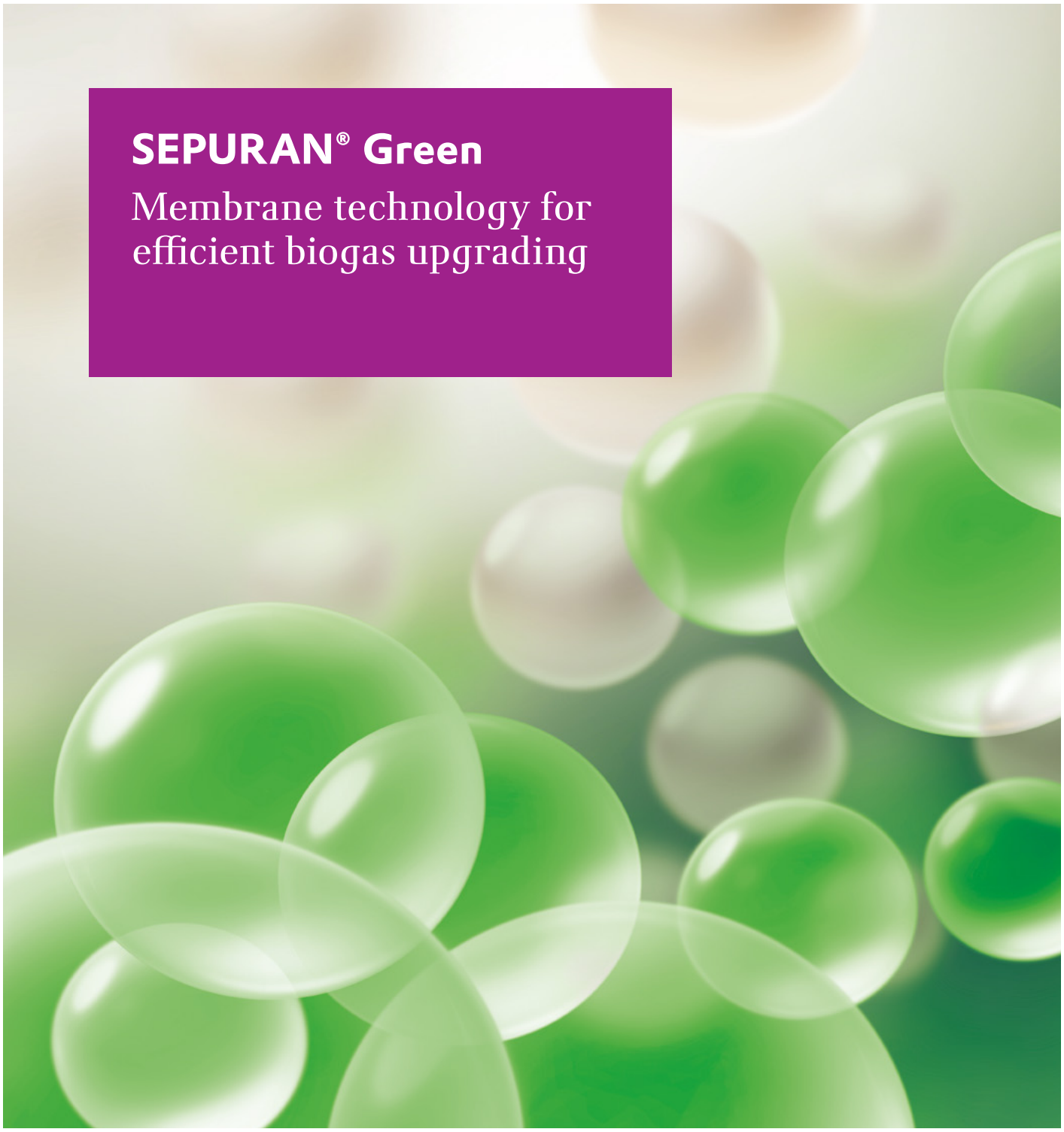
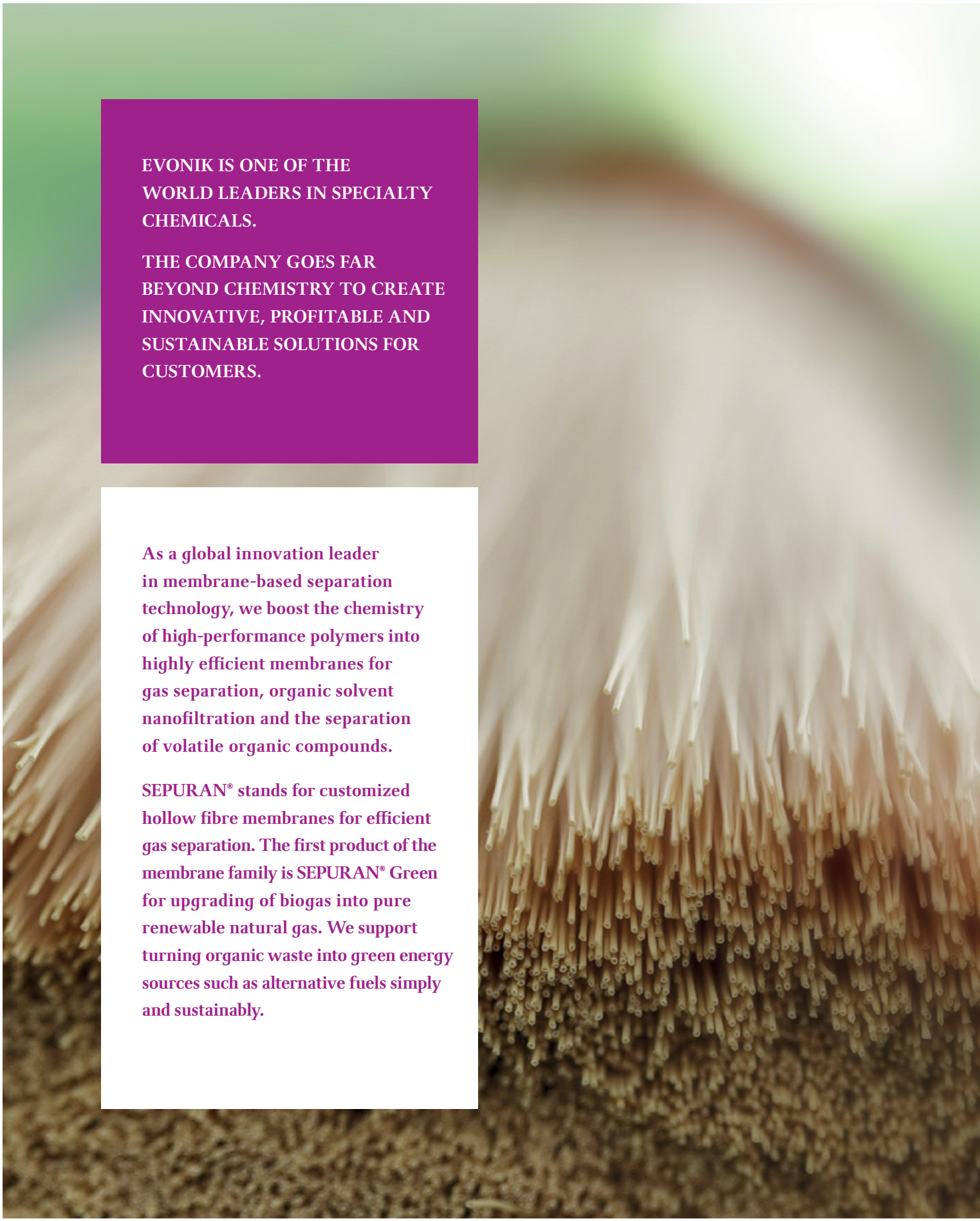


SEPURAN® Green

Membrane technology for efficient biogas upgrading

EVONIK
Leading Beyond Chemistry



EVONIK IS ONE OF THE WORLD LEADERS IN SPECIALTY CHEMICALS.

THE COMPANY GOES FAR BEYOND CHEMISTRY TO CREATE INNOVATIVE, PROFITABLE AND SUSTAINABLE SOLUTIONS FOR CUSTOMERS.

As a global innovation leader in membrane-based separation technology, we boost the chemistry of high-performance polymers into highly efficient membranes for gas separation, organic solvent nanofiltration and the separation of volatile organic compounds.

SEPURAN® stands for customized hollow fibre membranes for efficient gas separation. The first product of the membrane family is SEPURAN® Green for upgrading of biogas into pure renewable natural gas. We support turning organic waste into green energy sources such as alternative fuels simply and sustainably.

CONTENT

Don't waste the waste 4

Value chain 6

Substrates

Ways of using Bio-CO_2

Waste to fuel 8

Efficient biogas upgrading

How does the membrane work? 10

SEPURAN® Green product portfolio 11

Product overview

Latest generation G5X

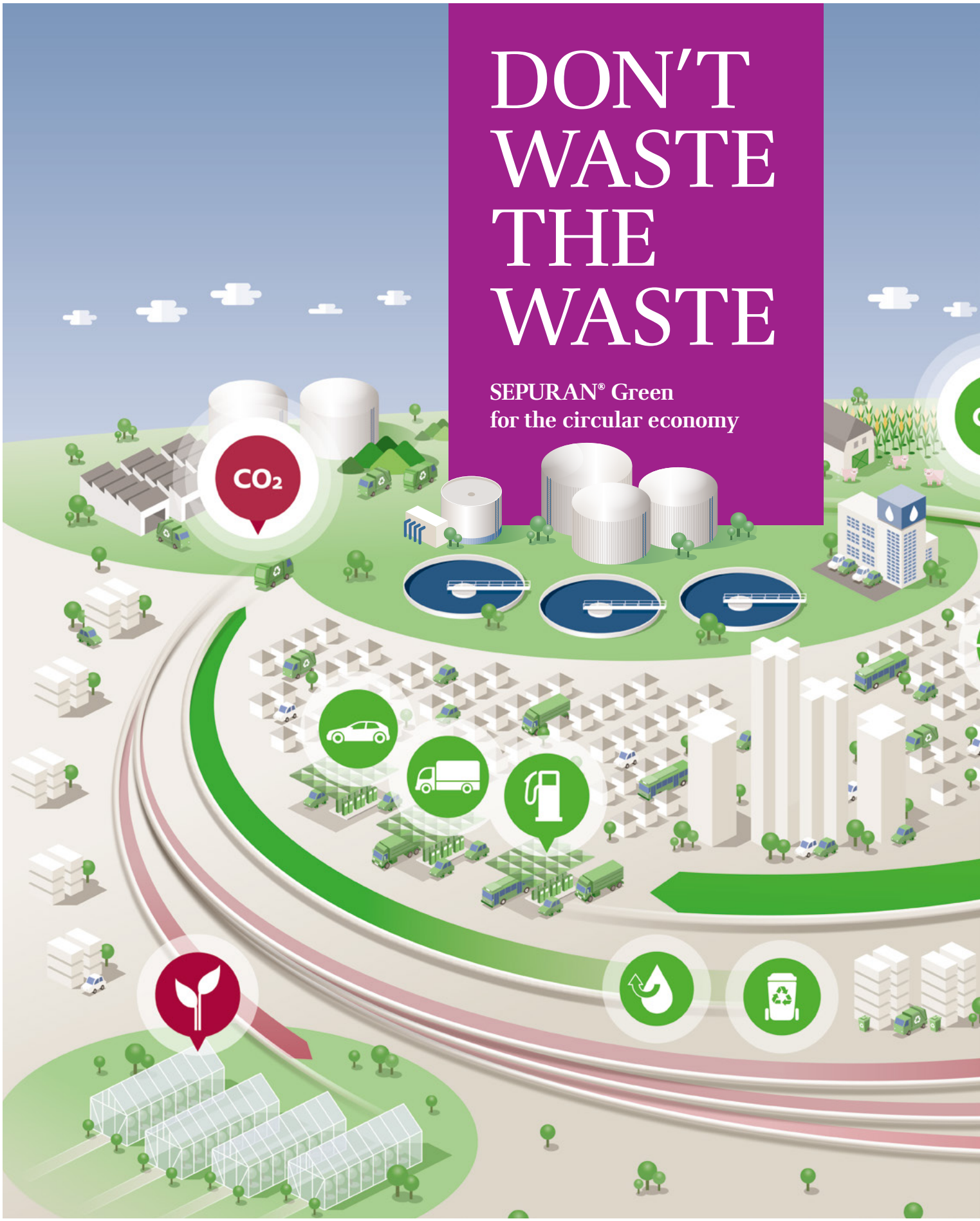
Process options 12

Patented 3-stage processes

References worldwide 14

GLOSSARY

Compressed Natural Gas	**CNG**
Liquefied Natural Gas	**LNG**
Renewable Natural Gas	**RNG**


DON'T
WASTE
THE
WASTE
SEPURAN® Green
for the circular economy
CO2


CH4
H2
CH4

SUBSTRATES

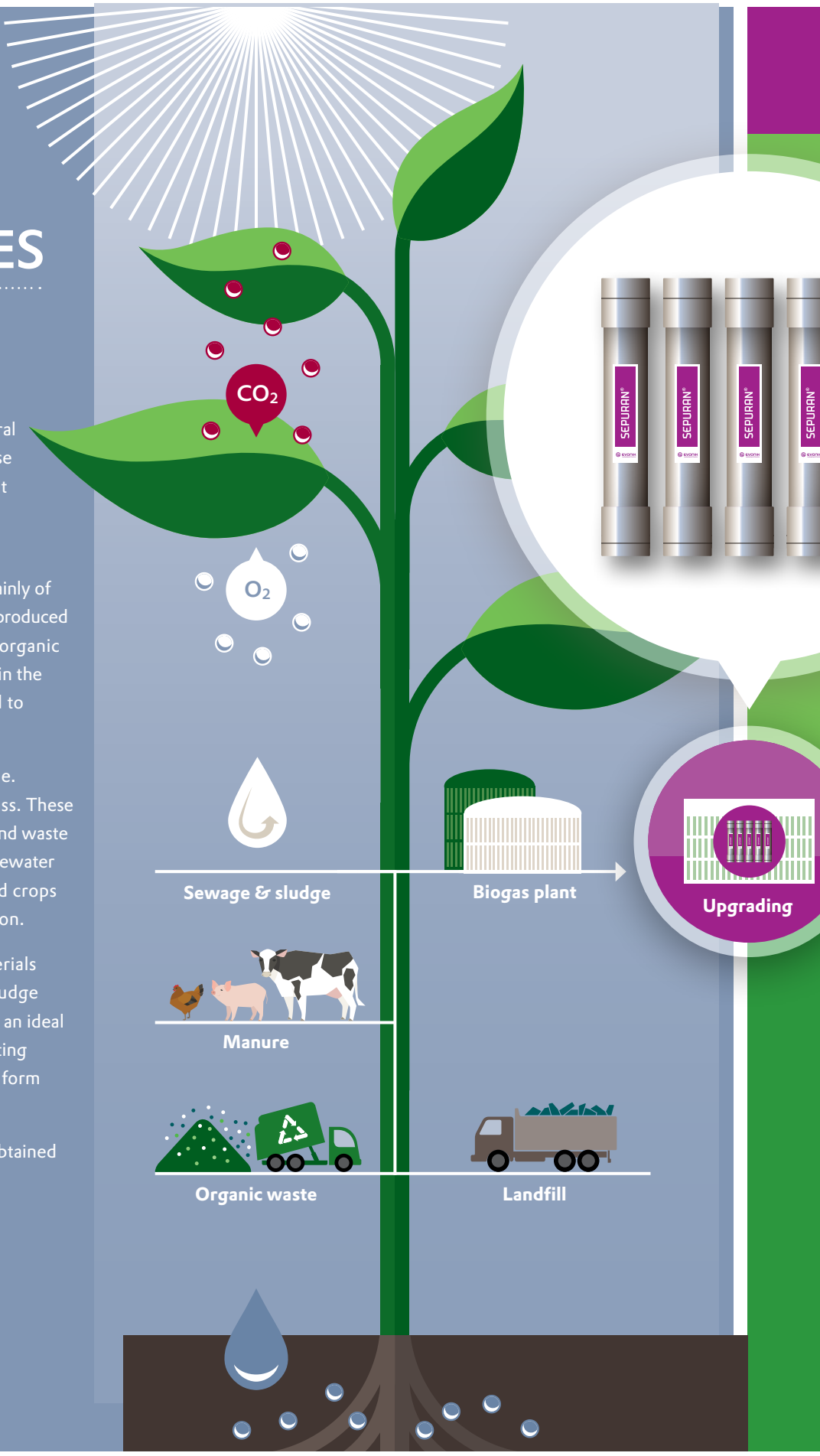
Renewable natural gas can make a significant contribution to reducing climate-damaging greenhouse gas emissions: It can replace fossil natural gas in numerous applications. Because it is chemically the same molecule, it is the climate-friendly and energy equivalent alternative.

Biogas is a gas mixture composed mainly of methane and carbon dioxide. This is produced by the microbial decomposition of organic (i.e. carbon-containing) substances in the absence of oxygen. This is referred to as anaerobic fermentation.

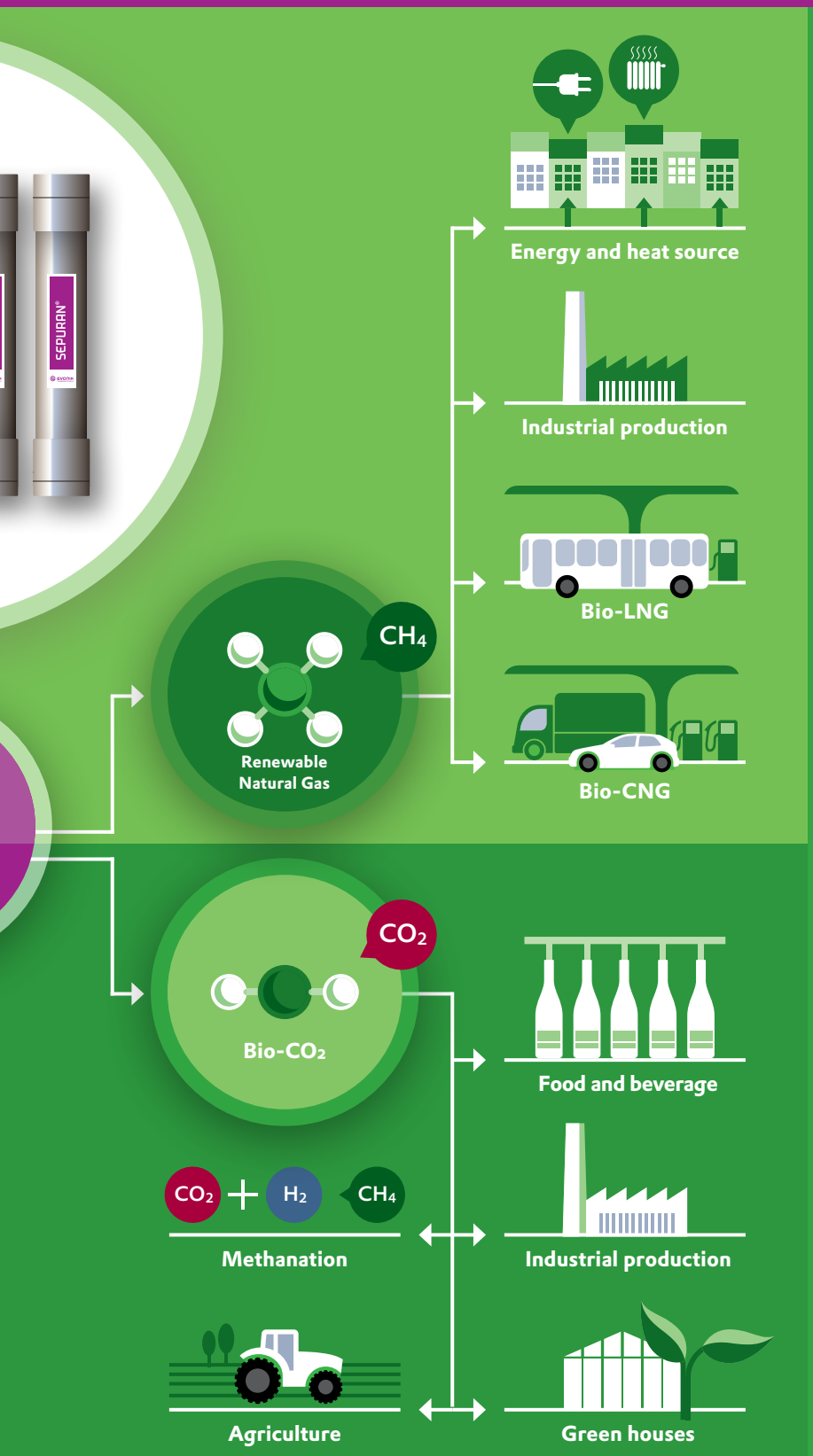
Feedstocks for biogas production (i.e. substrates) can be all types of biomass. These generally include manure, residual and waste materials, sewage sludge from wastewater treatment plants, plant residues and crops that are not used for food production.

The use of residual and waste materials such as liquid manure or sewage sludge from wastewater treatment enables an ideal circular economy in which the resulting biogas can be used regionally in the form of heat, electricity and fuels.

Renewable natural gas can also be obtained from the processing of landfill gas.



VALUE CHAIN



WAYS OF USING BIO-CO_2

At the beginning of the CO_2 cycle is photosynthesis. In this process, plants draw the carbon dioxide from the atmosphere and, together with water, minerals and sunlight, transform it into organic mass – it is thus taken from the atmosphere and bound. The anaerobic fermentation of this organic mass produces biogas.

Highly efficient purification of the biogas using Evonik's membrane technology produces two high-purity products: renewable natural gas and Bio-CO_2.

Renewable natural gas is the energy equivalent alternative to fossil natural gas. It has the same material and energy properties but is renewable. The renewable natural gas cycle is sustainable and does not release any additional fossil greenhouse gas emissions. It can thus be used in many ways: materially in chemical production, energetically as a heat source or even as a fuel in the form of Bio-CNG and Bio-LNG. In integrated systems, biogas or renewable natural gas can be used to power the entire process. By feeding it into the gas grid, it can also be stored and transported.

The use of Bio-CO_2 is not yet widespread. Liquefaction of the gas offers the possibility of making the high-purity CO_2 usable and storable. Bio-CO_2 can then be used in greenhouses to promote plant growth or in the food and beverage industries as a raw material for industrial production. It can also be used for methanation, a process in which the Bio-CO_2 reacts with hydrogen to produce synthetic methane.

Evonik makes it possible to turn organic waste into green energy.

Efficient biogas upgrading

Using the innovative membrane technology from Evonik, biogas released during wastewater treatment or the anaerobic digestion of household waste can be upgraded simply and efficiently to pure renewable natural gas and fed directly into the natural gas grid or used as alternative fuel.

WASTE TO FUEL

Evonik is a technology leader in high-performance polymers. We offer hollow fibre membranes for efficient and energy-saving gas separation.

Evonik makes it possible to turn biomass such as organic waste into alternative fuels. Biogas can be easily upgraded to renewable natural gas and used locally in liquid (Bio-LNG) form as a climate-friendly fuel. The decentralized supply of Bio-LNG shortens the transport distances of the fuel and reduces transport costs.

The use of regionally available substrates makes it possible to provide the fuel from the region for the region. Furthermore, new jobs are created along the local value chain.

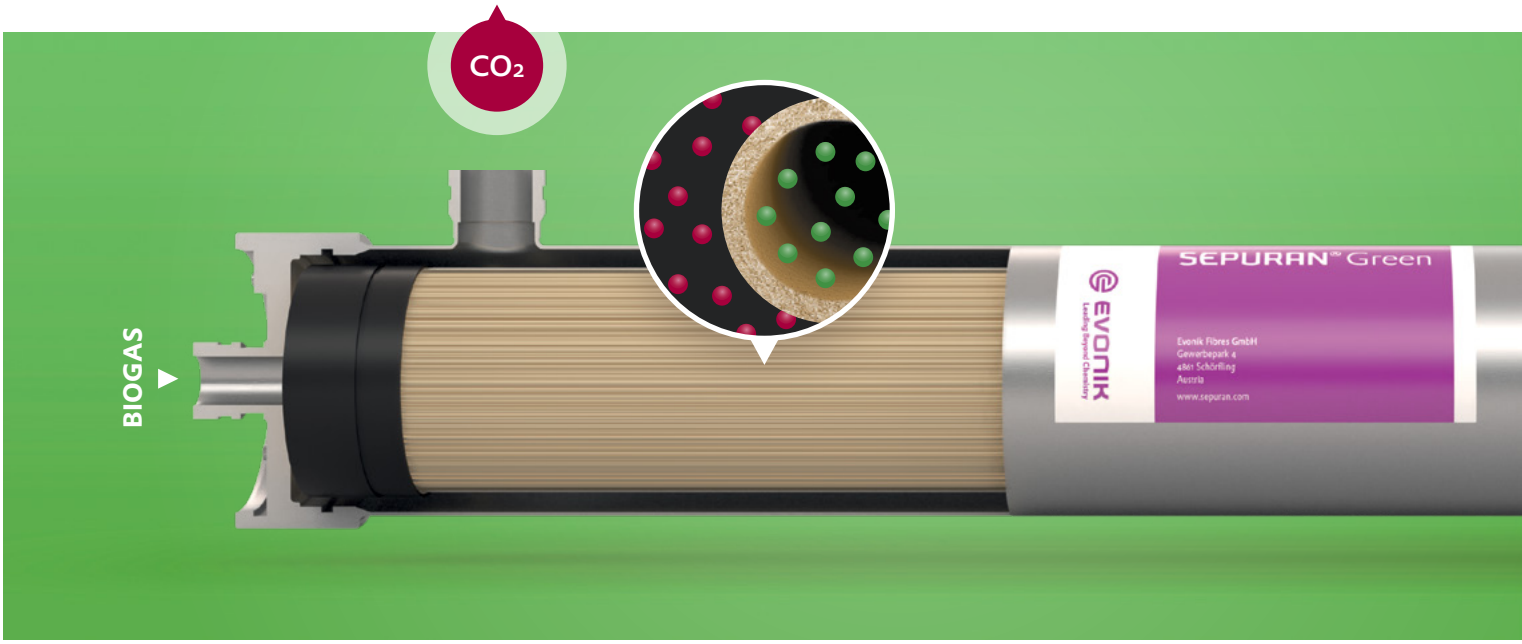
Another advantage of the decentralized production of Bio-LNG as fuel alternative is to reduce the dependency on other countries with respect to the import of fuels and energy.

Compared with other alternatives in transport in the context of climate-neutral mobility, renewable natural gas is already successfully in use today, accessible in relevant quantities, and makes considerable contribution to the defossilization of freight transport.

The environmental benefits of renewable natural gas as a climate-friendly fuel are obvious: in comparison to diesel engines, gas-powered vehicles:

- emit up to 80% less CO_2 than conventional diesel engines*
- release around 99% less fine dust particles
- reduce nitrogen oxide emissions by around 90%
- emit around 50% less noise

* well-to-wheel; https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2019/dena-Studie_Bio_LNG.pdf



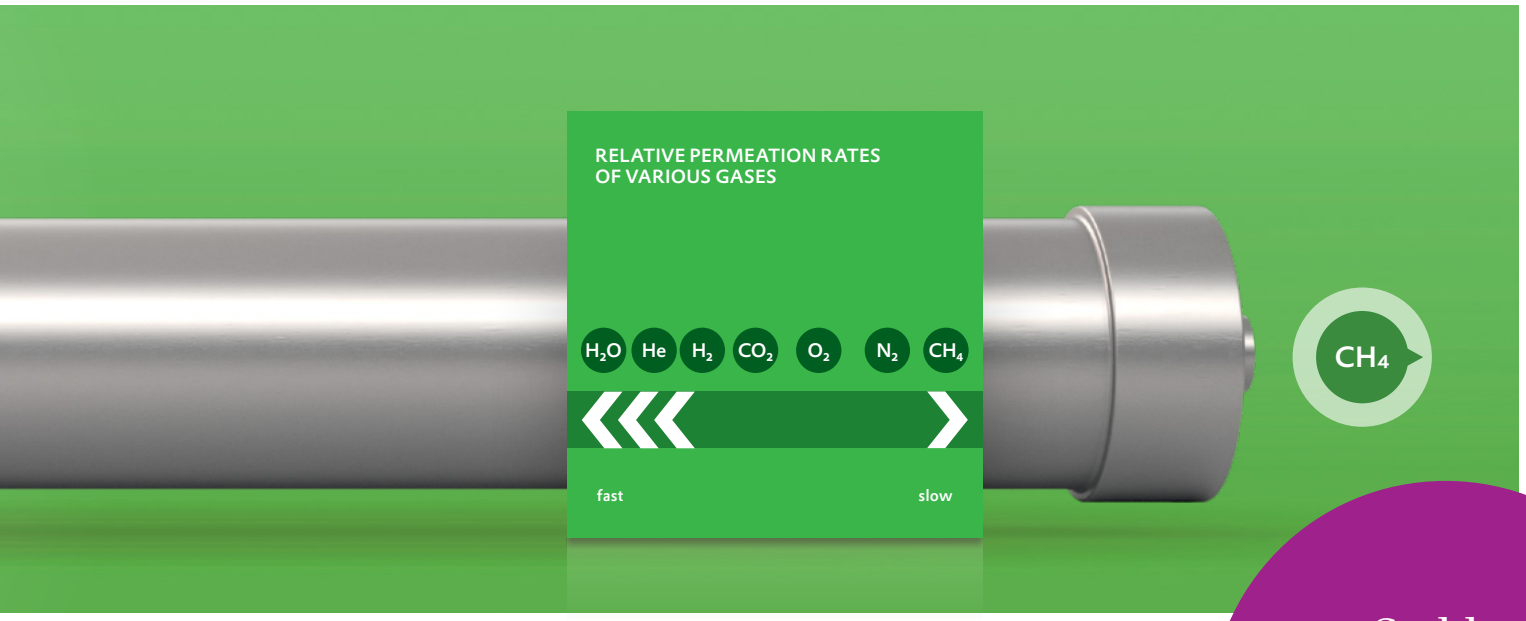
HOW DOES THE MEMBRANE WORK?

Gas separation membranes work on the principle of selective permeation through a membrane surface. The driving force for permeation of the gas through the membrane is the difference between the partial pressures of the gas on the retentate side (the interior of the hollow fibre) and the permeate side (the exterior of the hollow fibre).

The greater this difference, the higher the proportion of the gas that permeates the membrane. In a separation such as between carbon dioxide and methane, the permeation of carbon dioxide through the membrane is much faster, while methane is retained. The driving force required for the separation is obtained through a partial pressure gradient.

The permeation rate of each gas depends on its solubility in the membrane material as well as on the diffusion rate. Gases that have higher solubility and smaller molecular size permeate the membrane faster than larger, less soluble gases. The ratio of the transport speeds of two gases is referred to as selectivity.

The higher the selectivity, the higher the energy efficiency of the resulting membrane process.



Stable performance of more than 10 years!

THE SEPURAN® GREEN SYSTEM

Benefits

- Lower energy consumption through recycle rates of 30 - 40%
- H_2S Tolerance up to 3%
- No auxiliary materials such as water or sorbents required
- No emissions into the environment
- Separation at ambient temperature is possible
- Low space requirements
- Continuous separation process
- Simple, modular set-up
- Flexible and easily expanded
- Very high selectivity and high purity
- High yields of > 99%

Latest fibre generation G5X available in different sizes

4", 6" and 6" long!

The SEPURAN® Green membrane cartridge consists of several thousand hollow fibres manufactured from high-performance polymers and wrapped in a stainless steel casing. The ends are embedded in a resin. The membrane cartridge is contained in a stainless steel pressure vessel. The cartridge and housing together comprise the SEPURAN® Green membrane module.

The membrane module can now withstand a pressurised gas mixture in which multiple modules can be piped together. The simple, easy-to-handle set-up results in a compact upgrading plant.

At present, the stainless steel housings manufactured for the SEPURAN® Green cartridges are made to conform to the respective country-specific regulations. This allows plant construction companies to adapt flexibly to local pressurized equipment regulations. Housings for pressures of up to 20 barg (290 psig) and 25 barg (363 psig) are available.

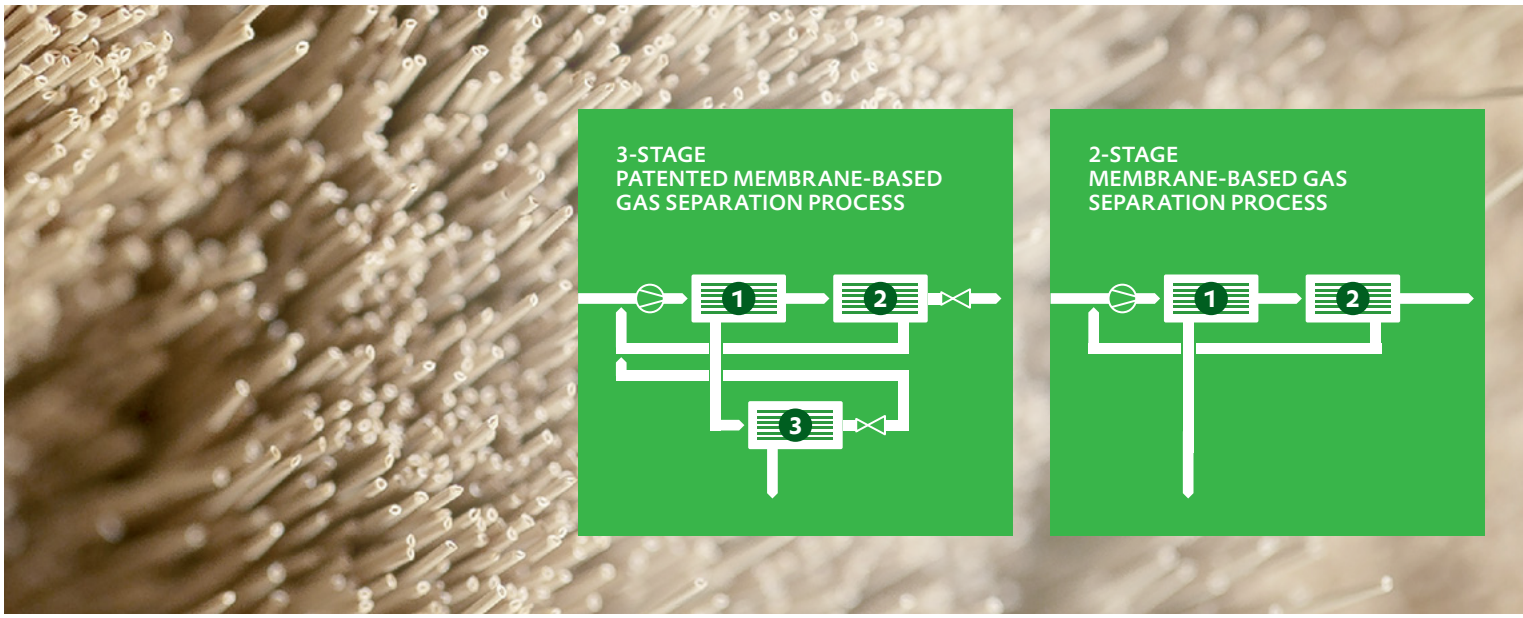
Today, Evonik offers SEPURAN® Green membranes and cartridge systems for biogas upgrading in various sizes. Choices of 4" or 6" diameter membranes are available for plants of all sizes.

LATEST GENERATION G5X

SEPURAN® Green G5X stands for the latest membrane generation and complements the current product portfolio for Biogas upgrading.

The innovative G5X fibre combines high selectivity and high capacity. This results in higher performance at lower cost.

The product is available in three different sizes in order to cover different project scales and to provide the optimum individual solution from farm-scale to industrial-scale projects.



MARKET AND PROJECT SPECIFIC PROCESS OPTIONS

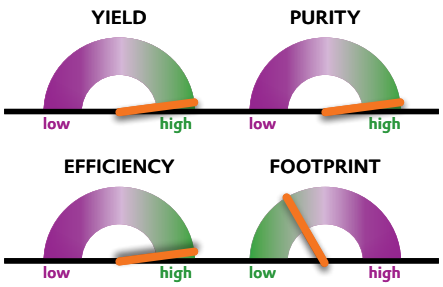
The market entry of Evonik into the Biogas upgrading industry in 2011 revolutionized the market and set new technology standards. The introduction of a highly selective SEPURAN® Green membrane in combination with a patent protected 3-membrane-stage process allowed for high methane yields and high product purities with an optimized energy consumption.

The more common 2-membrane-stage process, especially in capex sensitive markets, is gradually being displaced by the highly efficient 3-stage process.

Highest efficiency with 3-stage SEPURAN® Green

Markets asking for high efficiency and maximizing output choose the patented 3-stage process

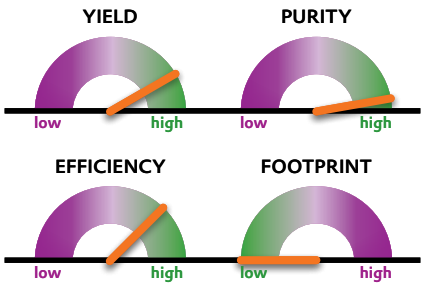
The preferred Evonik patented solution with more than 1000 references worldwide minimizes the loss of valuable renewable natural gas and therefore maximizes the amount of sales gas. The simplicity of a single compressor solution with the minimum recycle flow required provides the lowest maintenance and highest uptime. With its patented 3-stage membrane-based gas separation process, Evonik has set new European efficiency standards for biogas upgrading.



Optimized economics with SEPURAN® Green R2X

Markets desiring a lower up-front investment with simple process designs and fewer control parameters have the option of the 2-stage process

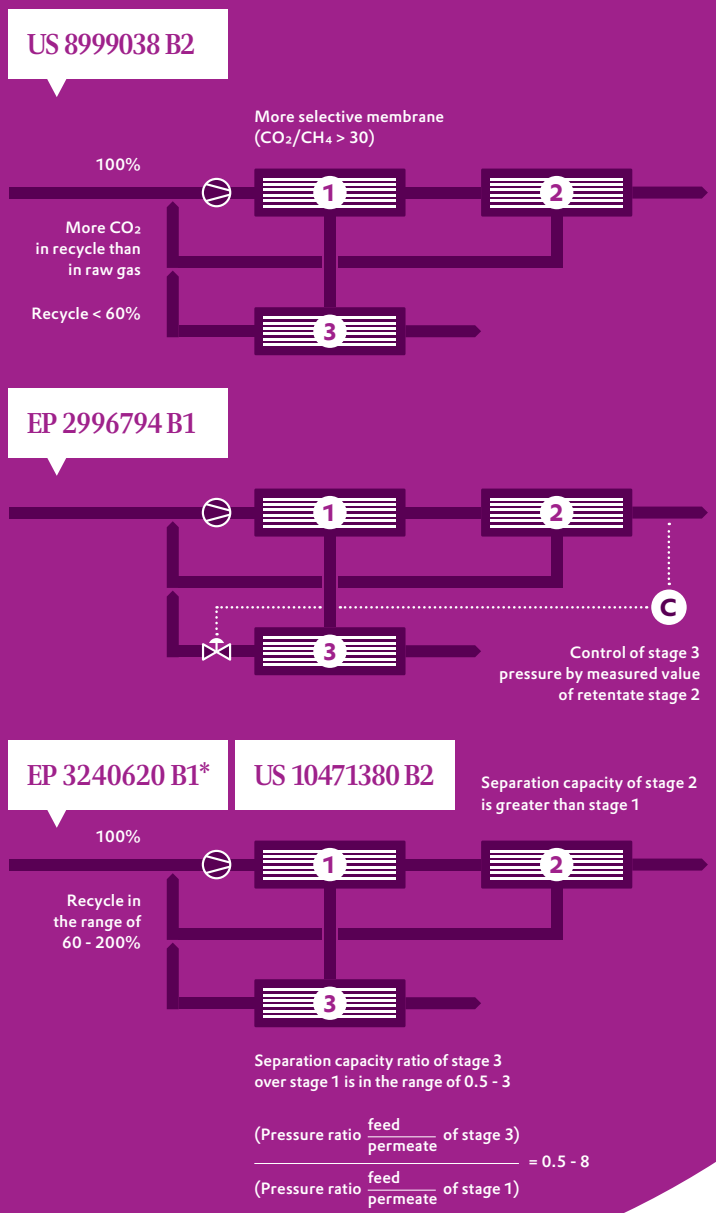
Good yields and a process optimized for capital-cost can be achieved with a 2-stage process delivering good efficiency (<2% methane slip) at lower cost and smaller footprint.



3-STAGE PROCESS

Find more information about the patent status on:

www.evonik.com/3-stage-patent



Patented 3-step membrane process

The 3-step membrane process developed by Evonik is patented in all major European markets in addition to the Americas and Asia.

At the core of the separation process are the innovative hollow fibre membranes of Evonik's SEPURAN® Green brand. These consist of a high-performance polymer, developed by Evonik, which can withstand high pressure and temperatures. The membranes also have excellent selectivity. In combination with the 3-stage separation process, recycling streams can be minimized. This helps to optimize the energy costs of biogas processing plants because only one compression step is needed. In addition, yields of above 99% can be achieved.

Evonik is cooperating with a selected group of strategic partners who integrate the SEPURAN® Green membranes into their plant design and engineering and ultimately become part of the turnkey Biogas upgrading plant. The Evonik partners are entitled to offer systems that can be operated with the 3-stage process developed and patented by Evonik and which make optimum use of the SEPURAN® Green membrane separation properties.

The protected process allows for highly efficient operation with high yields and reduced operational costs. Evonik partners can be recognized by the SEPURAN® Green certificate.

MORE THAN 1000 REFERENCES WORLDWIDE

As of: July 2023

More than 100 references in the Americas

USA, Wisconsin

- Manure
- 560 Nm^3/h (350 scfm)
- Grid injection

USA, Hawaii, Honululu

- Wastewater
- 600 Nm^3/h (370 scfm)
- Grid injection

USA, Lawrence, KS

- Landfill
- 2,500 Nm^3/h (1,600 scfm)
- Grid injection

France, Toulouse

- Wastewater
- 1,600 Nm^3/h (1,000 scfm)
- Grid injection

France, Germigny

- Crops
- 300 Nm^3/h (200 scfm)
- Grid injection

Sweden, Jönköping

- Organic waste manure
- 430 Nm^3/h (270 scfm)
- Bio-CNG production

China, Penglai City

- Chicken
- 1,500 Nm^3/h (950 scfm)
- Bio-CNG production

Korea, Seoul

- Wastewater
- 1,500 Nm^3/h (950 scfm)
- Grid injection

Italy, Verolanuova (BS)

- Agricultural by-products and zootechnical waste
- 550 Nm^3/h (340 scfm)
- Bio-LNG production

Number of plants

1-10 11-30 31-50 > 50

Take a look at our interactive reference world map!

This information and all technical and other advice are based on Evonik's present knowledge and experience. However, Evonik assumes no liability for such information or advice, including the extent to which such information or advice may relate to third party intellectual property rights. Evonik reserves the right to make any changes to information or advice at any time, without prior or subsequent notice.

EVONIK DISCLAIMS ALL REPRESENTATIONS AND WARRANTIES, WHETHER EXPRESS OR IMPLIED, AND SHALL HAVE NO LIABILITY FOR MERCHANTABILITY OF THE PRODUCT OR ITS FITNESS FOR A PARTICULAR PURPOSE (EVEN IF EVONIK IS AWARE OF SUCH PURPOSE) OR OTHERWISE. EVONIK SHALL NOT BE RESPONSIBLE FOR CONSEQUENTIAL, INDIRECT OR INCIDENTAL DAMAGES (INCLUDING LOSS OF PROFITS) OF ANY KIND.

It is the customer's sole responsibility to arrange for inspection and testing of all products by qualified experts. Reference to trade names used by other companies is neither a recommendation nor an endorsement of the corresponding product and does not imply that similar products could not be used.

® = registered trademark

Evonik Fibres GmbH
Gewerbepark 4
4861 Schörfling
Austria

PHONE +43 7662 6006-0
sepuran@evonik.com

www.sepuran-green.com
www.evonik.com

Evonik Corporation
2 Turner Place
Piscataway, NJ 08854
United States

PHONE +1 973 929-8000

Evonik Specialty Chemicals (Shanghai) Co., Ltd.
55 Chundong Road
Xinzhuang Industry Park
Shanghai 201108

08-23/US

EVONIK
Leading Beyond Chemistry