SEPURAN® Green
Membrane modules for upgrading biogas efficiently
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<td>SEPURAN® <em>Green</em> for biogas upgrading</td>
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<td>SEPURAN® <em>Green</em> Cartridge System</td>
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An attractive company

- One of the global leaders in specialty chemicals
- AiM: Profitable growth and sustained value creation
- Main shareholders: RAG-Stiftung, CVC Capital Partners
## Key figures 2012

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<tr>
<td><strong>Sales</strong></td>
<td>€13.6 billion</td>
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<tr>
<td><strong>Adjusted EBITDA</strong></td>
<td>€2.6 billion</td>
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<tr>
<td><strong>Profitability (adjusted EBITDA margin)</strong></td>
<td>19.0%</td>
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<tr>
<td><strong>Return on capital employed (ROCE)</strong></td>
<td>17.2 %</td>
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<td><strong>Employees as of Dec. 31, 2012</strong></td>
<td>33,298</td>
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New benchmark in biomethane production: SEPURAN® Green

Evonik’s contribution to an efficient biomethane purification process
Outline

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Illustration of a gas separation process in a hollow fibre membrane

Mode of operation of a membrane module for gas separation

Relative permeation rates of various gases
Evonik's Multi Step Biogas Upgrading Process with SEPURAN® Green is a game changer!

For the first time membrane technology can offer complete separation!
Profitability of biogas purification is highly dependant on plant size and technology

### Comparison between four biogas purification technologies

<table>
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<th>Technology</th>
<th>Product Pressure</th>
<th>Characteristics</th>
<th>Cost (ct/Nm³) 1)</th>
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</table>
| **SEPURAN® Green**          | Prod. pressure 6 bar | • Easy to operate
• No waste water
• No chemicals
• High yield and purity | 12.0 – 19.4 ct/Nm³ 1) |
| **Amine scrubbing**         | Product at 1 bara | • Large plant footprint
• Toxic chemicals
• Energy intensive
• High purity, low yield | 16.4 – 22.9 ct/Nm³ 1) |
| **Pressurized water scrubbing** | Output pressure 11 -16 bar | • Prod. pressure 6 bar
• High water consumption
• Low purity, high yield
• State-of-the-art 2011 | 12.5 – 21.1 ct/Nm³ 1) |
| **Pressure swing absorption** | Prod. pressure 4 bar | • Low purity, low yield
• Medium plant footprint
• Complex operation
• Energy intensive | 17.9 – 26.5 ct/Nm³ 1) |

1) Plant size 2,000 Nm³/h – 200 Nm³/h
The membrane removes CO$_2$ and dries the biogas at the same time.

Process steps of biogas upgrading with SEPURAN® Green Membranes

- **Raw Biogas**
- **Desulphurisation**
- **Filter**
- **Compressor**
- **Membrane Process**
  - H$_2$O Removal
  - CO$_2$ Removal
- **Biomethane**

The diagram shows the process steps involved in upgrading biogas using SEPURAN® Green Membranes. The membrane removes CO$_2$ and dries the biogas simultaneously.
10 Nm³/h Pilot Plant in Neukirchen a. d. Vöckla, Austria
Biogas Upgrading Pilot Plant with SEPURAN® Green Membrane Modules

Pilot tests in the field since 02/2011

Deliverables:

- **Separation behaviour Evonik Membranes**
  - Permeability, Selectivity over time
  - Influence of impurities of a real Biogas on the separation process
  - Long term behavior of the membranes

- **Implementation of Control System to guarantee:**
  - A constant Biomethane quality for changing compositions and amounts of raw Biogas

- **Mass and Energy Balance**
  - Methane Yield/ Loss
  - Module Capacity per Membrane Module
Results of the pilot plant in Neukirchen confirm the expectations since 02/2011.
Outline

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Biogas-Upgrading plants in different sizes can now be referenced in the market.

- **Sachsendorf, Germany**
  - Capacity: 150 m³/h
  - Start-up date: 10/2012

- **Prattln, Switzerland**
  - Capacity: 210 m³/h
  - Start-up date: 10/2012

- **Zeven, Germany**
  - Capacity: 250 m³/h
  - Start-up date: 10/2012

- **Poundbury, UK**
  - Capacity: 650 m³/h
  - Start-up date: 10/2012

- **Neukirchen, Austria**
  - Capacity: 10 m³/h
  - Start-up date: 2/2011
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SEPURAN® Green cartridge system preview - geared to the global market

The cartridge system complements the SEPURAN product portfolio

- meets global pressure regulations
- easy membrane replacement
- reduced replacement costs
- available 2013
Evonik will be a leading supplier of biogas upgrading membranes

Advantages of the Evonik membrane process with SEPURAN® Green

- Low methane slip (loss) of <1% during upgrading
- High methane yield of up to 99%, which means maximum added value for the operator
- Highest energy efficiency for upgrading (<0.2 kWel/Nm$^3$ crude biogas, <0.4 kWel/Nm$^3$ biomethane)
- No additional ancillary materials such as water or sorbents (amines, glycols) are required, so no emissions into the environment
- Easily regulated for changes in flow rate or composition
- Following the upgrading process with membranes, the biomethane is already dry and satisfies the dew-point requirement for feeding into the grid
- Easily scalable; can be used for small plants (10 Nm$^3$/h) as well as large (several hundred Nm$^3$/h)
- Starting and stopping of the plant is possible at short intervals, ensuring high flexibility; therefore ideally suited for operation of a biomethane filling station at the site
- Direct feeding (via a transmission pipeline) into the natural gas grid is possible without an additional compressor