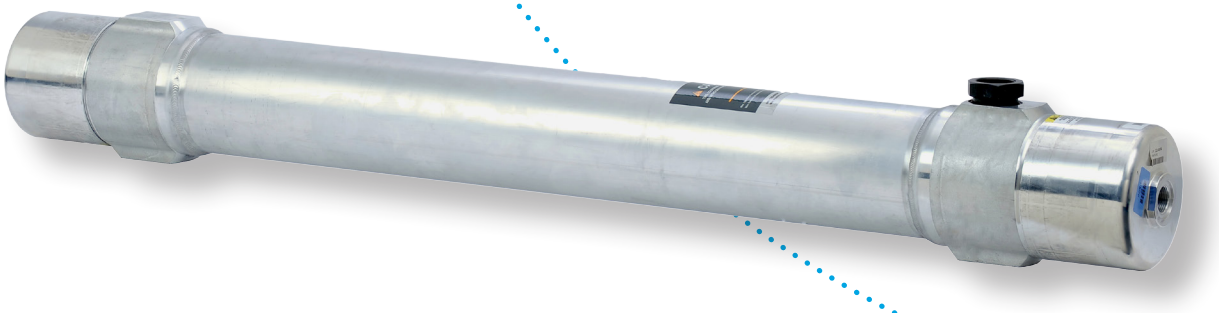
AIR PRODUCTS



PRISM® Membrane Separators for biogas upgrading . . .

tell me more

Biogas upgrading overview

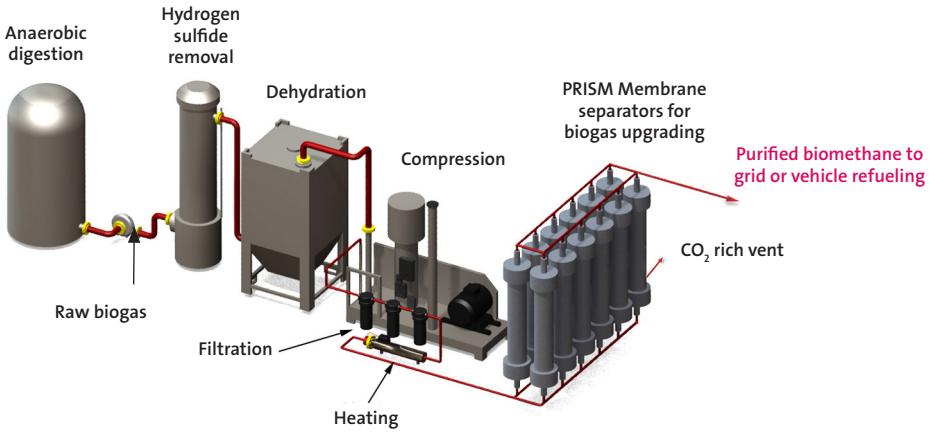
One source of biogas is the production of methane from anaerobic digestion of farm wastes, manure, or municipal waste. Biogas contains high concentrations of carbon dioxide, hydrogen sulfide, and other impurities which need to be removed to make the methane commercially viable. The purified biomethane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

Air Products' PRISM systems 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 shells.

When biogas is fed into the membrane separator under pressure, the unwanted gas molecules are selectively removed. The purified methane stream is typically 97% to 99% pure when it exits the membrane separator.

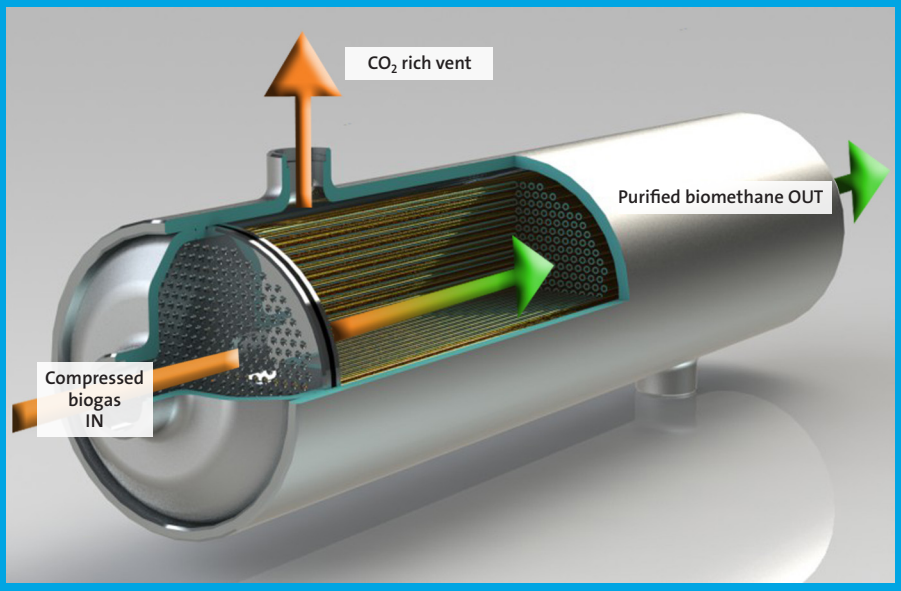
Upgrading your systems with PRISM membranes is affordable, robust, and simple. These units produce high-quality methane streams without secondary chemical scrubbing solutions.

Figure 1: Typical biogas process flow



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

PRISM Membrane biogas separators contain thousands of tiny hollow fibers. Some gas molecules, like carbon dioxide and water vapor, permeate through the membrane walls while other molecules like methane are transported the length of the fibers and exit from the end of the separator.



PRISM membrane advantages

High selectivity to impurities

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

Robust construction

PRISM membrane separators are engineered to operate in harsh environments. Vibration and corrosive atmospheres have little effect on system integrity.

Modular designs

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

Easy production cycling

Systems containing PRISM membranes don't require a lengthy start-up or shutdown. Membranes are ready for processing instantly.

Removes water vapor

Most of the water vapor is vented off with the carbon dioxide. This eliminates the need to completely dry the gas with expensive pretreatment equipment before processing.

Resists hydrogen sulfide

Our membranes are engineered to be resistant to impurities that might cripple other systems.

Great value

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

Simple to operate

PRISM membranes are a passive technology that doesn't require complex monitoring systems. This means that you don't need a degree in chemical engineering to operate them, nor pay a technician to manage their operation.

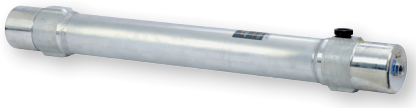
Competing technologies

Membrane technology is not the only way to separate methane from a biogas stream. Each system has distinct advantages and disadvantages for each application. The primary objectives of biogas upgrading are to remove carbon dioxide, hydrogen sulfide, and water vapor.

Technology description	Advantages	Disadvantages
Wash water scrubbing Compressed raw biogas is fed into a packed tower where CO_2 is dissolved into a counter-current stream of water. The saturated water is fed into a flash tank where the CO_2 is stripped off by an air stream and the water recycles to the tower. Power consumption 0.25 to 0.30 kW/Nm3 raw biogas.	Good technology where wash water is abundant. Also more efficient in cold climates as colder water increases CO_2 solubility. Able to process large volumes of gas. One percent methane loss to CO_2 vent stream.	Recirculated water systems experience biofouling and require removal of H_2S and CO_2. 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. Power consumption 0.65 to 0.70 kW/Nm3 raw biogas.	Higher selectivity than water reduces pumping requirements. Removes CO_2, H_2S, 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 filled with a carbon sieve under pressure. The CO_2 and H_2S molcules 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. Power consumption 0.27 to 0.32 kW/ Nm3 raw biogas.	Excellent 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-tube, membrane fibers. Fast gases permeate the membrane walls while slow gases exit the hollow tube. Power requirement 0.25 to 0.30 kW/Nm3 per hour of raw biogas.	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. Power requirement 0.25 to 0.30 kW/Nm3 per hour of raw biogas.	Energy required to heat gas plus compression. Requires H2S pretreatment to reach ppm levels in product gas.

PRISM membrane options for biogas upgrading

PB6050 Separator



High Methane Recovery Configuration

		Raw biogas	Biomethane	Vent
Composition				
Methane	mol%	55.0	98.0	0.3
Carbon Dioxide	mol%	45.0	2.0	99.7
Flow	nm^3/hr	60.0	33.6	26.4
Pressure	barg	12.0	11.8	0.0

Power = 0.22 $kW/nm^3/hr$ raw biogas
Methane recovery = 99.8%

Low Power Configuration

		Raw biogas	Biomethane	Vent
Composition				
Methane	mol%	55.0	98.0	7.0
Carbon Dioxide	mol%	45.0	2.0	93.0
Flow	nm^3/hr	120.0	63.3	56.7
Pressure	barg	12.0	11.8	0.0

Power = 0.15 $kW/nm^3/hr$ raw biogas
Methane recovery = 94%

Ordering information

Catalog number	Model number	End cap connection	Vent port connection
428294	PB6050-P3-8C-D6	1-inch SAE	$1^1/_2$-inch NPT
428295	PB6050-P3-8B-D7	1-inch BSPP	$1^1/_2$-inch BSPP

* Systems typically include multiple modules in parallel for greater flow rate and in series for greater purity requirement.

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

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The Air Products PRISM Membranes Business Unit's quality management system is certified to ISO9001 and AS9100C.

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