Biogas Upgrading with PSA and Membrane Technology

June 2014
Gas Purification, Separation & Filtration

Global presence, with headquarters in Montreal, Canada
Toronto Stock Exchange (TSXV: XBC)

Who we are

Leading designer, manufacturer and operator of gas purification, separation and filtration systems for crude-derived fuels displacement

Markets Focus

- Biogas
- Natural Gas
- Associated Gas
- Hydrogen

Strategy

Leverage key technological advantages into long term customer relationships to grow sales and profitability
International Presence

- Headquarters in Blainville (QC) - Manufacturing and Sales
- R&D in Blainville (QC)
- Customer support Office in Vancouver (BC)
- Manufacturing and Sales in Shanghai
- Sales Office in Singapore
- Sales & Engineering Office in Houston, Texas

Ability to gain business and service customers worldwide
A leader in the clean energy sector, offering customized purification, separation & filtration solutions to a global clientele

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1967</td>
<td>Xebec founded</td>
</tr>
<tr>
<td>1998</td>
<td>Dominick Hunter Ltd, A U.K. based filtration company acquires Xebec</td>
</tr>
<tr>
<td>2001</td>
<td>Xebec relocates to new manufacturing facility in Blainville</td>
</tr>
<tr>
<td>2005</td>
<td>Dominick Hunter is acquired by Parker-Hannifin, a U.S. based multinational</td>
</tr>
<tr>
<td>2007</td>
<td>MBO completed</td>
</tr>
<tr>
<td>2008</td>
<td>Xebec opens manufacturing facility in Shanghai, China</td>
</tr>
<tr>
<td>2009</td>
<td>Xebec completes reverse take-over of aPSA Technology Company, Lists on TSX:XBC</td>
</tr>
<tr>
<td>2014</td>
<td>Xebec opens Houston based U.S. operations, Launches Natural Gas Filter Line, Lists on TSXV:XBC</td>
</tr>
</tbody>
</table>
**Low Pressure XL Series**
20 BarG / 290 PSIG
Volume Flow Rate: 70 to 3500 Nm³/h
40 to 2060 scfm
Operating Temp: 0-80 °C / 32-176 °F
(120 °C elements are available)
Port size: ¼” to 3” / 6mm to 75mm

**Medium Pressure XM Series**
50 BarG / 725 PSIG
Volume Flow Rate: 450 to 22,300 Nm³/h
260 to 13,000 scfm
Operating Temp: 0-80 °C / 32-176 °F
(120 °C elements are available)
Port size: ½” to 3” / 13mm to 75mm

**High Pressure XH Series**
420 BarG / 6000 PSIG
Volume Flow Rate: 800 to 11,200 m³/h
480 to 6560 scfm
Operating Temp: 0-80 °C / 32-176 °F
(120 °C elements are available)
Pipe size: ¼” to 2” / 6mm to 53mm
Business Segments

**TSA Technology for NGV refueling stations**

- Growing market
- Cost leadership through Chinese manufacturing
  - **Key Customers:** Clean Energy, Petrochina, Sinopec, Shell, Angi Energy, Greenfield

**Biogas Upgrading Technology**

- Rapidly growing market
- High recovery, high purity, low energy plants
  - **Key Customers:** Sempra, Montauk Energy, Halla, FortisBC, Golden Green, Sirim, SKS

**PSA Technology for H₂, He, CH₄, CO**

- Growing market segment
- Market-leading performance for small & medium capacity purifiers
- Syngas purification
  - **Key Customers:** HydroChem, Haldor Topsoe, Air Liquide, Linde, Iwatani

**Membrane Technology – CH₄, CO₂, H₂, He, N₂**

- Rapidly evolving market
- High recovery, high purity, high selectivity & flux
- CH₄, H₂, He, N₂, CO Biogas
  - **Key Customers:** Weil Group, Apache
Proprietary Products and IP Assets

- 15 years of dedicated development in adsorption based gas purification, separation and filtration with over $60M invested
- Complete proprietary product line with respect to rotary valves, and fast cycle adsorption processes
- Integration of membranes into overall system designs
- Strong process capabilities in gas purification & separation
- Ongoing development of next generation purification products, especially membrane and hybrid systems
- Current adsorption technology is applicable to all products segments and is being augmented with membrane technology
- Continued R&D activity with multiple Universities and Research Institutes, focused on improved recovery and purity, while reducing costs
# Products

<table>
<thead>
<tr>
<th>Biogas Upgrading (BGX)</th>
<th>Natural Gas Drying (NGX)</th>
<th>Hydrogen (H2X)</th>
<th>Associated Gas (AGX)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rumpke Landfill in Ohio, US</td>
<td>MTA, Orange County</td>
<td>HydroEdge liquid H2 plant, Japan</td>
<td>Venoco Off-Shore Oil Platform</td>
</tr>
<tr>
<td>Hilarides Dairy, California</td>
<td>Trillium, California</td>
<td>MKK, Japan</td>
<td>PXP Oil Well, California</td>
</tr>
</tbody>
</table>
# Key Customers & Partner

<table>
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<tr>
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<th>Hydrogen (H2X)</th>
<th>Associated Gas (AGX)</th>
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</thead>
<tbody>
<tr>
<td>20 customers</td>
<td>500+ customers</td>
<td>60 customers</td>
<td>5 customers</td>
</tr>
<tr>
<td>25+ installations</td>
<td>1200+ installations</td>
<td>175 installations</td>
<td>5 installations</td>
</tr>
<tr>
<td>9 countries</td>
<td>40 countries</td>
<td>15 countries</td>
<td>3 countries</td>
</tr>
</tbody>
</table>

![Logos of various companies]
Biomethane and Natural Gas Value Chain

Sources of Biogas:
- Anaerobic Digester
- Waste Water Treatment Plant
- Landfill
- Natural Gas Pipeline

Direct Use:
- Biogas Upgrading Plant

Renewable Gas:
- Raw Biogas

Transportation:
- Gas Dryer
- Compressor
- Liquid Natural Gas Plant
- Storage Vessel System
- Natural Gas Vehicle Dispenser

Industrial, Commercial, and Residential:
- Home Heating & Cooking
- Electricity & Heat

www.xebecinc.com
Impact on GHG Emissions

U.S. DOE estimates 25% of all diesel fuel could be replaced by renewable gas

*reference vehicle: gasoline engine (induction engine), consumption 71 per 100 km

Source: German Energy Agency
Solutions for Landfill and Digester Gas

Landfill Gas

- Complexity reduction
  - One-step fast cycle multi-bed kPSA technology separates H₂O/CO₂/N₂/O₂ from landfill gas to produce biomethane product
  - Superior compared against conventional two-step membrane + PSA
- Greatly enhanced product recovery:
  - 92% (1-step) vs. 81% (2-step) = 13% more product to sell

Digester Gas

- Fast Cycle multi-bed adsorption or Membrane technology separates CH₄, H₂O & CO₂ from digester gas in one easy step
- Combining Fast Cycle PSA and Membrane technology permits unique design features
- Low to medium operating pressures, high recovery and high availability result in lower operating costs and higher returns on investment

![Graph of Optimized Recovery From Testing]

*Figure 7 - Optimized Recovery versus N₂ in the feed*
Performance Model for kinetic PSA

Best recovery in N2 and O2 contaminated gas streams
Superior revenue generation and low operating costs

**Xebec’s Solution for CO2 and N2 Removal from LFG**

Expected Performance versus Preliminary Lab Testing Results

- Methane Recovery (%) vs. Nitrogen Concentration in Feed (%)
- Expected Performance with optimized design

![Image of PSA equipment](image-url)
Xebeec created a unique value proposition

- Dedicated Technology for every Type of Biogas
- Customized Solutions to meet every Customers Particular Needs

### Conventional Technologies

<table>
<thead>
<tr>
<th></th>
<th>No N2/O2 Removal</th>
<th>N2 Removal Only</th>
<th>O2 Removal Only</th>
<th>N2 and O2 Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water wash</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Amine scrubbing</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>PSA</td>
<td>Yes</td>
<td>Yes *</td>
<td>Yes *</td>
<td>Yes *</td>
</tr>
<tr>
<td>Membrane</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

* Not all the PSA suppliers are capable to remove N2 and O2. Dedicated adsorbant is required

### XEBEC Technologies

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<td>PSA</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Membrane</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Hybrid System</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

** XEBEC can provide a solution if needed
BGX – A Wide Range Of Options

- Optional H2S and / or Siloxane Removal
- Optional Zero-Emission system with integrated Microturbine – no flare required
- Optional integrated CNG compression, storage and dispensing station
- Optional Product Flow meter
- Optional Flare/Burner
- Optional Xebec Leasing and Financing (EDC)

Mobile flare for start-up and maintenance with microturbine option

Microturbine option for electricity generation

Containerized CNG fuel option

Optional H2S removal
Fast Cycle Pressure Swing Adsorption (PSA)

G2 - Platform

Adsorbent

High Pressure

CH₄

CH₄, CO₂, H₂O

Xebec Purification Technology
Xebec Purification Technology

Fast Cycle Pressure Swing Adsorption (PSA)

G2 - Platform

Adsorbent

Low Pressure

CH₄ Product

CO₂, H₂O
BGX - Pressure Swing Adsorption (PSA) System

- Pressure Relief Valves
- Product Rotary Valve
- Feed Gas Entry
- PSA Adsorbent Vessels
- Feed Rotary Valve
- Product Gas Exit
- Grounding Point
- Exhaust Gas Exit
- Forklift Slots
BGX – PSA System

SIMPLIFIED PROCESS FLOW DIAGRAM
Main advantages

✓ Reliability (96% availability)
✓ Ideal for large plants and landfill gas upgrading
✓ Only technology to remove CO\textsubscript{2} / N\textsubscript{2} / O\textsubscript{2} in one stage
✓ Can upgrade biogas with high O\textsubscript{2} / N\textsubscript{2}
✓ All pollutants removed (not released with the exhaust)
✓ Low consumables consumption
BGX – PSA System

Pressure (psig)

0  20  1,200

M-3300  M-3200  G4 AND  G4 MULTI-VALVE

Feed Capacity (SCFM)

0  1,800  12,000

M-3300  M-3200  G4 AND  G4 MULTI-VALVE

G4 AND G4 MULTI-VALVE

M-3300  M-3200

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0  1,800  12,000

M-3300  M-3200  G4 AND  G4 MULTI-VALVE

G4 AND G4 MULTI-VALVE

M-3300  M-3200
For removal of CO$_2$ and H$_2$O from biogas and/or natural gas

Two types of membranes for biogas/natural gas separation, cellulose acetate (CA) spiral wound and polyimide (PI) hollow fiber membranes Xebec is working with a polyimide hollow fiber membrane developed by Evonik Industries

Xebec provides single, double and three stage membrane separation units, depending on customer requirements (considering cost, recovery and purity)
BGX – Membrane System

- CO₂, H₂O and CH₄ are separated due to different permeation rates
- Gas flow is sent in at a higher pressure to provide driving force (typical operating pressure is usually between 10-20 bar)
BGX – Membrane System

SIMPLIFIED PROCESS FLOW DIAGRAM

COMPRESSOR MODULE

CONDENSATE

H2S REMOVAL (OPTIONAL)

GAS COOLING

SILOXANE REMOVAL (OPTIONAL)

MEMBRANE

PRODUCT

OPTIONAL CNG COMPRESSOR & STORAGE

OPTIONAL FLOWMETER

OPTIONAL ANALYZERS

OPTIONAL MICROTURBINE

OPTIONAL BURNER
Main advantages:

- High methane yield of up to 99.5%,
- Excellent modularity and turndown capacity
- Possible elimination of exhaust treatment with high recovery three stage membrane configuration (extremely low methane slip, less than 1% possible)
- Ideal for small to medium plants from 10 to 1,400 NCMH, easily scalable
- Excellent energy efficiency for upgrading (<0.2 kWel/Nm³ crude biogas, <0.4 kWel/Nm³ biomethane)
- Ease of maintenance
Xebec developed a Hybrid System Combining Membrane & PSA Fast Cycle technology to obtain the Advantages of each Technology in One Plant

- Reliability and long life of a PSA
- Modularity and turndown capability of membranes
- Excellent flexibility and overall system performance
- Excellent recovery of CH4 (99%)
- High gas purity (99%) - if required
- O2 / N2 removal - if required
- Competitive investment (capex)
- Lower overall operating costs (opex)
BGX - Hybrid System

SIMPLIFIED PROCESS FLOW DIAGRAM

COMPRESSOR MODULE

H2S REMOVAL (OPTIONAL)

SILOXANE REMOVAL (OPTIONAL)

MEMBRANE

PSA

GAS COOLING

CONDENSATE

CONDENSATE

PRODUCT

OPTIONAL CNG COMPRESSOR & STORAGE

OPTIONAL FLOWMETER

OPTIONAL ANALYZERS

OPTIONAL MICROTURBINE

OPTIONAL BURNER
BGX - Hybrid System

PSA
Membrane
Siloxane removal (optional)
Gas Cooling
Compressor module
H2S removal (optional)
Case Studies and References
Case Study – LFG to CNG and Hydrogen

First Landfill Gas to Renewable Hydrogen Worldwide

Location: Trifyl, France
Developer: Verdemobil
Biogas Feed: Landfill Gas
Raw Biogas: 52% CH4
  ~250 Nm3/h
End-use: CNG for Refuse Trucks
  H2 for municipal vehicles
Start-up date: 2011 to CNG
  2013 to Hydrogen
Case Study – Waste Water Treatment Plant

**Location:** Southern California, US

**Developer:** Sempra Utilities

**Biogas Feed:** Waste Water Plant

**Raw Biogas:** 58% CH₄

~360 Nm³/h

**End-use:** Test/Pipeline

**Pipeline Operator:** Southern California Gas

**Start-up date:** 2011
Case Study – Mixed Waste to CNG

Location: Seoul, South Korea
Developer: Halla Environmental
Biogas Feed: Food Waste Digester
Raw Biogas: 60% CH4
~650 Nm3/h
End-use: CNG for Refuse Trucks
Start-up date: 2011
Case Study – Swiss Farm Collective

Location: Inwil, Switzerland
Operator: Swiss Farm Collective
Biogas Feed: Farm Waste Digester / Food Waste
Raw Biogas: 52% - 56 CH4 ~140 scfm / 225 Nm3/h
End-use: Injection into local pipeline, onsite heat and electricity
Owner: Swiss Farm Collective
Start-up date: 2008
Other Xebec References

Daegu, South Korea, Municipal Digester
1,400 NCMH
PSA System, 2013
Other Xebec References

Rumpke Landfill, Cincinnati
10,000-15,000 NCMH
PSA System, 2007
## Biogas Upgrading Installations

<table>
<thead>
<tr>
<th>Project</th>
<th>Location</th>
<th>Biogas Source</th>
<th>End-Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenic View Dairy</td>
<td>MI, US</td>
<td>Digester</td>
<td>Pipeline</td>
</tr>
<tr>
<td>Rumpke Landfill</td>
<td>OH, US</td>
<td>Landfill</td>
<td>Pipeline</td>
</tr>
<tr>
<td>Widnau</td>
<td>Switzerland</td>
<td>Digester</td>
<td>Pipeline</td>
</tr>
<tr>
<td>Lavigny Farm</td>
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<td>Pipeline</td>
</tr>
<tr>
<td>UNH</td>
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<td>Landfill</td>
<td>Turbine</td>
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<td>SKS</td>
<td>Austria</td>
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<td>CNG</td>
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<td>Swiss Farmer</td>
<td>Switzerland</td>
<td>Digester</td>
<td>Pipeline</td>
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<td>STEP</td>
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<td>Digester</td>
<td>Pipeline</td>
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<td>Hilarides Dairy</td>
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<td>Digester</td>
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<td>Daesung</td>
<td>Seoul, Korea</td>
<td>Landfill</td>
<td>CNG/LNG</td>
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<td>SKS</td>
<td>Austria</td>
<td>Digester</td>
<td>CNG</td>
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<td>Sempra Energy</td>
<td>CA, US</td>
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</table>

*Escondido, California - Waste Water Treatment Plant gas to pipeline - 2011*

*Salmon Arm, British Columbia - landfill gas to pipeline - 2012*
Why Chose Xebec for your upgrading Project

- **Reliable and Simple Technologies** (PSA, Membrane and Hybrid systems, robust and proven rotary equipment and valves)
- **Excellent Process Capabilities** (CO₂, N₂, O₂, H₂S, H₂O, VOCs, Siloxanes etc., ability to deal with varying feed gas qualities, while maintaining product gas specifications)
- **Flexible Designs** (Plants designed for your needs, recovery and gas purity rates tailored to your needs, variable CH₄ percentages in the exhaust gas for use in engines, boilers, turbines, etc.)
- **Complete Reference List** (for all types of biogas - landfill gas, food digesters gas, organic farm waste gas, POME gas, mixed waste gas, waste waster treatment plant gas)
- **Full Aftermarket Support** (Service and Parts support in the markets we operate in)
- **Remote monitoring** (via internet/satellite)
- **Financing through EDC** (for qualified buyers)
Thank you

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