PRE-BASIC BIOGAS

MALMÖ SWEDEN

ROY SPEE

GENERATING BIOMETHANE & LIQUID \text{CO}_2 FROM FOOD & BEVERAGE WASTE

7 YEARS OF BIOGAS UPGRADING EXPERIENCE
WE ARE DRIVEN BY A PURPOSE

DELIVERING SAFE & SUSTAINABLE ENERGY

MANAGING WATER USE

MEETING THE WORLD’S INCREASING DEMAND FOR FOOD

SUPPORTING, MAINTAINING & PROTECTING CRITICAL PROCESSES

Generating Biomethane & Liquid CO2 from Food & Beverage Waste
OUR CAPABILITIES AND RESOURCES SPAN THE GLOBE

~30,000 EMPLOYEES

7 CONTINENTS

$6.4 Billion ANNUAL REVENUE (2015)

~100 MANUFACTURING FACILITIES

500+ PRODUCT LINES

60+ SERVICE CENTERS

Generating Biomethane & Liquid CO2 from Food & Beverage Waste
PENTAIR FOOD & BEVERAGE PROCESS SOLUTIONS

**PENTAIR BEVERAGE SYSTEMS**
Enschede, The Netherlands

- Production of the Beer Membrane Filter (BMF) + cellar solutions
- Production of membranes and membrane modules using proprietary production equipment
- Solutions for process, wastewater treatment

**PENTAIR SÜDMO,**
Riesbürg, Germany
**Hamilton,** New Zealand

- Production of valves, fittings and integrated valve systems
- Provides sustainable processing solutions to maximize production time and operational flexibility, from design through to the final commissioning of your process system.

**PENTAIR HAFFMANS**
Venlo, The Netherlands

- Production of quality control and process equipment for the brewing and beverage industries
- Production of CO₂ recovery and biogas upgrading solutions for the brewing / beverage, bio-ethanol and biogas industry

NORDIC BIOGAS CONFERENCE 2016: Generating Biomethane & Liquid CO2 from Food & Beverage Waste
ARN: BIOGAS UPGRADING FROM BIOWASTE

- **WASTE STREAMS**
- **WASTE WATER**
- **MANURE**
- **ENERGY CROPS**
- **LANDFILL**

**ANAEROBIC DIGESTION**

**PRE-TREATMENT (COOLING, HEATING, H₂S REMOVAL)**

**HAFFMANS BIOGAS UPGRADING – PRODUCT PORTFOLIO**

- **STANDARD Membrane Solution**
  - Without CO₂-Liquefaction
  - <0.5% METHANE LOSS
  - BIO-METHANE → GRID INJECTION
  - BIO-METHANE → CNG
  - LNG FUTURE SOLUTION

- **ADVANCED Membrane Solution**
  - Without CO₂-Liquefaction
  - 0% METHANE LOSS
  - BIO-METHANE → GRID INJECTION
  - BIO-METHANE → CNG
  - LNG FUTURE SOLUTION

- **ADVANCED plus Membrane Solution**
  - Including CO₂-Liquefaction
  - 0% METHANE LOSS
  - BIO-METHANE → GRID INJECTION
  - BIO-METHANE → CNG
  - FOODGRADE CO₂
  - LNG FUTURE SOLUTION

**CURRENT PENTAIR-HAFFMANS PORTFOLIO**

- **195 W/Nm³ BIOGAS**
  - GENERATING BIO-METHANE & LIQUID CO₂ FROM FOOD & BEVERAGE WASTE

- **280 W/Nm³ BIOGAS**

- **360 W/Nm³ BIOGAS**

**FEEDSTOCK**

**VALUE**

**PRODUCT**

- **ELECTRICITY**
- **LOCAL HEAT**
BIOGAS UPGRADING - MEMBRANE GAS SEPARATION

Generating Biomethane & Liquid CO2 from Food & Beverage Waste
BIOGAS UPGRADING – STANDARD SYSTEM

Biogas AD

Flare

45% v/v CO₂
50% v/v CH₄

30% v/v CO₂
70% v/v CH₄

94% v/v CO₂
6% v/v CH₄

Low Pressure Stage

Fan Blower → Scrubber Chiller Heater → Activ Carbon (H₂S/VOC) → Low Pressure Conditioning

High Pressure Stage

Compression → High Pressure Conditioning

Membrane Stage 1 & 2

1st Stage → 2nd Stage → Temperature Conditioning

Revenue Stream

Quality Control → BioMethane

Flare / Digester

Methane Recovery

BIOGAS PART
Membrane Separation

3rd Stage

Vent

0.5 - 1% CH₄

Generating Biomethane & Liquid CO2 from Food & Beverage Waste
BIOGAS UPGRADING - ADVANCED plus SYSTEM

Biogas AD

Flare

Low Pressure Stage
- Fan Blower
- Scrubber Chiller Heater
- Activ Carbon (H₂S/VOC)
- Low Pressure Conditioning

High Pressure Stage
- Compression
- High Pressure Conditioning

Membrane Stage 1 & 2
- 1st Stage
- 2nd Stage
- Temperature Conditioning

Revenue Stream
- Quality Control
- BioMethane

Green CO₂ to free air / Local gas consumption

Flare / Digester

High Pressure Stage
- Compression
- High Pressure Conditioning

Purification & Liquefaction Stage
- Regenerative Activ Carbon & Drier
- CO₂ Liquefier
- Stripper - Reboiler + Pump

Revenue Stream
- Liquid CO₂ Storage tank
- Foodgrade Liquid CO₂

CO₂ PART Cryogenic Separation

BIOGAS PART Membrane Separation

45% v/v CO₂
50% v/v CH₄

30% v/v CO₂
70% v/v CH₄

94% v/v CO₂
6% v/v CH₄

Methane Recovery

Generating Biomethane & Liquid CO2 from Food & Beverage Waste
CO₂ is used in different forms: gaseous, liquid, solid or super critical

- **Agri-production**
  - Accelerate plant growth in greenhouses

- **Beverages**
  - Carbonation and beverage dispensing

- **Food industries**
  - Food preservation, freezing, chilling, packaging

- **Refrigerated transport**
  - Maintain the cold chain for fresh and frozen products

Many other applications: fire extinguishers, natural refrigerant, stunning of animals
ADDITIONAL REVENUE WITH CO₂ -BOLT-ON

Biogas AD

Flare

45% v/v CO₂
55% v/v CH₄

Methane Recovery ~2% of Biogas flow

98.5% v/v CO₂
1.5% v/v CH₄

High Pressure Stage
- Compression
- High Pressure Conditioning

Purification & Liquefaction Stage
- Regenerative Activ Carbon and Drier
- CO₂ Liquefier System
- Reboiler + Stripper + Pump

Revenue Stream
- Liquid CO₂ Storage tank
- Foodgrade Liquid CO₂

CO₂ purity acc EIGA Specs
440 W/Nm³ raw CO₂

EXISTING BIOGAS UPGRADING PLANT

Green CO₂ to free air / Local gas consumption

Generating Biomethane & Liquid CO₂ from Food & Beverage Waste
BIOGAS UPGRADING

Generating Biomethane & Liquid CO2 from Food & Beverage Waste
BIOGAS UPGRADING

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BIOGAS UPGRADING

Generating Biomethane & Liquid CO2 from Food & Beverage Waste
### REFERENCE VEGETABLE MATERIAL

<table>
<thead>
<tr>
<th>Customer</th>
<th>ARN waste processing industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market</td>
<td>Compost Processing industry</td>
</tr>
<tr>
<td>Capacity</td>
<td>530 Nm$^3$/h biogas</td>
</tr>
<tr>
<td></td>
<td>$\text{CO}_2$ for greenhouses (via Linde)</td>
</tr>
</tbody>
</table>
ARN: BIOGAS UPGRADING CHALLENGES

CHALLENGES

• Decreasing capacity and separation efficiency

• Controlling the gas quality due to variance in biomass

• Plugging of membranes by VOCs (terpene, limonene and ketone)
  – Frequent replacement of activated carbon
  – Self-cleaning membranes

• Very strict regulations on CO2 quality
<table>
<thead>
<tr>
<th>CUSTOMER</th>
<th>PRODUCT</th>
<th>COUNTRY</th>
<th>START-UP</th>
<th>CAPACITY</th>
<th>MARKET</th>
<th>OUTPUT</th>
</tr>
</thead>
</table>
| Fountain Civil Engineering, Cape Town | Advanced Plus | SA      | Mar-17   | 1600 Nm³/h Biogas | Food & vegetable based waste | • 1010 Nm³/h Bio-methane  
• 1040 kg/h Bio CO₂ |
| UTS, Raynham Farms               | Standard  | UK      | Jul-15   | 1000 Nm³/h Biogas | Organic Waste               | • 565 Nm³/h Bio-methane              |
| Indaver, Alphen a/d Rijn         | Advanced Plus | NL      | Jun-14   | 1050 Nm³/h Biogas | Garden & household organic waste | • 670 Nm³/h Bio-methane  
• 775 kg/h Bio CO₂ |
| Abfallverwertung, Augsburg       | Advanced  | D       | Oct-13   | 1000 Nm³/h Biogas | Garden & household organic waste | • 610 Nm³/h Bio-methane              |
| ARN, Weurt                       | Advanced Plus | NL      | Aug-12   | 530 Nm³/h Biogas | Garden & household organic waste | • 320 Nm³/h Bio-methane  
• 390 kg/h Bio CO₂ |
| Ecofuels, Well                   | Advanced Plus | NL      | Aug-11   | 450 Nm³/h Biogas | Vegetable-Fruit based waste   | • 270 Nm³/h Bio-methane  
• 330 kg/h Bio CO₂ |
PENTAIR REFERENCES & ADVANTAGES

29 Biogas Upgrading Projects

PROVEN TECHNOLOGY PROVIDER

- In-house membrane & CO₂ systems design & production
- Low membrane pressure and power consumption
- 7+ years proven membrane service life
- No methane slip possible (increased revenue, clean lean gas)
- Liquid & gaseous CO₂ as 2nd value stream
- CO₂ end quality according to EIGA
- Food safety risk assessment completed in cooperation with major gas company
- Standardized skid modules in low-cost buildings for short delivery time and easy maintenance
- 24/7 service desk & own service team
- Globally 450+ CO₂ recovery plants in operation
- Award winner 2016: Best process optimization
- CH₄ to pipeline, CNG & LNG

EIGA: European Industrial Gas Association
Thank you for your attention!