



# ACTIVATED CARBON FOR BIOGAS PURIFICATION

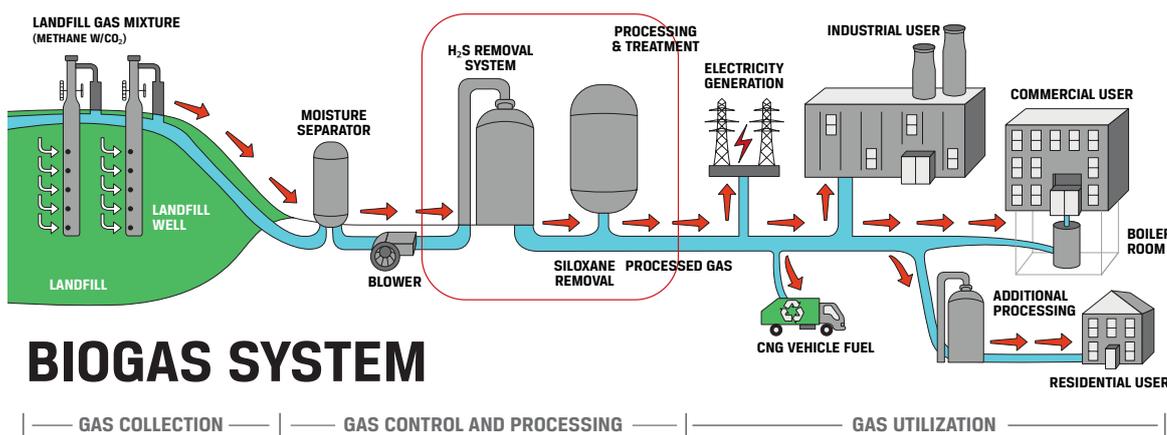


# BIOGAS: AN ECO-FRIENDLY SOURCE OF ENERGY

Biogas is growing in importance as an eco-friendly source of energy. It can be naturally produced from the decomposition of organic waste through a biochemical process, such as anaerobic digestion, or through thermochemical means such as landfills. As more uses for biogas are found, gas purity is a critical consideration. Biogas purity is essential for the protection of downstream equipment such as engines, membranes and fuel cells. Biogas purity standards are also being set for emerging applications such as renewable natural gas generation and vehicle fuel.

## Damaging and Unwanted Impurities in Biogas

Impurity	What is it?	Why remove it?
Hydrogen Sulfide (H <sub>2</sub> S)	A hazardous chemical compound present in biogas derived from agriculture, wastewater treatment, and landfills	Carries a foul odor, poisonous, corrosive, and flammable
Siloxanes	Man-made organic compounds often found in landfills and wastewater treatment facilities	Cause significant damage, destruction, and reduced efficiency to engines, turbines, fuel cells, and catalysts
Volatile Organic Compounds (VOCs)	Organic chemical compounds often found in biogas derived from agriculture, landfills, and wastewater treatment facilities	Cause significant damage to membranes and contributes to SO <sub>x</sub> and NO <sub>x</sub> emissions



We supply a diverse portfolio of activated carbon grades to purify biogas from undesirable compounds like hydrogen sulfide (H<sub>2</sub>S), siloxanes, and volatile organic compounds (VOCs). For example, our non-impregnated DARCO® BGI granular steam activated carbon offers superb H<sub>2</sub>S loading capacity and remains operationally efficient to change out enabling "total cost for H<sub>2</sub>S removal" improvement. Our NORIT® SILPURE™ activated carbon surface chemistry enables it to capture both large molecular weight siloxanes and difficult to remove small molecular weight siloxanes. NORIT RB4 activated carbon has the ideal pore structure for optimal removal of halogenated VOCs, which cause swelling in biogas upgrading membranes. All of our specialty activated carbon products are designed for the efficient removal of these challenging impurities making them ideal for biogas producers who require a lower cost for impurity removal and improved profitability.

## HYDROGEN SULFIDE REMOVAL

Hydrogen sulfide (H<sub>2</sub>S) is typically present in biogas, although concentrations vary based on feedstock. Waste streams that are high in proteins containing sulfur-based amino acids (methionine and cysteine) can significantly influence biogas H<sub>2</sub>S levels. The H<sub>2</sub>S contained in biogas causes odors, equipment corrosion and sulfur emissions when the gas is burned, and is dangerous for human and animal health.

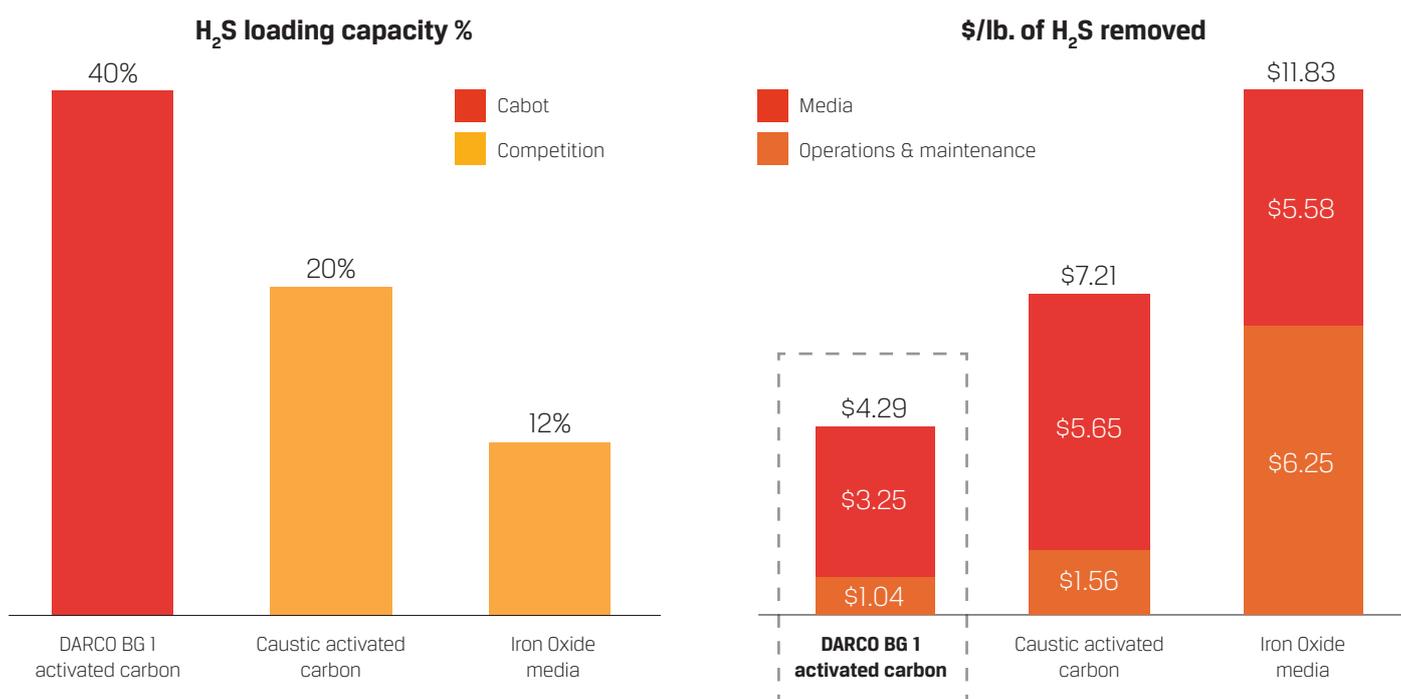
If the biogas is to be used in internal combustion engines, turbines or fuel cells, the removal of H<sub>2</sub>S from the biogas is recommended to protect the equipment. Purifying biogas and concentrating the methane also require the removal of carbon dioxide, water and other contaminants before it can be called biomethane and used interchangeably with natural gas.

Our family of DARCO® BG high performance granular activated carbons were developed specifically for removing H<sub>2</sub>S from biogas streams. Produced by a proprietary high temperature steam activated process which doesn't use any impregnate, the risk of bed fires due to exothermic reactions is greatly reduced.

DARCO BG activated carbons are a high performance, cost-effective solution for H<sub>2</sub>S removal and offer many benefits:

- ◆ Lower cost of H<sub>2</sub>S removed
- ◆ Longer bed life
- ◆ Less disposal costs
- ◆ Chemistry that is not conducive to bricking
- ◆ Low dust emission during handling
- ◆ Easy to load and remove

In the figure below, the bar graph on the left shows the H<sub>2</sub>S loading capacity of each competitive product. NORIT DARCO BG 1 activated carbon provides two times the loading capacity compared to caustic activated carbon and iron oxide media. The bar graph on the right shows the average \$/lb. cost of removing H<sub>2</sub>S for each product. Based on its much higher removal capacity, this graph illustrates how much more cost effective NORIT DARCO BG 1 activated carbon is to use.



For cost effective removal of H<sub>2</sub>S in biogas environments that require very low pressure drop, we recommend NORIT ROZ3 activated carbon. NORIT ROZ3 activated carbon has also been designed for environments exhibiting low relative humidity less than 80%.

### Our product portfolio Biogas - H<sub>2</sub>S removal

Product	H <sub>2</sub> S loading %	Pressure drop	Performance at < 60% relative humidity	Cost/kg of H <sub>2</sub> S removed
DARCO® BG 1 activated carbon	●	●	●	●
DARCO BGH activated carbon	●	●	●	●
NORIT® ROZ 3 activated carbon	●	●	●	●
NORIT® ROZ 4W activated carbon	●	●	●	●

● Best   ● Better   ● Good   ● Fair   ○ Poor

# SILOXANE REMOVAL

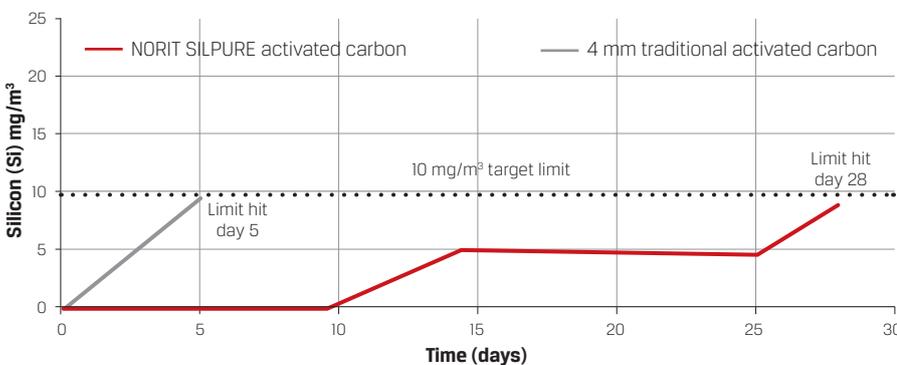
Siloxanes are a group of man-made organic compounds used to produce personal hygiene, health care and industrial products. This class of impurities presents a significant challenge along with volatile organic compounds (VOC) to operational efficiencies and costs in biogas production. Widespread use of siloxanes has contributed to significant amounts of impurities found in wastewater and landfills. Even at levels of 0.5 PPM in raw biogas, siloxanes can cause significant damage to and reduced efficiency of engines, turbines, boilers, fuel cells and catalysts. Siloxane damage leads to higher costs and can seriously impact biogas upgrading.

NORIT SILPURE activated carbon uses proprietary technology to preferentially adsorb siloxanes over high BTU volatile organic compounds commonly found in biogas. This process increases loading capacity and gas purity is improved, resulting in lower maintenance costs, less frequent material change-outs, and increased gas processing capability.

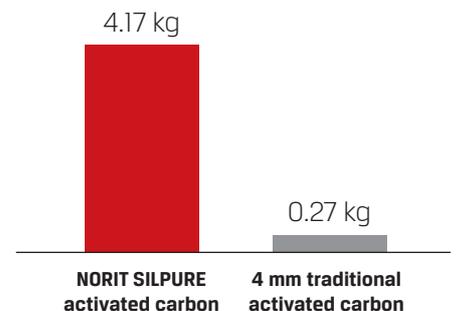
NORIT SILPURE activated carbon's surface chemistry:

- ◆ Removes 15 times more siloxanes in the field vs. traditional activated carbon
- ◆ Enables capture of both large molecular weight siloxanes and difficult to remove small molecular weight siloxanes
- ◆ Improves gas purity
- ◆ Increases loading capacity resulting in lower maintenance costs
- ◆ Increases service life 5 times over traditional activated carbon

## Field trial results from Suez's Packington Landfill in the United Kingdom



## Kilograms of siloxanes adsorbed per metric ton of activated carbon



**On an equal weight basis, NORIT SILPURE activated carbon has been shown to remove 15 times more siloxanes in the field**

	NORIT SILPURE activated carbon			4 mm traditional activated carbon		
Total # of kg	720			3000		
	Raw gas	Adsorbed	% Adsorbed	Raw gas	Adsorbed	% Adsorbed
Siloxanes (kg)	5.8	3.0	52%	5.8	0.8	12%
H <sub>2</sub> S (kg)	123	112	91%	123	25	22%

This data represent siloxane and H<sub>2</sub>S adsorption in actual field test conditions at Suez's Packington Landfill in the United Kingdom. Siloxane removal under lab conditions should be considered carefully, as labs may not accurately mimic real biogas conditions due to the large number of competing compounds present in the gas stream, including siloxanes, VOCs, H<sub>2</sub>S and other sulfur species. The physical adsorption of siloxanes becomes significantly more difficult in the field due to competitive adsorption dynamics, which is why we designed NORIT SILPURE activated carbon to have a specific affinity for the removal of siloxanes.

# VOLATILE ORGANIC COMPOUND REMOVAL

Biogas derived from landfill gas (LFG) and from agriculture and wastewater treatment facilities is usually heavily contaminated with volatile organic compounds (VOCs). As the market for biogas continues to shift from power generation to renewable natural gas (i.e. biomethane), the removal of halogenated VOCs has become extremely important to biogas upgrading systems and the effective operation of the system's gas permeation membranes. Membrane processes are one of the most effective means for removing carbon dioxide (CO<sub>2</sub>) to upgrade biogas and VOCs often contain essential oils (e.g. terpenes) that are harmful to the membranes themselves. In addition, these oils, at very low concentrations, give off a very strong odor. This strong odor can mask the effects of the odorants added to the upgraded gas as a safety requirement.

To prevent this, the VOCs in biogas are removed through the use of activated carbon. Our NORIT RB4 activated carbon has been optimized for highly efficient VOC adsorption to help biogas upgrading systems operate with the most precision. The removal of VOCs offers significant benefits which include:

- ◆ Membrane performance improvement
- ◆ Improved gas quality
- ◆ Greater operational efficiency
- ◆ Reduced operational costs
- ◆ Reduced downtime
- ◆ Increased volume of gas processed

## Our biogas product portfolio – siloxane/VOC removal

Product	Application	Siloxane loading %	VOC loading %	Pressure drop	Reduction in operational costs
NORIT SILPURE activated carbon	Engine site	●	◐	◐	●
NORIT RB 4 / RB 4W activated carbon	Biomethane	◐	●	●	◐
NRS CARBON EA 3-4 <sup>*)</sup>	Biomethane	◐	◐	◐	◐

<sup>\*)</sup> NRS CARBON EA 3-4 is a reactivated product and is available based on customer location

● Best ◐ Better ◑ Good ◒ Fair ○ Poor

<sup>\*)</sup> For optimal removal efficiency of H<sub>2</sub>S, siloxanes, and VOCs in a single filter, we recommend a layered media approach. Please contact your local application engineer for support.



We supply a diverse portfolio of activated carbon grades to purify the biogas from undesirable compounds like H<sub>2</sub>S, siloxanes and VOCs. Our activated carbon products are specifically designed for the removal of these challenging impurities, making us an ideal partner for biogas producers who require a lower cost of impurity removal and improved profitability.

# APPLICATION SUPPORT

Ongoing technical support is always close at hand at Cabot. Our application knowledge and expertise is always available to address your purification needs. We look forward to becoming your activated carbon partner.

If you have any questions or would like to obtain the following information, contact your nearest Cabot office:

1. An analysis of your activated carbon needs
2. Technical bulletins
3. Test information
4. Norit standard test methods (NSTM)
5. Specific application information
6. General information on activated carbon
7. Product information
8. Samples for testing

# PARTNERING WITH US

We are the world's oldest and most experienced producer of activated carbon. Our history of innovation allows us to provide the right solution to meet each customer's application needs and ensuring better performance than "off the shelf" products. Our products are manufactured in ISO certified facilities and backed by a global network of sales, technical service and customer support professionals.

# AHEAD OF THE CURVE ON PURIFICATION

Building on our 100-year history of innovation in manufacturing and product development, Cabot Norit Activated Carbon is the world's most experienced and one of the largest producers of activated carbon serving customers in more than 100 countries with manufacturing facilities in seven countries. Our products are used to efficiently and cost-effectively remove pollutants, contaminants and other impurities from water, air, food and beverages, pharmaceutical products and other liquids and gases. We have developed more than 150 different grades of activated carbon – produced from a variety of raw materials – that provide our customers with precise solutions for their specific application needs. Additionally, we offer a full range of activated carbon services including rental systems, carbon reactivation, bulk delivery and change-out, carbon evaluation and direct technical support.

Our sales, technical service and customer service teams are prepared to serve customers around the world. Contact us at [cabotcorp.com/activatedcarboncontact](http://cabotcorp.com/activatedcarboncontact)



[cabotcorp.com](http://cabotcorp.com)

**NORTH AMERICA**  
Cabot Norit Americas, Inc.  
3200 University Avenue  
Marshall, Texas 75670  
USA  
**T** +1 800 641 9245  
**F** +1 903 923 1035

**EUROPE, MIDDLE EAST & AFRICA**  
Cabot Norit Nederland B.V.  
Astronaut 34  
3824 MJ Amersfoort  
THE NETHERLANDS  
**T** +31 33 4648911  
**E** [amersfoort.info@cabotcorp.com](mailto:amersfoort.info@cabotcorp.com)

**ASIA PACIFIC**  
Cabot China Ltd.  
558 Shuangbai Road  
Shanghai 201108  
CHINA  
**T** +86 21 5175 8800  
**F** +86 21 6434 5532

**SOUTH AMERICA**  
Cabot Brasil Indústria e Comércio Ltda.  
Rua do Paraíso 148 – 5 andar  
Sao Paulo 04103-000  
BRAZIL  
**T** +55 11 2144 6400  
**F** +55 11 3253 0051

The data and conclusions contained herein are based on work believed to be reliable, however, Cabot cannot and does not guarantee that similar results and/or conclusions will be obtained by others. This information is provided as a convenience and for informational purposes only. No guarantee or warranty as to this information, or any product to which it relates, is given or implied. This information may contain inaccuracies, errors or omissions and CABOT DISCLAIMS ALL WARRANTIES EXPRESS OR IMPLIED, INCLUDING MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE AS TO (i) SUCH INFORMATION, (ii) ANY PRODUCT OR (iii) INTELLECTUAL PROPERTY INFRINGEMENT. In no event is Cabot responsible for, and Cabot does not accept and hereby disclaims liability for, any damages whatsoever in connection with the use of or reliance on this information or any product to which it relates.

NORIT and DARCO are registered trademarks of Cabot Corporation or its subsidiary.

©2018 Cabot Corporation. All rights reserved worldwide.