Dynamic Adsorption Symposium 2019
14 May, Leipzig, Germany

sysadvance®

Industrial Application of Adsorption-based Gas Separation Processes

Patrick Bárcia R&D Manager

THE COMPANY

- Founded in **2002 as Spin-off of U. PORTO**
- High specialization in **gas separation processes**
- Strong experience in several sectors of industry and provides turnkey solutions for industrial gases generation
- World leader in **VPSA technology portfolio**
- **+ 3000 PSA systems installed** worldwide | Present in **+ 40 countries**

N_2 | O_2 | O_2 VSA | MEDICAL O_2 GENERATORS | BIOGAS | He | H_2 | SF_6 PURIFICATION

SYSADVANCE is present today in +40 countries, rendering a solid growth

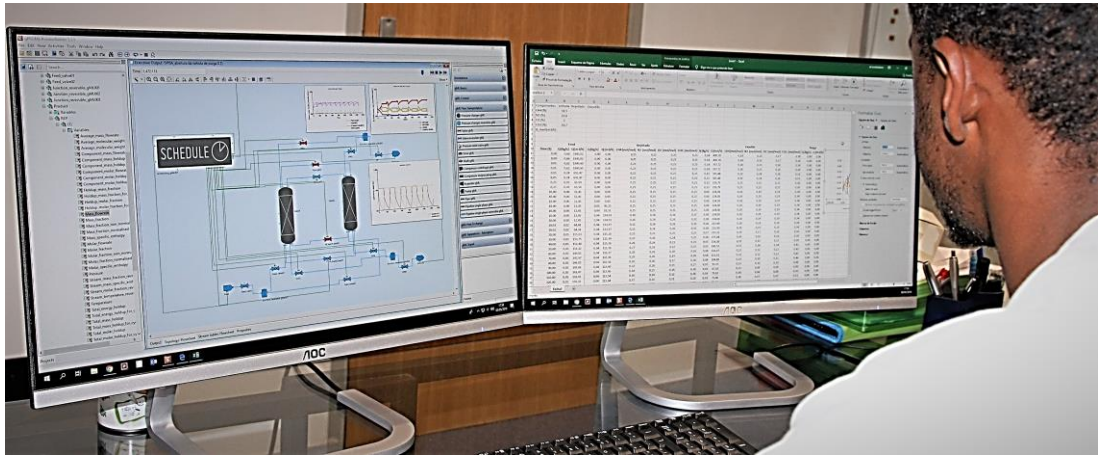
SOME REFERENCE PLANTS IN THE INDUSTRY SECTOR

sysadvance®

FIELDS OF ACTION

sysadvance®

RESEARCH & DEVELOPMENT | ENGINEERING & DESIGN | MANUFACTURE | SERVICE



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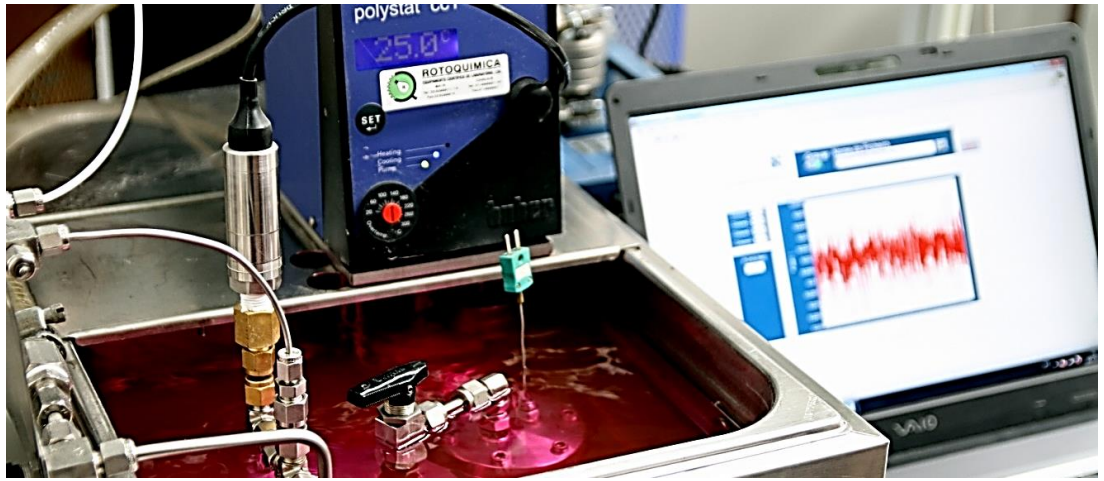
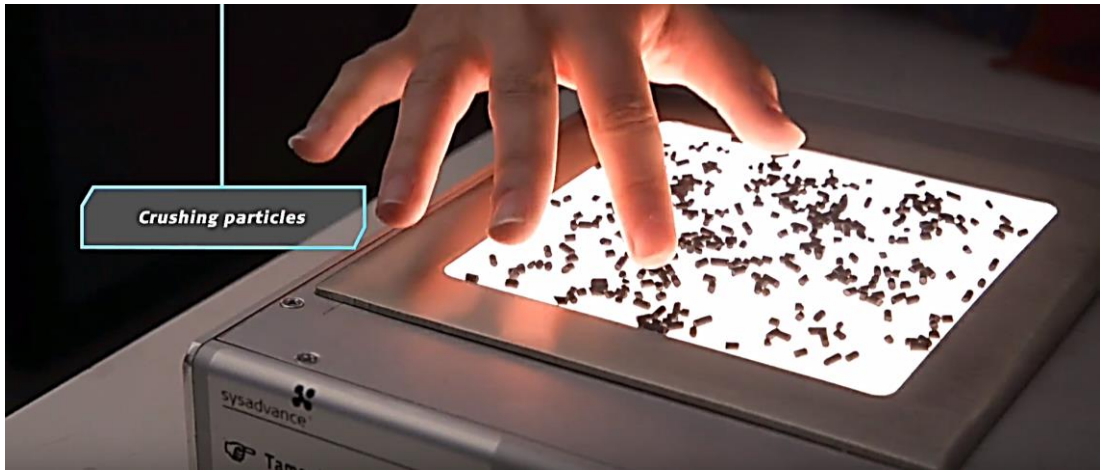
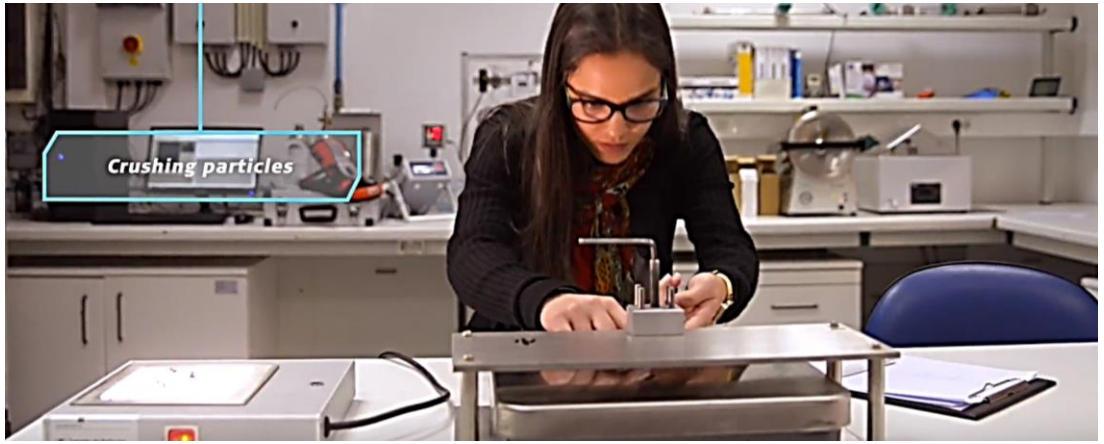
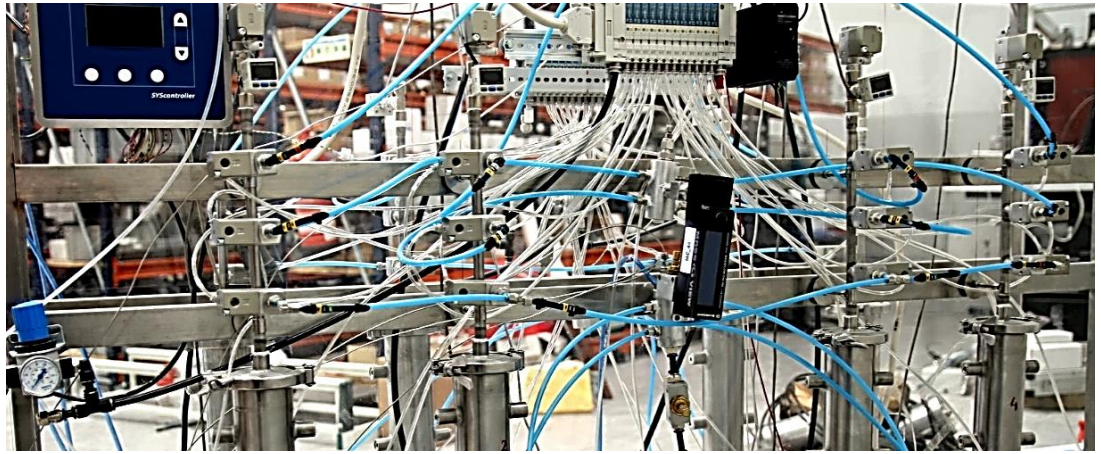
R&D | LAB FACILITIES FOR ADSORBENT CHARACTERIZATION & CYCLE TESTING









BUSINESS AREAS

INDUSTRIAL

MEDICAL

ENERGY

PROCESSES PORTFOLIO

sysadvance®

AIR *to* **N2**  *NITRO*GEN PSA

AIR *to* **O2**  *OXY*GEN PSA

AIR *to* **O2**  *OXY*GEN VSA

AIR *to* **O2**  *OXY*GEN$_{bio}$

LOW PURITY **NITROGEN** *to*  *ULTRA PURE N2* **DEOXO**

RECYCLED **HELIUM** *to*  *REUSABLE* He *HELISYS*

BIOGAS *to*  BIOMETHANE *METHA*GEN®

LANDFILL GAS *to*  BIOMETHANE *METHA*GEN®$_{2S}$

*METHA*GEN **ADD-ON** *for*  100% RECOVERY ZERO EMISSIONS *METHA*BOOST

BIOGAS WASTE STREAM *to*  CO2 *CARBO*GEN

FLUE GAS *to*  CO2 *CARBO*GEN

INDUSTRIAL PRODUCTS - OXYGEN from AIR (PSA)

sysadvance®

- Purity up to 95vol% O2
- OPEX [0.8 to 1.1 kWh/Nm3]
- Wide range of production capacity

- 2nd stage available for 99 vol% O2

INDUSTRIAL PRODUCTS - OXYGEN from AIR (VSA)

sysadvance®

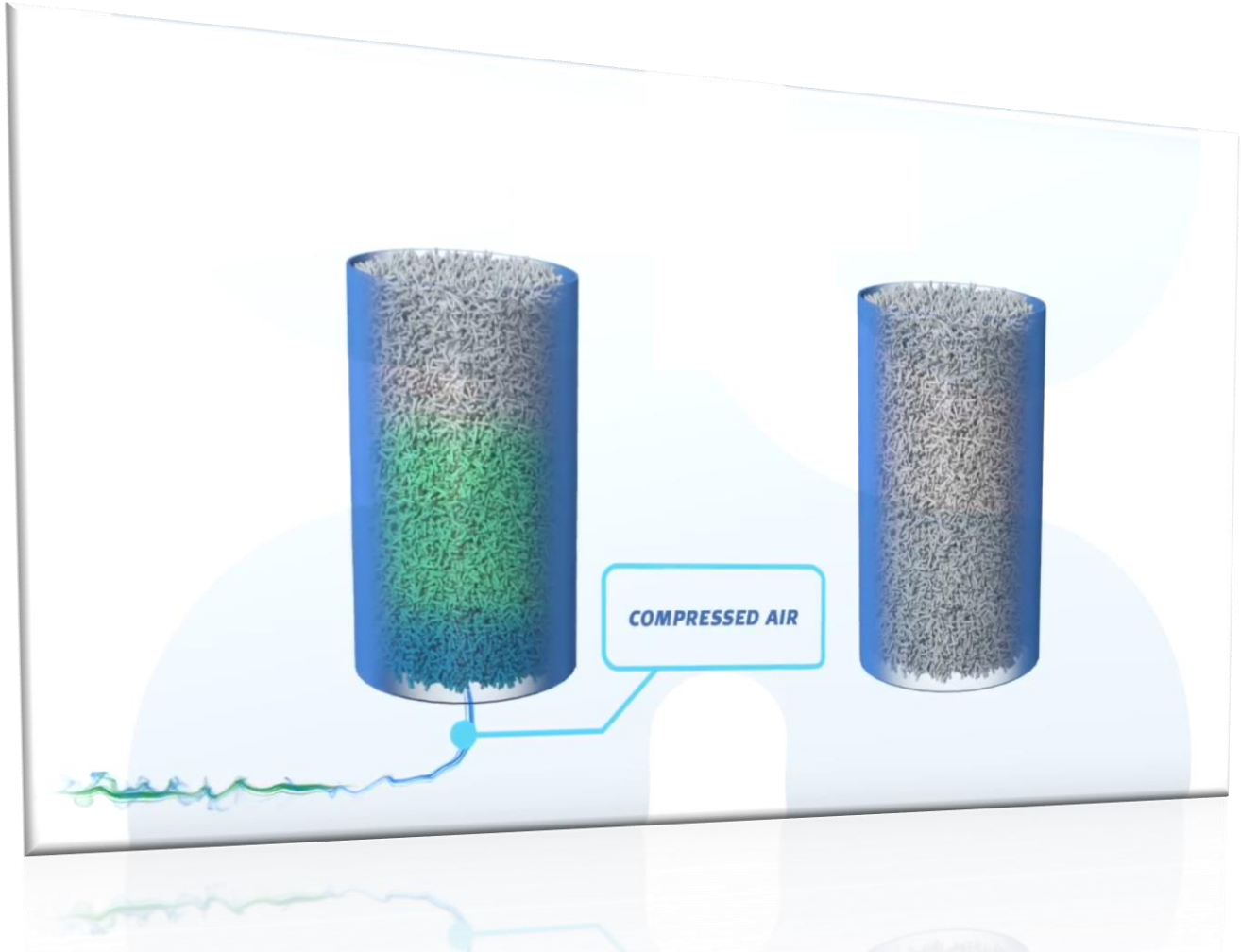
sysadvance®

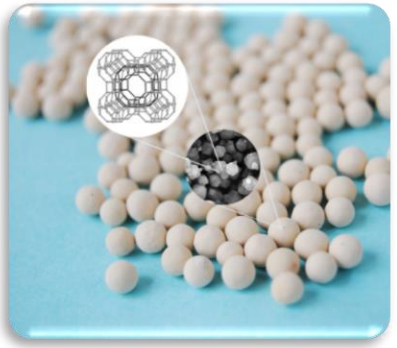
O2 VSA

- Purity up to 94 vol% O2
- OPEX [0.3 to 0.5 kWh/Nm3]
- From 20 to 200 Nm3/h

How does Pressure-Swing Adsorption Works?

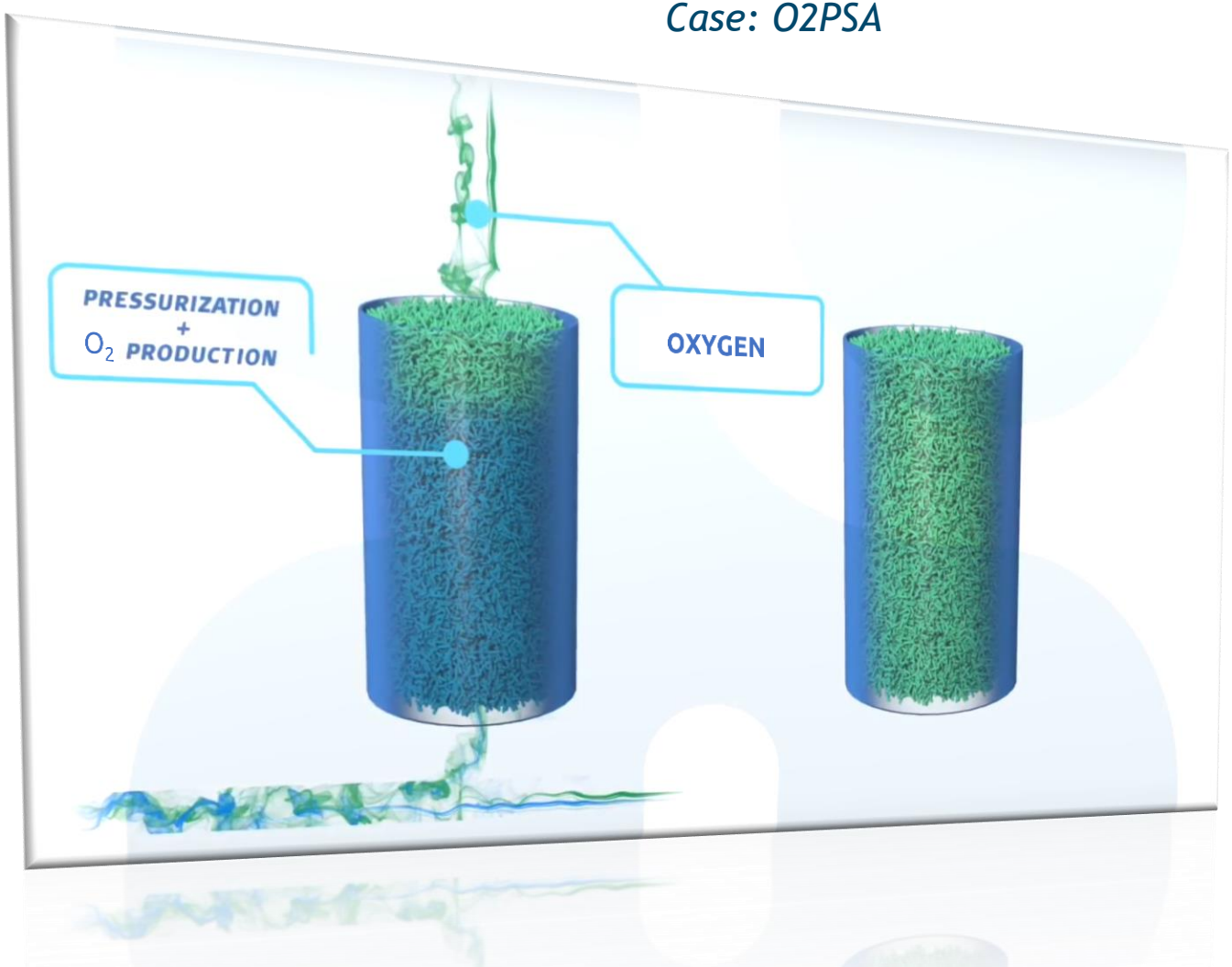
Case: O2PSA

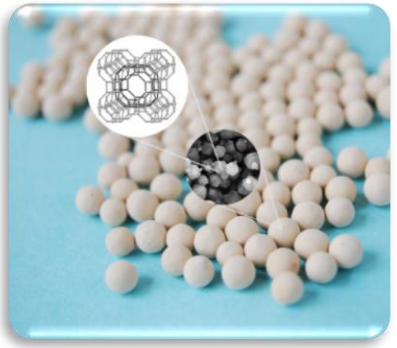




How does Pressure-Swing Adsorption Works?

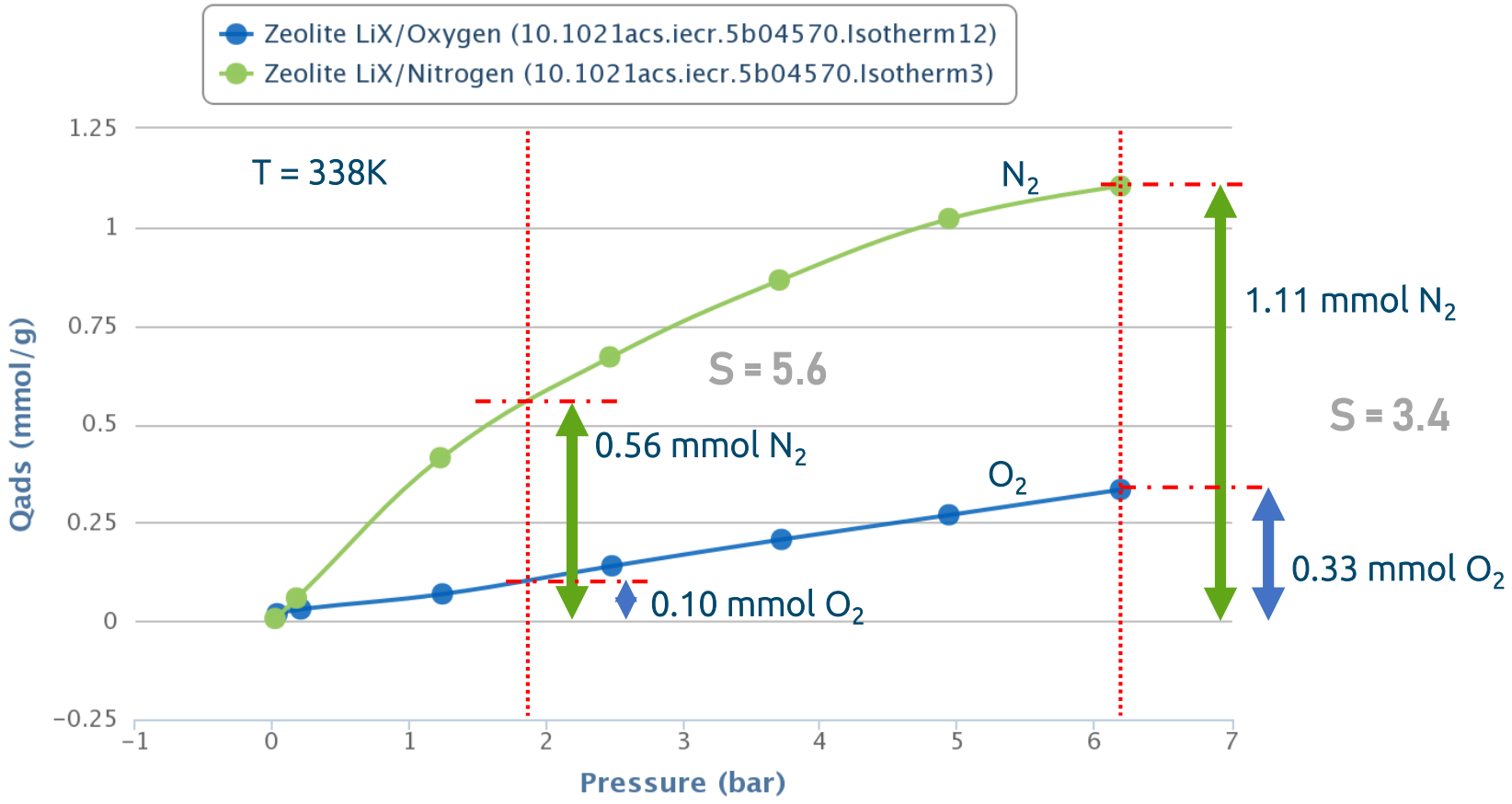
Case: O2PSA

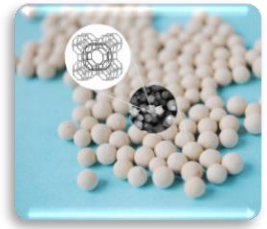




What is Equilibrium Separation?

Case: O2PSA 13X

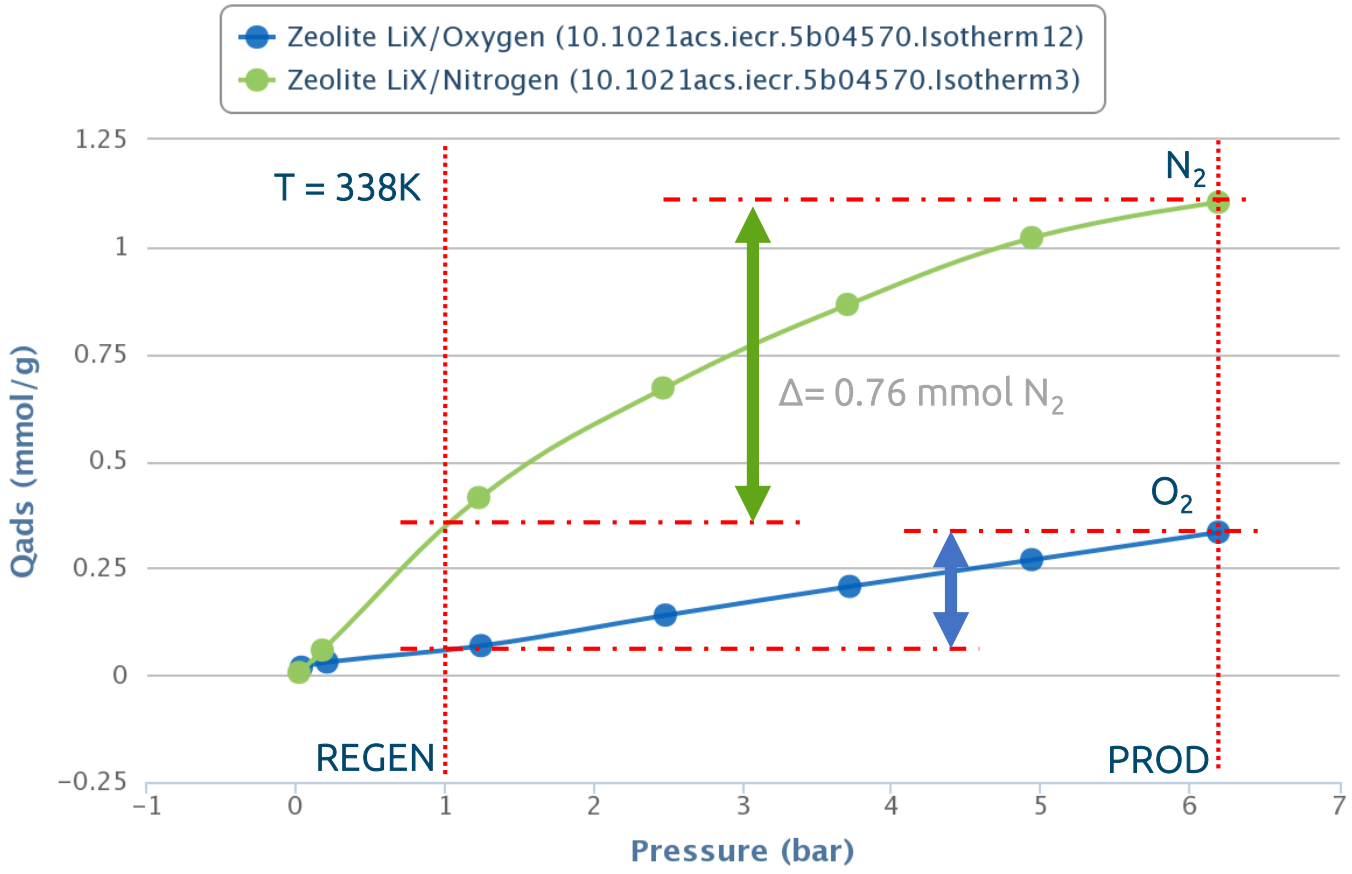


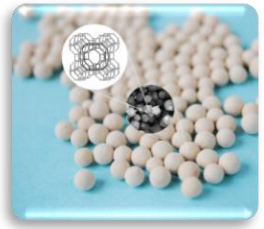


Source: NIST National Institute of Standards and Technology U.S. Department of Commerce

What is Working Capacity?

Case: O2PSA 13X





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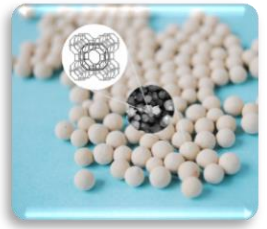
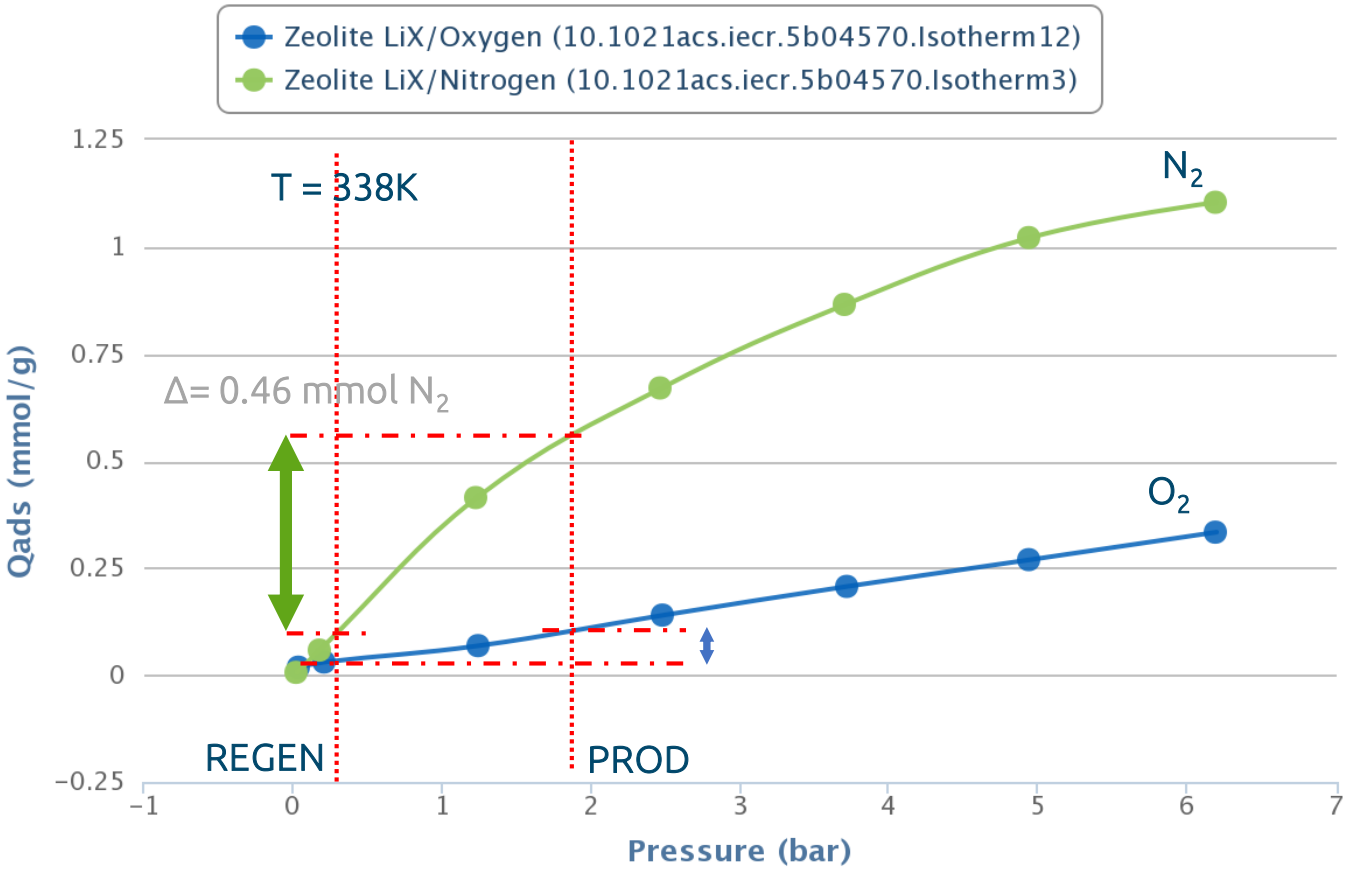
What is Working Capacity?

Case: O2VSA 13X





Solution:

LiX offers 2 times more selectivity allowing VSA to reach the same productivity than PSA

Source: NIST National Institute of Standards and Technology U.S. Department of Commerce

INDUSTRIAL PRODUCTS - NITROGEN from AIR

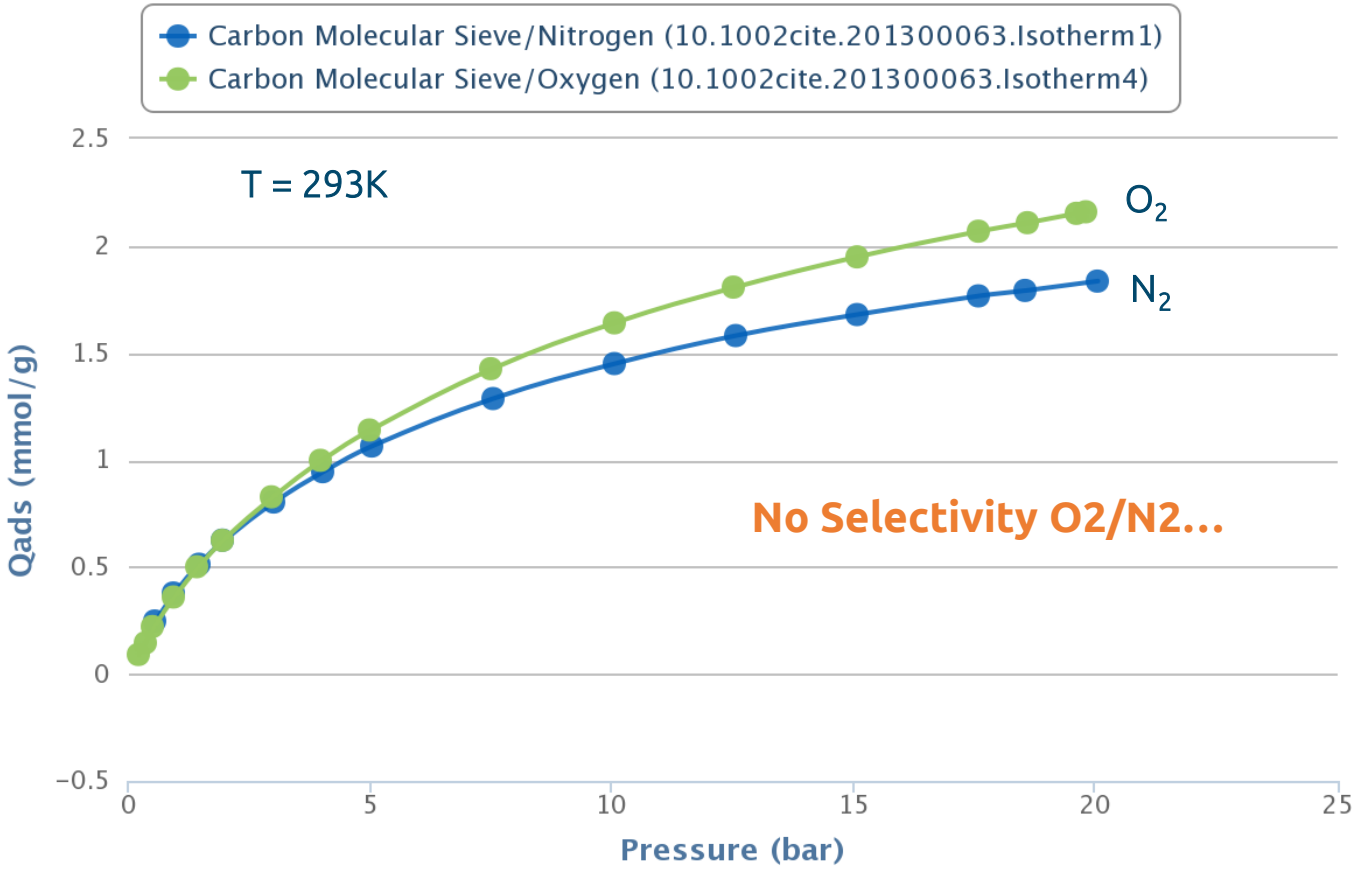
sysadvance®

- Purity up to 99.9995 vol% N2
- OPEX [0.2 to 0.7 kWh/Nm3]
- From 5 LPM to 500 Nm3/h per PSA

- VARIO option for dynamic cycle time compensation as a function of N2 consumption

What is Kinetic Separation?

Case: N2PSA



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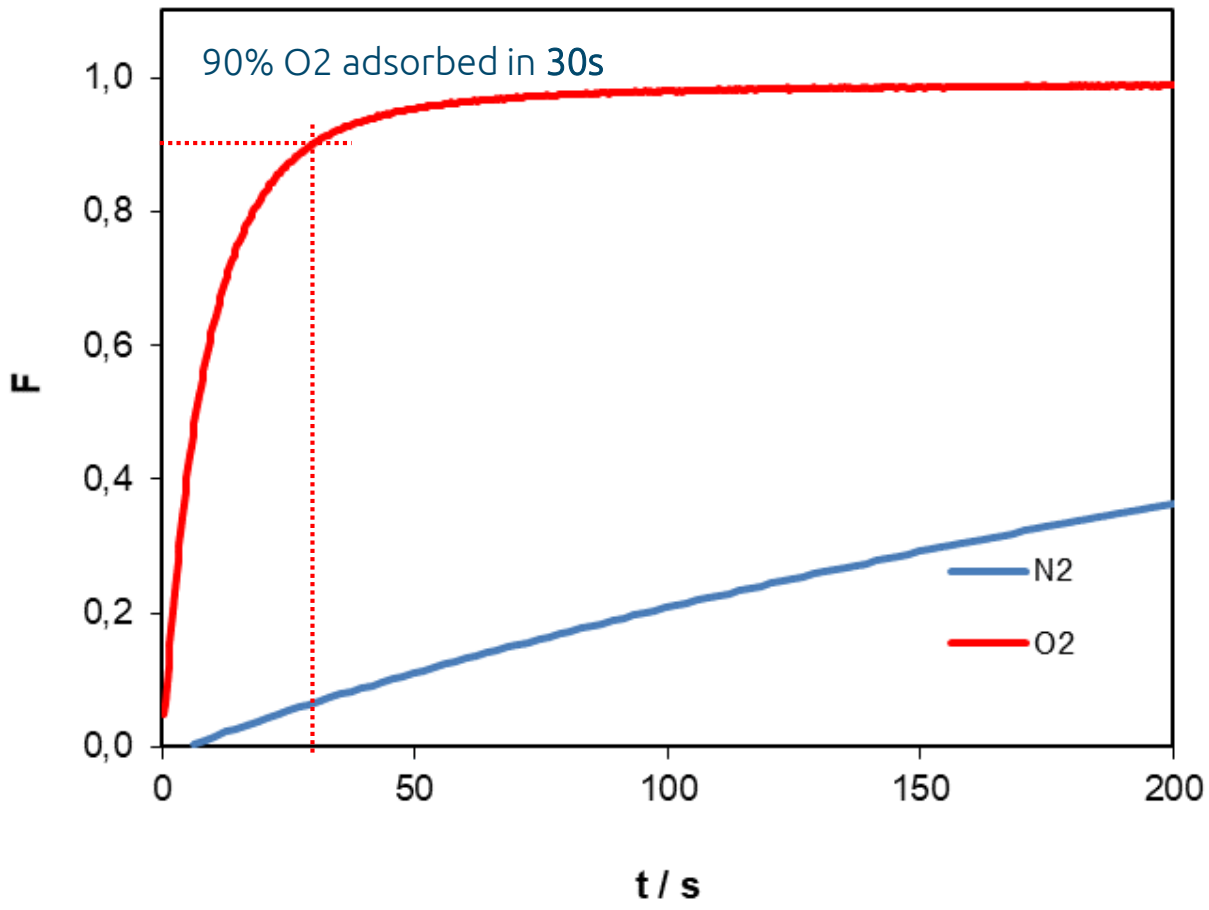
What is Kinetic Separation?

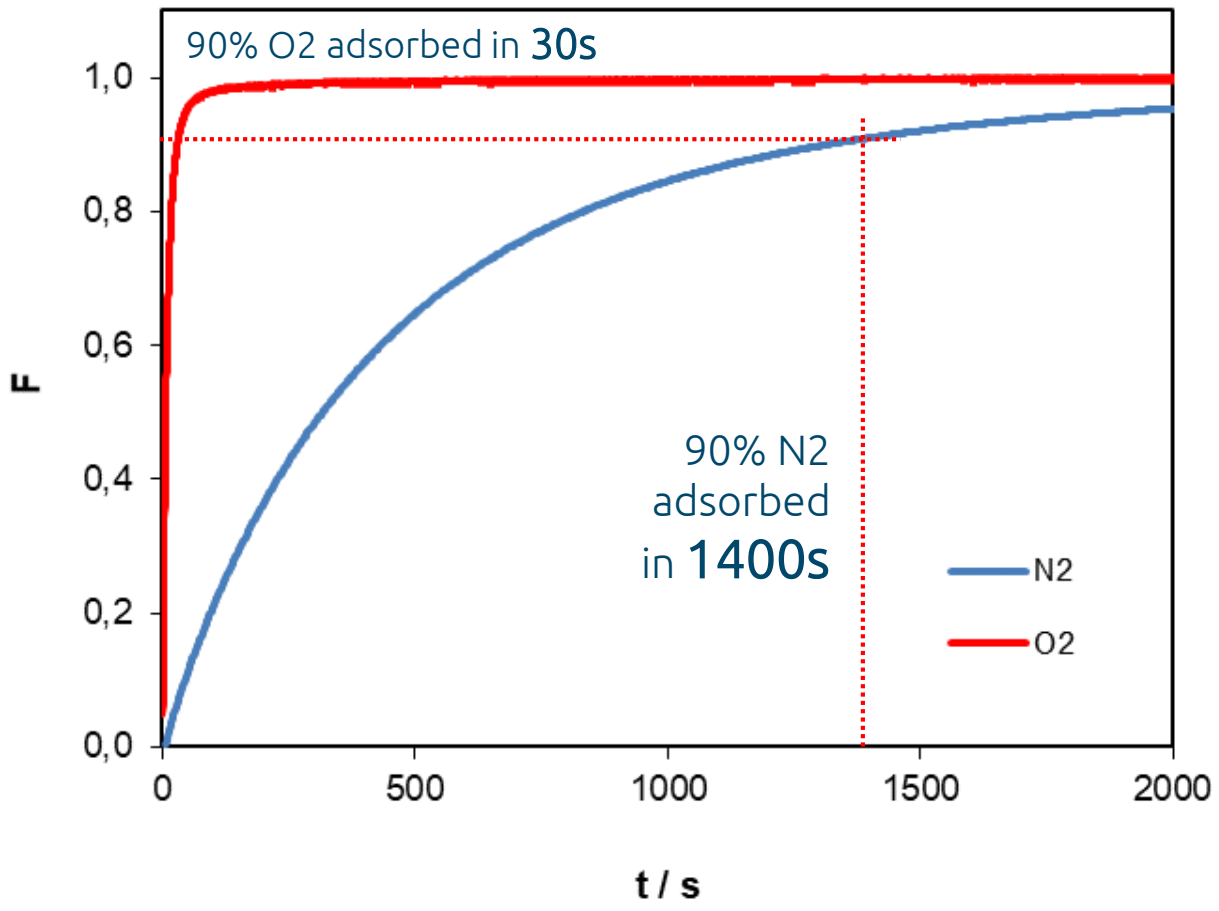
Case: N2PSA



Source: SYSADVANCE ADSORBENTS DATABASE

What is Kinetic Separation?

Case: N2PSA



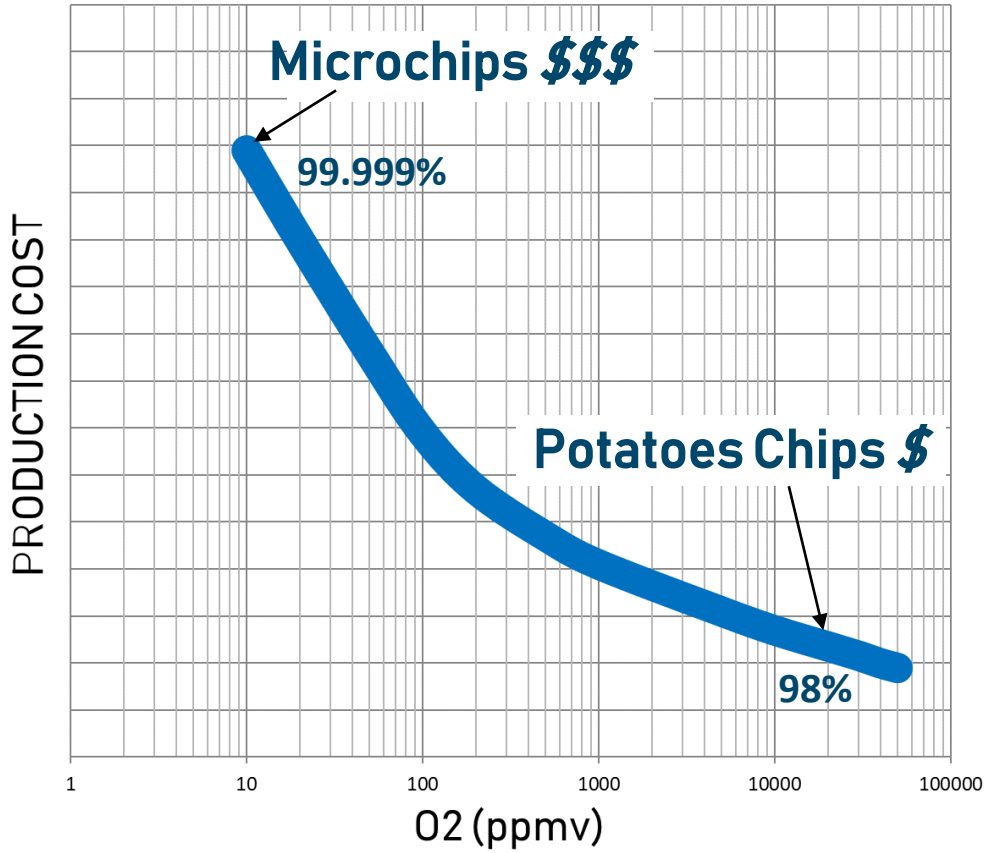
O_2 adsorption is > 50x faster

Source: SYSADVANCE ADSORBENTS DATABASE

sysadvance®

Adjusted to Application Requirements

From Potatoes Chips to Microchips



Source: SYSADVANCE DATABASE

INDUSTRIAL PRODUCTS - DEOXIDIZER for Ultrapure NITROGEN

sysadvance®

sysadvance®

DEOXO

- Special gas mixing chamber
- Highly accurate H2 dosing
- Pd catalyst

- Cooling and drying step post reactor

- < 10 ppmv of O2 in product
- < 1000 ppmv of H2 in product

- ***OPEX*** < *0.45 kWh/Nm3 (PSA99,5% + DEOXO)*

INDUSTRIAL PRODUCTS - HELIUM Recovery and Purification Loop

sysadvance®

- Works in closed circuit
- Dynamic response to change in flow
- Remove excess N2|O2|CO2|H2O
- Keeps purity constant
- Purity is adjustable

- Generate significant savings!

sysadvance®

Decentralized Industrial Gas Production

The Sustainable Way

sysadvance

+ 3000 PSA | VSA | VPSA Units

+ 3 Mton*

of Industrial Gas Produced in +40 Countries

Decentralized Production

Automony | Low Carbon Footprint

Ajusted to Your Needs

Energy efficiency | Savings

** SYSADVANCE ESTIMATIVE*

ENERGY

CO2 APPLICATIONS

sysadvance®

Thinking Now on Carbon Dioxide

CO2 Purity Grades Adapted to Different Applications

Existing uses

- Enhanced oil recovery (EOR)
- Urea yield boosting (non-captive use only)
- Other oil and gas industry applications
- Beverage carbonation
- Wine making
- Food processing, preservation and packaging
- Coffee decaffeination
- Pharmaceutical processes
- Horticulture
- Pulp and paper processing
- Water treatment
- Inerting
- Steel manufacture
- Metal working
- Supercritical CO_2 as a solvent
- Electronics
- Pneumatics
- Welding
- Refrigerant gas
- Fire suppression technology

Source: GLOBAL CCS INSTITUTE

CO2 APPLICATIONS

sysadvance®

Thinking Now on Carbon Dioxide

CO2 Purity Grades Adapted to Different Applications

Emerging uses

- Enhanced coal bed methane recovery (ECBM)
- Enhanced geothermal systems (EGS)
- Power generation – CO2 as a working fluid
- Polymer processing
- Chemical synthesis (excl. polymers & liquid fuels/hydrocarbons)
- Algal bio-fixation
- Formic acid
- Calcium carbonate and magnesium carbonate
- Baking soda (sodium bicarbonate)
- CO2 concrete curing
- Bauxite residue treatment (‘red mud’)
- Renewable metanol (methanation)
- Renewable methane (methanation)
- Genetically engineered micro-organisms for direct fuel secretion

Source: GLOBAL CCS INSTITUTE

CO2 APPLICATIONS

sysadvance®

Anthropogenic CO2 Emissions:

30 Gtpa

- *18 Gtpa to reach 1.5°C in 2050*

Market of CO2 Reused :

160 Mtpa *(0,5%)*

Potential w/ Energy Storage Concept :

1500 - 3000 Mtpa *(5-10%)*

Which CO2 Sources Allow
Highest Energy Efficiency for Capture?

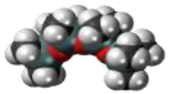
Source: ClubCO2

Biogas is a Mixture of...

PRE-TREATMENT

H_2S (up to 2000 ppmv)
Toxic and corrosive gas
Must be removed before upgrading

H_2O (saturated at 30-45ºC)
Biogas must be dried for NG grid or NGV



Silox. (up to 2 vol. %)
Predominant in WWTP or Landfill
Must be removed to prevent engine damage

UPGRADING PROCESS

CH_4 (45-65 vol. %) *the desired molecule*

CO_2 (40-50 vol. %) *the main contaminant*

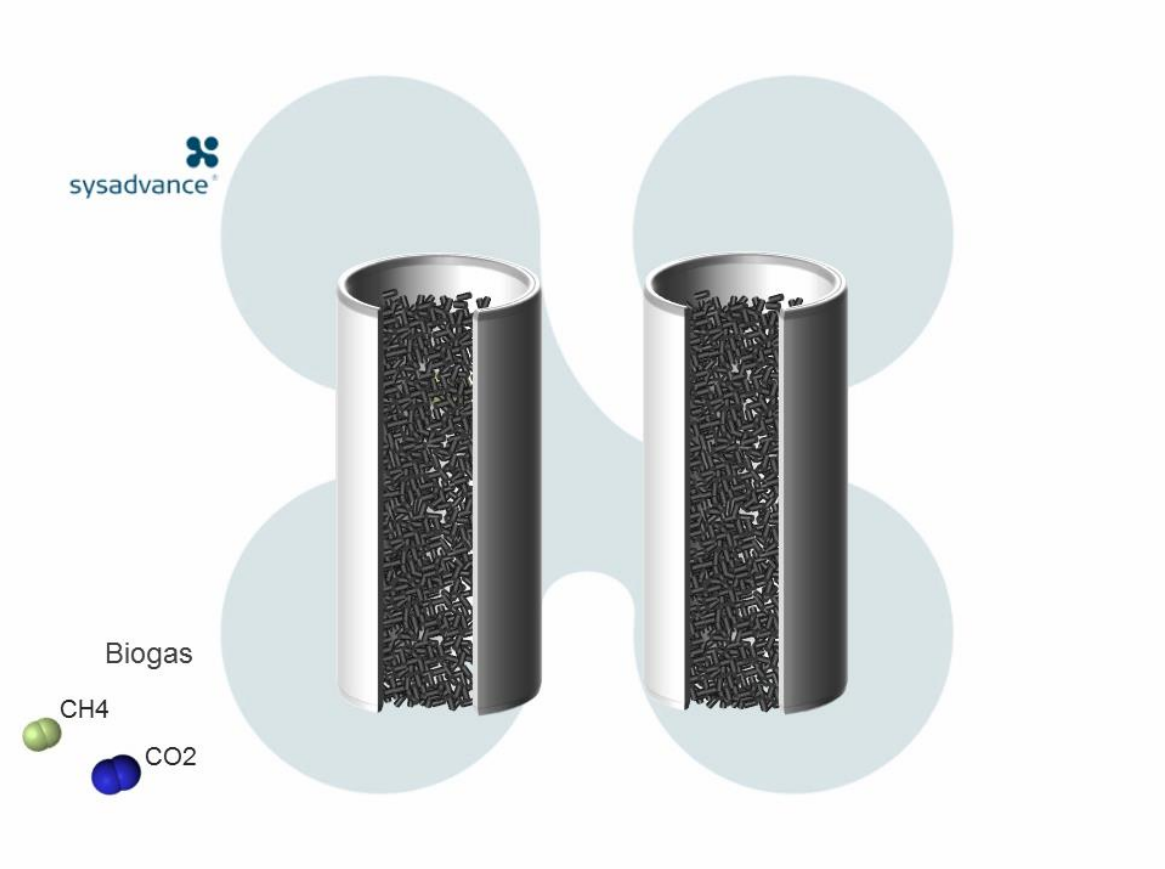
O_2 (up to 2 vol. %)
Often introduced for H2S reduction
Regulations for NG grid and NGV establish limits for O_2

N_2 (up to 18 vol. % in landfill gas)
the most challenging separation

Biomethane from Biogas

RENEWABLE	*produced from organic waste*
ENDOGENOUS	*decentralized energy source, less energy import*
Non-INTERMITTENT	*unlike solar, wind, hydropower...*
STORABLE	*virtually infinite cap. in the NG grid, or LNG*

How does the VPSA Upgrading Technology Works?



METHAGEN | Biogas Upgrading

sysadvance®

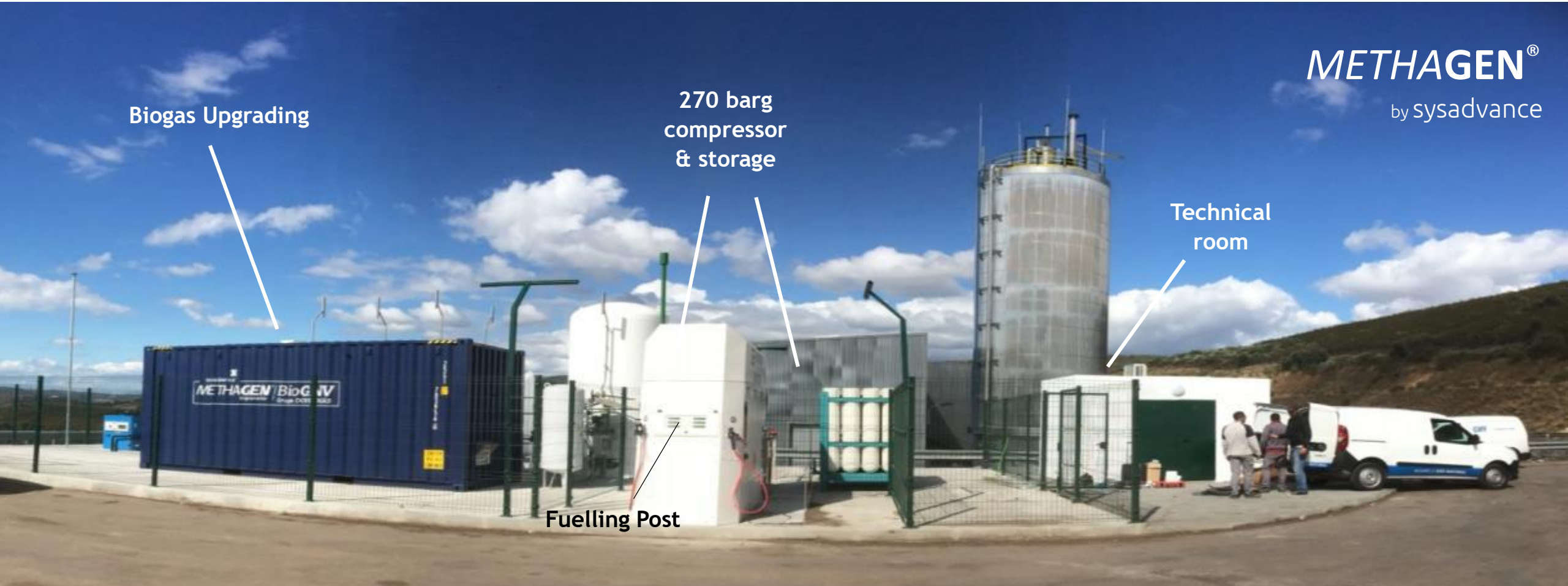
SINGLE STAGE METHAGEN PLANT FOR ORGANIC WASTE DIGESTER

The first
biogas upgrading
plant in Portugal (2016)

EUROPE

SINGLE STAGE METHAGEN PLANT

VPSA biogas upgrading plant bio-CNG refulleling station



METHAGEN | Biogas Upgrading

sysadvance®

UPGRADING of BIOGAS w/ high level of N2 and O2

Double-stage VPSA Process for a Challenging Separation

Biogas from urban waste but with very stringent specs for NG grid

Perris, California (2017)
1st injecting biomethane in the NG grid in California

USA

METHAGEN | Biogas Upgrading

sysadvance®

LANDFILL GAS UPGRADING

Double-stage VPSA Process for a Challenging Separation

Landfill
Southern Paris, France

1st Landfill in France injecting in the NG grid w/ non-cryogenic technology (2018)

The highest Landfill-to-Grid injection capacity in operation in France

EUROPE

METHAGEN | Biogas Upgrading

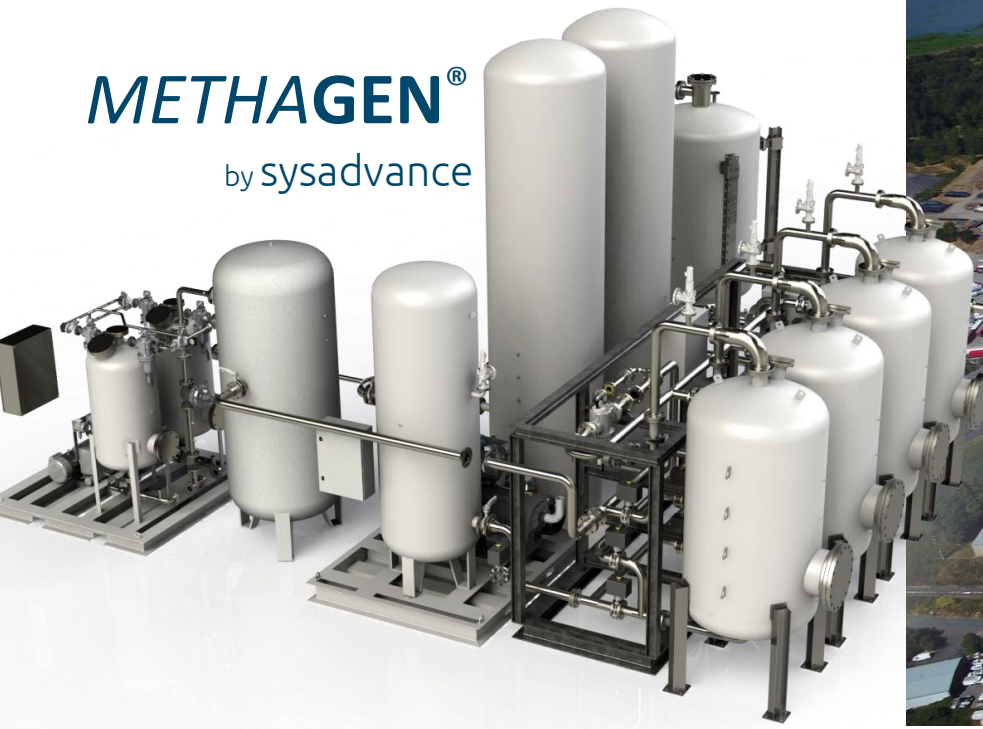
sysadvance®

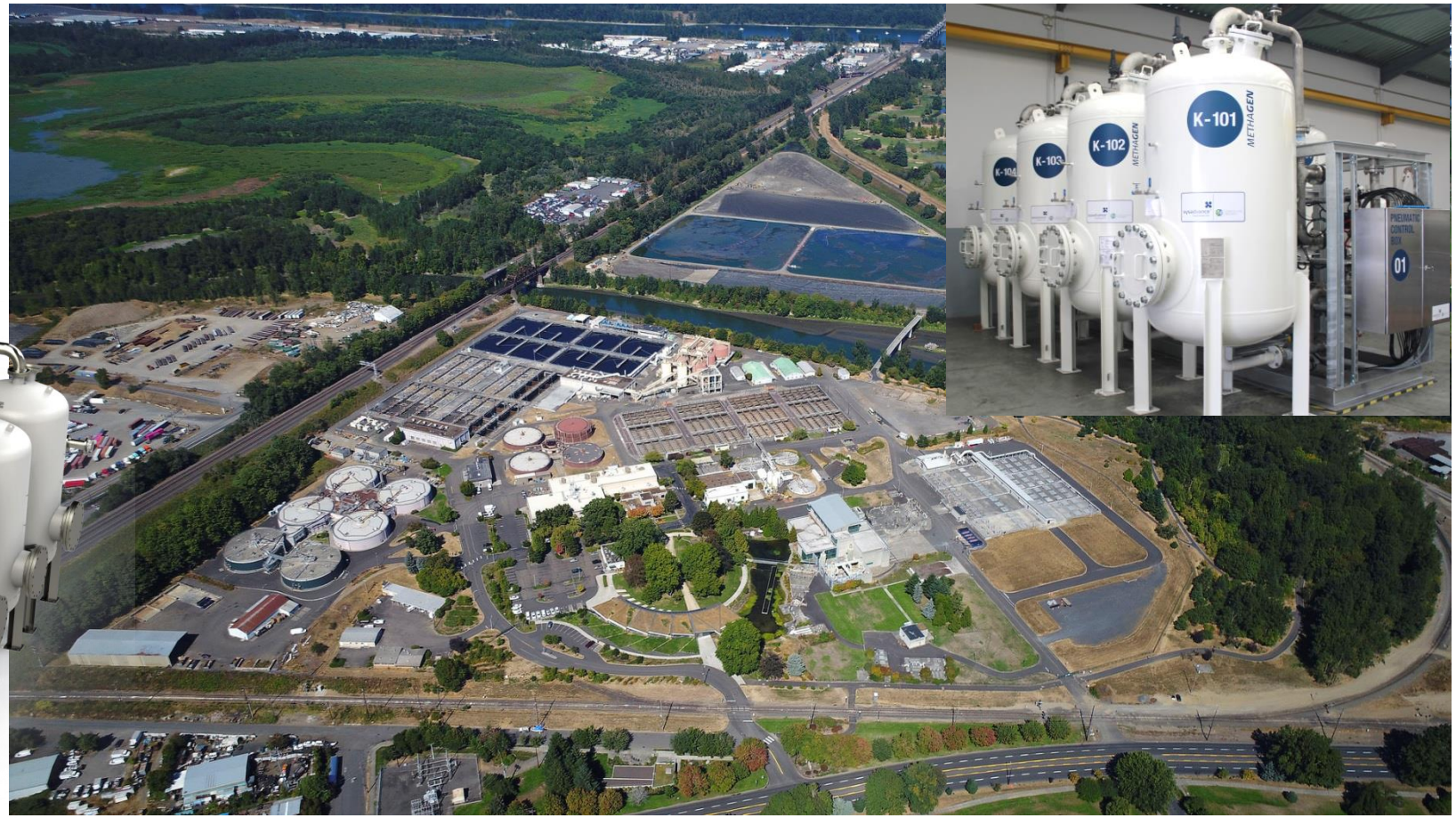
LANDFILL GAS UPGRADING

1.4 million m3 of biomethane injected in the grid per year

WWTP City of Portland (USA)

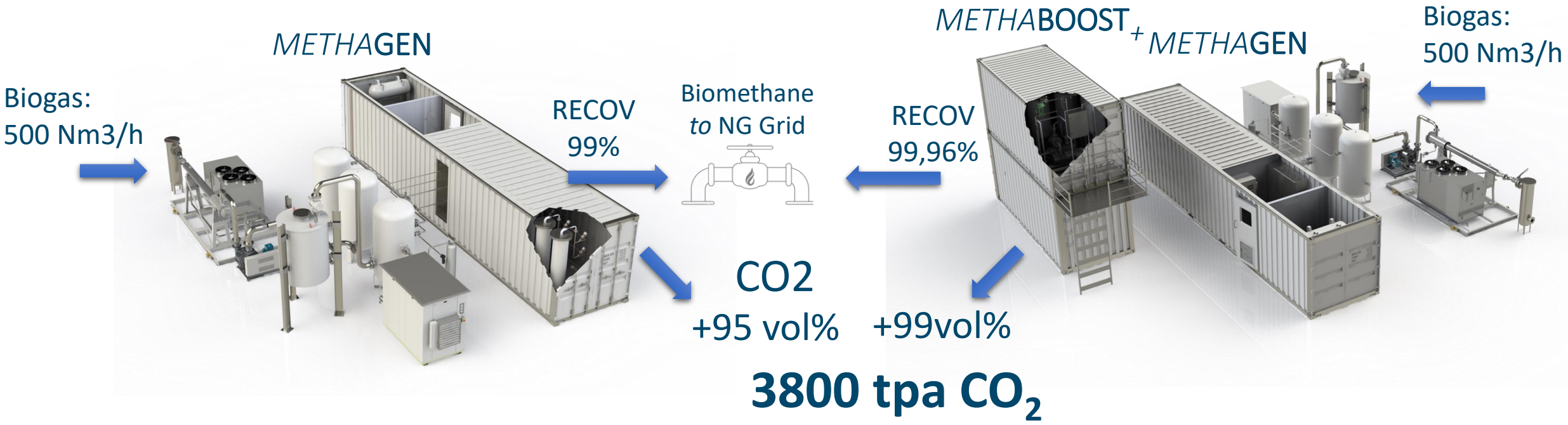
(to be commissioned 2Q 2019)





The CO2 Balance

CO2 Production from Biogas

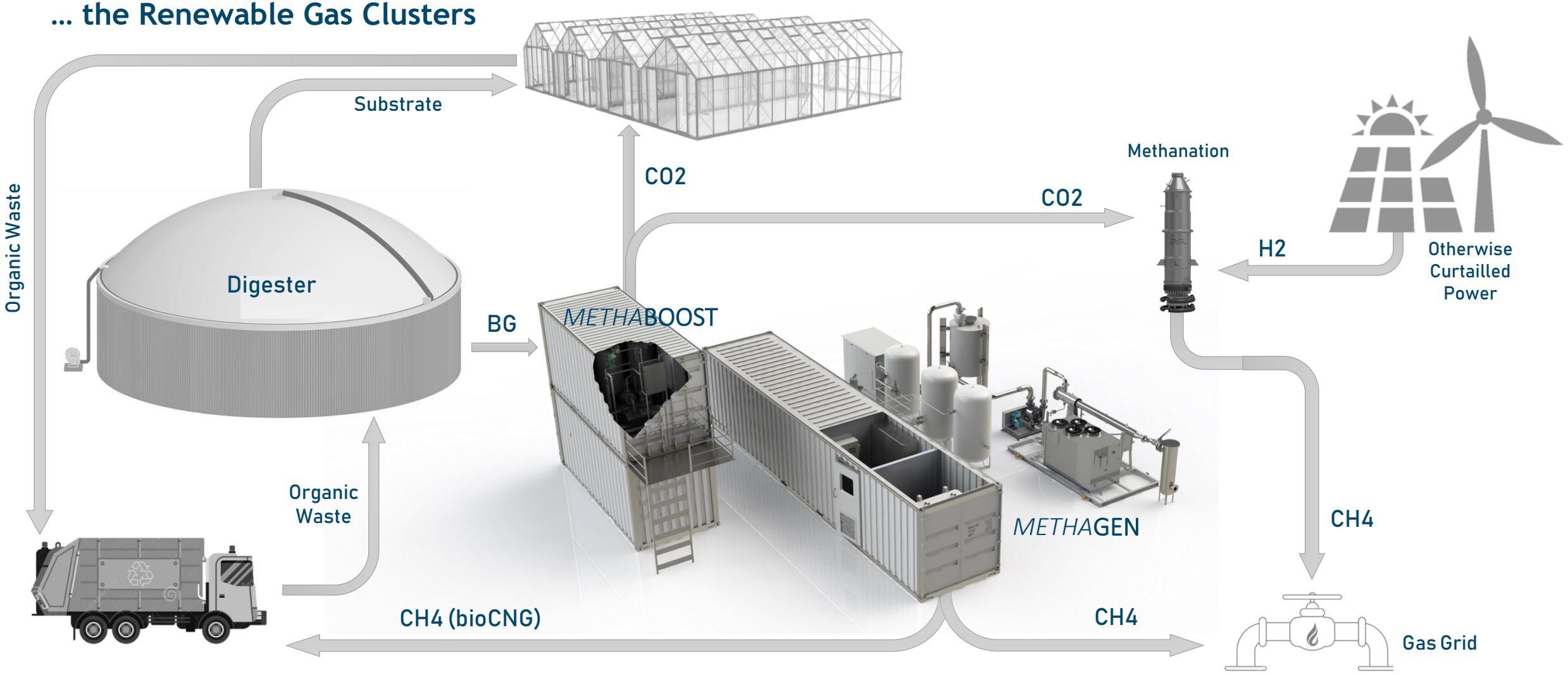


3800 tpa CO_2

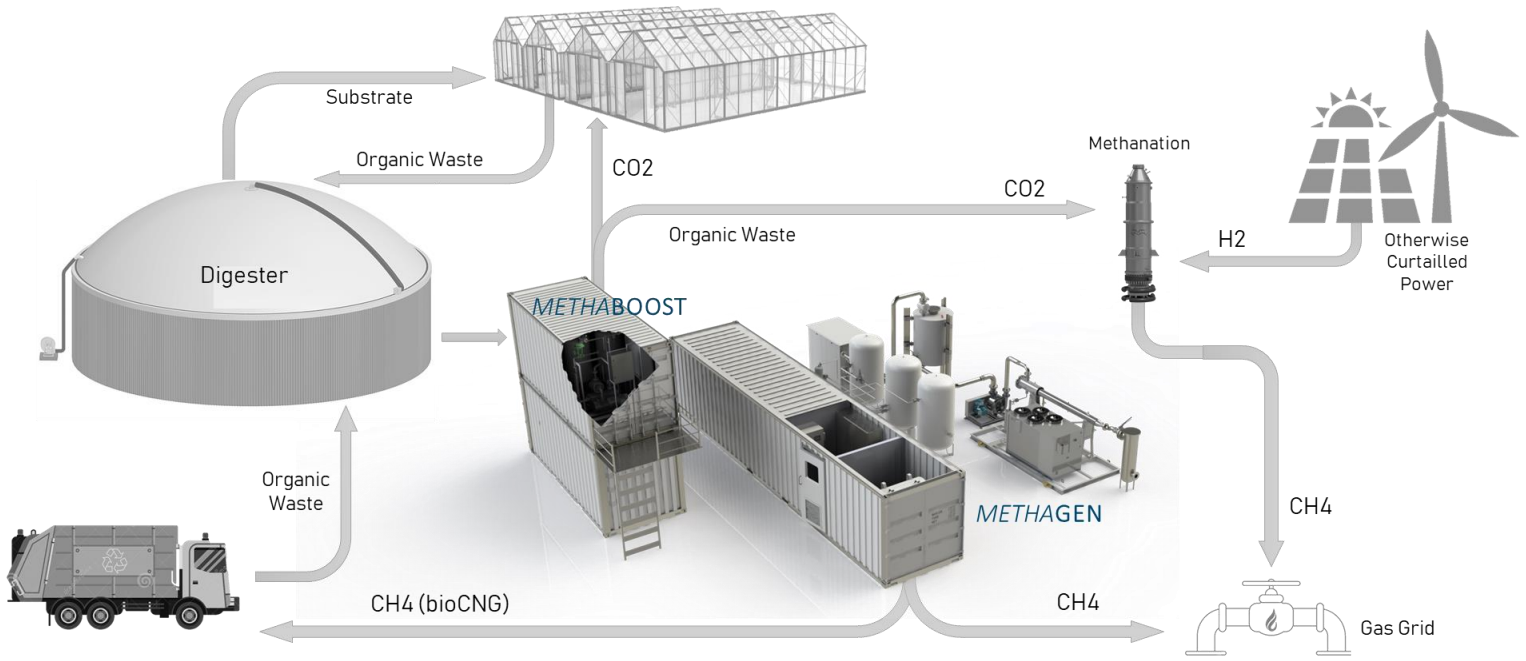
x **18 000** biogas plants in Europe (2019) → **+ 60 Mtpa CO2** !!!

The Petrochemical Clusters…

… the Renewable Gas Clusters



The New *bioClusters*



Decentralized CO2 Production

Small/Medium Scale Plants

Close to CO2 Consumption

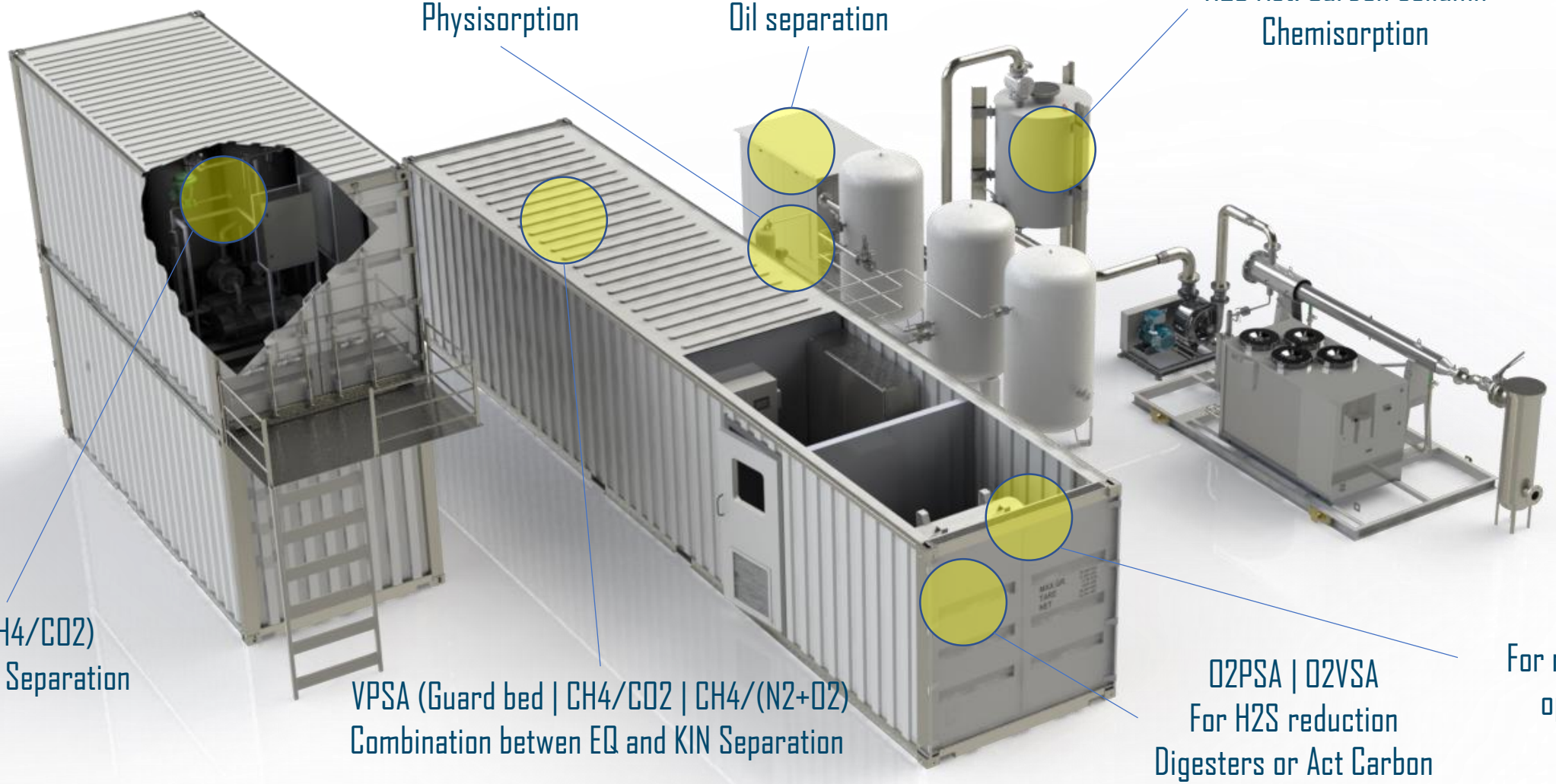
Integrated with Energy Storage

Promoting Circular Economy

Towards Energetic Transition

METHAGEN | Biogas Upgrading

sysadvance®




CO2

METHABOOST | CO2 Capture from Biogas Waste Stream

sysadvance®

CO2 RECOVERY AND PURIFICATION

Valorization of biogas waste stream from an existing upgrader

CO2 Purification for industrial application

The 1st Closed-Loop Organics Waste Management System in North America

CANADA

CARBOGEN | CO2 Capture and Purification from Flue Gas

sysadvance®

CO2 RECOVERY AND BULK SEPARATION

Flue Gas < 10 vol% CO2

CO2 application: Chemical Production

NO_x+ H_2O : Adsorbents Resistant to Nitric Acid Attack!

Specific Energy Consumption
<160 kWh/ton$_{CO2}$ concentrated up to 50 vol%

EUROPE

CO2 Capture and Purification

sysadvance®

OPEX for CO2 Capture from Different Sources

CO2 Source	$CO2\%_{IN}$	$CO2\%_{OUT}$	Pot. Application	kWh/ton_{CO2}
From Flue Gas *CARBO*GEN	**10%** *Patm, sat*	**50%** *20 mbarg, Wet*	Carbonates, Concrete Curing Greenhouse, Algae Cultivation…	150
From Landfill Gas w/o Upgrading *CARBO*GEN	**42%** *Patm, sat*	**98,0%** *20 mbarg, Wet*	Greenhouse, Algae Cultivation, Fire Extinguisher…	153
After Biogas Upgrading Water Wash + *METHA*BOOST	**84%** *1,5 barg, sat.*	**99,8%** *20 mbarg, wet*	Inerting/Purging Batch Digesters	35
After Biogas Upgrading *METHA*GEN	**94,0%** *20 mbarg, wet*	**99,9%** *20 mbarg, wet*	Industrial Grade or Food Grade *(after liquefaction)*	51
After Biogas Upgrading *METHA*GEN + *METHA*BOOST	**99,9%** *20 mbarg, wet*	**99,9%** *20 mbarg, wet*	Industrial Grade or Food Grade *(after liquefaction)*	~0

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