wastes- animal dung and human waste, agricultural wastes in a centralized collection place.



The waste is mixed and shredded then put in the biogas digesters



Raw biogas is then purified- Bottled and filled in cascade of cylinders for transportation in rural areas.

Can be used for cooking or filling in the vehicle cylinders for transport,

Can be used for generating power using 100 % biogas engines

GOBAR BANK



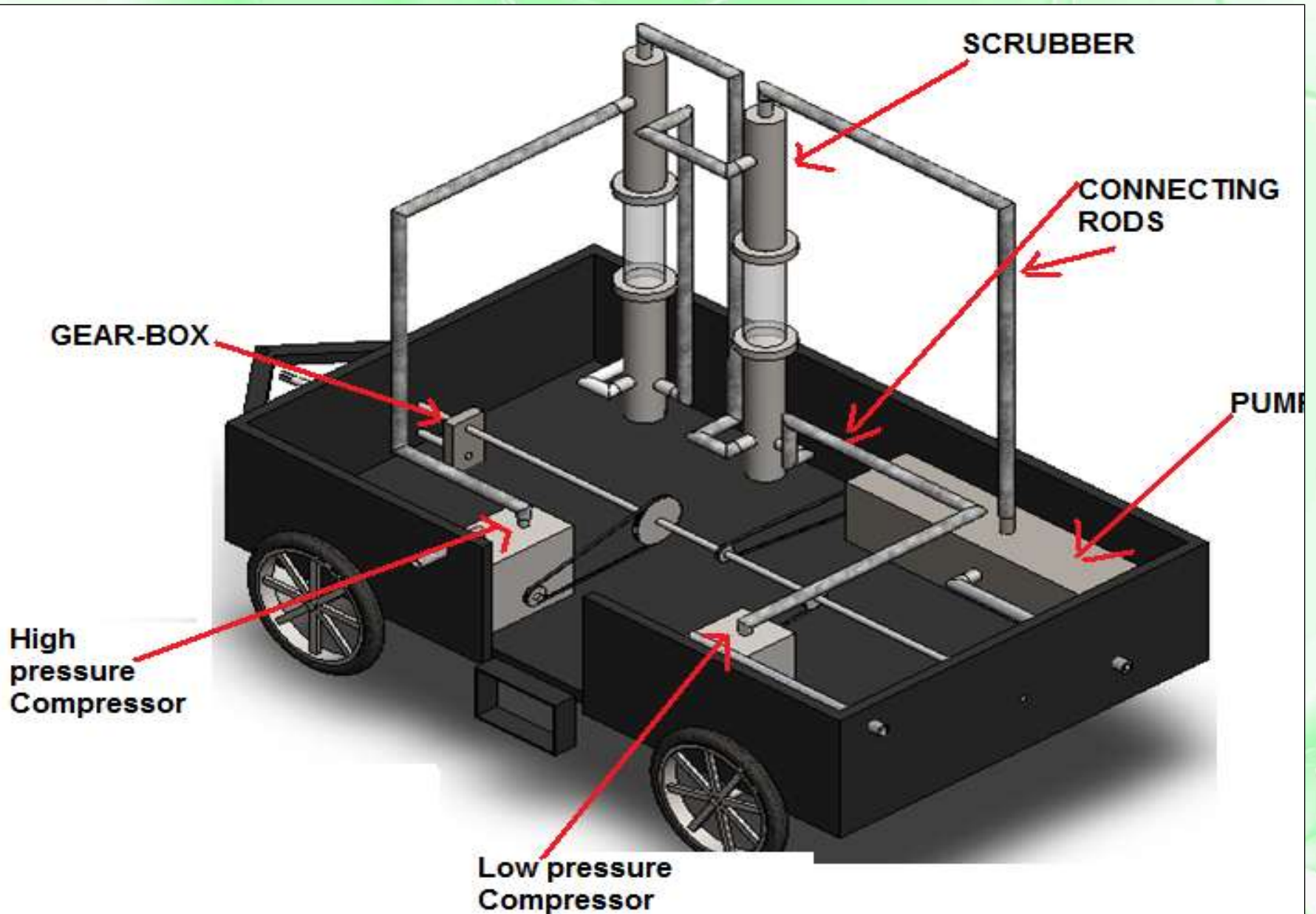
Community Biogas Plant (CBP)



Mobile biogas upgrading unit

- Upgradation unit is attached to a vehicle mounted on a trolley. This unit can cater to more than one biogas plants in a cluster.
- The trolley mounted machine with the help of a vehicle can be transported to the digesters located at different locations and raw biogas is filled up in the storage vessel.
- The raw biogas can be upgraded by these mobile units and can fill up CNG cylinders for storage at high pressure and transported to the required place with ease, causing an uninterrupted supply of upgraded biogas

Mobile biogas upgrading unit



Conclusions





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