



**PRISM<sup>®</sup> Membrane Separators**  
for biogas upgrading . . .  
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# Biogas upgrading overview

Biogas is the production of methane from anaerobic digestion of farm wastes, manure, or municipal waste. Biogas contains high concentrations of carbon dioxide, hydrogen sulfide, and other impurities which need to be removed to make the methane commercially viable. The purified biomethane is used to generate heat and power, compressed for powering vehicles, or fed directly into the natural gas grid for resale.



Air Products' PRISM separators use proprietary hollow fiber membranes to selectively remove unwanted elements from biogas streams produced during the anaerobic digestion process. Thousands of tiny hollow fibers are spun from polymers in our state-of-the-art production facility and assembled into durable and lightweight aluminum casings.

When biogas is fed into the membrane separator under pressure, the unwanted gas molecules are selectively removed. This results in a purified stream of biomethane which is ready for industrial use and does not require secondary chemical scrubbing solutions.

### Success Story

PRISM PB membrane separators are being used in the first biogas-to-hydrogen vehicle fueling station in Shikaoi, Japan.



Air Products Prism Membranes markets PB membrane separators through a network of value-added resellers that we call our Preferred Partners. If you are interested in incorporating our membrane separators into your engineered biogas upgrading systems, please contact our business development specialists.

We look forward to working with you.

# PRISM membrane advantages



## High selectivity to impurities

Carbon dioxide, hydrogen sulfide and water vapor are removed from the production gas with efficiencies greater than 90%.

## Size and selectivity options

PRISM PB membrane separators are available in a variety of sizes and selectivities. This allows for fine-tune engineering of each stage to design a more efficient biogas upgrading system.

## Robust construction

PRISM membrane modules are engineered to operate in harsh environments. Vibration, corrosive atmospheres, and changing elements have little effect on membrane performance.

## Modular designs

Capacity can be increased or decreased by adding or removing membrane modules from the biogas flow.

## Easy production cycling

PRISM membrane separators are ready for processing instantly, and do not require lengthy start-up or shutdown preparations.

## Removes water vapor

Water vapor is vented off with the undesirable elements in the gas stream. This selectivity eliminates the need to completely dry the gas before processing with expensive pretreatment equipment.

## Resists ammonia vapor and hydrogen sulfide

PRISM membranes are engineered to tolerate many impurities that cripple other systems. These undesirable elements are selectively removed and vented off in the biogas upgrading systems permeate stream without affecting the system performance.

## Great value

Compared to other technologies, membranes require a very small capital investment to begin processing.

## Simple to operate

PRISM Membrane separators are passive technology and have no moving parts. Complex system monitoring equipment is not necessary.

## Competing technologies

The primary objectives of biogas upgrading systems are to remove carbon dioxide, hydrogen sulfide, water vapor, and oxygen. Membrane technology is one of several ways to separate methane from a biogas stream and each technology has distinct advantages and disadvantages.

Operations which have access to copious water, like a publicly owned treatment facility, may consider a water scrubbing tower as a viable technology. Alternatively, facilities with less access to water and limited capital resources, may find water scrubbing outside the scope of their project. This table lists some of the characteristics from different upgrading technologies.



### Technology description

### Advantages

### Disadvantages

#### Wash water scrubbing

Raw biogas is fed into a column of water where the CO<sub>2</sub> and methane dissolve into the water. This saturated water is then fed into a flash tank where the pressure is reduced, the methane strips off, and the CO<sub>2</sub> departs with the water.

Good technology where wash water is abundant. Also more efficient in cold climates as colder water increases CO<sub>2</sub> solubility. Able to process large volumes of gas.

Requires 150 liters of water per normal meter cube per hour (Nm<sup>3</sup>) of raw biogas. Recirculated systems experience biofouling and require removal of H<sub>2</sub>S and CO<sub>2</sub>. Introduces oxygen and moisture into gas stream. Electrical demand for pumping and cooling.

#### Polyethylene glycol absorption

Similar to water scrubbing with polyethylene glycol as the liquid contactor.

Higher selectivity than water reduces pumping requirements. Removes CO<sub>2</sub>, H<sub>2</sub>S, and halogenated hydrocarbons. Good for landfill gas. Closed loop system.

Requires regeneration of polyethylene glycol with inert gas. Saturated solvent requires hazardous material disposal.

#### Carbon molecular sieves

Biogas is fed into reaction chambers which are filled with a carbon sieve under pressure. The CO<sub>2</sub> and H<sub>2</sub>S molecules are adsorbed into the carbon sieve. The methane flows to an adjacent chamber with reduced pressure. A vacuum strips the first column of the unwanted molecules, and the pressure swing cycle repeats.

Successful at removing a number of different compounds present in raw biogas. Can produce 96% pure methane. No solvents to dispose. Carbon sieves' usable lifetime up to 3 years.

Some methane losses to environment during adsorb cycle. Requires significant energy for compressors. Many mechanical components require maintenance.

#### Membrane separation

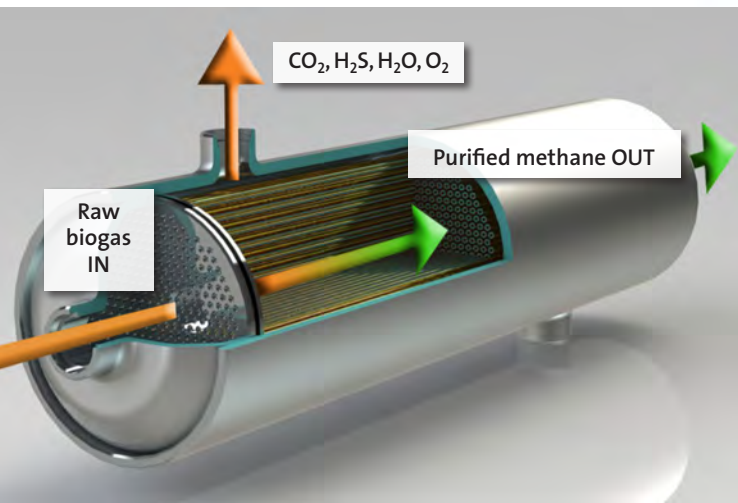
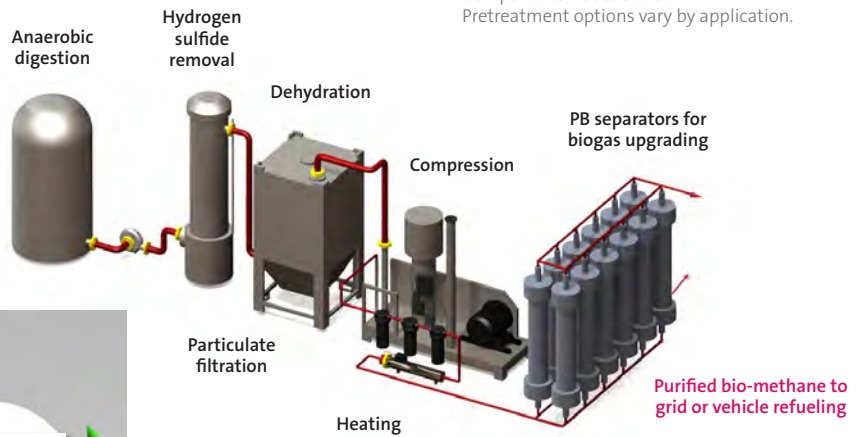
Biogas is compressed and fed into modules which contain thousands of porous, hollow fiber membranes. Fast gases permeate the membrane walls while slow gases exit the hollow tube.

Passive technology requires minimal supervision. Systems scalable by adding or reducing the number of modules online. Multiple stage systems can produce 99% pure methane. Efficient at removing water vapor. Low capital investment. Membranes' usable lifetime 8 to 12 years.

Single stage 88% to 93% purity. Energy required to heat gas plus compression.

## Typical biogas process flow

For illustration purposes only.  
Components not to scale.  
Pretreatment options vary by application.



PRISM membrane separators for biogas upgrading contain thousands of tiny hollow fibers. Smaller gas molecules, like carbon dioxide and water vapor, diffuse through the membrane walls while the larger methane molecules are transported the length of the tube and exit from the end of the module.

### PRISM PB separator ordering information

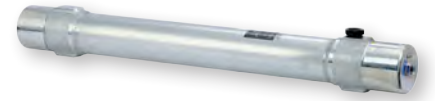
Catalog Number	Model Number	Product Description		
456239	PB4030N1-6G-0B	With 3/4" BSPP connection	3/4" BSPP permeate port	ABS in aluminum sleeve
456240	PB4030N1-9H-0C	With 1/16" SAE connection	1/16" SAE permeate port	ABS in aluminum sleeve
456241	PB4030P3-6G-DB	With 3/4" BSPP connection	3/4" BSPP permeate port	ABS in aluminum sleeve
456242	PB4030P3-9H-DC	With 1/16" SAE connection	1/16" SAE permeate port	ABS in aluminum sleeve
456243	PB4050N1-6G-0B	With 3/4" BSPP connection	3/4" BSPP permeate port	ABS in aluminum sleeve
456244	PB4050N1-9H-0C	With 1/16" SAE connection	1/16" SAE permeate port	ABS in aluminum sleeve
456245	PB4050P3-6G-DB	With 3/4" BSPP connection	3/4" BSPP permeate port	ABS in aluminum sleeve
456246	PB4050P3-9H-DC	With 1/16" SAE connection	1/16" SAE permeate port	ABS in aluminum sleeve
439848	PB6050N1-8B-G9	With 1" BSPP connection	1/2" BSPP permeate port	aluminum shell and caps
439849	PB6050N1-8C-GA	With 1" SAE connection	1/2" SAE permeate port	aluminum shell and caps
433385	PB6050P3-8B-D9	With 1" BSPP connection	1/2" BSPP permeate port	aluminum shell and caps
439850	PB6050P3-8C-DA	With 1" SAE connection	1/2" SAE permeate port	aluminum shell and caps

# PRISM membrane options for biogas upgrading

## High methane recovery configuration

		Raw biogas IN	Biomethane OUT	Vent
<b>Composition</b>				
Methane	mol%	55.0	98.0	0.3
Carbon Dioxide	mol%	45.0	2.0	99.7
<b>Flow PB6050P3</b>	nm <sup>3</sup> /hr	60.0	33.6	26.4
<b>Flow PB4050P3</b>	nm <sup>3</sup> /hr	23.0	13.0	10.0
<b>Flow PB4030P3</b>	nm <sup>3</sup> /hr	13.8	7.8	6.0
Pressure	barg	12.0	11.8	0.0

Power = 0.22 kW/nm<sup>3</sup>/hr raw biogas  
Methane recovery = 99.8%



## Low power configuration

		Raw biogas IN	Biomethane OUT	Vent
<b>Composition</b>				
Methane	mol%	55.0	98.0	0.3
Carbon Dioxide	mol%	45.0	2.0	99.7
<b>Flow PB6050P3</b>	nm <sup>3</sup> /hr	120.0	63.3	56.7
<b>Flow PB4050P3</b>	nm <sup>3</sup> /hr	46.4	24.4	21.9
<b>Flow PB4030P3</b>	nm <sup>3</sup> /hr	28.0	14.7	13.2
Pressure	barg	12.0	11.8	0.0

Power = 0.15 kW/nm<sup>3</sup>/hr raw biogas  
Methane recovery = 94%

## Low capital configuration

		Raw biogas IN	Biomethane OUT	Vent
<b>Composition</b>				
Methane	mol%	55.0	98.0	0.3
Carbon Dioxide	mol%	45.0	2.0	99.7
<b>Flow PB6050N1</b>	nm <sup>3</sup> /hr	350	176.8	173.2
<b>Flow PB4050N1</b>	nm <sup>3</sup> /hr	135.5	68.5	67.0
<b>Flow PB4030N1</b>	nm <sup>3</sup> /hr	81.6	41.2	40.4
Pressure	barg	12.0	11.8	0.0

Power = 0.17 kW/nm<sup>3</sup>/hr raw biogas  
Methane recovery = 90%  
Two stage system example

For more information regarding Air Products' PRISM membrane products, please contact our Customer Service department.

**Air Products PRISM Membranes**

11444 Lackland Road  
Saint Louis, Missouri 63146 USA  
T 314-995-3300  
F 314-995-3500  
Membrane@airproducts.com  
or visit [airproducts.com/membranes](http://airproducts.com/membranes)

**Permea China LTD**

60 Jinshajiang Road  
Shandong, 264006 China  
T +86-535-2165333  
F +86-535-2165336  
fungp@airproducts.com  
or visit [airproducts.com/membranes](http://airproducts.com/membranes)

**Air Products Japan K.K.**

Kamiyacho Prime Place 9F  
4-1-17 Toranomom, Minato-ku,  
Tokyo 105-0001 JAPAN  
T +81-3-5405-6304 direct  
T +81-3-5405-6300 office  
F +81-3-5405-6301  
M +81-90-8584-8474  
higucht@airproducts.com  
or visit [airproducts.co.jp](http://airproducts.co.jp)

**PED Certification**

The quality system of Air Products Prism Membranes has been assessed and found to comply with respect to the conformity assessment procedure described in ANNEX III MODULE D OF DIRECTIVE 97/23/EC ON PRESSURE EQUIPMENT. This certificate is valid for Pressure Vessels: Membrane Gas Separators PB6050, PB4050, PB4030.



**ISO 9001 and AS9100 Certification**

Air Products Prism Membranes has been found to conform to the Management System Standard: ISO 9001:2008 and AS9100C (technically equivalent to EN 9100:2009 and JISQ 9100:2009) and has been audited in accordance with the requirements of AS9104/1:2012. Essential functions include the design, development and manufacture of hollow fiber membrane separators for the aerospace, air compression, oil and gas, petrochemical and other related industries.



The information contained in this document is believed to be true and accurate at time of publication. Air Products PRISM Membranes reserves the right to change product specifications without notification. Please consult current *Product Design and Reference* manual for detailed information associated with these products.

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