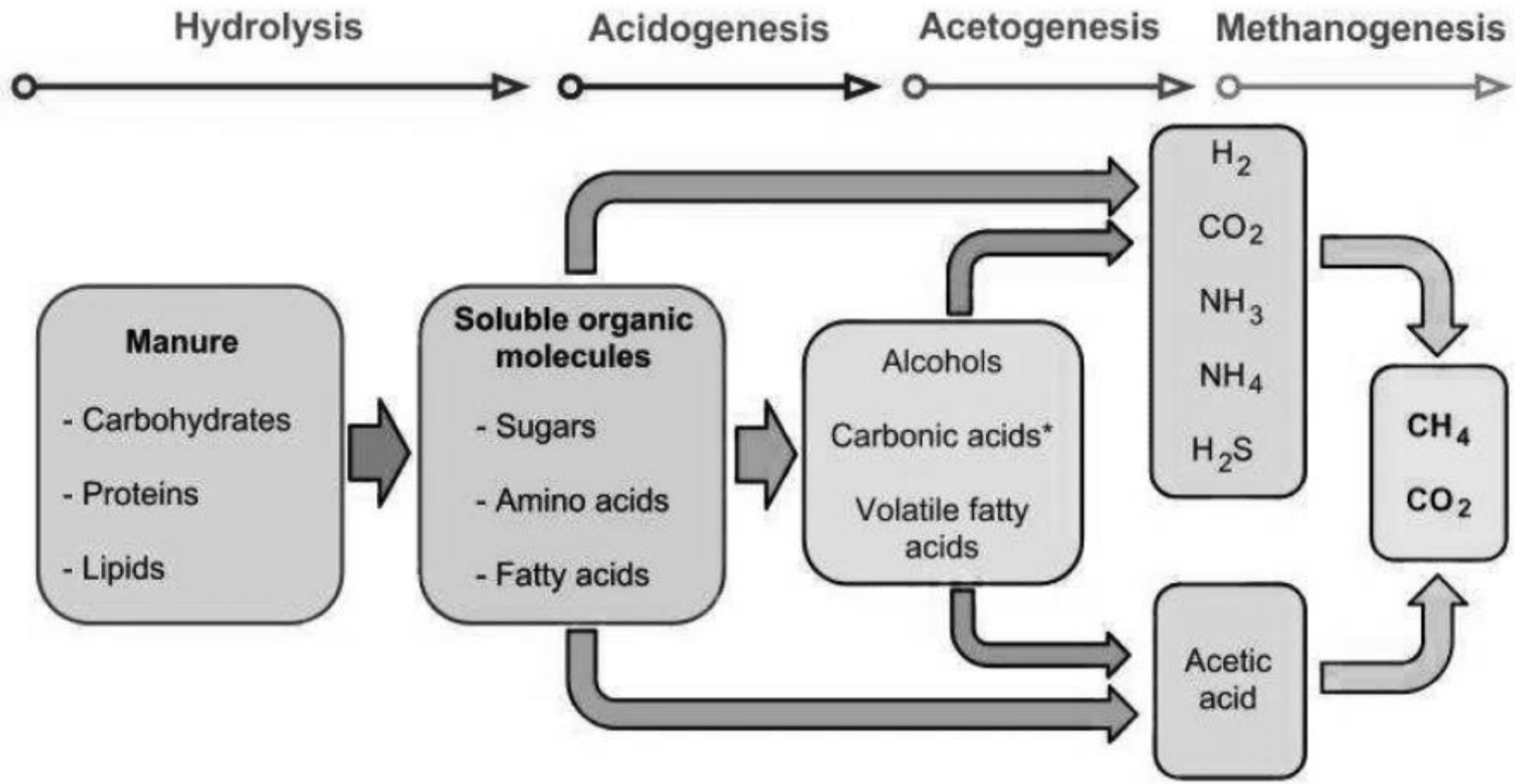
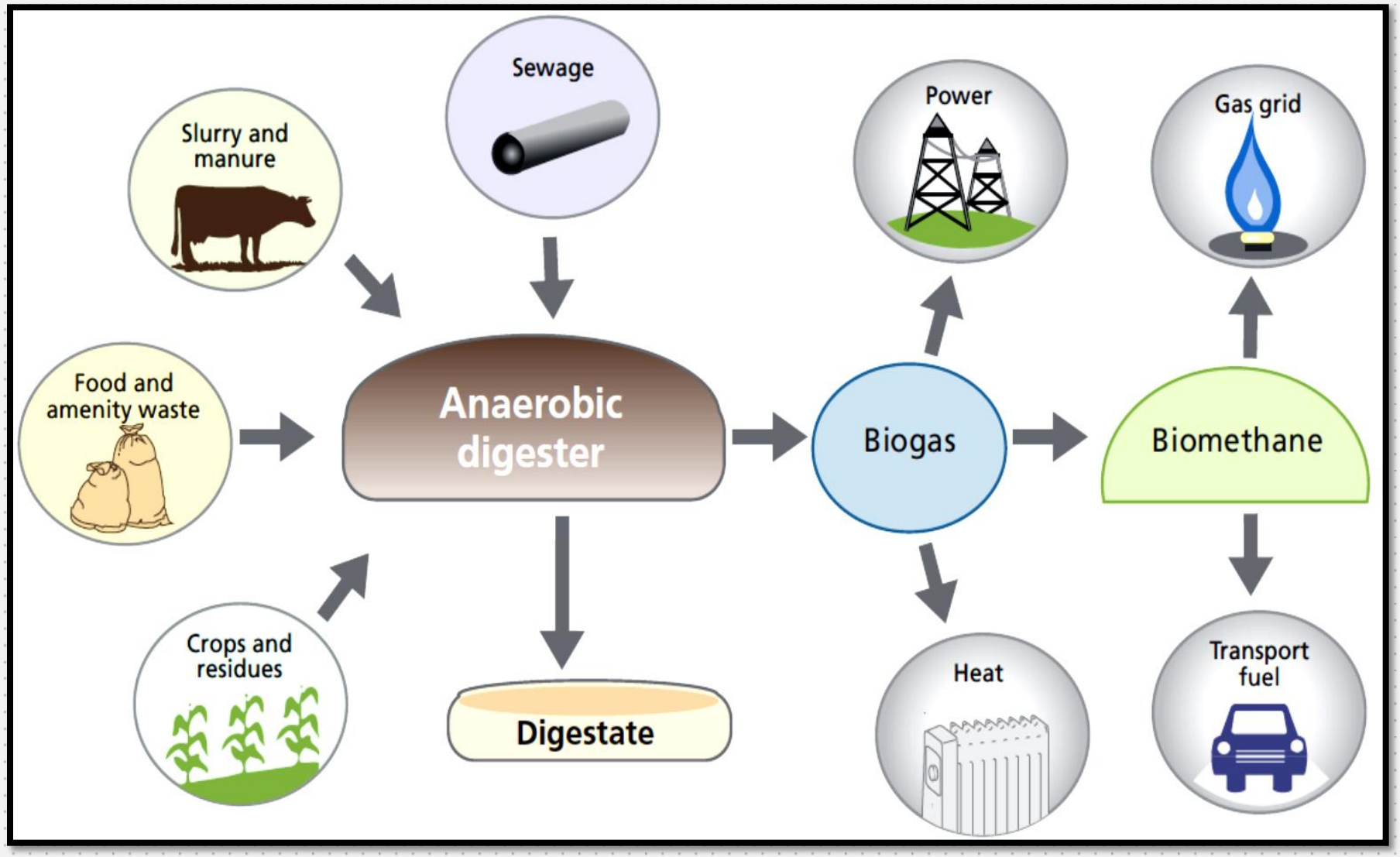
# Technologies for Biogas Upgrading

**Prof. Virendra K. Vijay**
Head, Centre for Rural Development & Technology, IIT, Delhi
vkvijay@rdat.iitd.ernet.in

# What is biogas?



# Biogas Production & Utilization




*(Source: OFGEM, 2011)*

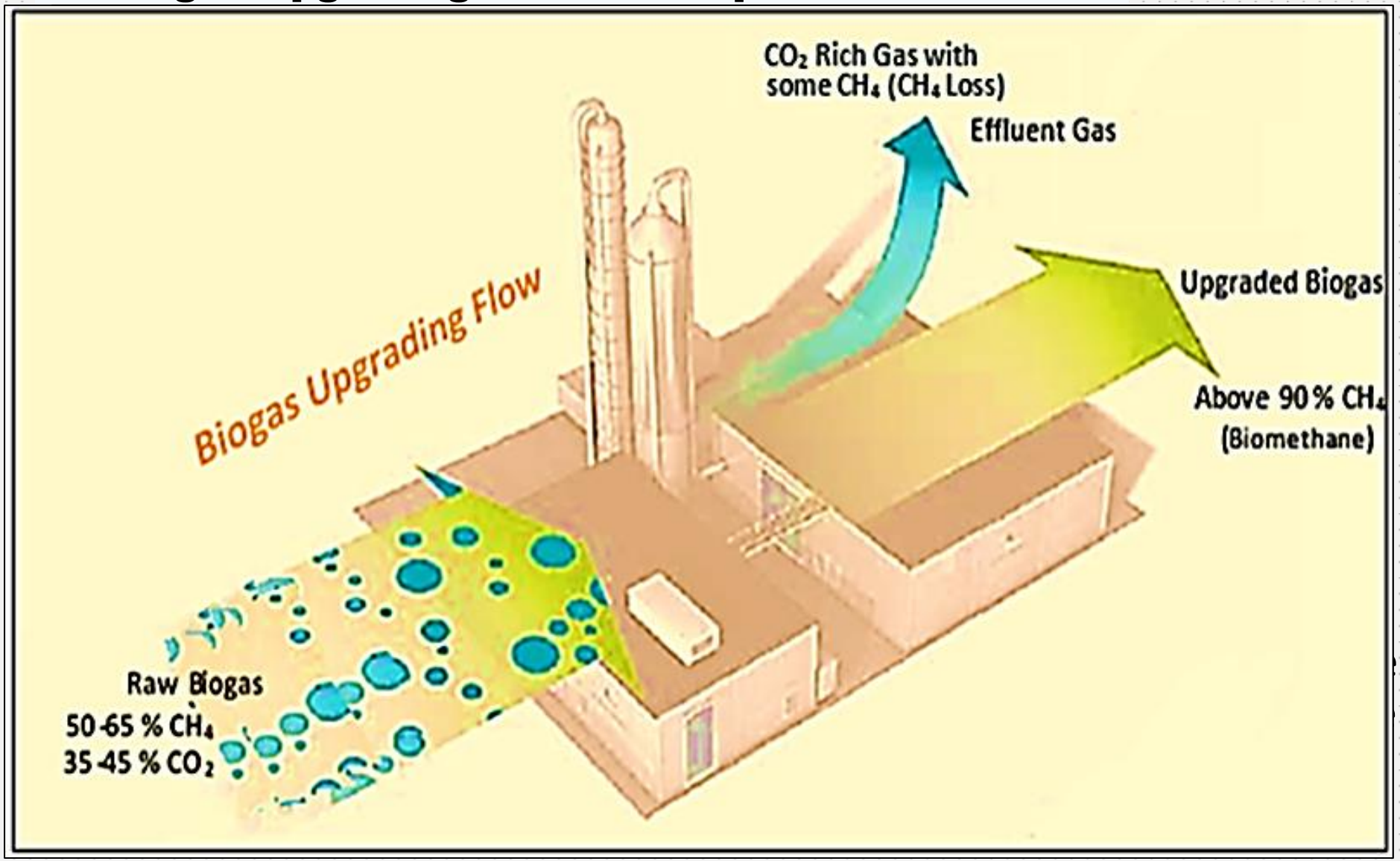
# Upgraded & Bottled Biogas as a Replacement of Existing Petroleum Fuels for Mobility Applications

# Biogas as an Alternate to Natural Gas!

| Properties | Natural Gas | Raw Biogas | Upgraded Biogas(CBG/Biomethane) |
|---|---|---|---|
| Composition% (v/v) | $CH_4$ – 89.14%<br>$CO_2$ – 4.38%<br>$H_2$ – 0.01%<br>$N_2$ – 0.11%<br>$C_2H_6$ – 4.05%<br>$C_3H_8$ – 0.83%<br>Iso-$C_4H_{10}$ – 0.28%<br>Neo-$C_4H_{10}$ – 0.66%<br>Iso-$C_5H_{12}$ – 0.09%<br>Neo-$C_5H_{12}$ – 0.28%<br>$C_6H_{14}$ -0.17% | $CH_4$ – 50- 65%<br>$CO_2$ – 35-45%<br>$N_2$ – 1-25%<br>$O_2$ – 0.1-5 %<br>$H_2S$ – 10- 3000 ppm | $CH_4$ *Min* - 90%<br>$CO_2$ *Max* (v/v) – 4%<br>$CO_2 + N_2 + O_2$ *Max* (v/v) – 10%<br>$O_2$ *Max (v/v)* – 0.5 %<br>$H_2S$ mg/$m^3$ *Max* – 30.3<br>Moisture mg/$m^3$*Max* -16 |
| Lower Heating Value | 44.39 MJ/kg | 20.5 MJ/kg | 42.62 MJ/kg |
| Relative Density | 0.765 | 1.014 | 0.714 |
| Flame speed (cm/sec) | 34 | 25 | – |
| Stoichiometric A/F (kg of Air/ kg of Fuel) | 17.03 | 17.16 | 17.16 |
| Auto-ignition Temperature ($^0$C) | 540 | 650 | – |

Raw Biogas ⇢ Cleaned/Upgraded Biogas

## Biogas Upgrading: The Gas Separation Problem



# Utilization of Upgraded Biogas


First Biomethane bus in India


Biomethane Bus in Sweden


Biogas car in Sweden

Biogas Train in Sweden

# Upgraded & Bottled Biogas for Cooking and Vehicular Applications


Cascades of Upgraded biogas being transported


Biogas Motorcycle in Thailand

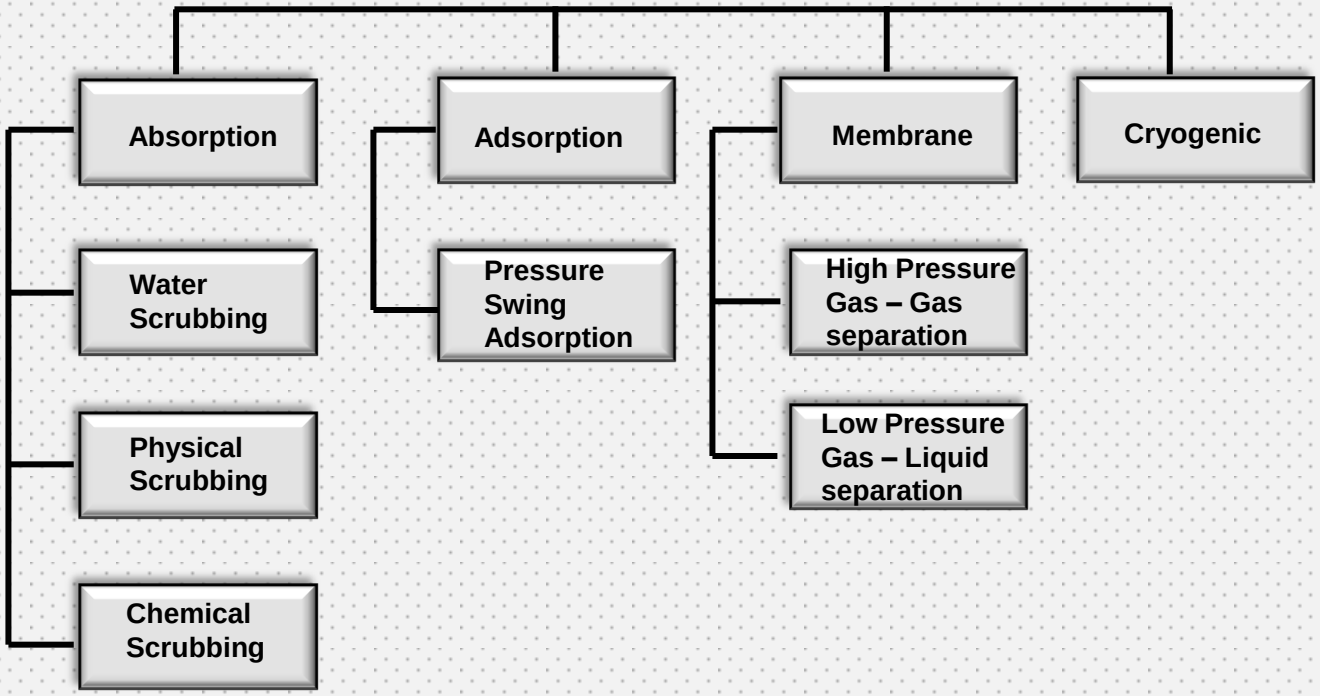
Biogas Car in India

Upgraded and bottled biogas for use as a cooking fuel

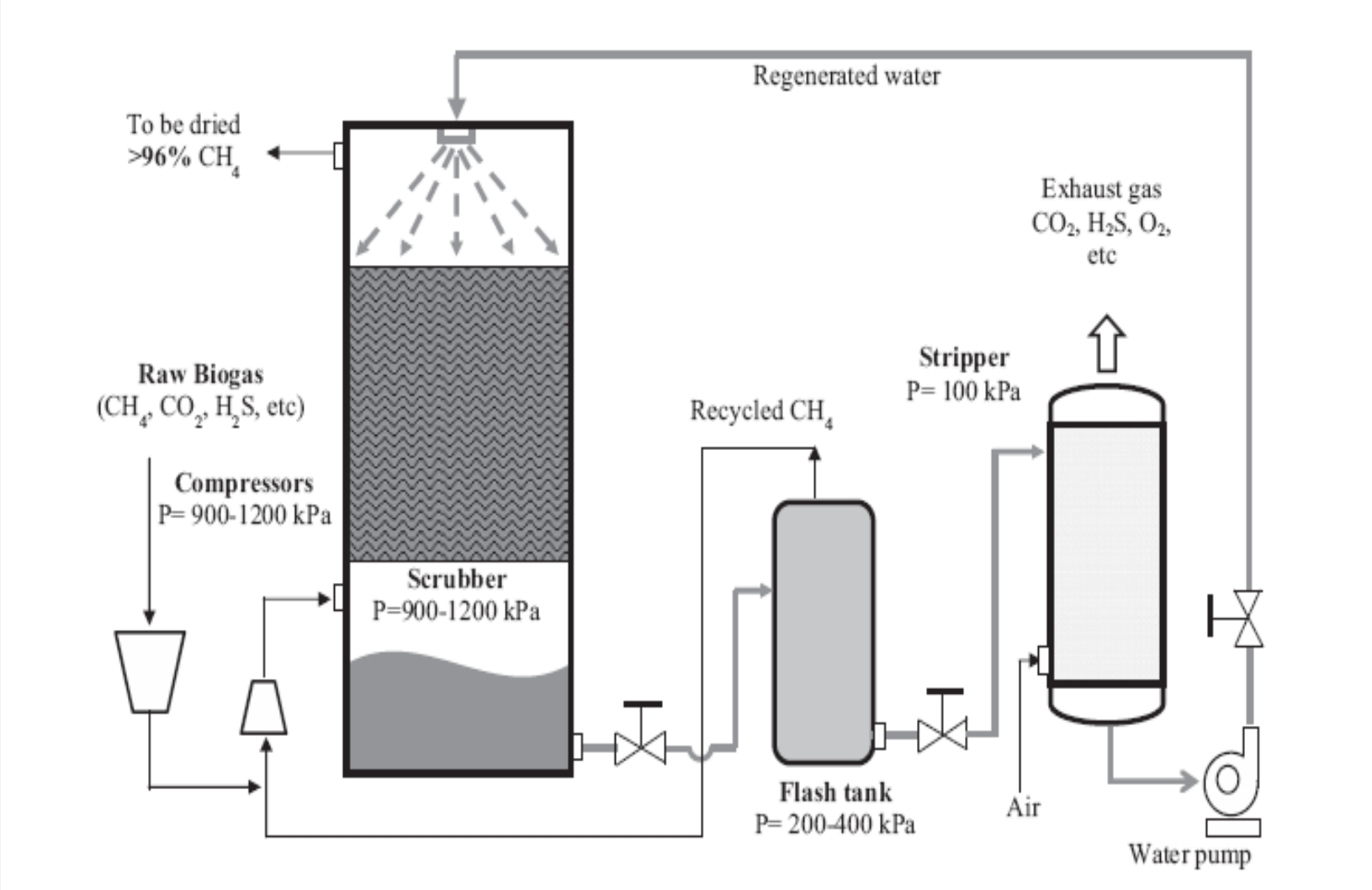

Bottled biomethane used for power generation

*http://www.pluginindia.com/advantagesusesofbiogas.html*

# Techniques for Biogas Cleaning/Upgrading

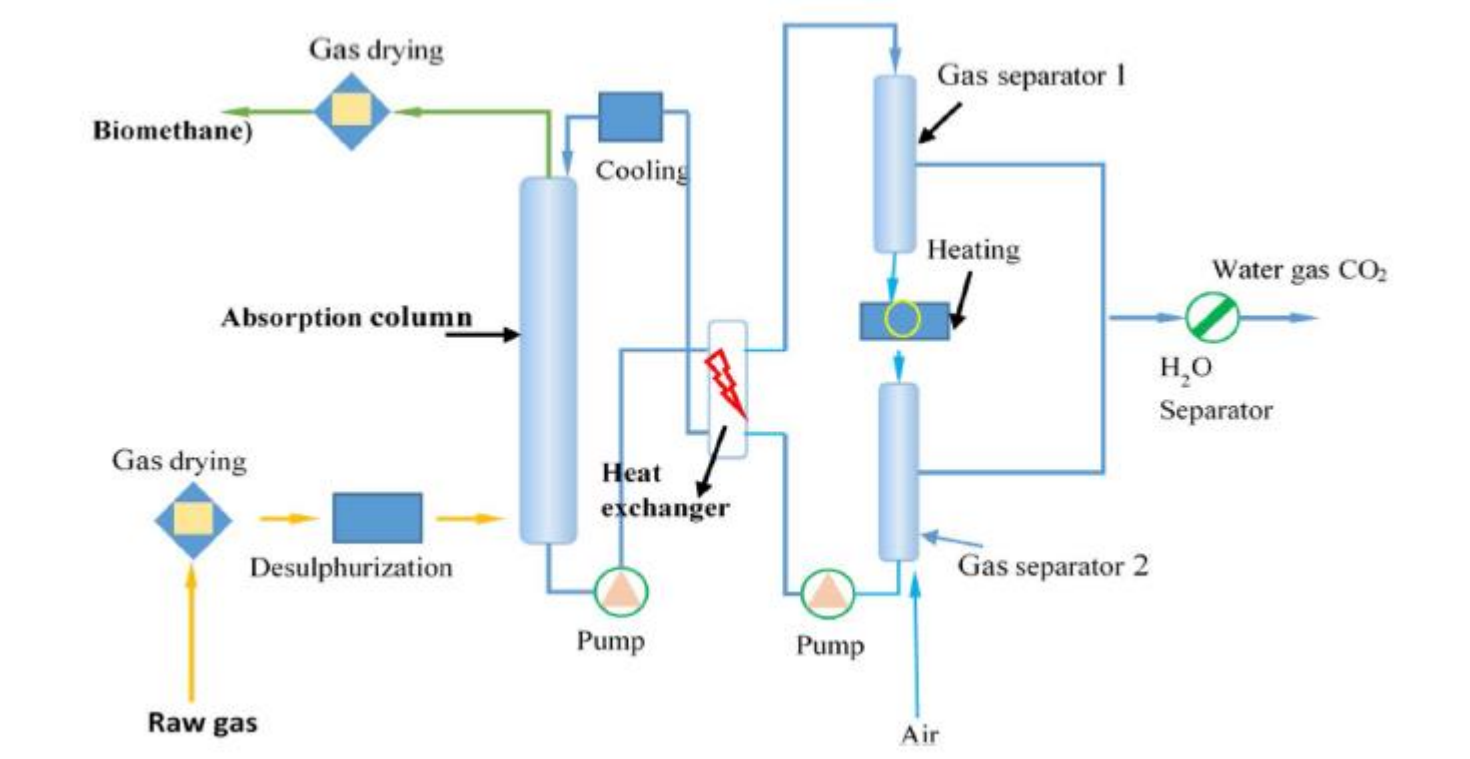



- Decide for suitable technology primarily NOT by investment costs
- Select suitable technology according to:
  - Upgrading capacity
  - CH4 recovery
  - Turn down ratio
  - Shut down / start up performance and ease of operation
  - Product quality required
  - Chemicals and energy consumption



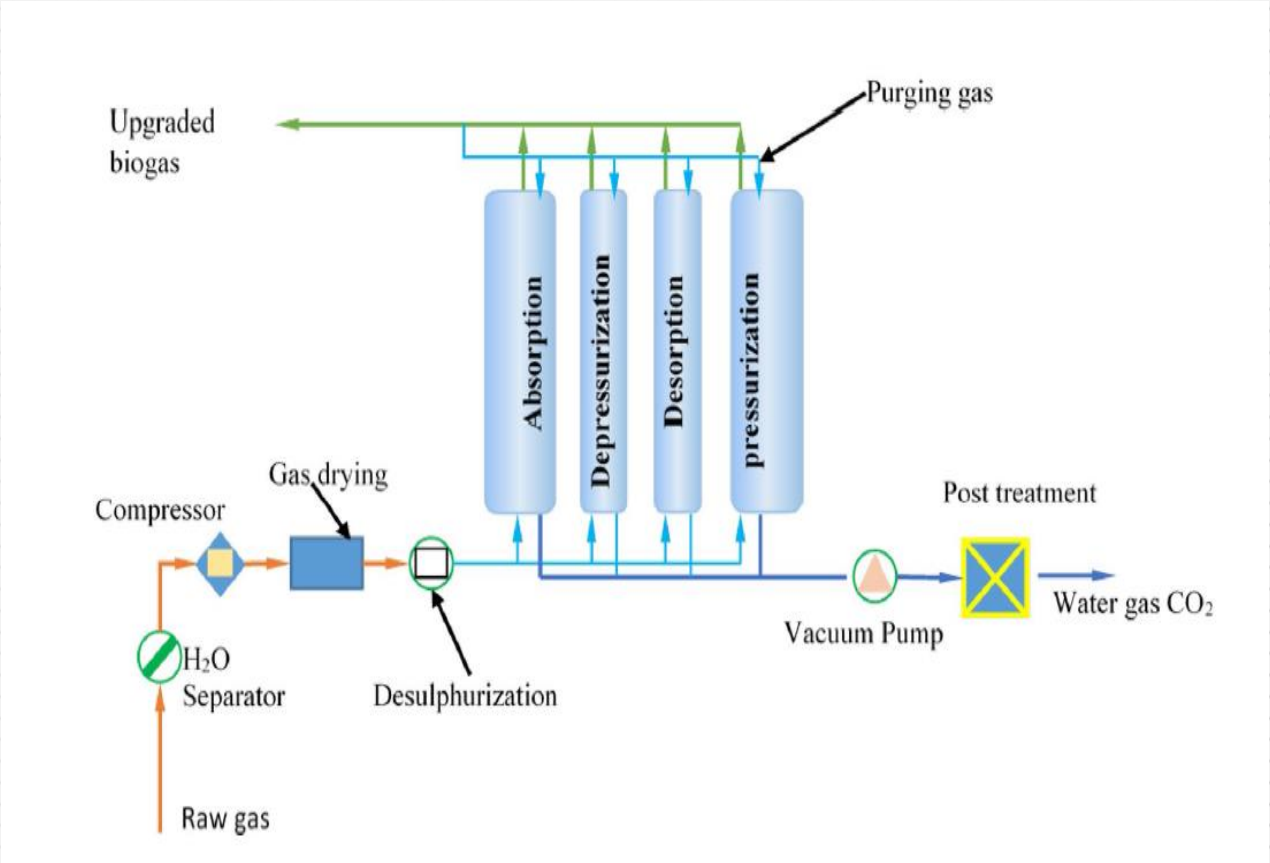

- Simple process
- Based on high solubility of CO2 and H2S in water
- H2S pre-removal is not mandatory
  - Can tolerate 300–2500 ppmv
- Low investment and operational cost
- Low methane slip
- High energy efficiency >96%
- Best in Medium and Large Applications
- Proven technology
- Robust system
- Regeneration is simple with depressurisation of water
- Water is recycled

Water Scrubbing Process for Biogas Upgradation



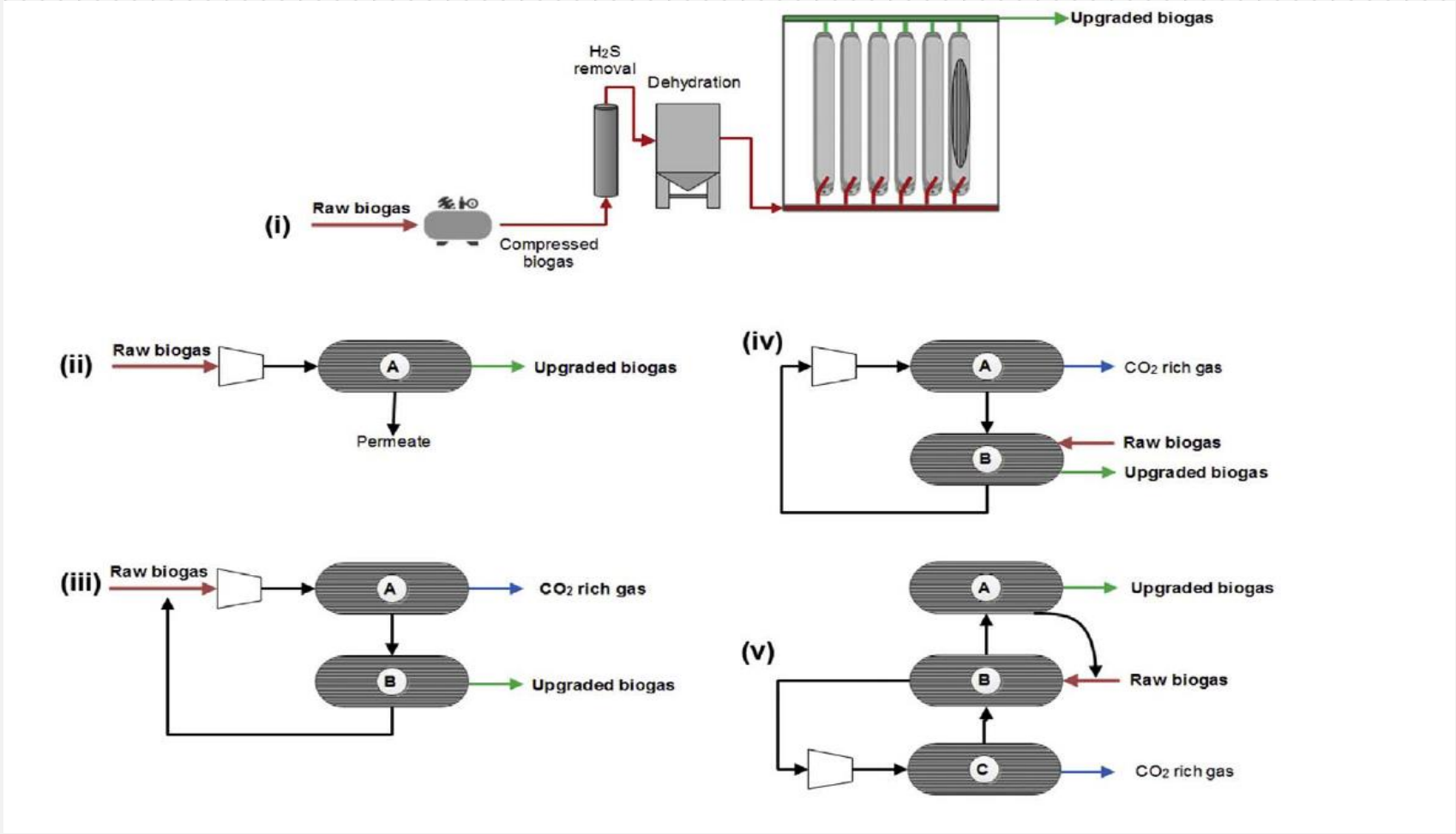

- Chemical absorption of CO2 into chemicals
  - MEA/DMEA
- High selectivity for CO2
- Low methane loss
- Regeneration by heating spent chemical at high temperatures
- H2S pre-removal is mandatory
  - Otherwise H2S will also be absorbed in the solvent leading to higher heating requirements for regeneration

Chemical Scrubbing Process for Biogas Upgradation




- Adsorption on activated carbon or zeolite under pressure
- Adsorbent is regenerated by sequential decrease in pressu
- Pre-removal of H2S is mandatory
- Low biomethane recovery

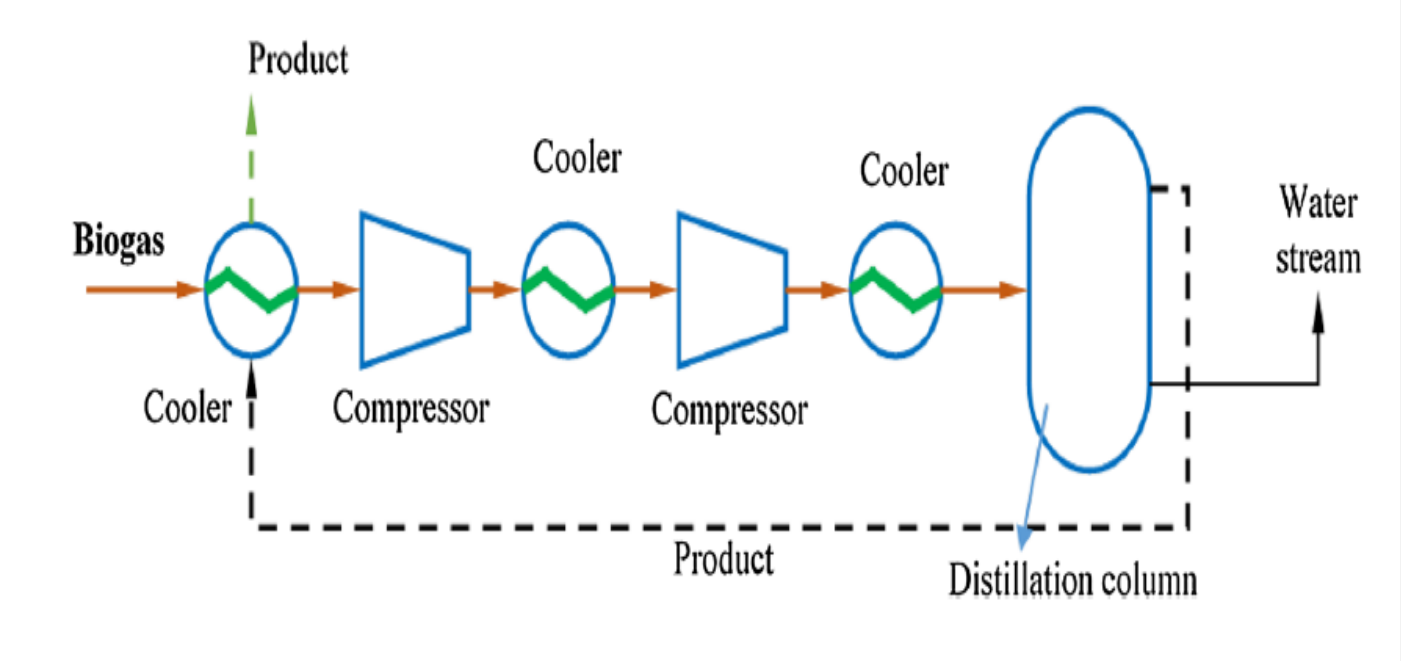
Pressure Swing Adsorption Process for Biogas Upgradation




- Low investment and operational cost
- Low methane slip 98% with multi stage systems
- Compact
- Simple on/off Simple on/off
- Best for low and Medium Flows

## Membrane Cascade Separation System For Biogas Upgradation

i) General Design, Ii) Single Stage Configuration, Iii) Two-stage Configuration With A Recirculation Loop, Iv) Two-stage Configuration With Sweep And V) Three-stage Configuration With Sweep




- **Liquefied $CO_2$**
- **Complex Technique**
- **High energy requirement for**
  - **High pressure**
  - **low temperatures**

Cryo-technology for Biogas Upgradation

# Summary of Biogas Upgrading Technologies

**Water scrubbing technology is one of the most widely implemented and mature technology with over 41% plants out of 503 biogas upgrading plants installed worldwide (IEA, 2017).**

- Based on physical absorption of gases in water- no chemical reaction involved.
- No pre-cleaning of $H_2S$ required, since solubility of $H_2S$ is higher than $CO_2$, it will also get dissolved in water at high pressures.
- Water is used as a solvent – cheap, easily and abundantly available.
- Regeneration of water is simple – release of pressure.
- No heat requirement during absorption or regeneration process.
- No complicated and complex equipment required.
- Easy operation and maintenance.
- No use of chemicals.
- Cheap, Investment cost is less.

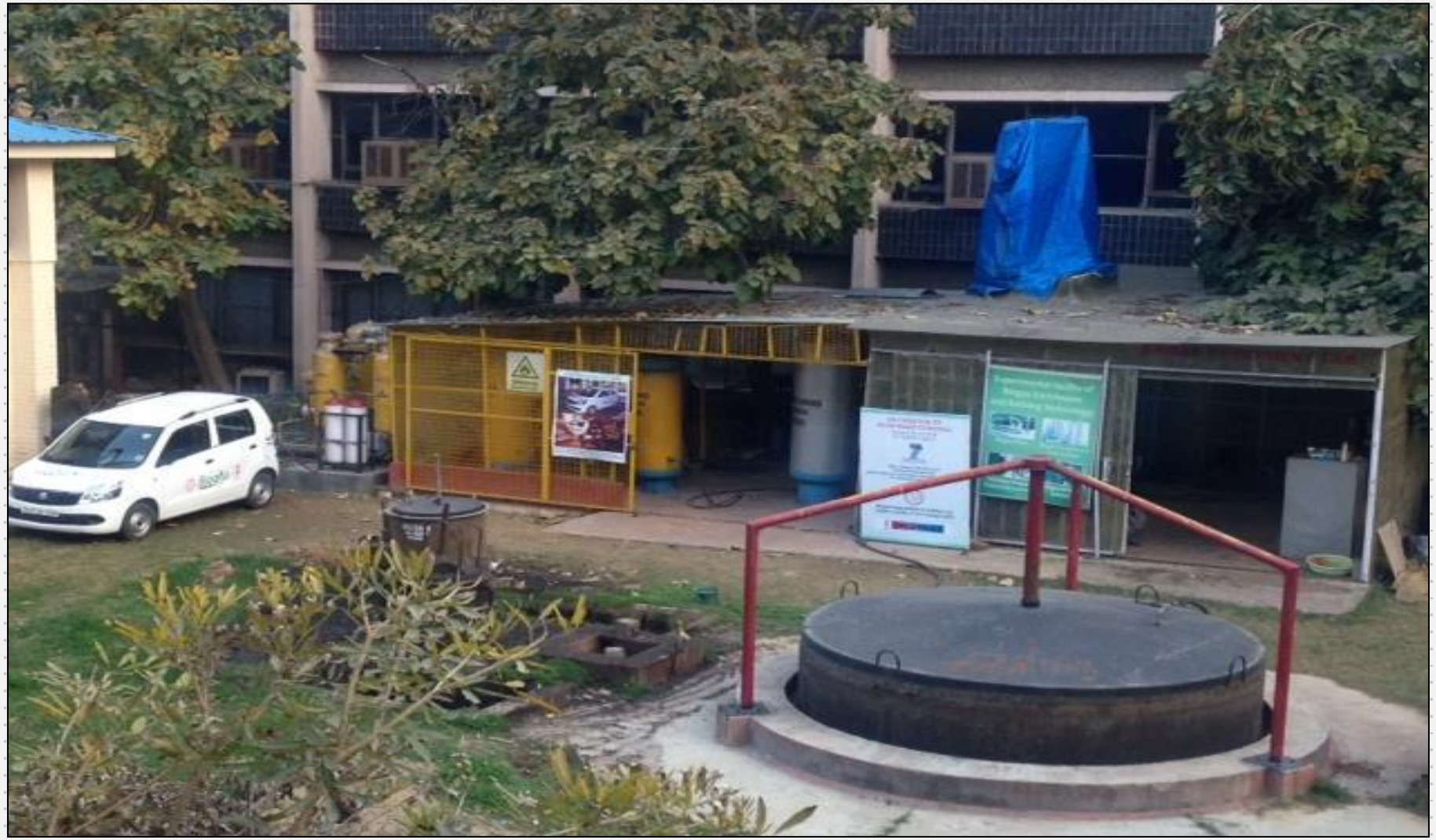
*State of the Art*

# Water Scrubbing based Bio$CH_4$ and Bio$CO_2$ Production Technology Developed at IIT Delhi, India

**Awarded: Patent No. 284588** is granted on 27/06/2017 for "A Device and a Process for Conversion of Biogas to a Fuel Gas with enhanced Thermal Efficiency. V.K.Vijay, P.M.V. Subbarao, R.R. Gaur and S.S. Kapdi. Patent Application No. 161/DEL/2006 dated 20.1.2006

**Applied:**

V .K. Vijay, Rimika Kapoor, P.M.V. Subbarao, "A System for Biomethane and Bio Carbon Dioxide Production from Biogas and a Method Thereof". (Indian) – Patent Application No.: 201811018965, Dated: May 21, 2018.



**Water Scrubbing based Bio$CH_4$ and Bio$CO_2$ Production System at IIT Delhi**


| | WS1 (BioCH4 Production) | WS2 (BioCO2 Production) |
|---|---|---|
| Capacity Gas Flow Rate | 10$Nm^3/h$ | 5 $Nm^3/h$ |
| Quality of Gas Obtained | 95% BioCH4 | 99.9% BioCO2 |
| Recovery of Gas | 91% | 88.5% |

# Upgraded Biogas Dispensing System at IIT Delhi


High Pressure Compressor


Two cylinder cascade for bottling of upgraded biogas

Dispensing Nozzle - NZ type

# Bio$CH_4$ Application as Vehicular Fuel

Biogas three-wheeler vehicle

# $BioCO_2$ Application

- Algae Cultivation
- Grain Fumigation
- Greenhouses
- Chemical Manufacturing

# Mobile Biogas Upgradation System developed at IIT Delhi


# THANK YOU