PENTAIR

BIOGAS UPGRADE,

GENERATING DUAL VALUE STREAMS: CO_2 + CH_4

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BIOGAS UPGRADING

- Biogas Sources
- Biogas Usage, Common Practice
- Biogas Upgrading Technology, Haffmans Membrane
- TCO
- Case studies
- Service

BIOGAS UPGRADING - SOURCES

Industries	Process	Basic nutrient for the anaerobic fermentation	Ratio CH_4 / CO_2
INDUSTRIAL WASTE WATER TREATMENT SYSTEMS, Potable water companies, Water authorities	Waste Water Treatment Plant (WWTP)	Semi-solid organic residues from water & solids (sludge)	65 - 80 % / 20 - 35%
BREWERIES, DISTILLERIES, BioEthanol, Agricultural sector	Mono-fermentation	Agricultural-based materials (corn silage, spent hops, spent grain etc.) 1 ton Spent grain → ~ 122 Nm^3 biogas	55% / 45%
Livestock farms	Co-fermentation	Manure (cattle, pig, chicken) mixed with agricultural-based materials	55% / 45%
Compost-processing industry	Decomposition	Fruit-vegetables-garden-based materials	55 - 70% / 30 - 45%

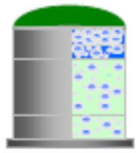
BASIC BIOGAS USAGE – COMMON PRACTICE

WWTP

Gas Grid

Biogas :

55% CH_4 + 45% CO_2



BioMass Digestor

Combined Heat & Power (CHP) Units

33% Electrical energy (power)

66% Thermo energy (heat)

- Useful when required
- Unused → Waste heat

Combustion gases :

NO_x H_2S, CO_2

(Bio)Gas fired Boiler

Thermo energy (heat)

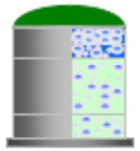
- Useful when required

- Dirty low caloric gas is burned
- When NO heat is required only 33% energy is put to good use → Low efficiency
- No buffering capacity
- Combustion gasses are purged: CO_2 is a waste product

BIOGAS UPGRADING TECHNOLOGY – HAFFMANS MEMBRANE

WWTP

~~Gas Grid~~



BioMass Digestor

Biogas

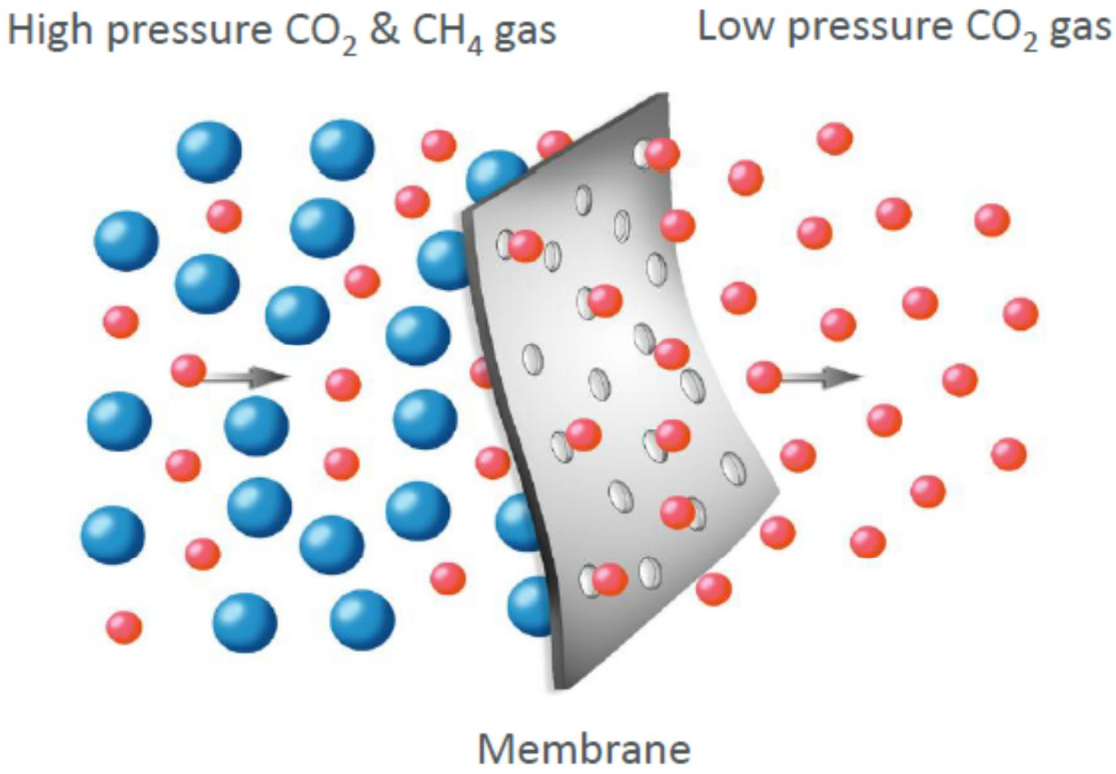
Biogas Upgrading &
CO_2 Recovery System

"Green" CO_2
Liquid / Gas

Bio-Methane
97% CH_4

- Biogas is upgraded to clean high caloric gas → CH_4 up to 97%
- Bio-methane is fed into grid → Buffer capacity
- High CH_4 yield up to 100 % CH_4 recovery → No loss
- Liquid Green CO_2 is product → Extra source of income

BIOGAS UPGRADING TECHNOLOGY



BIOGAS UPGRADING TECHNOLOGY – DUAL REVENUE

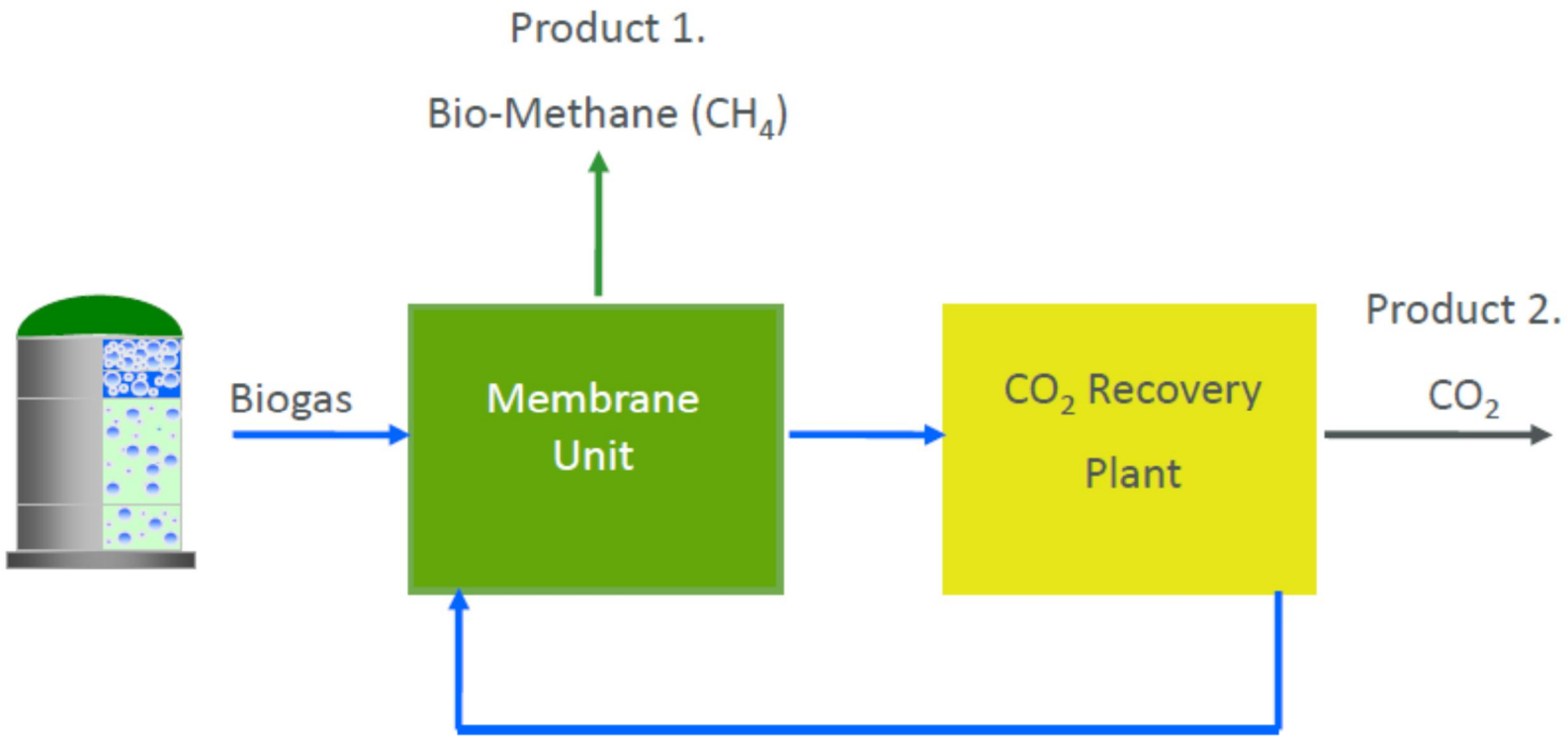
PRODUCT 1: BIOMETHANE (CH_4)

- ✓ High CH_4 yield: 100 % CH_4 recovery
- ✓ No CH_4 slip (emission)
- ✓ High caloric Bio-Methane: CH_4 up to 97%
- ✓ No use of chemicals

PRODUCT 2: CARBON DIOXIDE (CO_2)

- ✓ Extra revenue: Food grade CO_2
- ✓ High CO_2 purity: Meets ISBT specs
- ✓ CO_2 from biogas = Green = short-cycle CO_2
- ✓ Low CO_2 emission

BIOGAS UPGRADING TECHNOLOGY



BIOGAS UPGRADING TECHNOLOGY – FLOW

MEMBRANE UNIT

BioGas 250 Nm^3/h (8000 h/y)

(55% CH_4 + 45% CO_2)

Bio Methane:

153 Nm^3/h

1.22 mil. Nm^3/y

NH_3, H_2S Removal

(CO_2 Gas)

(10% Return flow
Membrane Unit
50% CH_4 & 50% CO_2)

CO_2 RECOVERY SYSTEM

CO_2 Gas

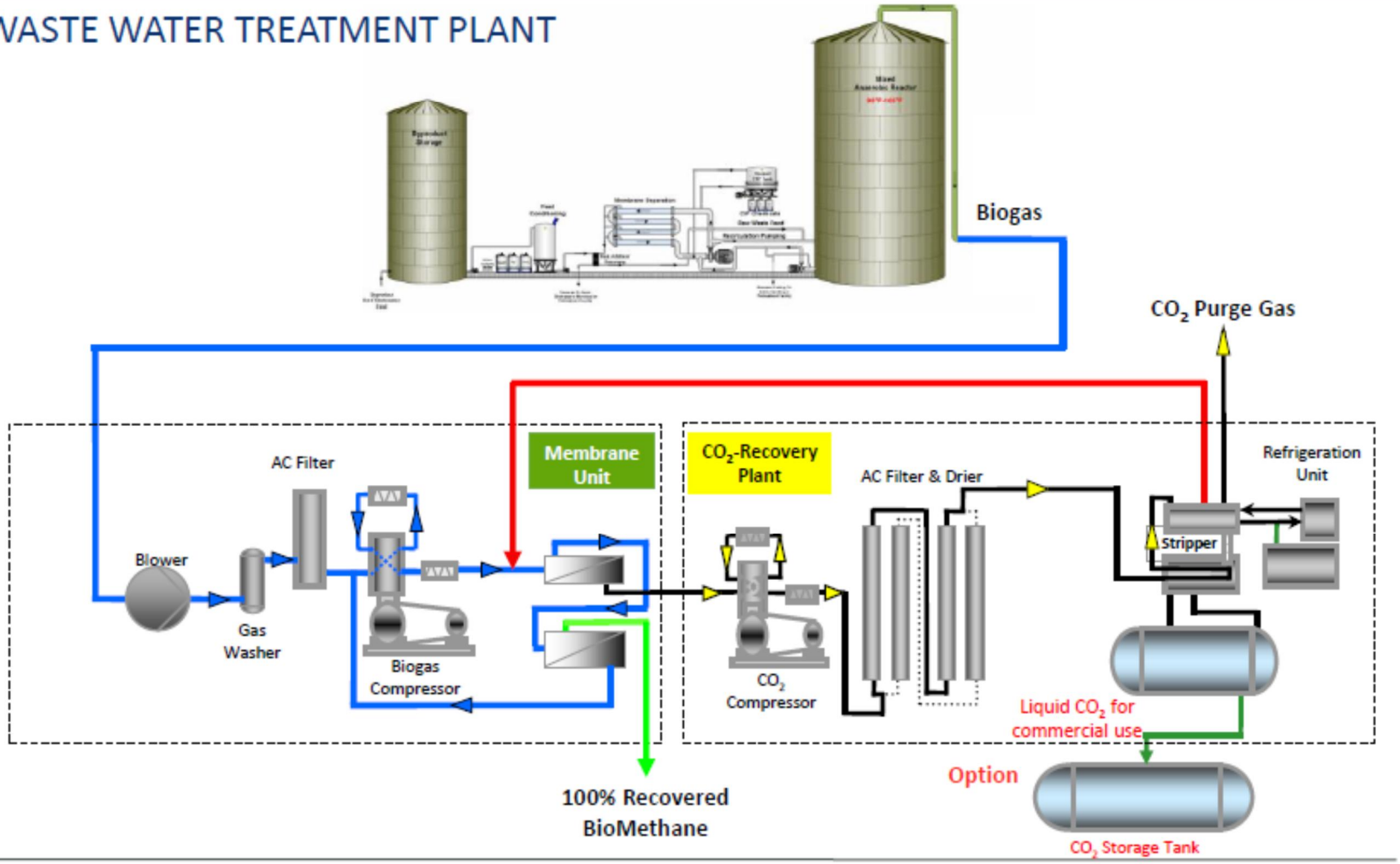
(10 CH_4 + 90 % CO_2)

Liquid CO_2:
175 kg/h
1.403 TON/y

Power consumption subject to mass balance of configuration
Based on Dutch grid specs : BioMethane ~ 90% CH_4

BIOGAS UPGRADING TECHNOLOGY – DIAGRAM

WASTE WATER TREATMENT PLANT



TCO BIOGAS UPGRADING – DUAL REVENUE

TCO PER Nm^3 BIOMETHANE

- Biogas upgrading : 0.080- 0.095 EUR / Nm^3 Bio Methane
- **"Free" food grade CO_2 for consumption / export purposes**

TCO PER TON CO_2

- CO_2 recovery : ~ 100 EUR / ton liquid CO_2
- **"Free" Bio Methane to utilize**

TCO values based on :

- Biogas upgrade installation > 1.000 Nm^3 / hr.
- Electrical power 0.06 EUR / kWh
- Amortization 10 years at interest rate 6%

BIOGAS UPGRADING CASE STUDY - 300 NM^3/H (BEVERWIJK)

Plant Capacity	**300 Nm^3** Biogas/hour ➔ **183 Nm^3** Bio-Methane/hour
Biogas source	***Wastewater treatment plant***
Ratio : CH_4 / CO_2	55% / 45%
Operating Pressure	8 barg
BioMethane produced	1,47 Million Nm^3/ year (operation ~8000hrs / year)
CH_4 Loss	None
CO_2 Recovered	1,68 Million kg / year
CO_2 Usage	INTERNAL PROCESS : pH correction of treated water ➔ OPEX savings
Injection into grid	According to Dutch Gas Grid Specifications

BIOGAS UPGRADING CASE STUDY - 350 NM^3/H (WITTEVEEN)

Plant Capacity	**350 Nm^3** Biogas/hour ➔ **214 Nm^3** Bio-Methane/hour
Biogas source	**Vegetable-based material (Corn silage, spent hops, spent grain, etc.)** **Mono-Digestion** (consumption per year ~12.000 ton)
Ratio : CH_4 / CO_2	55 % / 45 %
Operating Pressure	8 barg
BioMethane produced	1,71 Million Nm^3 / year (operation ~8000hrs / year)
CH_4 Loss	None
CO_2 Recovered	1,96 Million kg / year
Injection into grid	According to Dutch Gas Grid Specifications

BIOGAS UPGRADING CASE STUDY - 450 NM^3/H (WELL)

Plant Capacity	**450 Nm^3** Biogas/hour ➔ **275 Nm^3** Bio-Methane/hour
Biogas source	**Vegetable-based material (Compost-processing industry)**
Ratio : CH_4 / CO_2	55 % / 45 %
Operating Pressure	8 barg
BioMethane produced	2,20 Million Nm^3/ year (operation ~8000hrs / year)
CH_4 Loss	None
CO_2 Recovered	2,52 Million kg / year
CO_2 Usage	EXPORT : Greenhouse / Cooling agent / Dry-ice ➔ EXTRA REVENUE
Injection into grid	According to Dutch Gas Grid Specifications

REFERENCE MANURE/ CO FERMENTATION (SNEEK)

Plant Capacity	**350 Nm^3** Biogas/hour ➔ **214 Nm^3** BioMethane/hour
Biogas source	**Manure from Cattle Farm**
Ratio : CH_4 / CO_2	55 % / 45 %
Operating Pressure	8 barg
BioMethane produced	1,71 Million Nm^3 / year (operation ~8000hrs / year)
CH_4 Loss	None
CO_2 Recovered	1,96 Million kg / year
CO_2 Usage	EXPORT : Greenhouse / Cooling agent / Dry-ice ➔ EXTRA REVENUE
Injection into grid	According to Dutch Gas Grid Specifications

LIQUID CO_2 STORAGE (Well)

SERVICE AT ITS BEST

GLOBAL MODULAR SERVICE SOLUTIONS

- More than 60 years of experience
  - ✓ Audits and assessments
  - ✓ Laboratory and analysis services
  - ✓ Gas chromatograph
  - ✓ Process design and engineering
  - ✓ Technology supply and turnkey projects
  - ✓ Pentair Academy (training)
  - ✓ Total lab solutions
  - ✓ Global service program
- Global service network
- Large installed base

HAFFMANS BIOGAS UPGRADING

- **No** methane loss
- 2 value streams
  - CH_4
    - Gas to grid
    - CNG / LNG
  - Sustainable / food grade CO_2
- Pentair Haffmans technology
  1. Membrane step
  2. Cryogenic step
- For all Biogas industries (sources)

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THANK YOU FOR YOUR KIND ATTENTION

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