STRATCON
Environmental Developers & Consultants

Introduction to Waste to Fuel Technologies

- *Biogas to Bio CNG*

Steve Peters

2015

Methane Sources

Food waste

Landfills

Animal Faeces

Biogas 30-65% Methane (CH4)

Factory waste water (palm, cassava, ethanol, brewery, food processing)

Sewerage

Anything Putrescible High Carbon as COD

Methane Key Points

STRATCON
Environmental Developers & Consultants

CH4 – Flammable Gas, Main Gas in Natural Gas and CNG.
Good Source of Energy – must purify for use
Green House Gas 22 times worse than CO2.

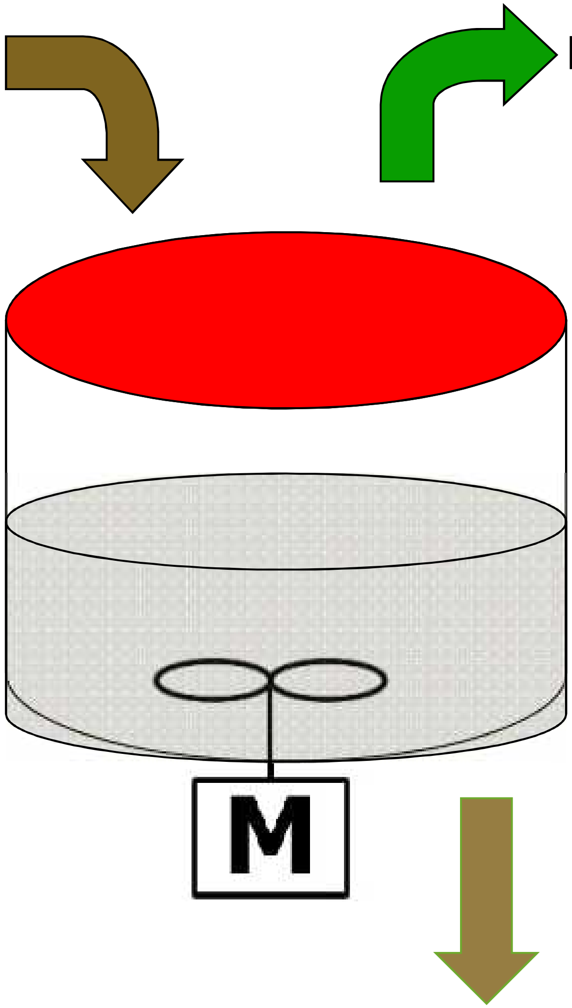
Best to avoid smoking near it!

Methane – Biogas

Input Sources

A watery slurry of about 10% solids from various sources:

- Food waste
- Cassava Starch Effluent,
- Brewery Effluent
- Palm Oil Mill Effluent,
- Ethanol Factory Effluent,
- Sewerage Plant Sludges



Biogas

Sludge

Mix of methane, CO_2, H_2S & trace gases.

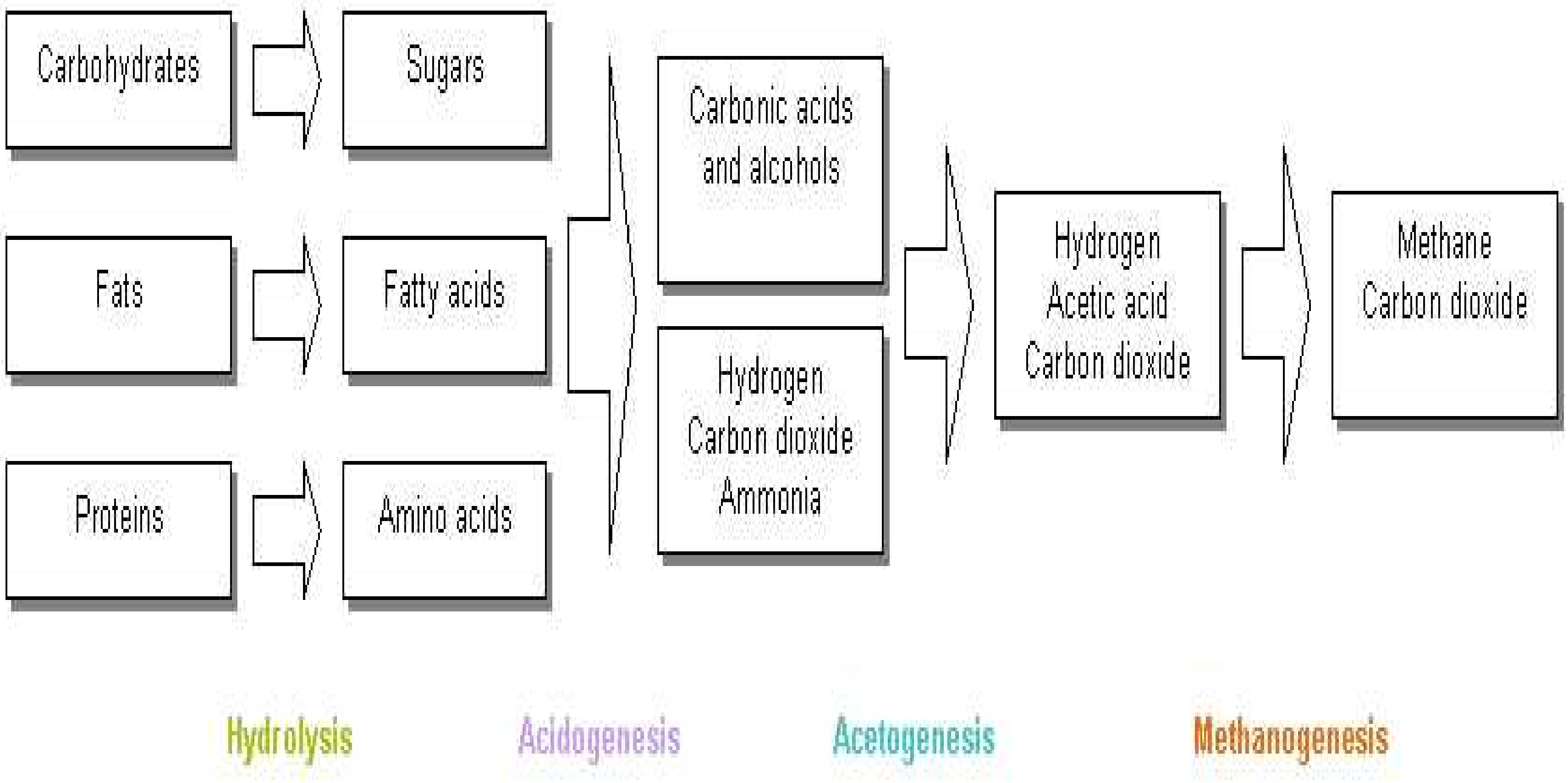
Typically ~55-65% Methane

Sewer Gas ~ 45% Methane

Landfill Gas ~20-50% Methane

Hydrogen Sulphide varies from 1-3% (must be removed).

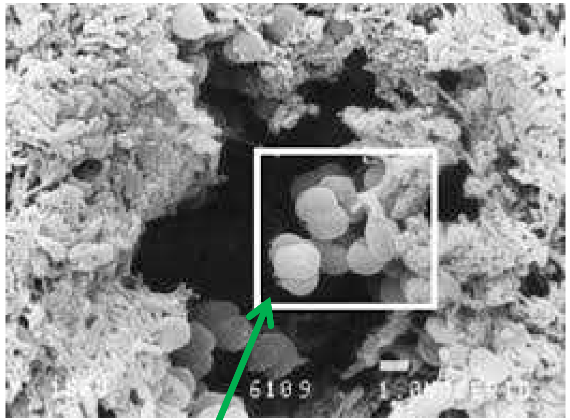
The Science of Biogas



Types of Bacteria and Reactions

STRATCON
Environmental Developers & Consultants

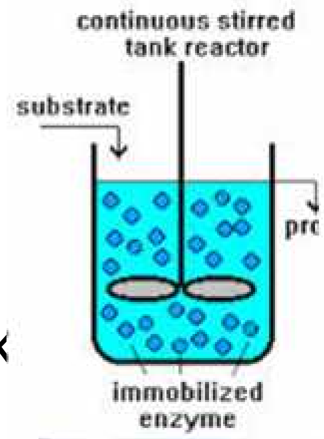
- **Hydrophilic** – performance related to Volume, works well in tropical climates with constant ambient temperatures.
- **Mesophilic** – takes place between 35°C and 50°C. Depending on location heating will be required.
- **Thermophilic** – takes place above 50°C. Requires heating for tanks and insulation to ensure constant temperature.
- **Exotics** – saline tolerant and temperature tolerant methanogens. These have not been widely used.

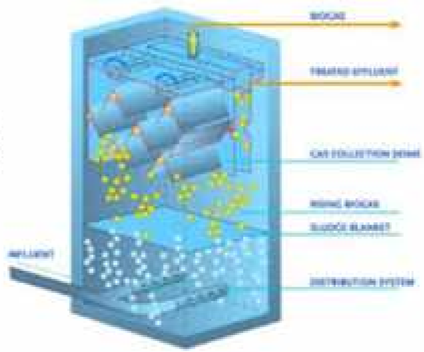


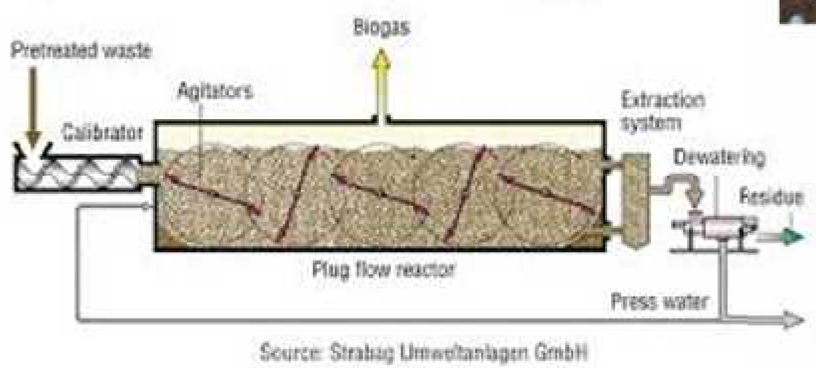
Methanogens in action

Process Names and Terms of Systems

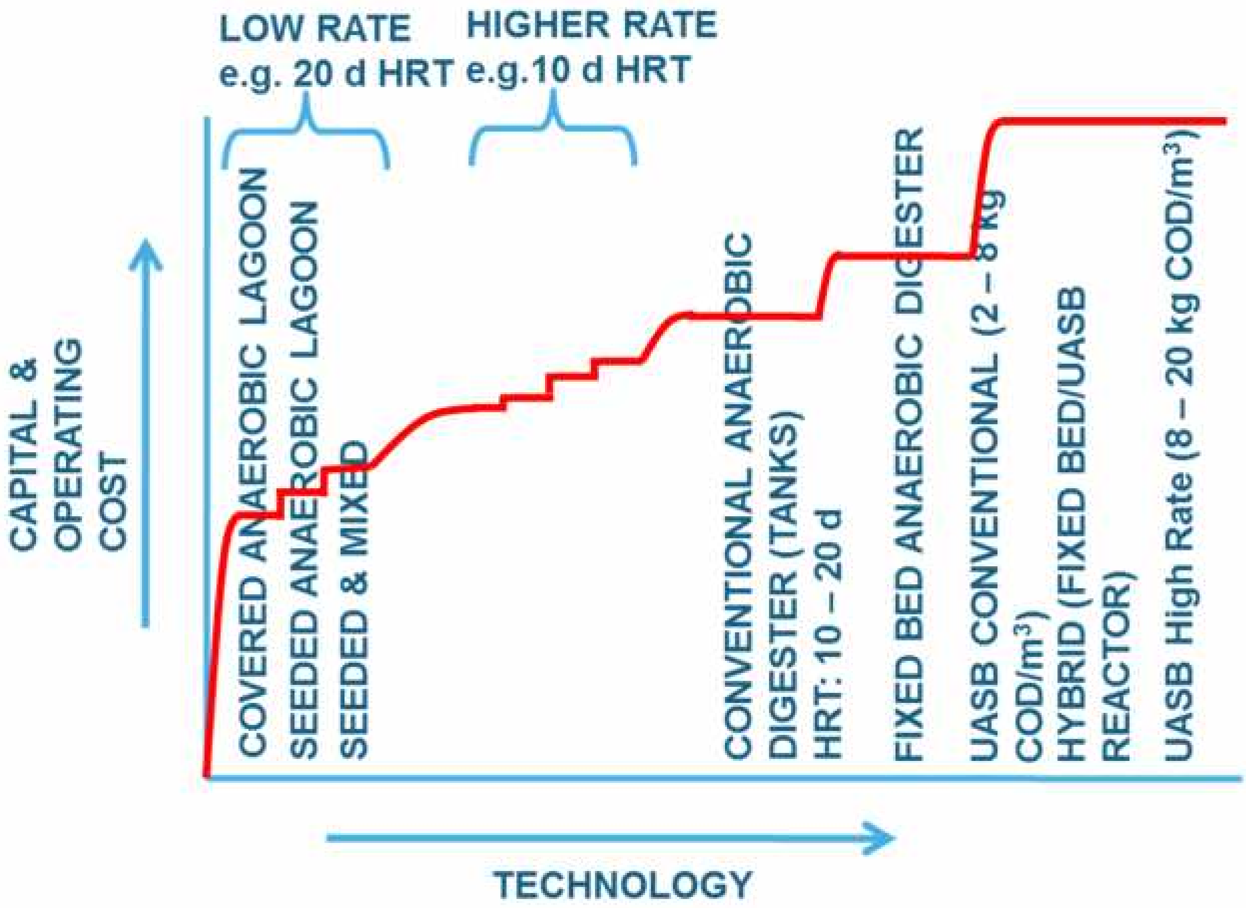
- **CST** Continuous Stirred Tank
- **CIGAR** Covered In Ground Anaerobic Reactor
- **UASB** Upflow Anaerobic Sludge Blank
- **Hybrid** Where process Modified to suit feed stock make up (pH, Solids size/conc or Contaminants)
- **Dry Fermentation** - High solids low water use





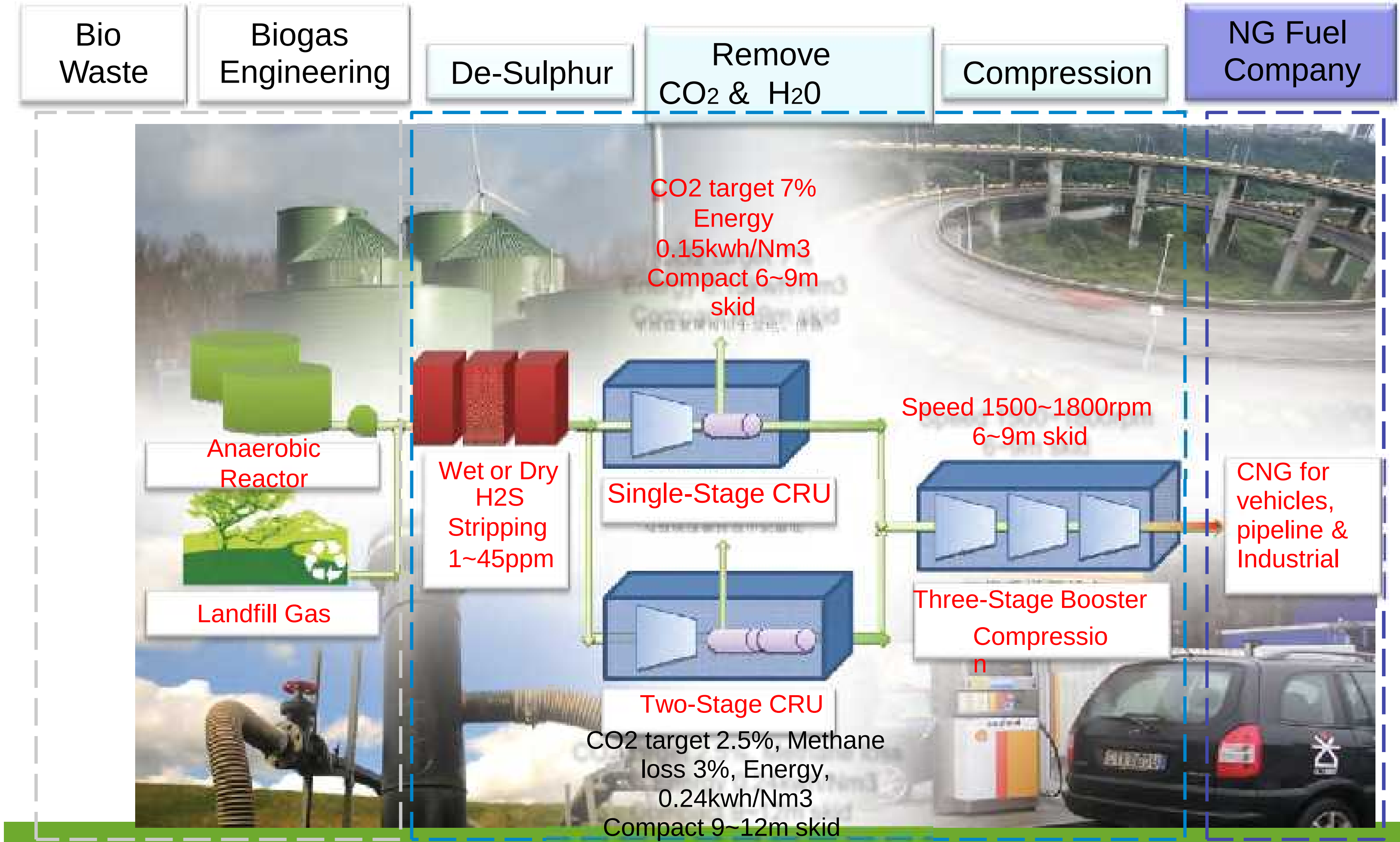


Types of Systems



NOTE: Typical process parameters for cogeneration systems.

The Process from Waste to Bio CNG (Membrane)



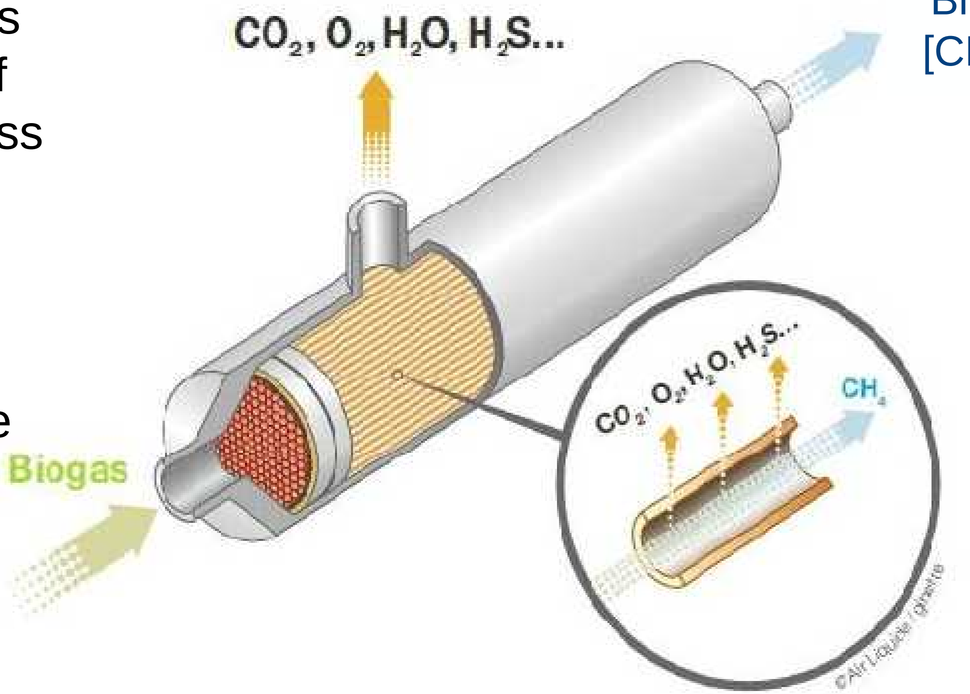
Hollow Fiber Membrane Technology for CO_2 / CH_4 Separation

The membrane separates gases by the principle of selective permeation across the membrane wall.

Relatively fast permeable gases such as CO_2 and H_2O to pass through the membrane wall quickly are diverted.

The slow permeable gasses such as CH_4 and N_2 flows straight through are part of the product gas.

The medium is permeable gasses such as O_2 and H_2S will be partially separated.



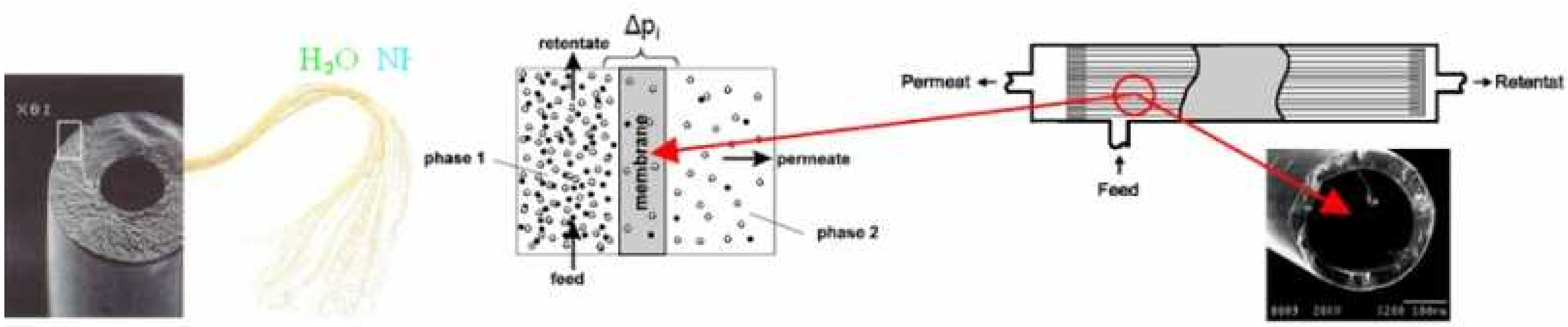
Biomethane

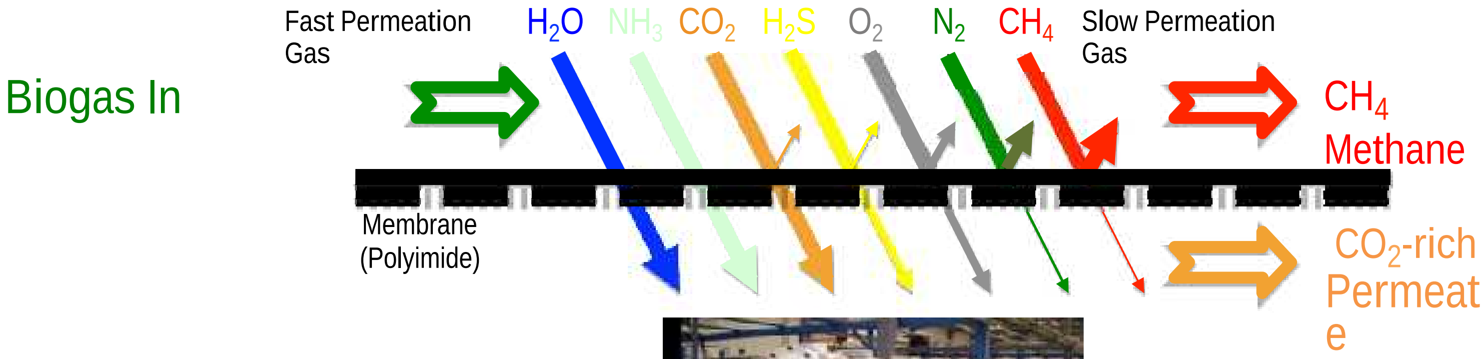
[CH_4] > 98%

(max)

Different types of membrane

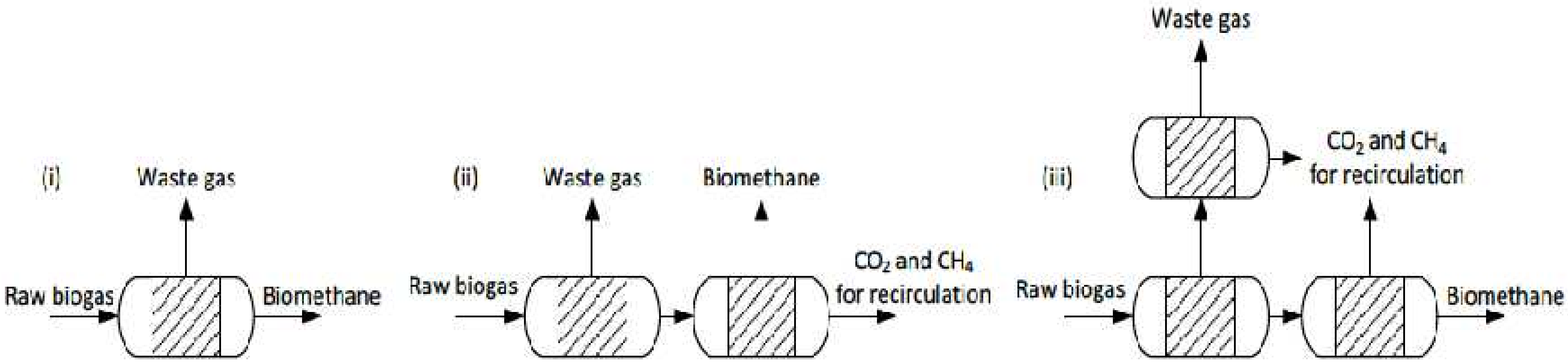
Hollow Fiber Membrane Technology for CO_2 / CH_4 Separation





Types of Hollow Fiber Membrane Technology

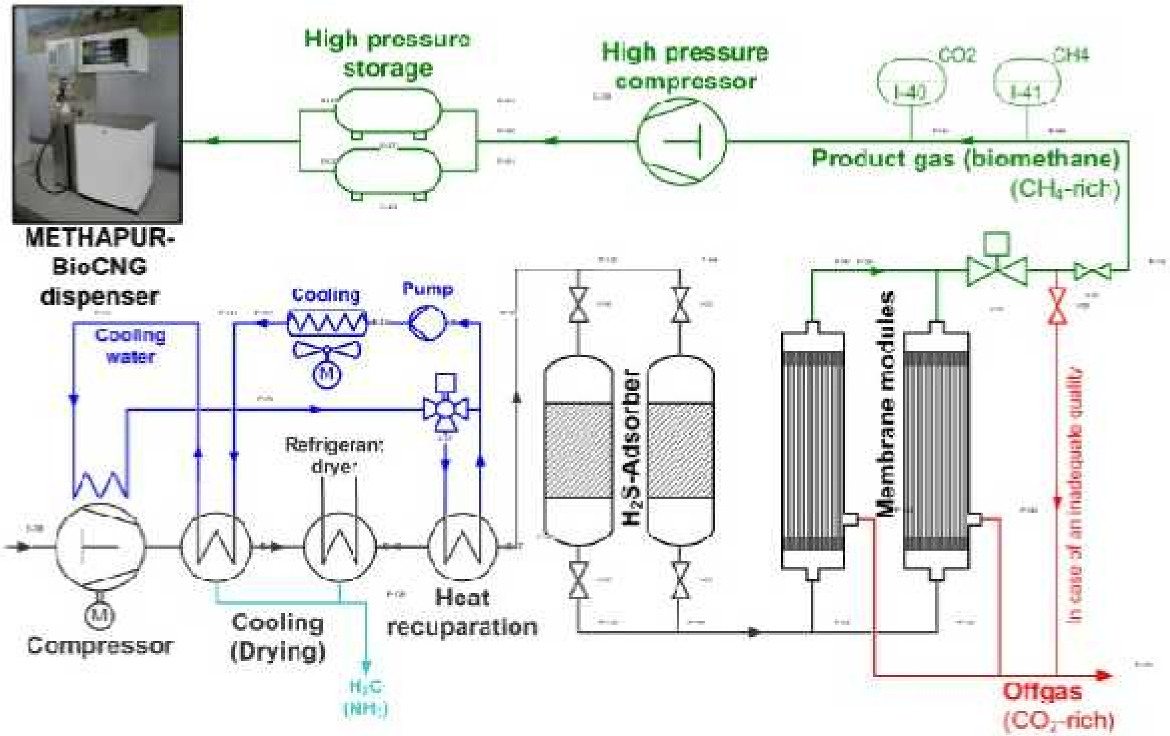
Single Stage | Two Stage | Three Stage



Gas Quality in percentage of methane (CH4)

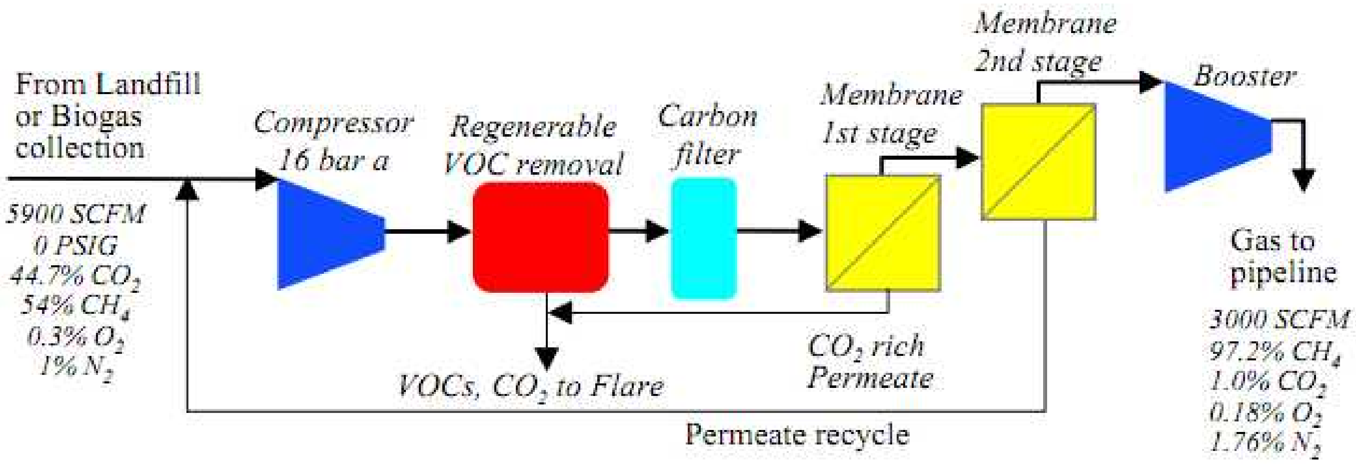
< 92% | **< 95%** | **< 98%**

Simplified P&ID for Bio-CNG as NGV fuel



This is a flow design of the single stage membrane in parallel. The advantage of single stage membrane design is that due to less number of membrane used, the equipment capital cost is much less than the 2 stage design. The disadvantage is that the CH_4 recovery rate is lower.

Concept of Biogas Upgrading & Performance of Membrane



Flow schematic: biogas/landfill gas purification unit

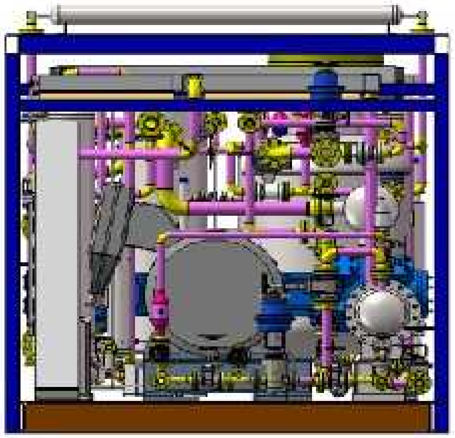
Gas Type	Particulars	Rating
CH_4	Recovery rate	>95%
	Product gas purity	90% ~ 99%
CO_2	Removal target	0.5% ~ 3%
H_2S	% Product = % Feed	x 0.3
O_2	% Product = % Feed	x 0.6
N_2	% Product = % Feed	x 1.2

This is the 2 stage membrane design for high methane recovery rate.

Note that the feedback flow design is important to ensure the high recovery rate.

Important take home message – 2 stage!

Configuration Example



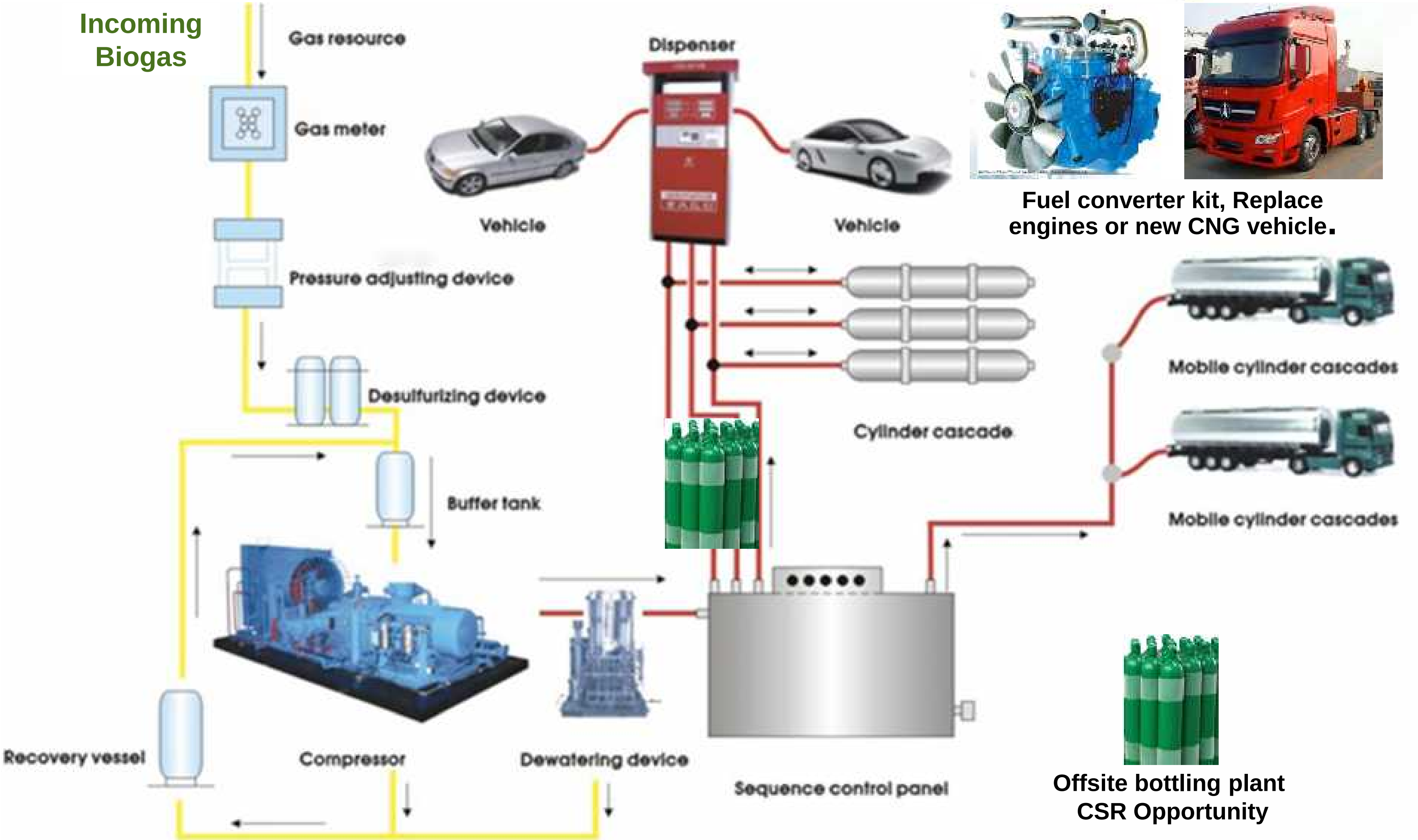
Skid mounted MRC compression unit to CASIC for 30,000 m3/D natural gas liquefaction project for CNOOC. It is the smallest MRC compressor package for such application and the whole system is made to be portable with high compression efficiency and low refrigerant loss.

Example of **Ingenco, Cedar Hills LF, Seattle, WA, USA**

Startup on: Feb, 2009

Raw gas feed: 16 MMSCFD (18,800 Nm3/h)

Full Infrastructure Solution



CNG Filing Infrastructure, Trucking & Bottling

Mobile daughter station can transport CNG Anywhere
Making a “Virtual Pipeline”

From Biogas pond/tank to vehicle solutions to replace diesel with CNG to repowered fleet vehicles – reliable, plentiful, ecofriendly and where you want it.

Different Processes to Purify Biogas

TECHNOLOGY	Pressure Swing Adsorption	Pressure washing technology	Amine Washing Separation	Chemical Absorption Separation	Selective Solvent Separation Technology	Membrane Adsorbtion
ABBREVIATION	PSA	DWW	MEA/DEA	LP Cooab	Genosorb	Hollow Fiber Membrane
Working Principle	High-pressure activated carbon adsorption of CO2	High-pressure water-soluble CO2	Atmospheric pressure amine absorption	Cooab chemicals absorption CO2 under certain temperature and pressure conditions	The Organic Chemical solvent absorpt H2O, H2S and CO2 under certain temperature and pressure conditions	Through different gas activity with different rate of penetration in the membrane and separation of fast gas CO2 and slow gas of CH4, while removing a certain amount of N2, O2 and H2S
Working Process	Physical	Physical	Chemical	Chemical	Chemical	Physical
Working Pressure	6-8 bar	8-12 bar	0-1 bar	6-8 bar	6-8 bar	12 bar – 15 bar
System Pressure Loss						2 – 3 bar
Outlet Pressure						>10 bar (Important)
Working Medium	Activated Carbon	Water	Amine	Cooab Chemicals	Genosorb organic chemical solvent	Fiber membrane polymer materials
Requires Working Heat	No	No	Large Quantity Needed (160℃)	Large Quantity Needed	Yes (55-80℃)	No, but can improve the efficiency at high ambient temperature
Purification Chemicals Required	No	No	Yes	Yes	Yes	No
Water Requirement	No	Large Amount	Large Amount	No	No	No
Requires De-Water Drying before Purification	Yes	No	No	No	No	No, but if dewatered prolongs membrane life
Requires Sulfur Removal before Purificaiton	Yes	No	Yes	Yes	No	No
Maximum sulfur content allowed in gas before Purification	5 mg/Nm3 Rohgas	500 ppmv	5 mg/Nm3 Rohgas	Little	100 PPMV	Unrestricted, Maximum can also be used for the desulfurization process of 10 ~ 30mole%
Dewater drying after Purification required	No	Yes	Yes	Yes	No	No
Pressurization to CNG required after Purification	No	No	Yes	Yes	No	No
The methane content of the purified gas	96%	97%	99%	99%	93%	90 ~ 99% Adjustable
The purified gas flow regulating range	85-100%	50-100%	50-100%	50-100%	50-100%	10 – 100%
Methane escape rate	3-8%	0.05-6%	<0.1%	<0.1%	0-18%(2-4%)	1 ~ 5%
exhaust gas processing system	Required	Required	Not Required	Not Required	Required	Not Required
Technical system Complexity	Complicated	Complicated	Relatively Simple	Relatively Simple	Complicated	Simplest
Power Consumption	0.24-0.29	0.22-0.4	0.06-0.14	0.15	0.511	0.15 – 0.25 Compression of electrical energy consumption, the film group no power consumption
Heat Consumption		0.1	0.3-0.7	0.58	0.07	0
Energy Consumption	Low	Low	Low	Low	High	Very Low
The characteristics of the equipment package	Container type, easy to transport, install and commision	Container type, easy to transport, install and commision	Container type, easy to transport, install and commision	Set block-style modular	Container type, easy to transport, install and commision	Container type, easy to transport, install and commission
Biogas purification engineering scale	Large Scale	Large Scale	Medium Scale	Small Scale	Large Scale	Large, Medium and Small Scale
One-time investment of equipment	High	Medium	Relatively Low	Relatively Low	High	Medium to High, varies according to manufacturer
System operating costs	High	Medium	Relatively Low	Relatively Low	High	Very Low
System reliability	High	High	Needs to be Improved	Needs to be Improved	High	Very High
Equipment maintenance costs	High	Medium	Relatively Low	Relatively Low	High	Only the compressor requires maintenance, the membrane assembly is a fixed, no maintenance required
Practical engineering experience	Many	Many	Few	Few	Few	Many in USA. Few in Europe because mft are in USA

Existing Examples of WTF Projects

Location (City, Country)	Capacity (Nm³/h)	Working Since	Feedstock	Use of upgraded biogas
Kobe, Japan	2 x 330 = 660	2006	WWTP	CNG Vehicles (Cars & Buses)
Lille, France	2 x 600 = 1.200	2006	Municipal Solid Waste	CNG Vehicles (Buses)
Kobe, Japan	150	2004	WWTP	CNG Vehicles (Cars)
Trollhättan 2, Sweden	400	2000	WWTP	CNG Vehicles (Cars)
Sorpa, Iceland	90	1999	WWTP	CNG Vehicles (Cars)
Kalmar, Sweden	90	1998	WWTP	CNG Vehicles (Cars)
Uppsala, Sweden	90	1998	WWTP	CNG Vehicles (Cars & Buses)
Linköping, Sweden	2 x 330 = 660	1997	Organic Waste	CNG Vehicles (Cars & Buses)
Bromma, Sweden	90	1997	WWTP	CNG Vehicles (Cars & Buses)
Trollhättan, Sweden	140	1995	WWTP	CNG Vehicles (Cars & Buses)
Sonzay, France	100	1994	WWTP	CNG Vehicles (Cars)
Lille (Marquette), France	100	1993	WWTP	CNG Vehicles (Cars)

More Existing Examples of WTF Projects

Location (City, Country)	Capacity (Nm³/h)	Working Since	Feedstock	Use of upgraded biogas
Skarpnäck, Sweden	2 x Totara 4.000	Commissioning 2011	Organic Waste	CNG Vehicles (Cars)
Katrineholm, Sweden	Rimu 800	Commissioning 2010	Organic Waste	CNG Vehicles (Cars)
KTG, Germany	Totara 2.000	Commissioning 2010	Crops / Waste	Pipeline injection
Catalyst, Canada	Rimu 800	Commissioning 2010	Organic Waste	Pipeline injection
Stresow, Germany	Matai 1.200	Commissioning 2010	Crops	Pipeline injection
Lidköping, Sweden	Totara 2.000	Commissioning 2010	Organic Waste	CNG Vehicles (Cars)
Zwickau, Germany	Rimu 800	Commissioning 2010	Crops	Pipeline injection
Västevik, Sweden	Manucka+ 130	Commissioning 2010	WWTP	CNG Vehicles (Cars)
Örebro, Sweden	Totara 2.000	2009	Organic Waste	CNG Vehicles (Cars)
Lille (Marquette), France	Manuka 80	2009	WWTP	CNG Vehicles (Cars)
Motala, Sweden	Manuka 80	2009	WWTP	CNG Vehicles (Cars & Buses)
Katrineholm, Sweden	Manuka 80	2009	WWTP	CNG Vehicles (Cars)
Seoul, Korea	150	2009	WWTP	CNG Vehicles (Cars)
Guströw, Germany	5 x 2.000 = 10.000	2009	Crops	Pipeline injection
Madrid, Spain	2 x 2.000 = 4.000	2009	Municipal Solid Waste	Pipeline injection, CNG Vehicles (Buses) & Power Gen

Waste Supply Chain and Linkages for Waste