Valorisation of Food waste to Biogas

Presented by:

Rimika Kapoor (Phd. Research Scholar)

Under the Guidance of

Prof. Virendra K. Vijay

Centre for Rural Development & Technology

Coordinator- BDTC

IIT, Delhi

vkvijay@rdat.iitd.ernet.in

Project Title : Valorisation of Food waste to Biogas

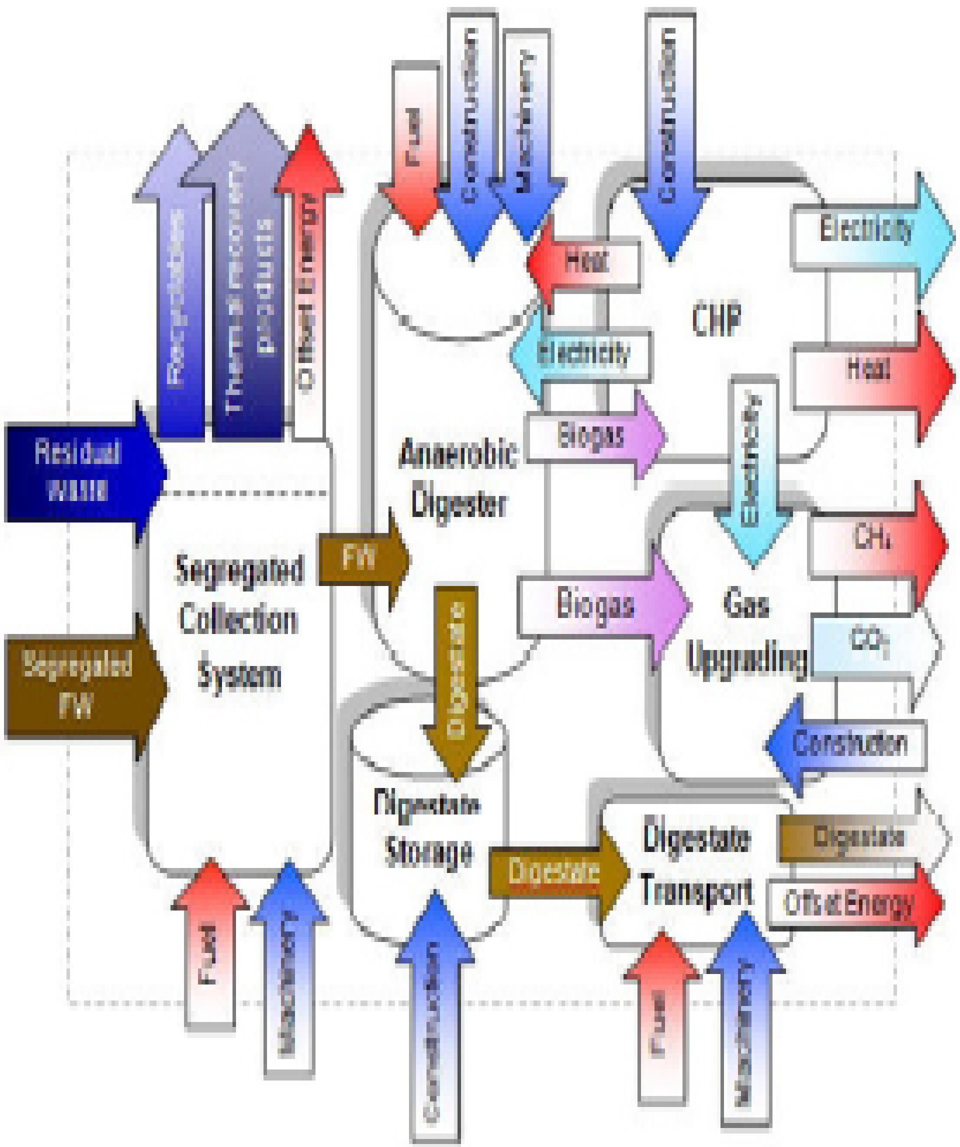
Project Acronym : VALORGAS

Funding Scheme : Collaborative Project

Topic : Energy.2009.3.2.2 Biowaste as second generation feedstock

List of participants:

Participant no.	Participant legal name	Country	Organisation type
1	University of Southampton *	UK	University
2	Università degli Studi di Verona	Italy	University
3	Università Ca' Foscari di Venezia	Italy	University
4	MTT Agrifood Research Finland	Finland	Government Research Institute
5	Indian Institute of Technology Delhi	India	Higher Education Institute
6	Veolia UK(EF) Ltd	UK	Industrial service provider and end user
7	Valorsul - Valorização e Tratamento de Resíduos Sólidos da Área Metropolitana de Lisboa (Norte), SA	Portugal	Industrial technology provider and end-user
8	AnDigestion Ltd	UK	SME technology provider and end-user
9	Aerothermal Group PLC	UK	SME technology provider
10	Ecosolids International Ltd	UK	SME technology provider
11	Biocycle South Shropshire Ltd	UK	Non-profit SME
12	Metener Oy	Finland	SME technology provider
13	Jyvaskyla Innovation Ltd	Finland	Non-profit SME regional development organisation



Energy inputs and outputs in the anaerobic digestion of source segregated food waste

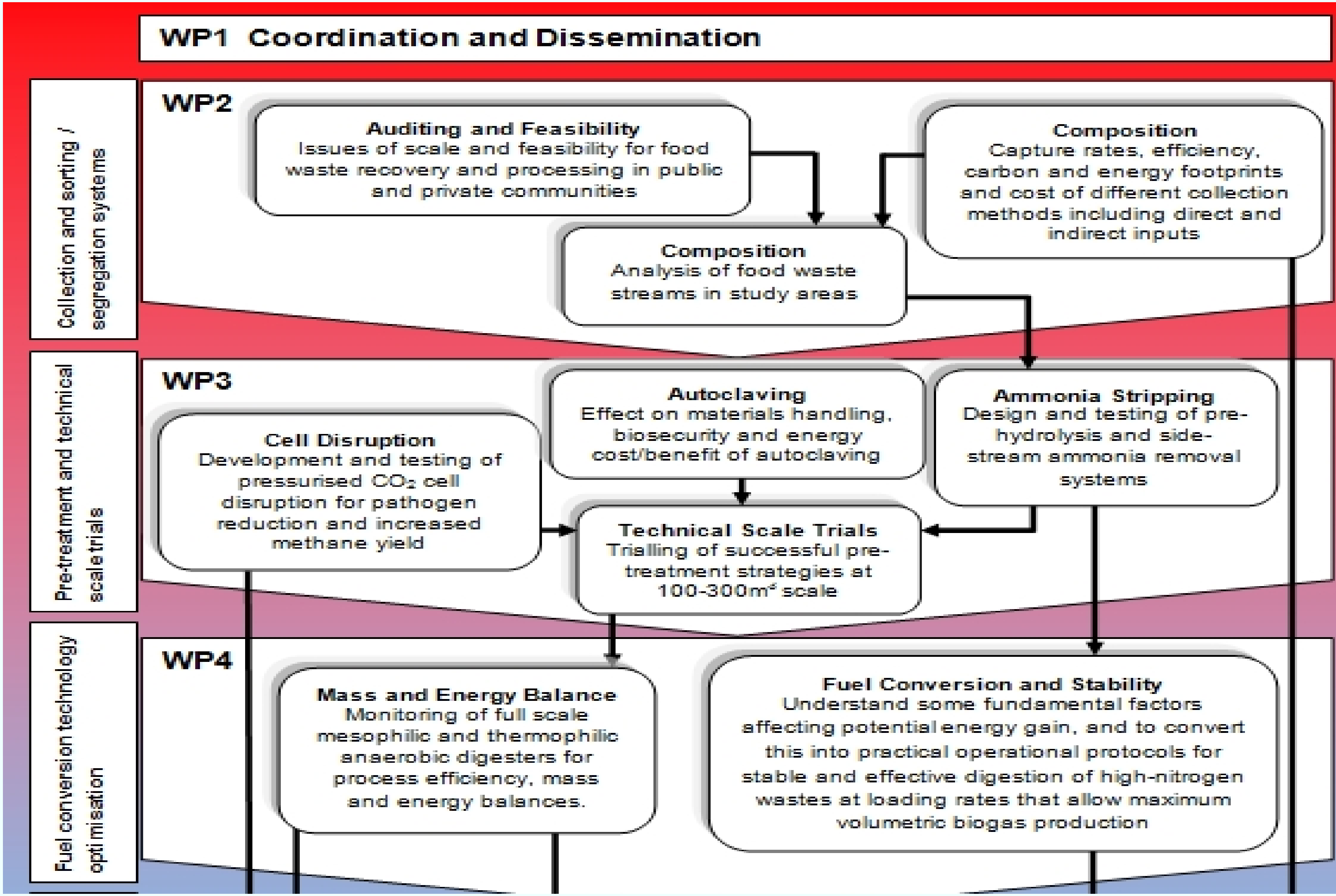
Key concept of the research

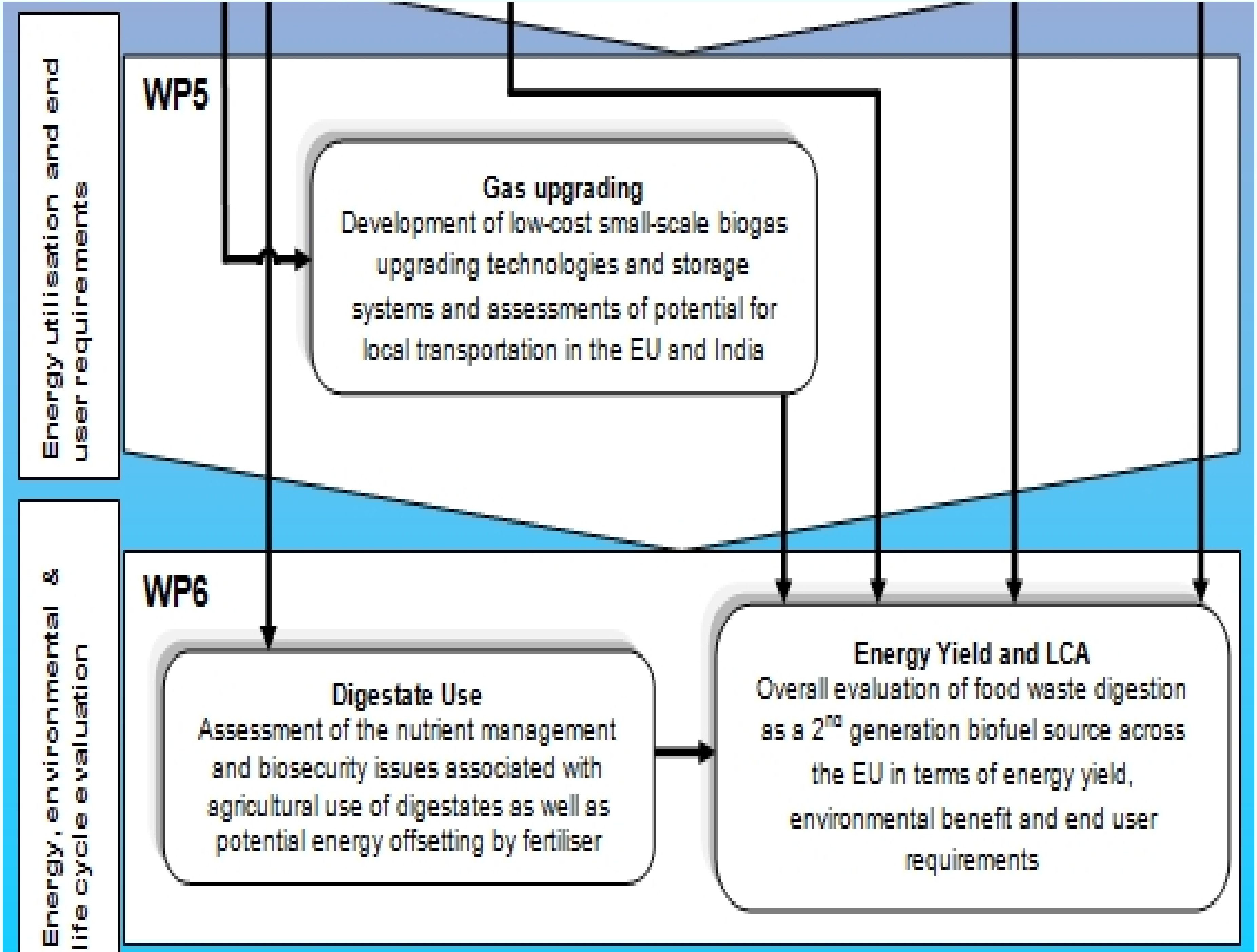
To valorise the energy from food waste by anaerobic digestion (AD), with full evaluation of the overall life cycle energy balances associated with this process. AD is not a new technology, but its application for energy recovery in the field of municipal waste treatment is only just becoming established in Europe, and only for mixed wastes. The use of source segregated food wastes as substrate is not yet widespread, possibly because of technical challenges linked with collection, handling, pre-treatment and digestion of this material. The research includes a number of closely related components with a common underlying goal: to evaluate and where possible improve the energy production process from the perspective of the overall net energy gain achieved within defined system boundaries that include collection, sorting, processing, and beneficial use of recovered material.

Objectives


YES-156
VOLVO
V70
BI-FUEL
Lanta on polttoaineeni
kulutus: 0.5m3 lantaa tai 60kg keittiojätettä / 100km
biokaasuauto.com

Work Packages





Energy utilisation and end user requirements
WP5
Gas upgrading
Development of low-cost small-scale biogas upgrading technologies and storage systems and assessments of potential for local transportation in the EU and India
Energy, environmental & life cycle evaluation
WP6
Digestate Use
Assessment of the nutrient management and biosecurity issues associated with agricultural use of digestates as well as potential energy offsetting by fertiliser
Energy Yield and LCA
Overall evaluation of food waste digestion as a 2nd generation biofuel source across the EU in terms of energy yield, environmental benefit and end user requirements

Tasks for IIT Delhi

- Contribution to dissemination and exploitation of results (WP1)
- Major contribution to food waste trials for private and public communities (WP2)
- **Leader** on development and assessment of small-scale biogas upgrading systems for vehicle fuel use with case studies (WP5)
- Contribution to development and refinement of energy models (WP6)

The project is expected to overcome many of the technical problems associated with reliable recovery of energy from food waste, thus making it more acceptable for general and widespread adoption and enabling anaerobic digestion of food waste to make a significant contribution towards country renewable energy targets for second generation biofuels.

OBJECTIVES:-

•**WP 2 -** To evaluate the efficiency and yield of source segregated food waste collection schemes from domestic properties, restaurant and catering facilities, food markets and food manufacture to evaluate the capture rate and efficiency of different types of collection schemes.

Main Objective of IIT Delhi **- Food waste and AD audits for public and private communities.**

•**WP 5 -** To develop low-cost small-scale biogas upgrading technologies and storage systems for application in transportation and local low-pressure distribution systems. To estimate the potential for small-scale biogas upgrading in local transportation in the EU and in India.

Food waste collection,sorting and transportation

✓World wastes 1.3 billion tons of food waste per year. By 2050 the world's population is projected to increase by 32% – and food production must nearly double to meet demand. As food production increases, so will the waste in production.

✓Urban food waste is going to increase by 44% globally between 2005 and 2025.

✓Asia is predicted to experience the largest increase in food waste production, from 278 million to 416 million tons.

✓If present waste management trends are maintained, land filled food waste is predicted to increase world CH4 emissions from 34 million to 48 million tons and the landfill share of global anthropogenic emissions from 8% to 10%.

Source: [FAO report ,2011,The international congress 'Save Food", May 2011,Germany, Adhikari,B.K.,(2006)]

Types of Food waste

- Uneaten food and food preparation

- Commercial establishments such as restaurants, institutional sources like school cafeterias, and industrial sources like lunchrooms

- Vegetable and fruit wastes

Most food waste ends up in landfills where it rots giving off methane, a powerful greenhouse gas. Using anaerobic digestion (AD) to recycle food waste captures the methane to generate clean energy, producing a valuable biofertiliser and reducing greenhouse gas emissions.

http://www.biogen.co.uk/food-industry.asp *www.wrap.org.uk/foodanddrinkwaste*


Food Waste
Recycling


Food
waste only
688


EUROCARGO
IVECO
GN10 JBO

INDIA……………..

Present Situation
-Composting
- Anaerobic Digestion
- Sold as piggery waste
- Land filling

WP 5

Energy utilization and end user requirements

The NEED……………………..

Raw Biogas → Upgraded Biogas

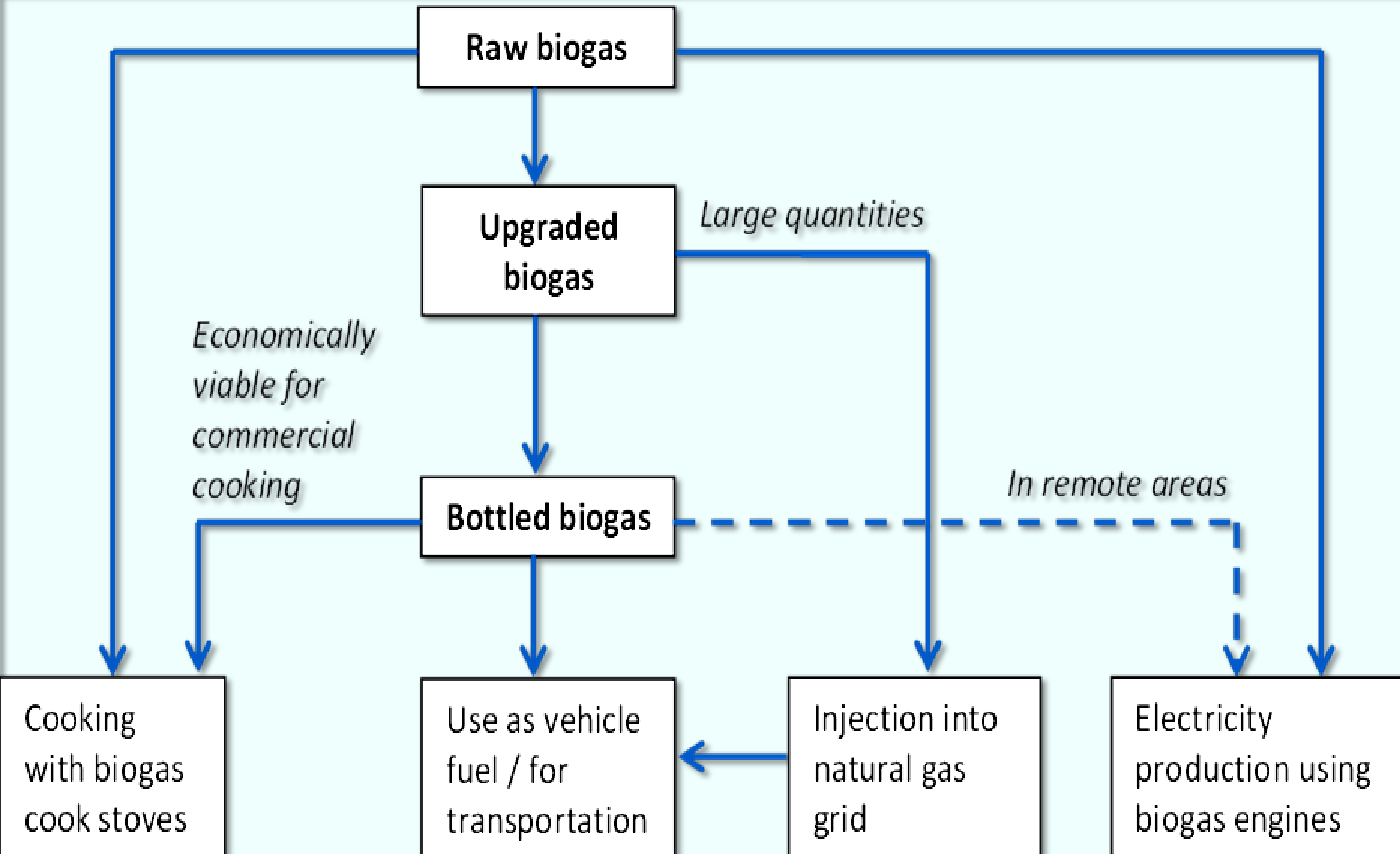
Raw Biogas

- **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 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.

Upgraded Biogas

- **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
    - 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

Biogas lamp

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 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.*

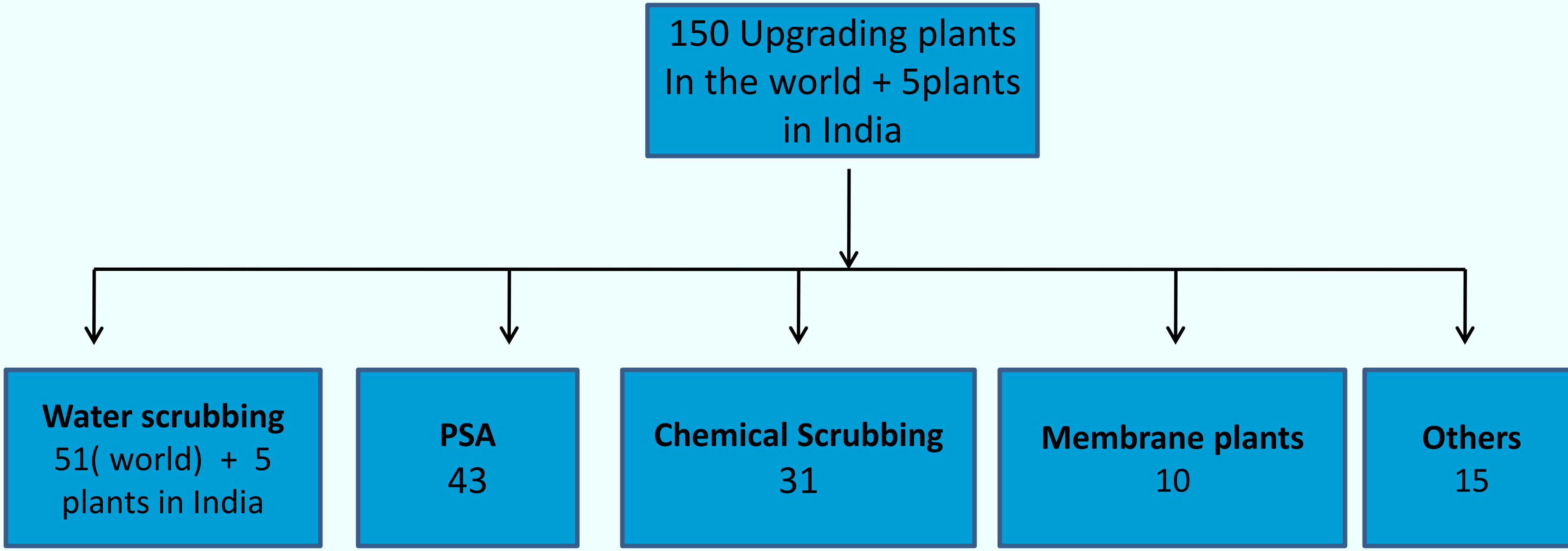
Comparison between selected parameters for common upgrading processes

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 %	1-2 %	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 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.

- In India there are 5 biogas upgrading plants till 2011.



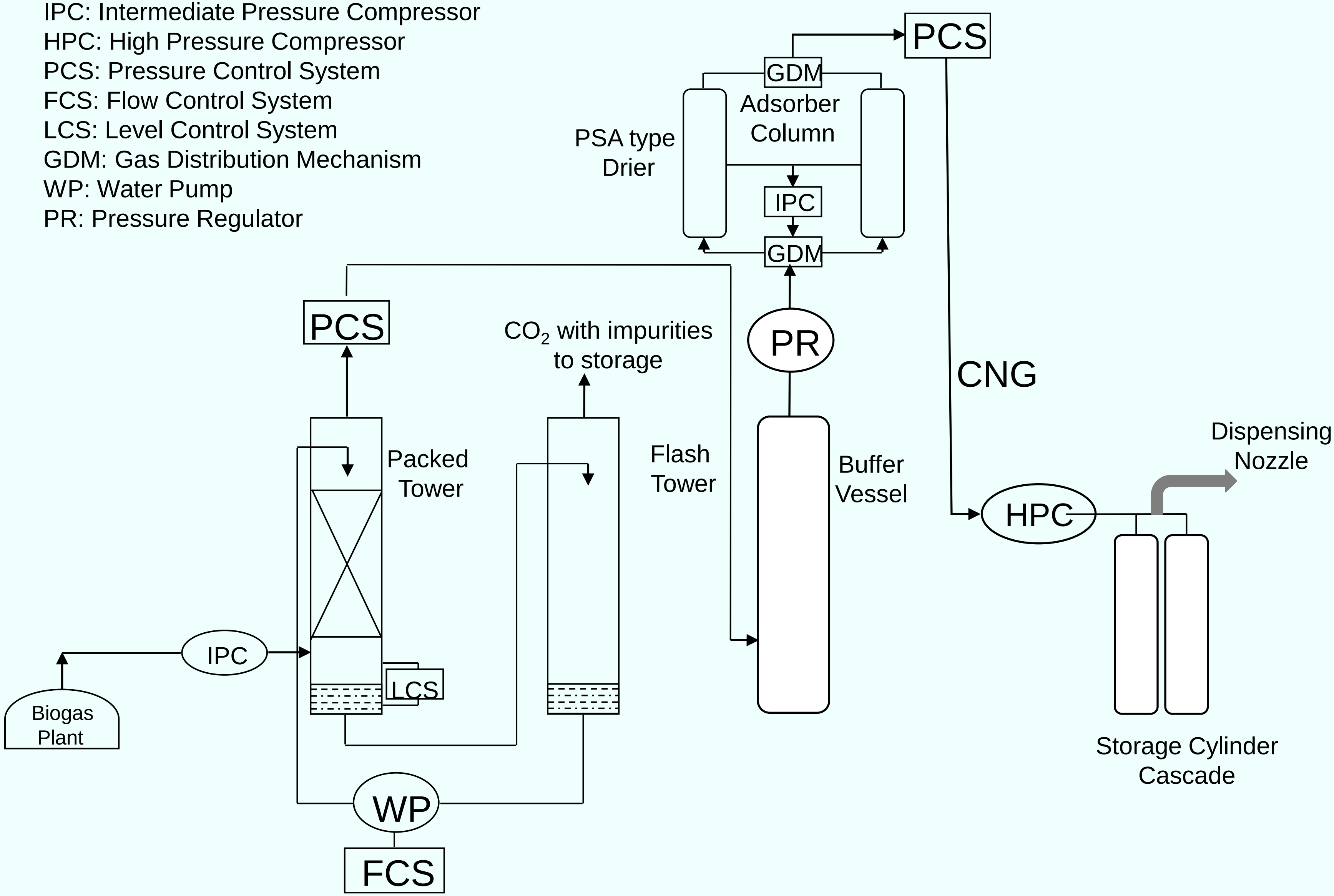
Source: http://www.iea-biogas.net/_download/publi-task37/upgrading_rz_low_final.pdf

Biogas Enrichment Plant Parameters

Raw Biogas Flow Rate	20Nm3/Hr
Vapour phase	Biogas (63% CH_4, 34% CO_2)
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

- A fully automatic plant of 20 Nm^3/Hr capacity has been developed successfully at IIT Delhi.

- Desired composition of purified gas (CH_4: 95% (min), H_2S: 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

Availability and conversion of biomass and bio-waste for bio-economy

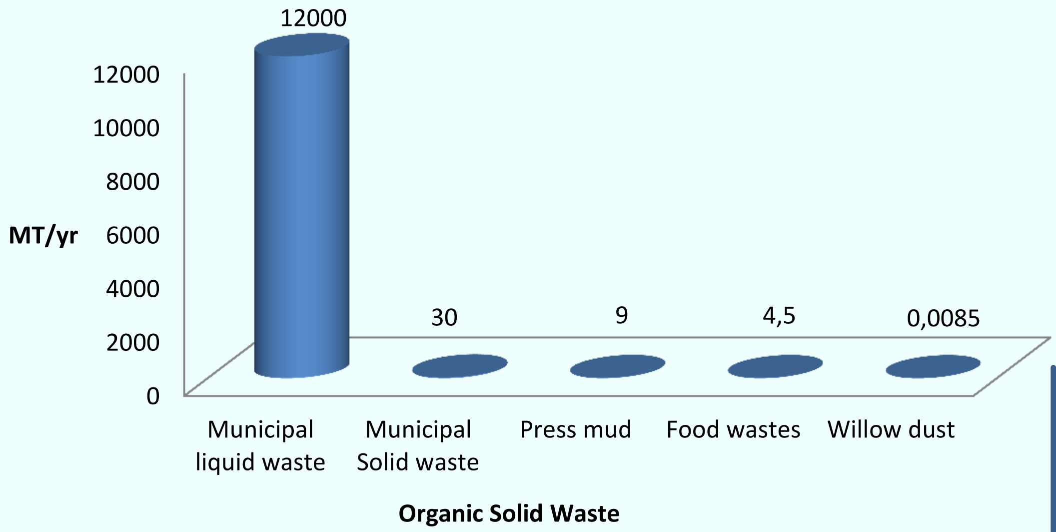
Biogas in INDIA

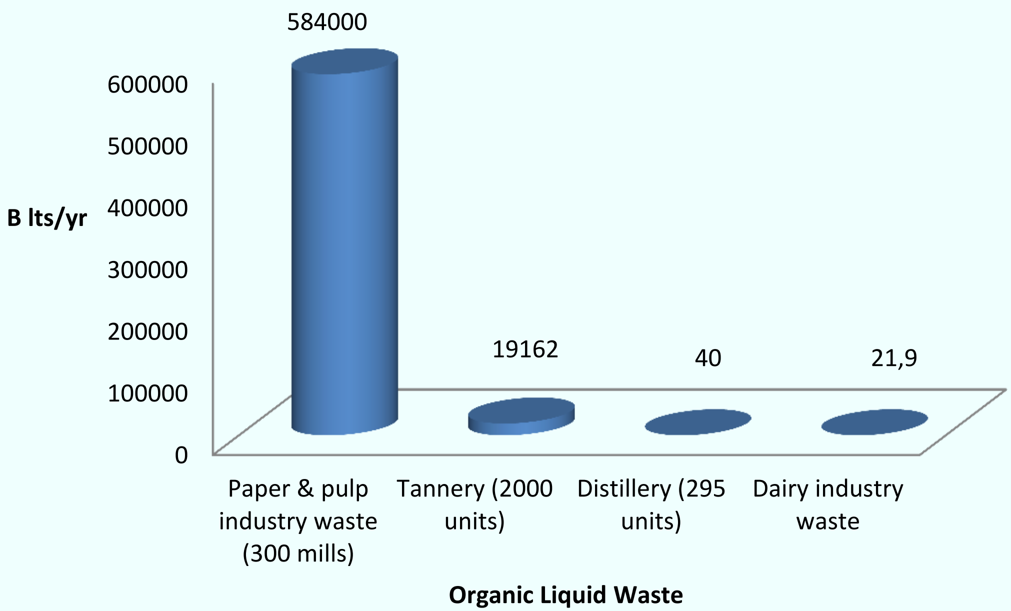
- An estimate indicates that India has a potential of generating 6.38 X 10^{10} m^3 of biogas from 980 million tones of cattle dung produced annually.

- 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.

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.

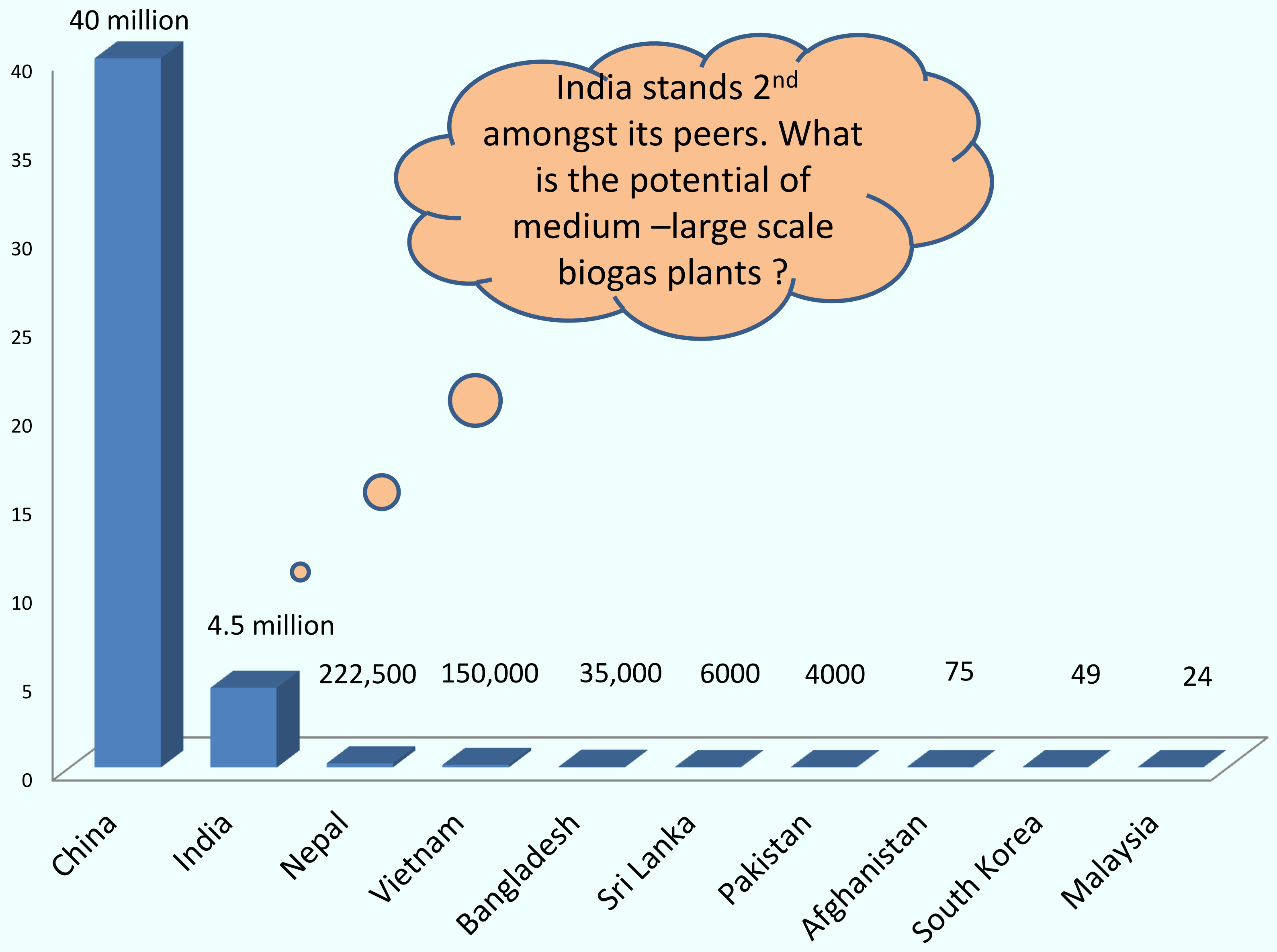
Source: MNES Report, Renewable Energy in India and business opportunities, MNES. Govt. of India, New Delhi

BIOGAS PRODUCTION IN DEVELOPING COUNTRIES

- **Biogas technology is a proven and established technology in many parts of the world, especially Asia where domestic size biogas plants are more popular.**

- **Several countries in this region have embarked on large-scale programmes on domestic biogas, such as China, India and Nepal with millions of domestic biogas plants installations.**

Domestics Size Biogas Plants installed upto 2010 in some developing countries



Sources: Based on various source as mentioned in references

In developing economies like India 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

→

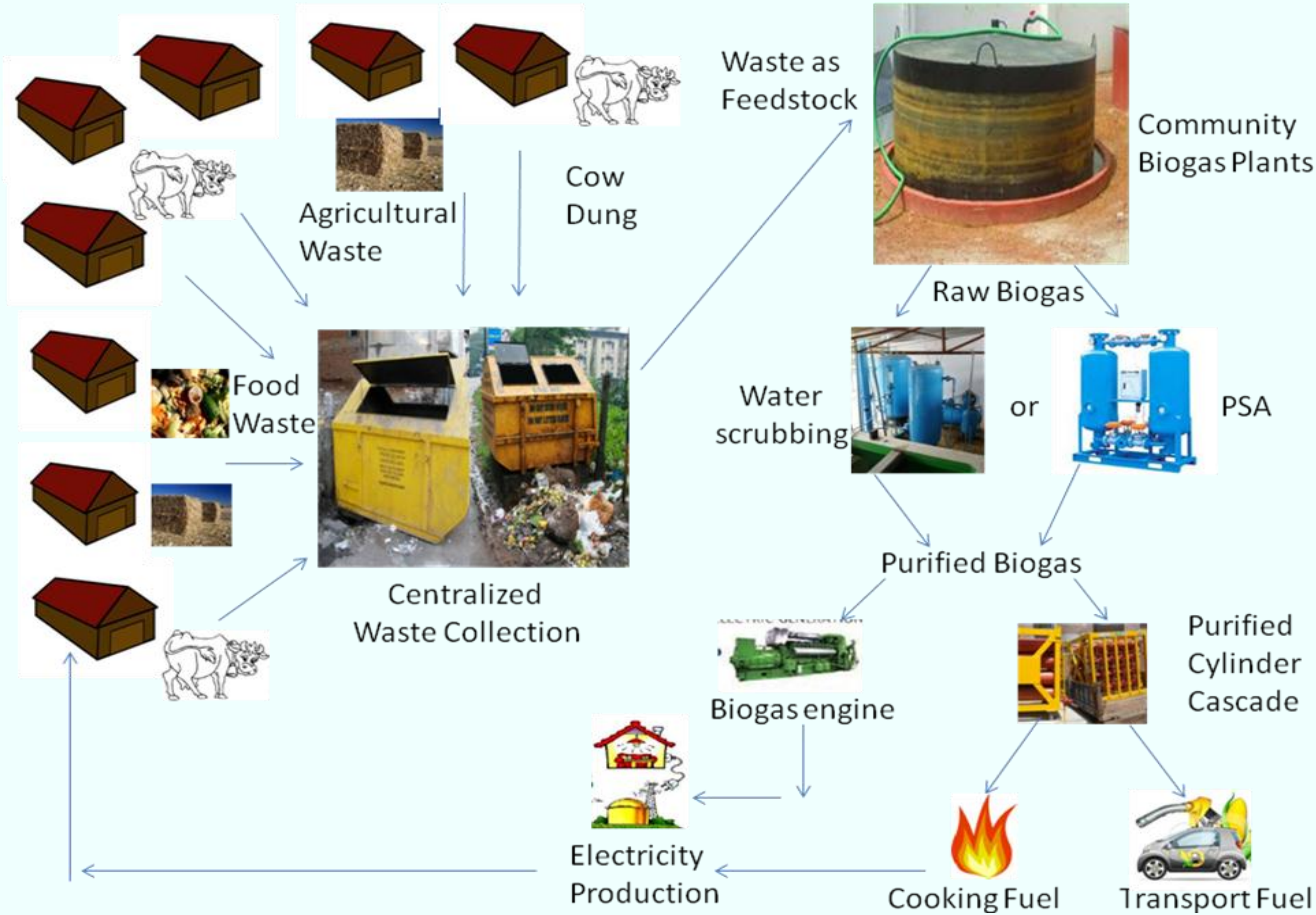
Raw biogas is then purified-

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
85 M^3/Day Digester
Solex
SOLAR SYSTEM
BIOGAS PLANT :
Manufactured and commissioned by:
Excel electricals pvt.ltd.
Vashier, Valsad
Community Biogas Plant (CBP)

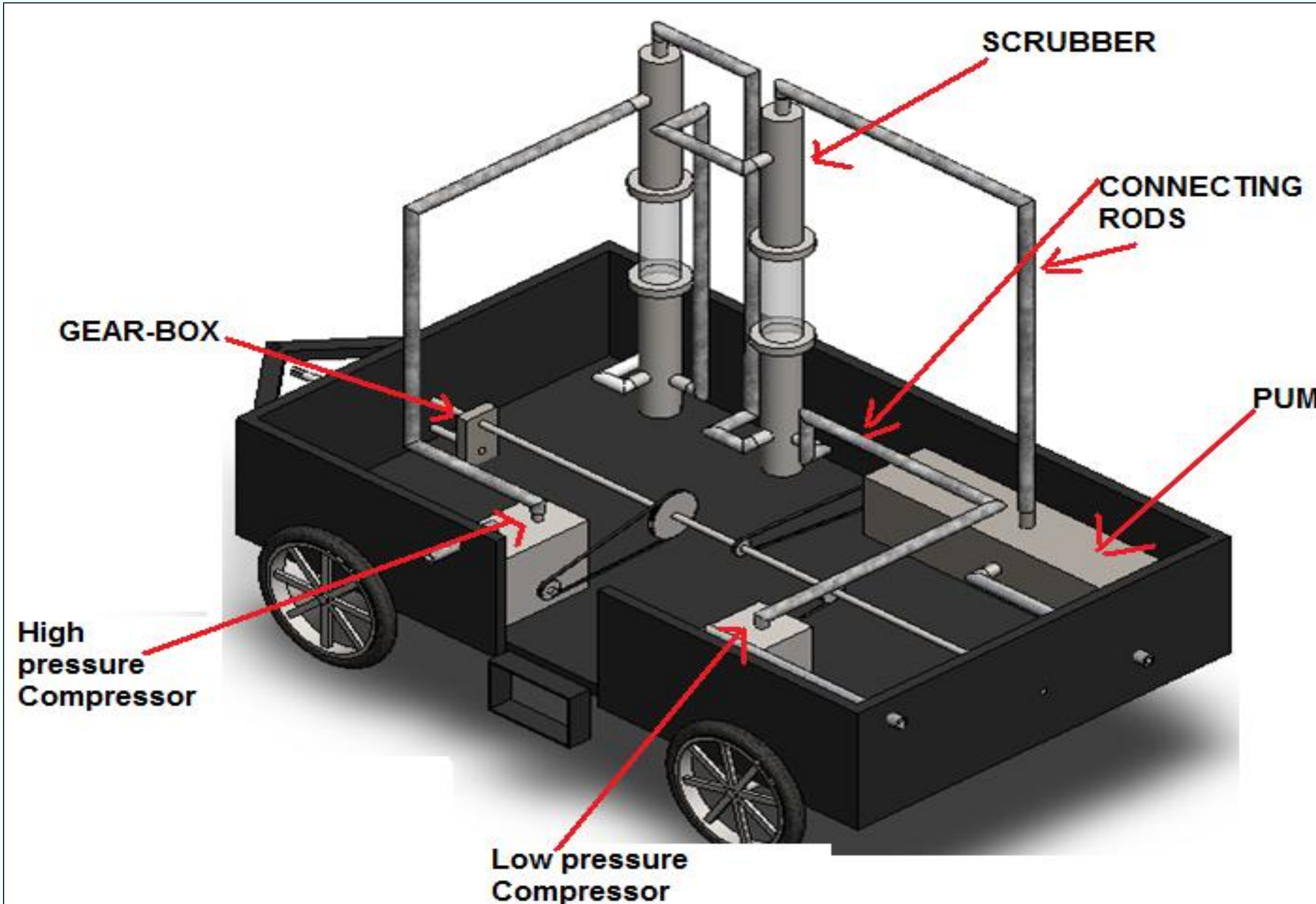


Waste as Feedstock
Community Biogas Plants
Cow Dung
Agricultural Waste
Food Waste
Raw Biogas
Water scrubbing
or
PSA
Purified Biogas
Centralized Waste Collection
Purified Cylinder Cascade
Biogas engine
Electricity Production
Cooking Fuel
Transport Fuel

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



Economic viability of 200 m^3 day^{-1} biogas production and 20 m^3 $hour^{-1}$ upgrading plant

Biogas Plant:		
	Biogas Production	**200 Nm^3 day^{-1}**
A.	**Cost:**	**Rs. 2 million (~ €30,000)**
Biogas Upgrading and Bottling System (20 m^3 $hour^{-1}$)		
	Purified Gas Quantity	**~ 80 kg day^{-1}**
	Purified Gas Composition	**CH_4: 95 %, CO_2: 3, H_2S: < 20 ppm, Moisture: < 20 ppm**
	Cost of biogas upgrading system	**Rs. 4.5 million**
	Cost of biogas bottling system	**Rs. 0.5 million (including high pressure compressor system, cylinders for gas storage and gas dispensing system)**
B.	**Total cost of biogas upgrading and bottling system**	**Rs. 3.5 million (~ € 75,000)**
Slurry Management System		
	Slurry Production	**~ 1.5 tonnes (50 % solid)**
C.	**Cost:**	**Rs. 1million (~ € 15,000)**
D.	**Other Costs : Land preparation, Civil work, High pressure gas storage cylinders taxes, Logistic etc.**	**Rs. 1million (~ € 15,000)**
	Total Initial Cost of Project (A+ B+ C+D)	**Rs.9 million (~ € 1,35,000)**

Revenue: if upgraded biogas is sold as a vehicle fuel		
	Purified Gas: as vehicle fuel	(Rs. 35 kg) * (80 kg) = Rs. 2800 day^{-1}
	Slurry:	(Rs. 3 kg^{-1}) * (1500 kg) = Rs. 4500 day^{-1}
	Total Revenue	Rs. 7300 day^{-1}
E.	Annual Revenue:	(Rs. 7300 day^{-1}) * (350 day) = Rs. 2.6 million (~ € 39,000)
	Cost of Dung	(Rs. 250 $tonne^{-1}$) * (5 tonnes day^{-1}) = Rs. 1250 day^{-1}
	Annual cost of dung	(Rs. 1250 day^{-1}) * (365) = Rs. 0.45 million
	Annual cost of water and electricity	Rs. 0.15 million (Annual)
	Annual cost of manpower	Rs. 0.2 million (Annual)
	Annual Maintenance cost	Rs. 0.15 million
F.	Total Recurring cost	Rs. 0.95 million (~ € 14,200)
	Annual Profit:	Rs. 1.65 million (~ € 25,000)
	Subsidy (Power Equivalent)	Rs. 1.6 million
	Beneficiary Expenditure	Rs. 7.4 million (~ € 1,10,000)
	Payback Period	4.625 years
Revenue: if upgraded biogas is sold as a cooking fuel		
	Purified Gas as cooking fuel Commercial gas cost @ 72 kg	(Rs. 70 kg^{-1}) * (80 kg) = Rs. 5600 day^{-1}
	Slurry:	(Rs. 3 kg^{-1}) * (1500 kg) = Rs. 4500 day^{-1}
	Total Revenue	Rs. 10,100 day^{-1}
G.	Annual Revenue:	(Rs. 10,100 day^{-1}) * (350 day) = Rs. 3.56 million (~ € 52,000)
	Total Recurring cost	Rs. 0.95 million (~ € 14,200)
	Annual Profit:	Rs. 2.61 million (~ € 39,000)
	Subsidy (Power Equivalent)	Rs. 1.6 million
	Beneficiary Expenditure	Rs. 7.4 million (~ € 1,10,000)
	Payback Period	2.84 years

Part II

Carbon dioxide Recovery and purification from water scrubbing based biogas upgrading plant


FOSSIL FUEL
BIO GAS
WWW.seppo.net

THANK YOU