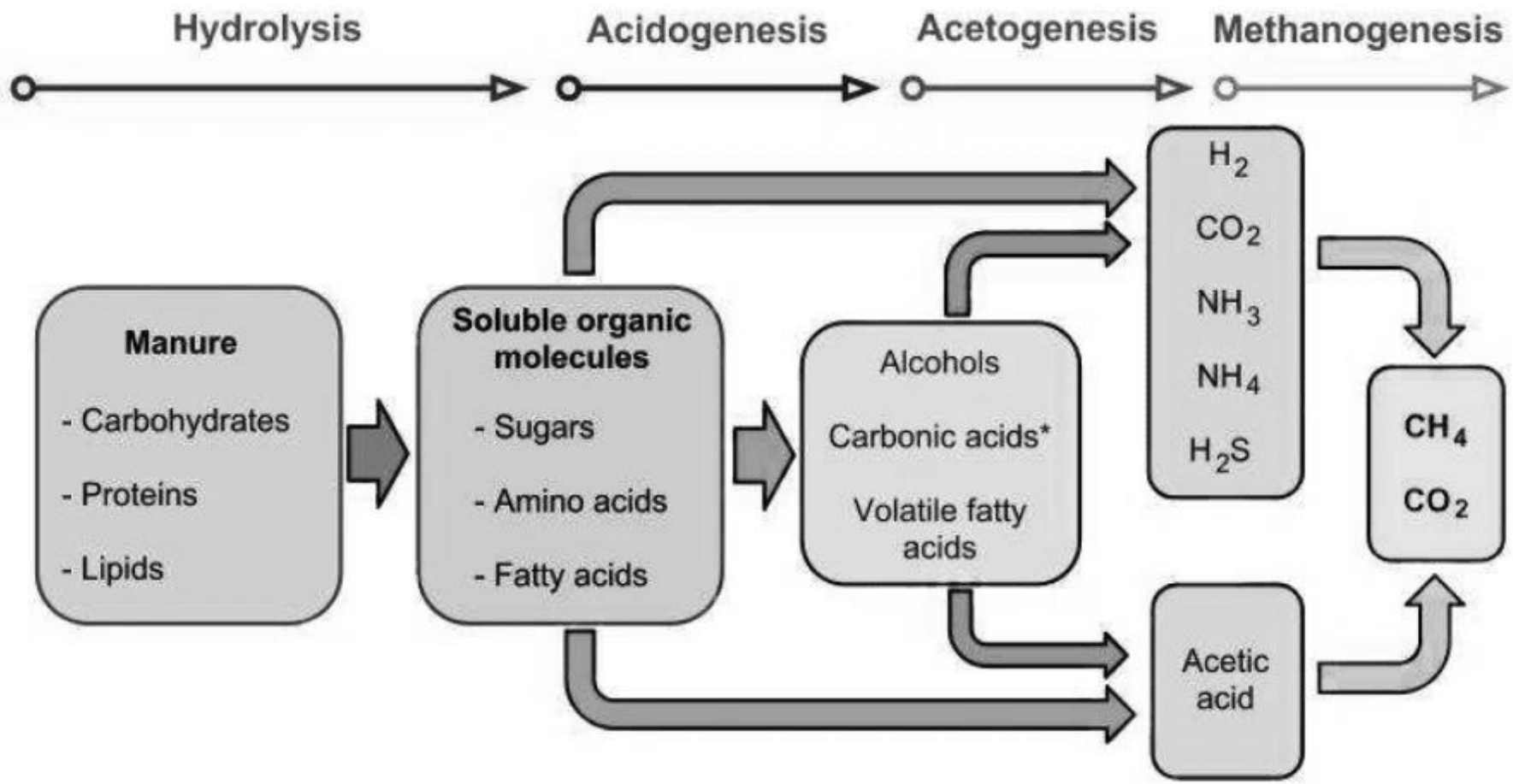
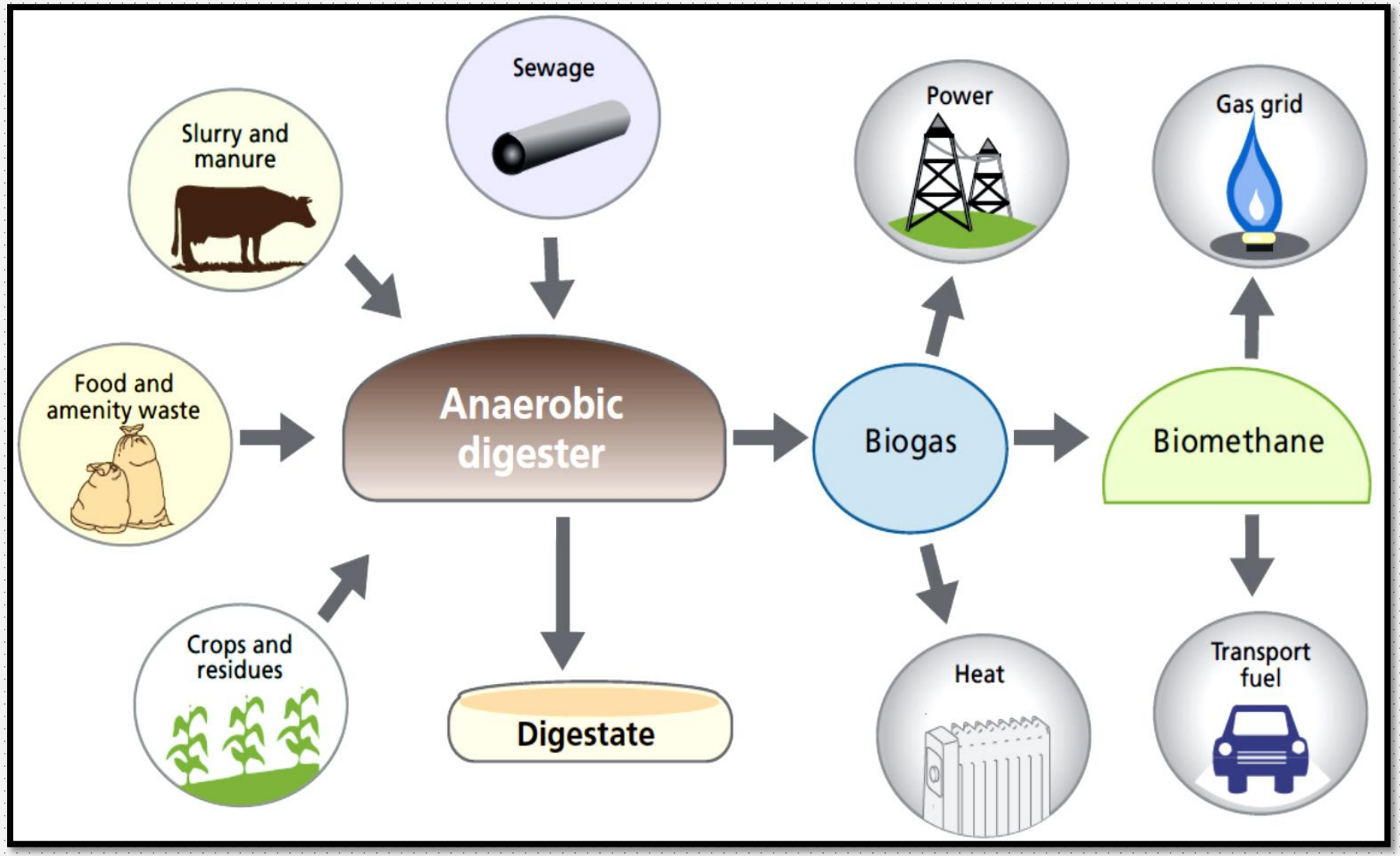
Technologies for Biogas Upgrading

Dr, Rimika Kapoor
PDF, Centre for Rural Development & Technology,
IIT, Delhi

What is biogas?



Biogas Production & Utilization



(Source: OFGEM, 2011)

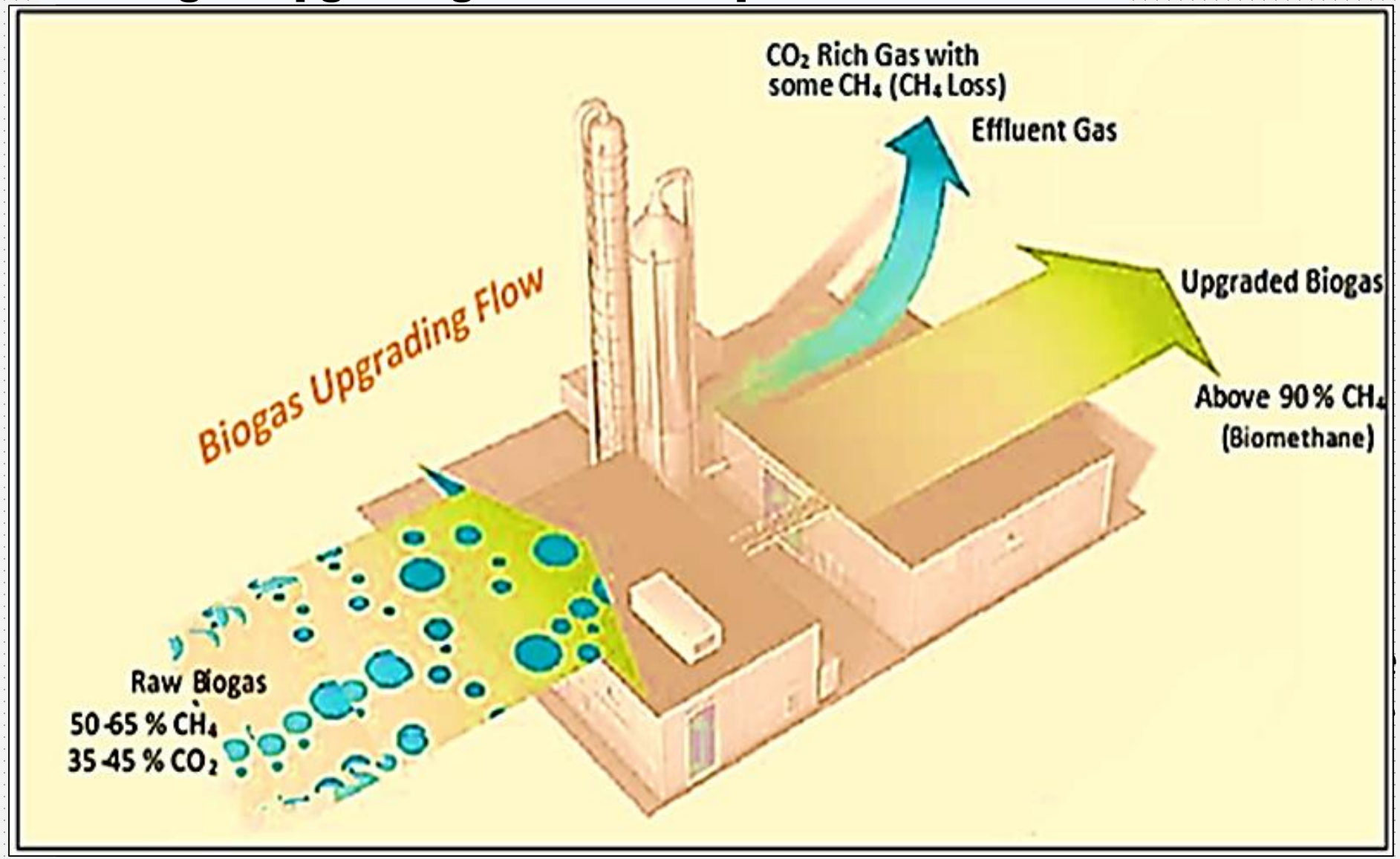
Upgraded & Bottled Biogas as a Replacement of Existing Petroleum Fuels for Mobility Applications

Biogas as an Alternate to Natural Gas!

Properties	Natural Gas	Raw Biogas	Upgraded Biogas(CBG/Biomethane)
Composition% (v/v)	CH_4 – 89.14% CO_2 – 4.38% H_2 – 0.01% N_2 – 0.11% 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 – 50- 65% CO_2 – 35-45% N_2 – 1-25% O_2 – 0.1-5 % H_2S – 10- 3000 ppm	CH_4 *Min* - 90% CO_2 *Max* (v/v) – 4% $CO_2 + N_2 + O_2$ *Max* (v/v) – 10% O_2 *Max (v/v)* – 0.5 % H_2S mg/m^3 *Max* – 30.3 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

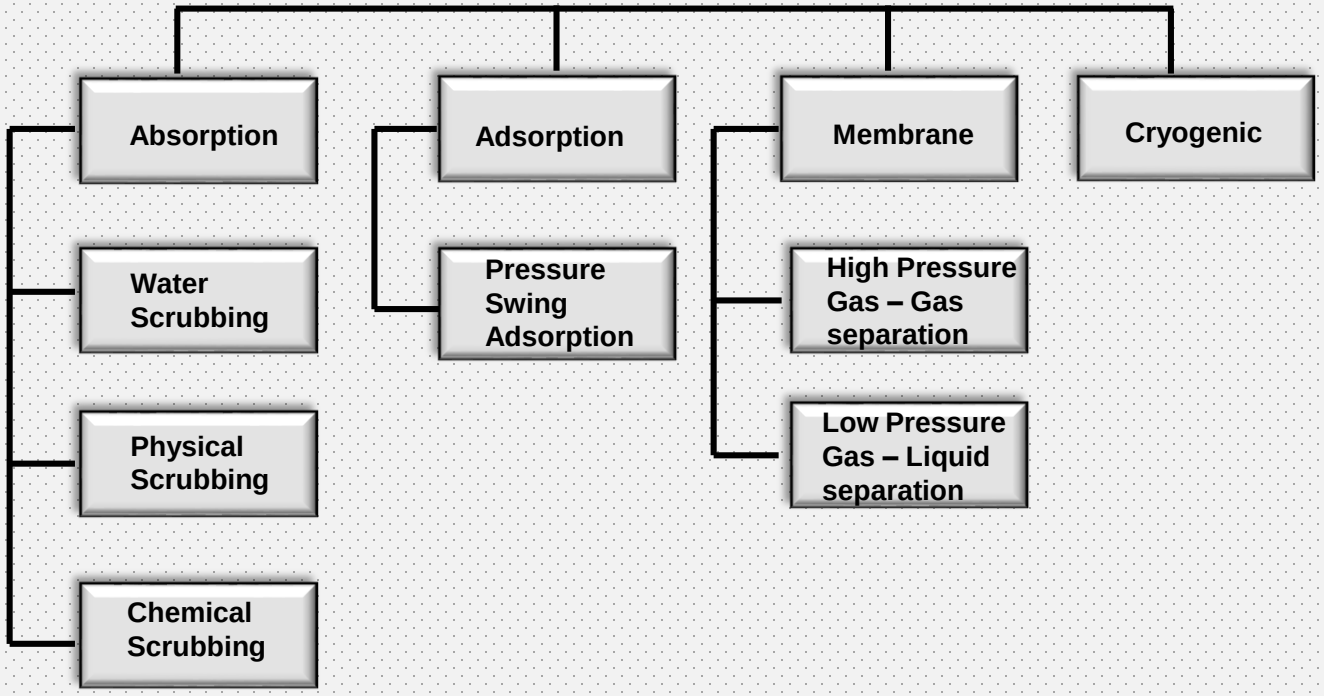
Biogas Car in India

Upgraded and bottled biogas for use as a cooking fuel

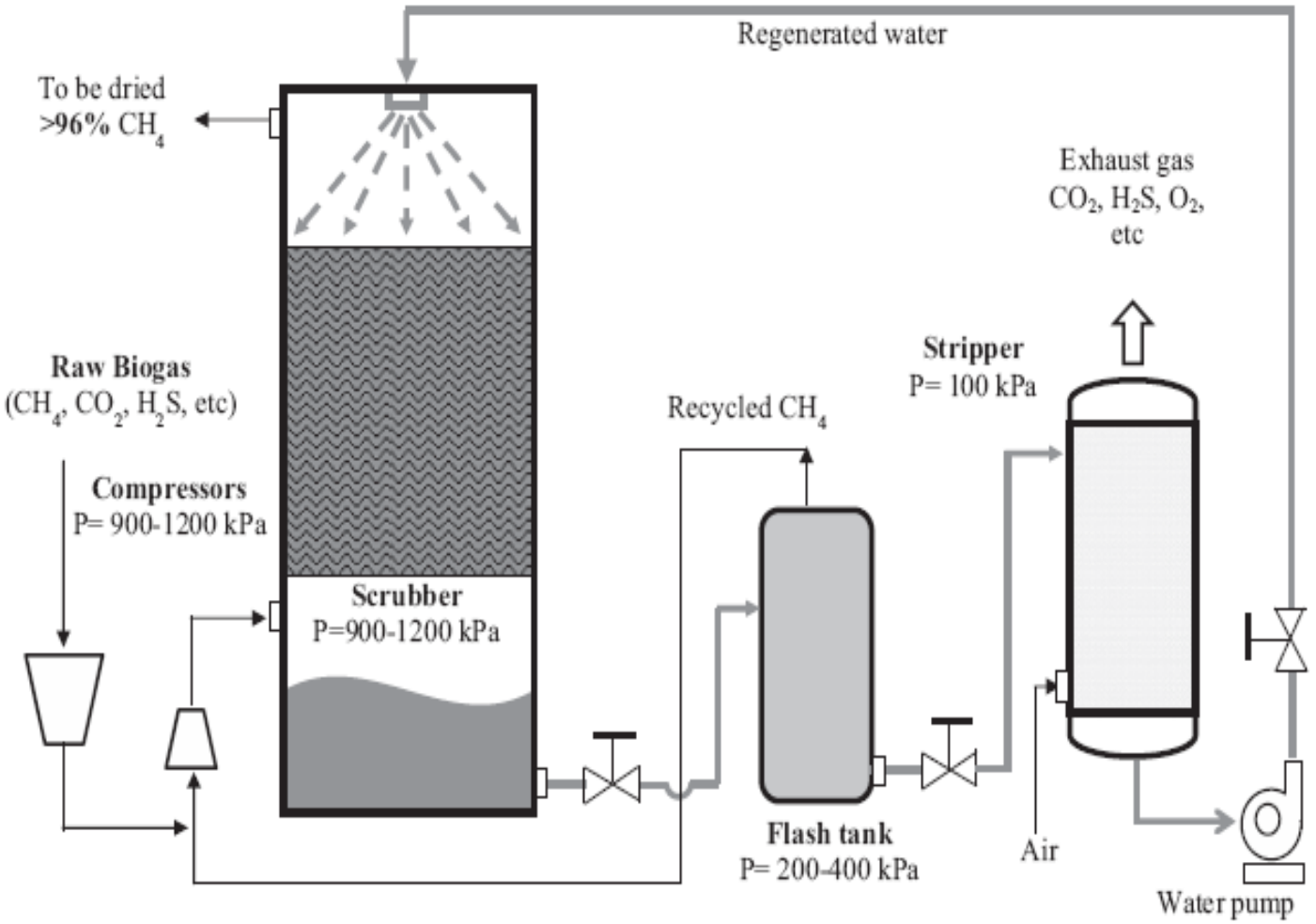
Bottled biomethane used for power generation

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

Techniques for Biogas Cleaning/Upgrading

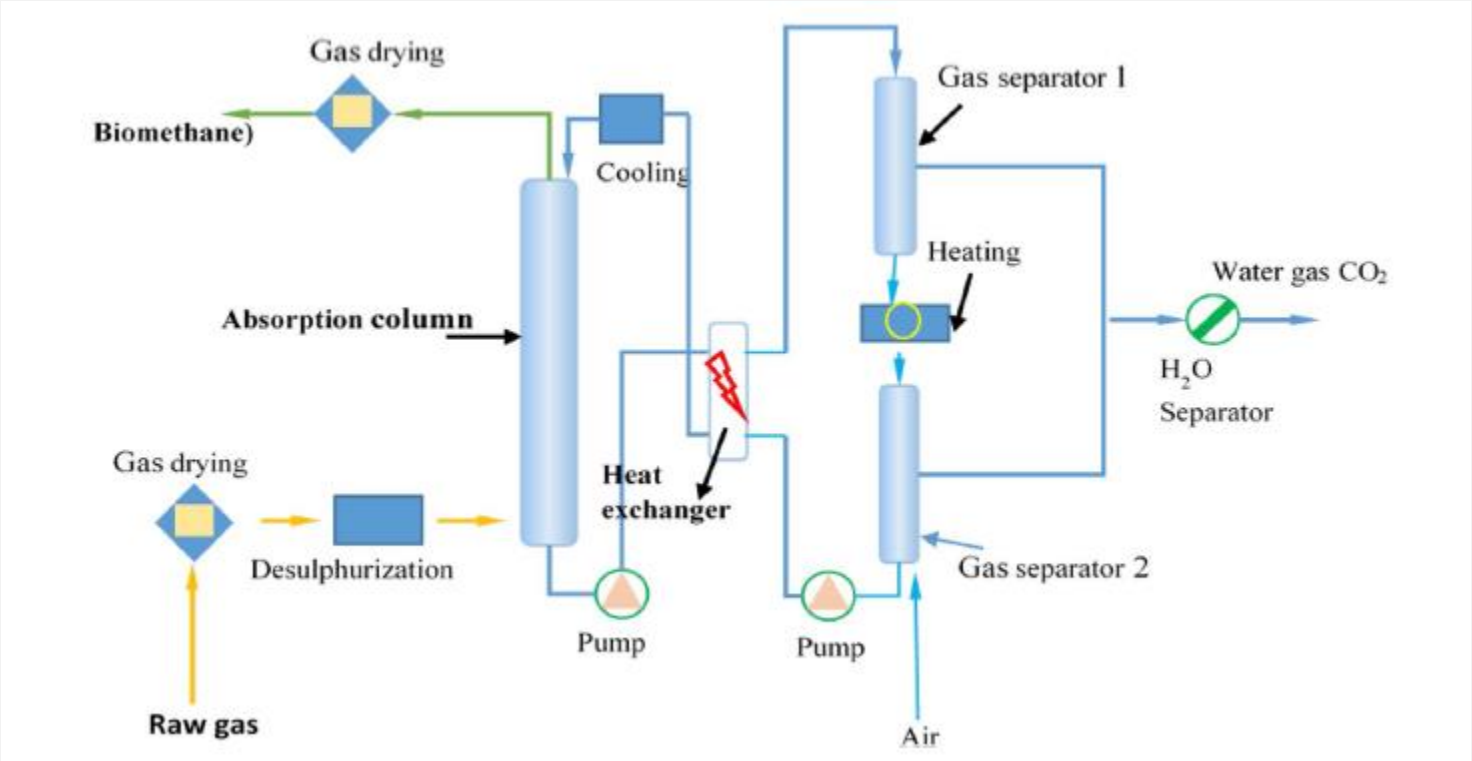


- Decide for suitable technology primarily NOT by investment costs
- Select suitable technology according to:
  - Upgrading capacity
  - CH4 recovery
  - Turn down ratio
  - Shut down / start up performance and ease of operation
  - Product quality required
  - Chemicals and energy consumption



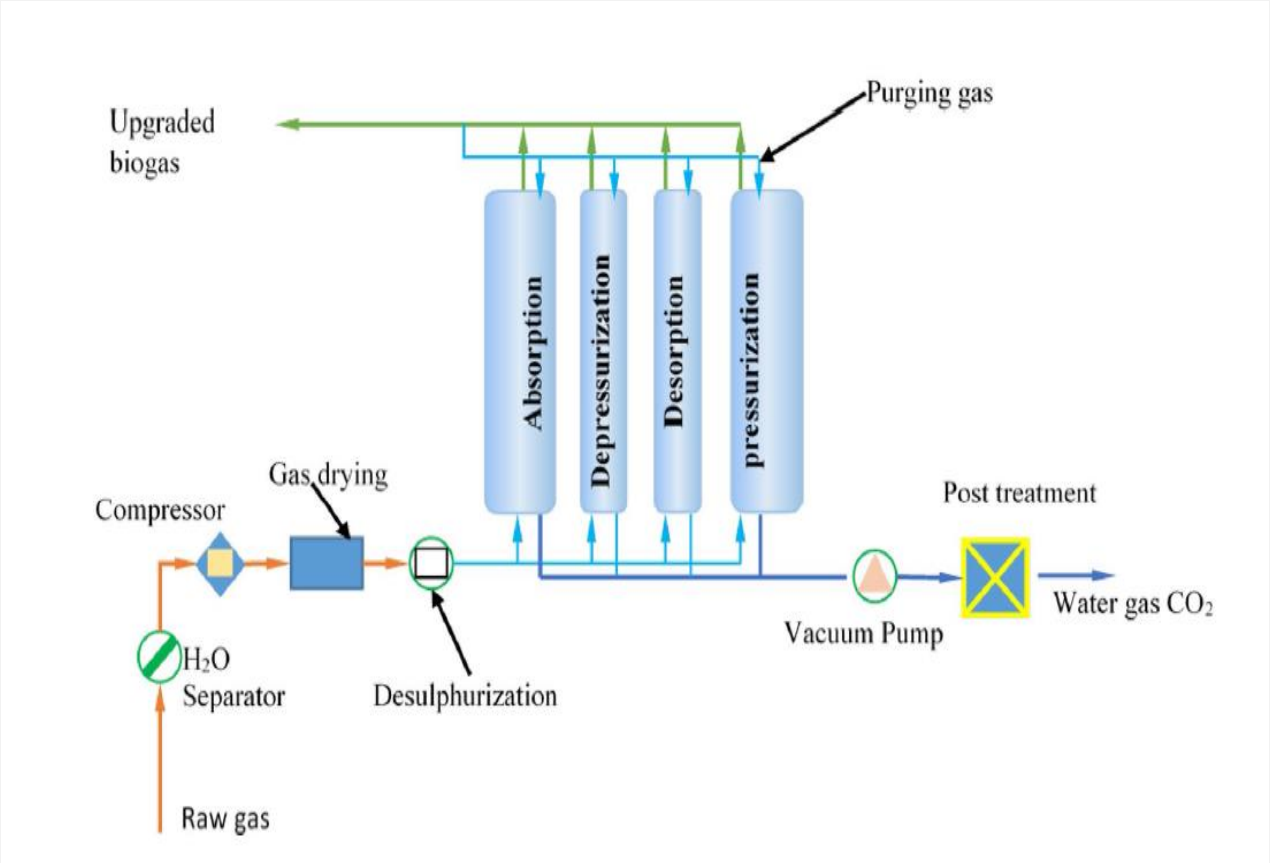
- Simple process
- Based on high solubility of CO2 and H2S in water
- H2S pre-removal is not mandatory
  - Can tolerate 300–2500 ppmv
- Low investment and operational cost
- Low methane slip
- High energy efficiency >96%
- Best in Medium and Large Applications
- Proven technology
- Robust system
- Regeneration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

Water Scrubbing Process for Biogas Upgradation



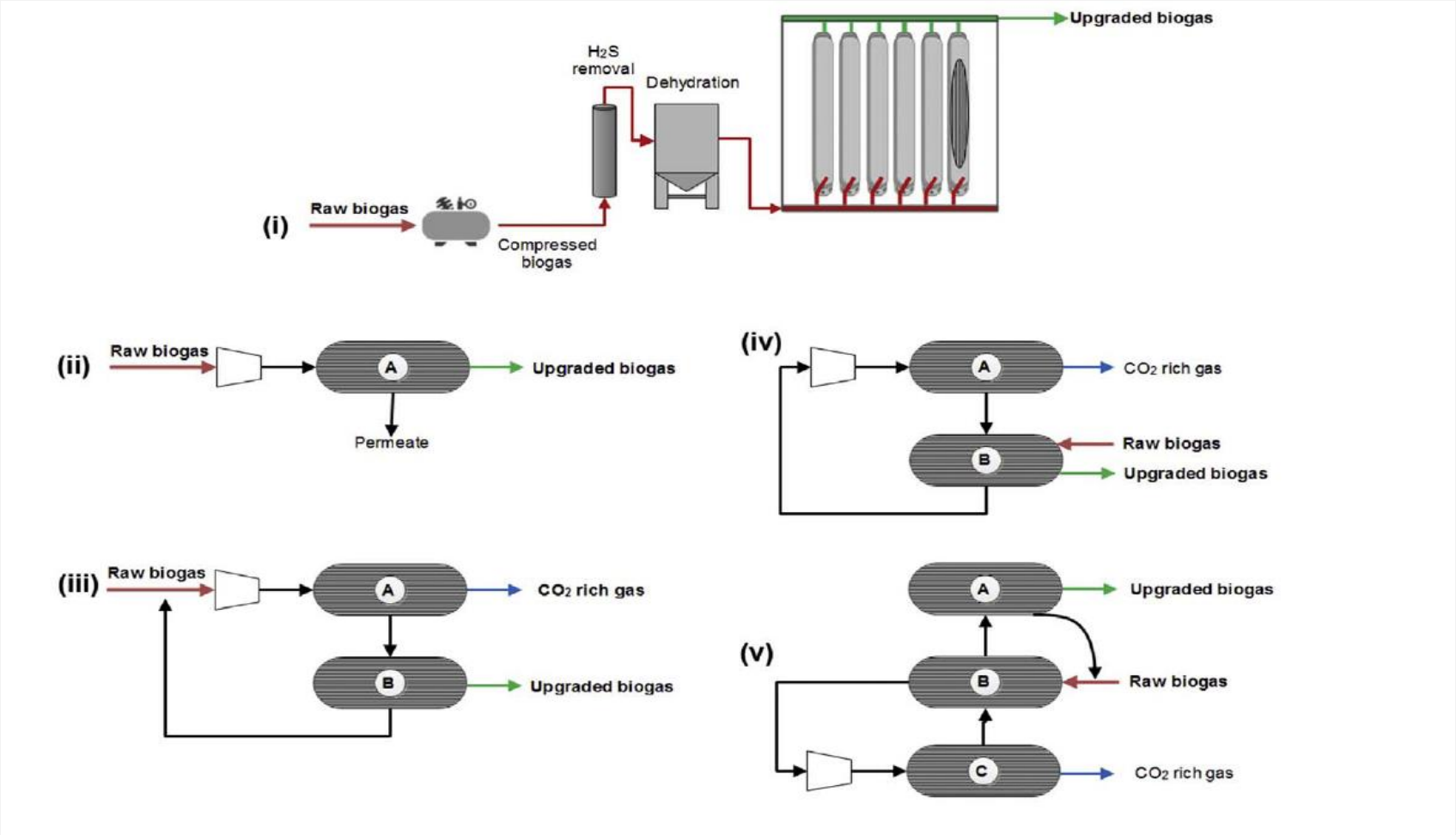
- Chemical absorption of CO2 into chemicals
  - MEA/DMEA
- High selectivity for CO2
- Low methane loss
- Regeneration by heating spent chemical at high temperatures
- H2S pre-removal is mandatory
  - Otherwise H2S will also be absorbed in the solvent leading to higher heating requirements for regeneration

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

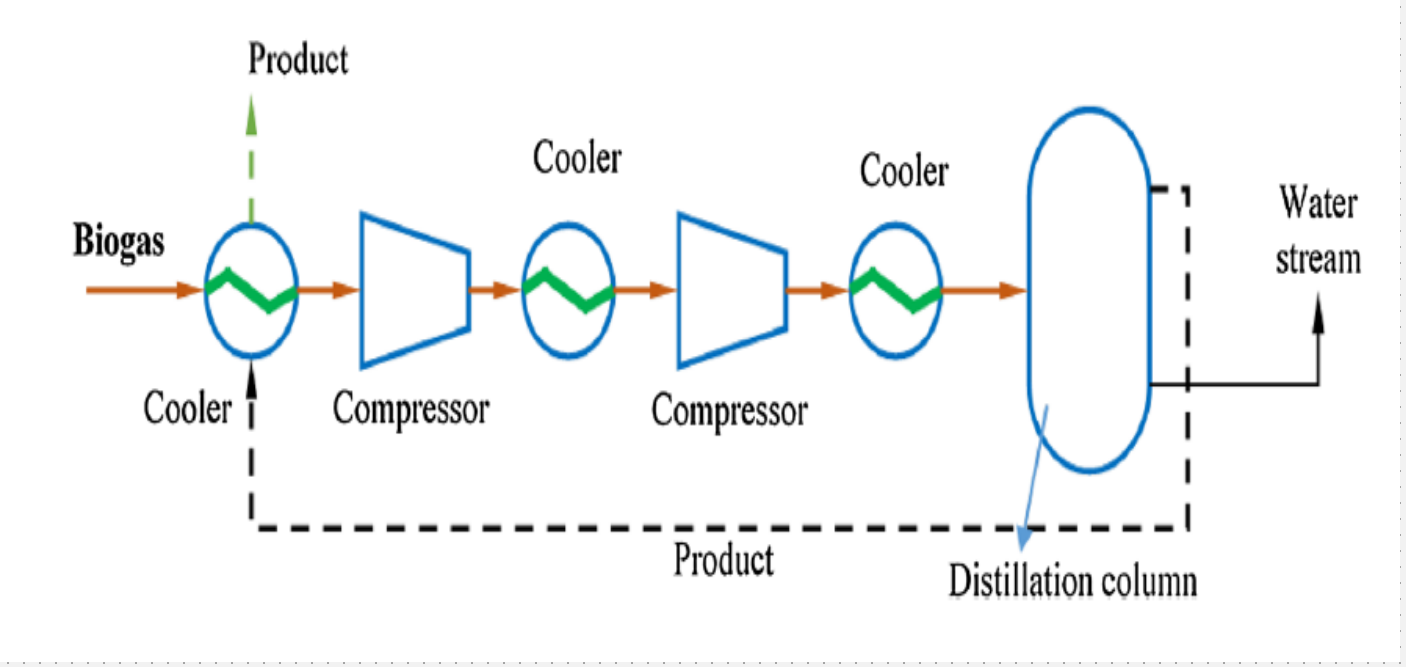
Pressure Swing Adsorption Process for Biogas Upgradation



- 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 BioCH_4 and BioCO_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 BioCH_4 and BioCO_2 Production System at IIT Delhi

	WS1 (BioCH4 Production)	WS2 (BioCO2 Production)
Capacity Gas Flow Rate	10Nm^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

$BioCH_4$ Application as Vehicular Fuel

$BioCO_2$ Application

- Algae Cultivation
- Grain Fumigation
- Greenhouses
- Chemical Manufacturing

Mobile Biogas Upgradation System developed at IIT Delhi

THANK YOU