CO_2-ABSCHEIDUNG BEI BIOGASANLAGEN

BIOGAS FORUM BAYERN

DR. UWE KIKILLUS

27. SEPTEMBER 2018

SEPARATING INTO TWO PUBLICALLY-TRADED CO'S

WATER

PENTAIR

SUSTAINABILITY

A Leading Global Water Company Focused on Smart, Sustainable Water and Fluid Processing Applications

ELECTRICAL

nVent®

PROTECTION

A High-Performance Electrical Company Focused on Improving Utilization, Lowering Costs, and Maximizing Customer Uptime

Two new companies in May 2018

THE NEW PENTAIR

Our capabilities and resources span the globe

Leading partner in CO_2 and biogas upgrading

CO_2 Plants for Breweries & CSD

CO_2/O_2 in Breweries BioSENSE

1400+ CO_2 PLANTS

20.000+ MEASUREMENT DEVICES

5000 Nm^3/h Biogas
55000 Nm3/h Industrial

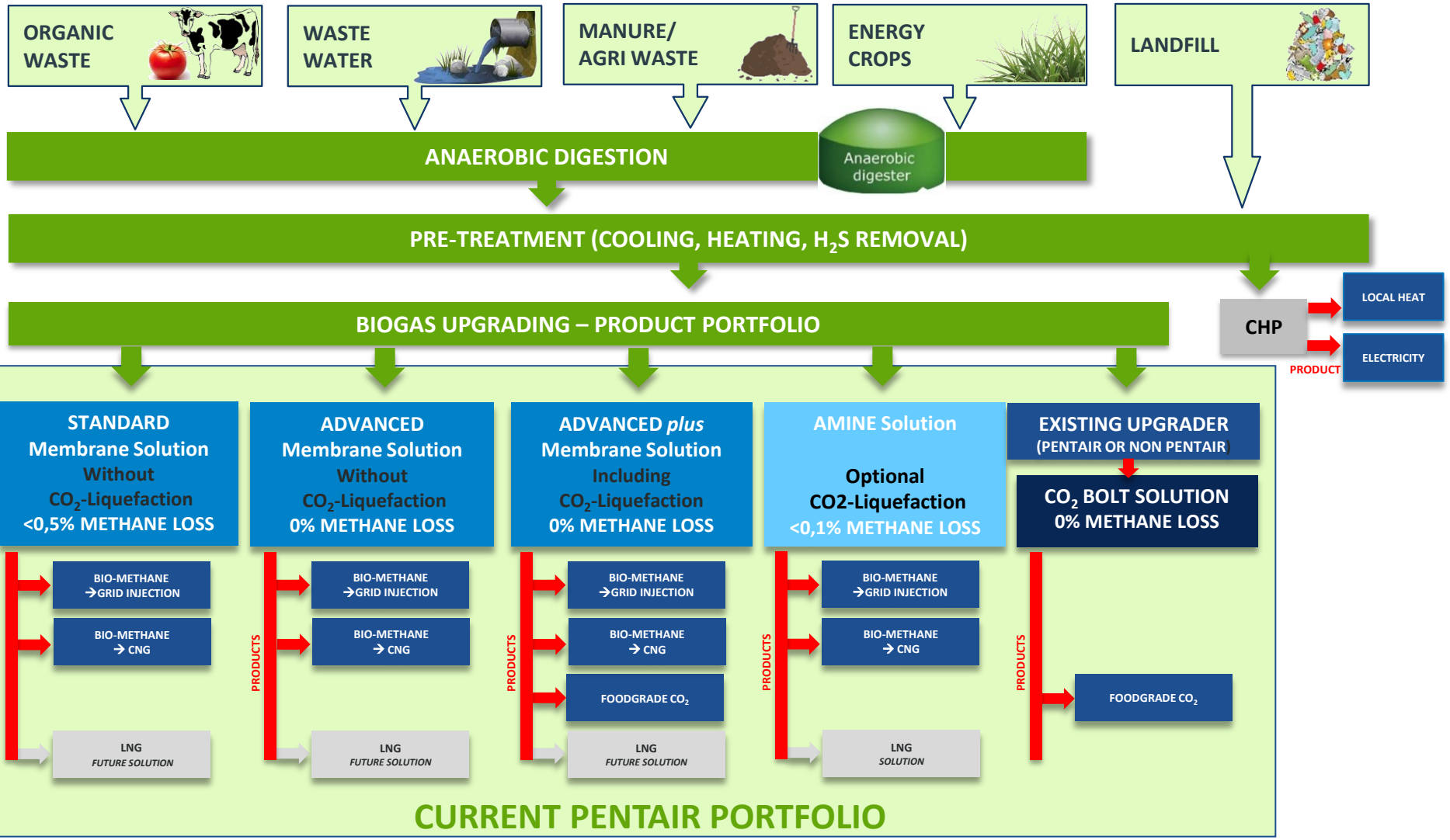
300+ AMINE PLANTS

40+ MEMBRANE PLANTS

3 Stage & 2 Stage with CO_2
> 3000 Nm^3/h
No Methane Slip

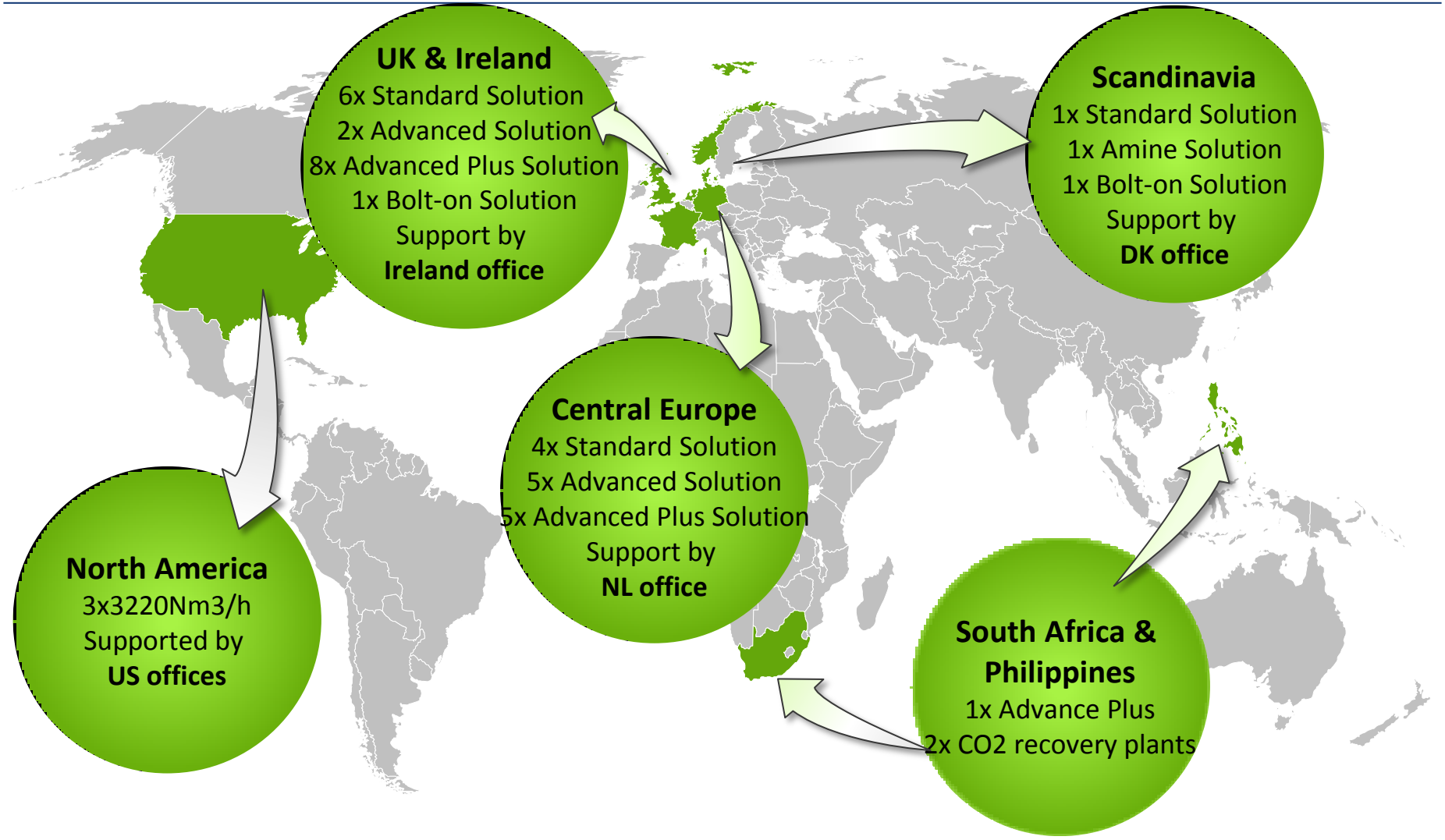
HAFFMANS & UNION: COMBINING 60 YEARS OF PROCESS TECHNOLOGY

PENTAIR GAS SOLUTIONS



0% METHANE LOSS & CO_2 ADDITIONAL REVENUE

REFERENCES BIOGAS UPGRADING AND BOLT-ON CO2



Our installed plants can fuel 133,000 homes or 275,000 cars

Summer 2018 CO_2 crisis in the news

CO2 supply crisis hits Europe

By Joanna Sampson | 19 June 2018

In what has been described as the "worst supply situation to hit the European carbon dioxide (CO_2) business in decades", many consumers of CO_2 - especially the carbonated drinks producers - are desperate for supplies of the product.

CO2-KNAPPHEIT

Brauereien in Nordeuropa warnen vor Bier-Krise

28. Juni 2018

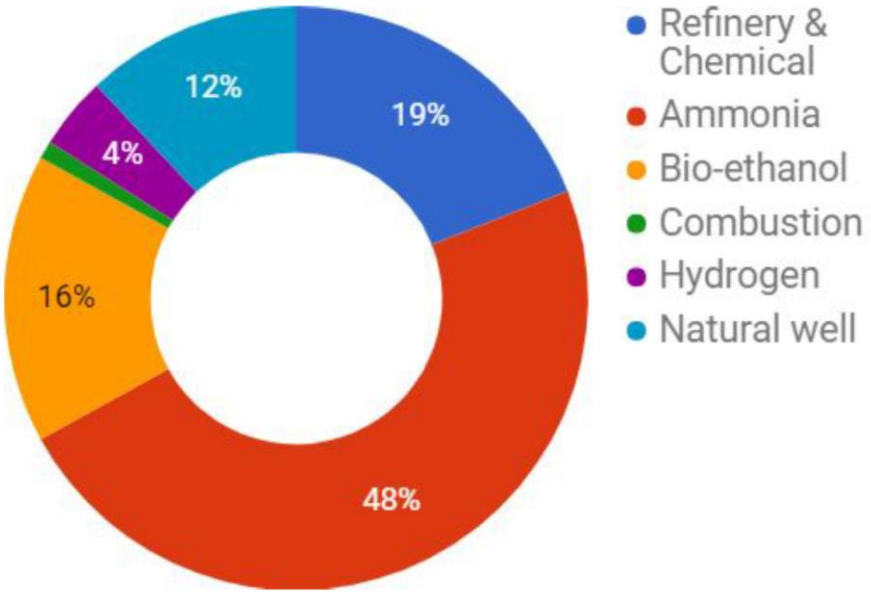
Source: BevTech Europe 2018, AirLiquide, G. Constantin

CO_2 shortage as never experienced before

The background of the CO_2 crisis

Installed CO_2 plants in Europe

- Total installed capacity: ~ 20 000 tpd
- About 100 CO_2 plants
- Nominal oversupply with regional imbalances
- Sources for CO_2 plants by weight



Fertilizer market

- High cost of NG in Europe vs. RoW
- 30 % fertilizer production overcapacity ww.
- Fertilizer imports to Europe increased to 45 %
- Extended maintenance periods from March to July

European CO_2 crisis

- From **March to July** 2018 about **7 fertilizer sources** were in **partial production or stopped** at a given time
- The **level of CO_2 stored** by IGC (in plants, trailers or at customer storages) has decreased
- In June about 10 CO_2 sources were simultaneously down triggering the **worst CO_2 crisis in Euope**

Source: BevTech Europe 2018, AirLiquide, G. Constantin

Reduction of fertilizer production is the root cause

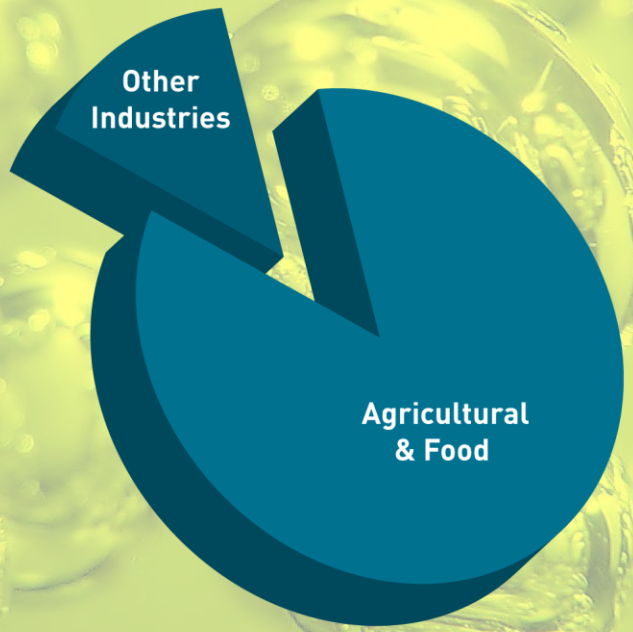
CO_2 applications

Agri-production
Accelerate plant growth in greenhouses

Beverages
Carbonation and beverage dispensing

Food Industries
Food preservation, freezing, chilling, packaging, extraction

Refrigerated Transport
Maintain the cold chain for fresh and frozen products



pH Control
Water treatment

Chemistry
Reactive agent

Industrial Cleaning
Solvent free cleaning for surfaces

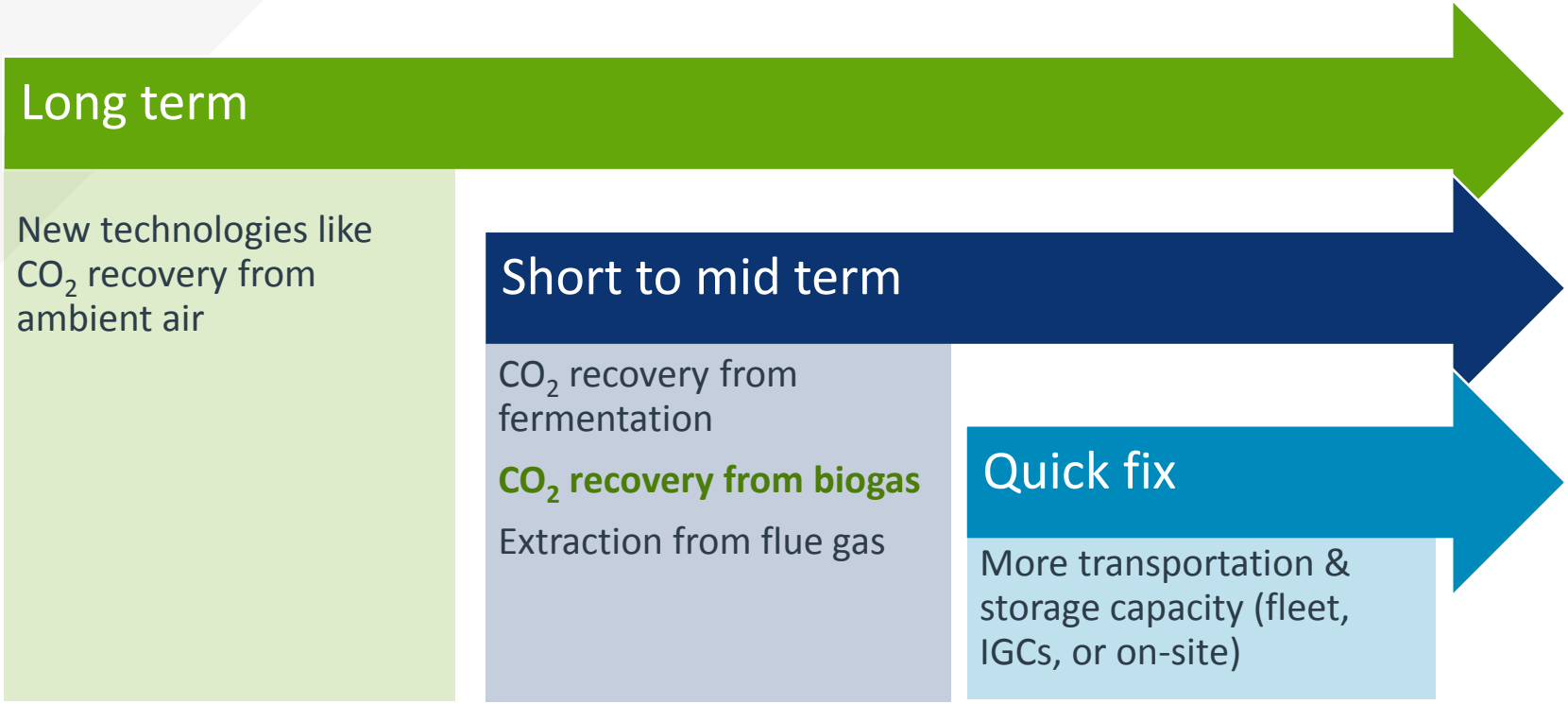
Welding
Arc stabilisation in MAG welding

Many other applications:
e.g. in fire extinguishers, as natural refrigerant, ...

THE FUTURE: DRY ICE – POWER-TO-GAS – POWER-TO-LIQUID

Raw CO_2 supply shortage can be solved

During summer 2018 a shortage in raw CO_2 caused serious problems for the beverage industry. Innovative solutions are reachable short, medium and long term:



Solutions are available and new ones to come

EIGA DOC 70/17: Food-Grade CO_2 from biogas

Revised EIGA DOC 70 released in February 2017

(EIGA = European Industrial Gases Association)

Biogas from anaerobic digestion listed as carbon dioxide source

- Biogas from **energy crop** is handled similar to yeast-based fermentation (ethanol)
- Biogas from **bio-waste** digestion or co-digestion requires greater care in the evaluation
- [Biogas from **landfills** with variety of waste types requires extensive risk assessment]

Risk assessment process for AD plants for food & beverage CO_2

- The food safety risk analysis (HACCP) includes the **digester biogas process**
- Final product carbon dioxide is always compliant with the **Appendix A**
- Complete **on-line or complete batch analysis** of CO_2 before supply to customer
- A **food safety management system** (e.g. ISO 22000) is strongly recommended for the carbon dioxide plant
- Compliance of the AD plant (and feedstock) with the **EU regulations for animal by-products**

ISBT Bulk Carbon Dioxide Quality & Food Safety Guidelines under Revision

EIGA DOC 70/17: Food-Grade CO_2 from biogas

APPENDIX A:

EIGA LIMITING CHARACTERISTICS

FOR CARBON DIOXIDE TO BE USED IN BEVERAGES FOR SOURCE SPECIFICATION[3]

Component	Concentration
Assay	99.9% v/v min.
Moisture	20 ppm v/v max
Ammonia	2.5 ppm v/v max.
Oxygen	30 ppm v/v max.
Oxides of nitrogen (NO/NO2)	2.5 ppm v/v max. each
Non-volatile residue(particulates)	10 ppm w/w max.
Non-volatile organic residue (oil and grease)	5 ppm w/w max.
Phosphine ***	0.3 ppm v/v max
Total volatile hydrocarbons (calculated as methane)	50 ppm v/v max. of which 20 ppm v/v max non-methane hydrocarbons.
Acetaldehyde	0.2 ppm v/v max.
Aromatic hydrocarbon	0.02 ppm v/v max.
Carbon monoxide	10 ppm v/v max.
Methanol	10 ppm v/v max.
Hydrogen cyanide*	0.5 ppm v/v max
Total sulfur (as S) **	0.1 ppm v/v max.
Taste and odour in water	No foreign taste or odour
Appearance in water	No colour or turbidity
Odour and appearance of solid CO2 (snow)	No foreign odour or appearance

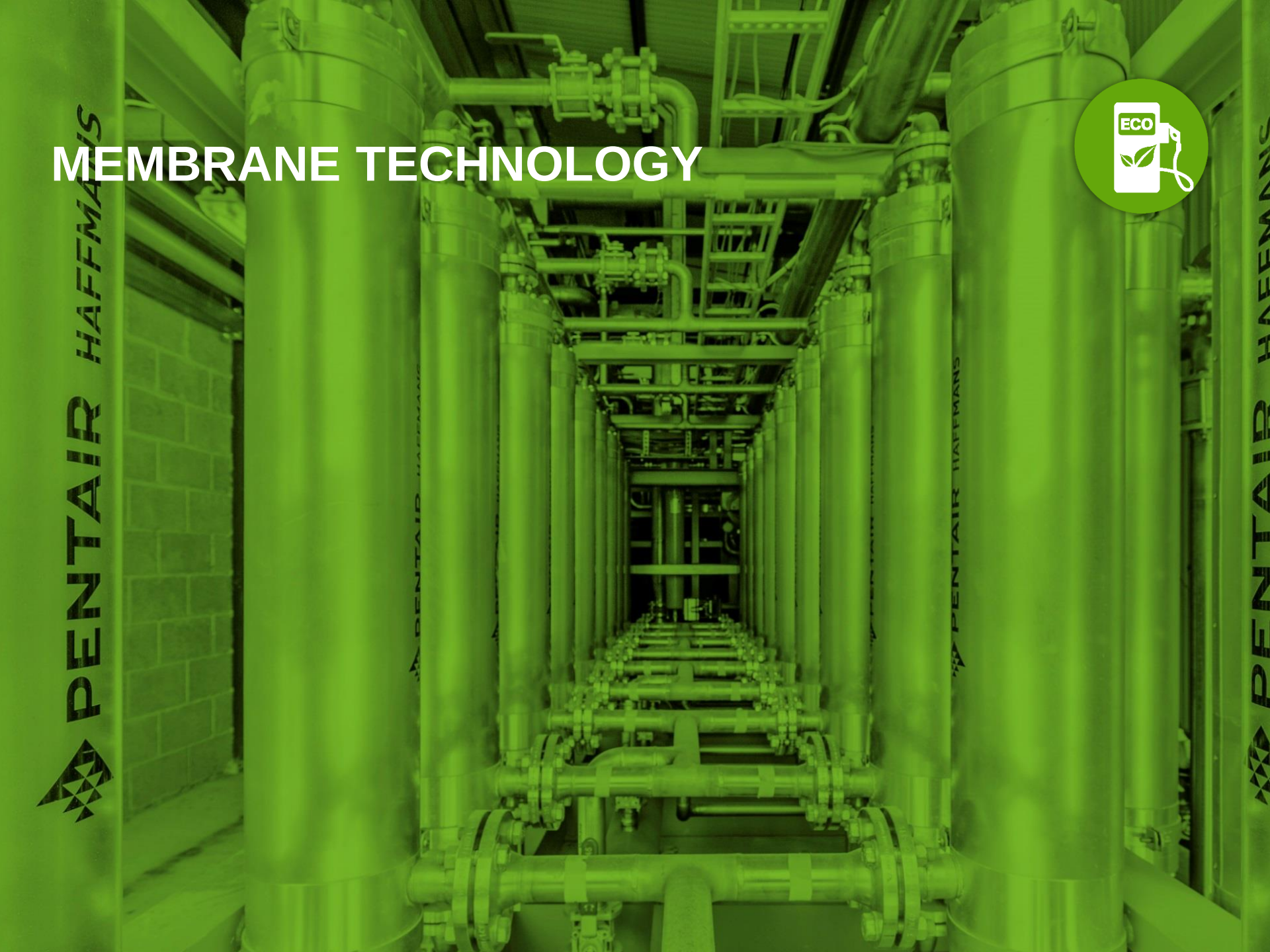
APPENDIX B:

Possible trace impurities by source type (Excluding air gases and water)

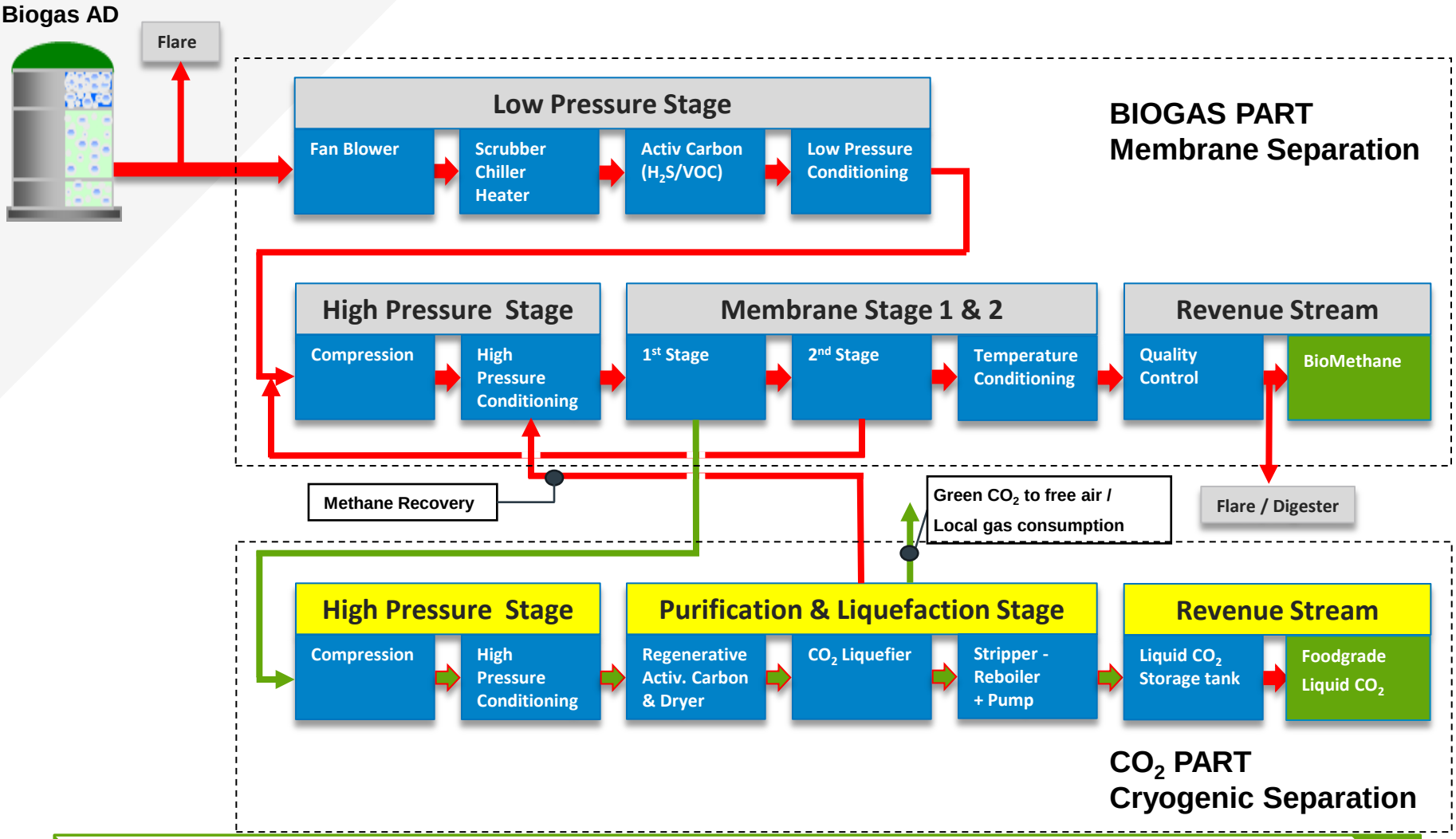
The source types are generic sources and there are variations in individual processes. Therefore, the supplier should assess whether or not all of the components listed are applicable to the actual plant.

Component	Combustion	Wells/ Geothermal	Fermentation /bioethanol AD (purely energy crops)	Anaerobic digestion (waste)	Hydrogen or Ammonia	Phosphate Rock	Coal Gasification	Ethylene Oxide	Acid Neutralisation	Vinyl acetate
Aldehydes	√	√	√	√	√		√	√		√
Amines	√				√					
Benzene	√	√	√	√	√		√	√	√	√
Carbon monoxide	√	√	√	√	√	√	√	√	√	√
Carbonyl sulphide	√	√	√	√	√	√	√		√	
Cyclic aliphatic hydrocarbons	√	√		√	√		√	√		√
Dimethyl sulphide		√	√	√		√	√		√	
Ethanol	√	√	√	√	√		√	√		√
Ethers		√	√	√	√		√	√		√
Ethyl acetate		√	√	√			√	√		√
Ethyl benzene		√		√	√		√	√		√
Ethylene oxide							√	√		
Halocarbons	√			√			√	√		√
Hydrogen cyanide	√						√			
Hydrogen sulphide	√	√	√	√	√	√	√	√	√	√
Ketones	√	√	√	√	√		√	√		√
Mercaptans	√	√	√	√	√	√	√	√		√
Mercury	√	√					√			
Methanol	√	√	√	√	√		√	√		√
Nitrogen oxides	√		√	√	√		√	√	√	□
Phosphine						√				
Radon		√				√			√	
Sulphur dioxide	√	√	√	√	√	√	√		√	
Toluene		√	√	√	√		√	√		√
Vinyl chloride	√						√	√		√
Volatile hydrocarbons	√	√	√	√	√		√	√		√
Xylene		√	√	√	√		√	√		√

MEMBRANE TECHNOLOGY

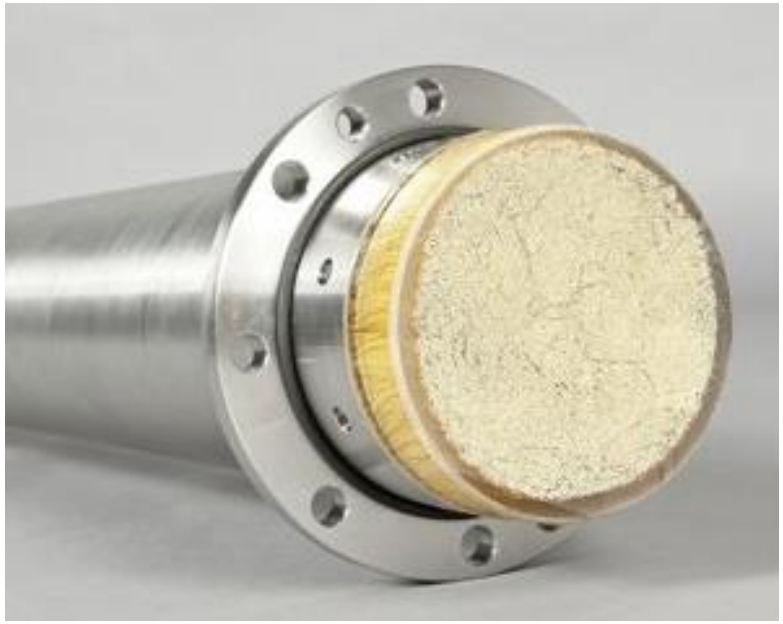


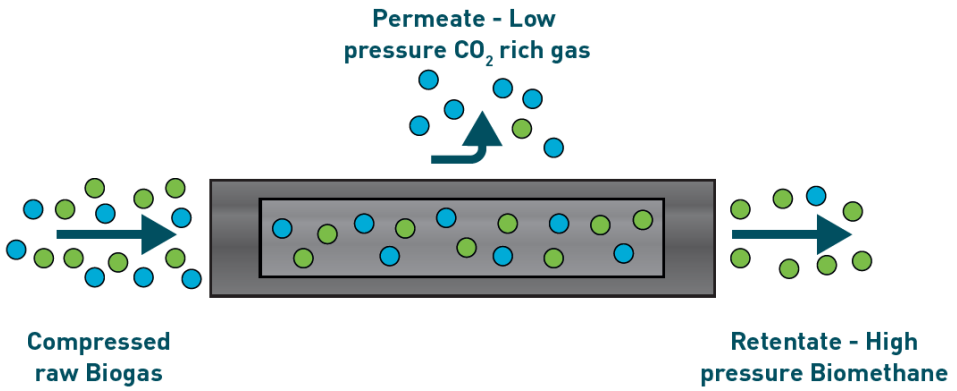
Biogas upgrading – ADVANCED *plus*

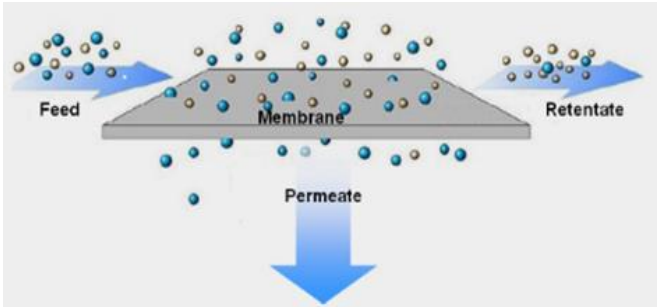


INTEGRATED PROCESS – 0 CH_4 SLIP – FOOD-GRADE CO_2 – LESS ENERGY

MEMBRANE GAS SEPARATION





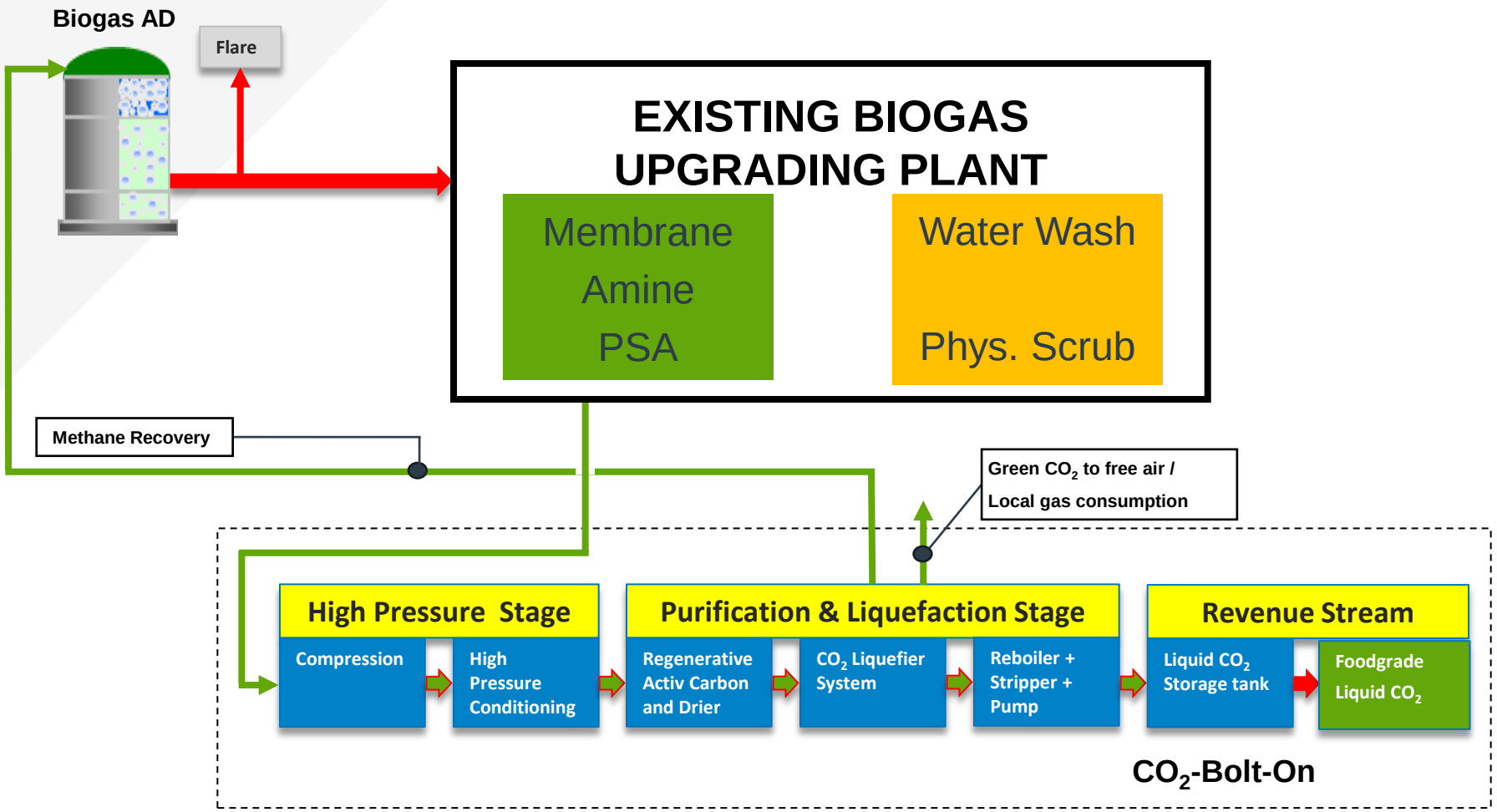


NL 2011: 450 Nm3/h biogas to grid & green CO_2

7 YEARS OF LIQUID CO_2 RECOVERY

BIOGAS UPGRADING – COMPACT & ENCLOSED

ADDITIONAL REVENUE WITH CO_2-BOLT-ON

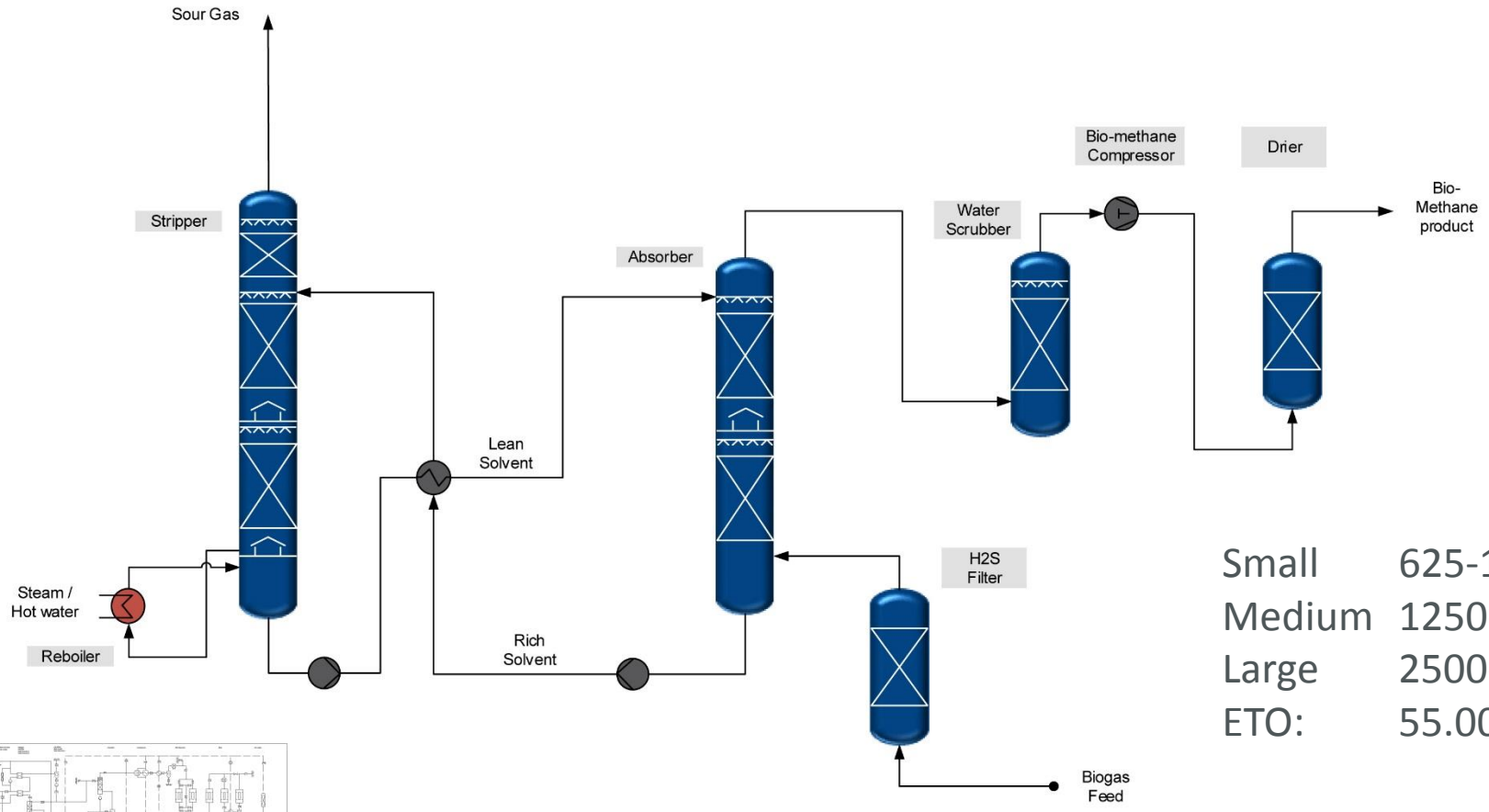


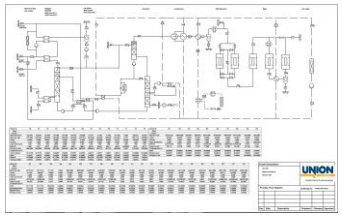
FOR VARIOUS UPGRADING PROCESSES – LARGE INSTALLED BASIS

AMINE TECHNOLOGY

We supply the most robust and innovative amine-based biogas upgrading plants. We have decades of experience in amine technologies for various purposes.

AMINE BASED BIOGAS UPGRADING



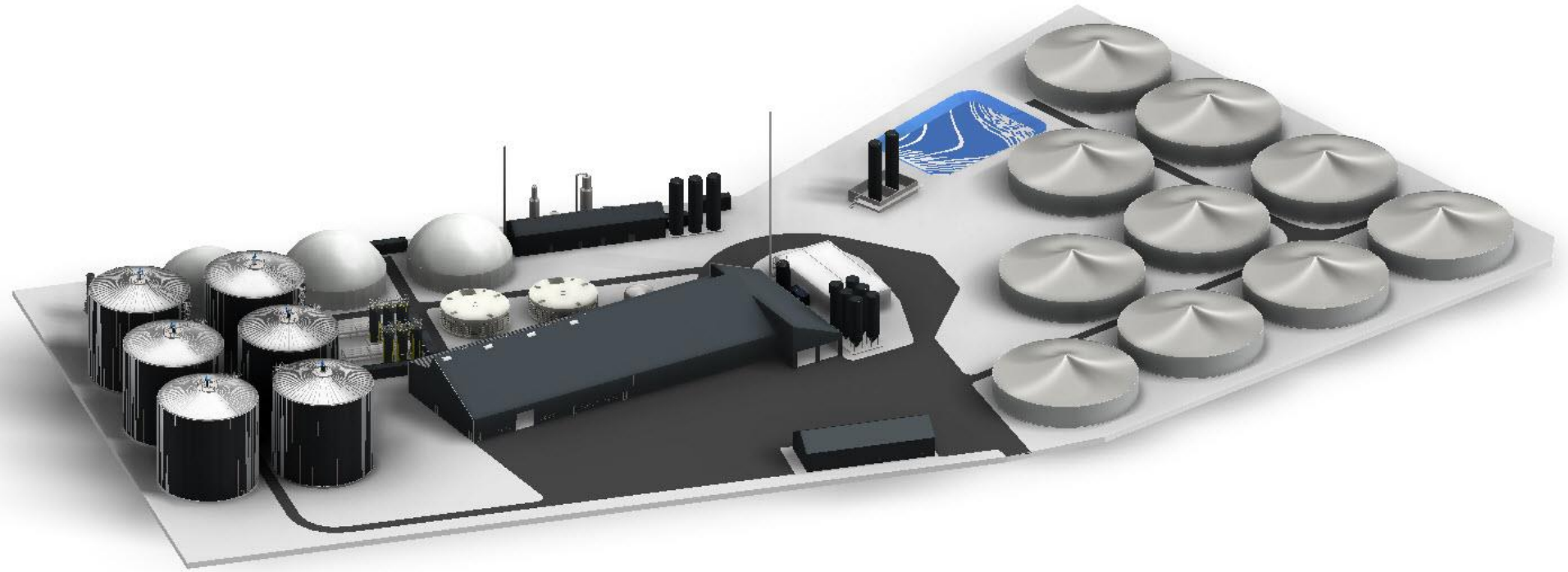


Small	625-1250
Medium	1250-2500
Large	2500-5000
ETO:	55.000 Nm3/h

BASED ON OVER 60 YEARS OF EXPERT KNOWLEDGE

KALUNDBORG BIOENERGI

5000 Nm^3/h raw biogas with heat recovery to AD



BIGADAN BUILT THE BIGGEST BIOGAS PLANT IN DK – COMMISSIONED IN 2018

KALUNDBORG BIOENERGI

- Capacity 5000 Nm3/h
- Amine Based Unit
- Biogas upgrading
- 0.1 % methane slip (can be upgraded to zero)

SAFEGUARDING THE CO_2 QUALITY

Cleaning steps of raw biogas before membrane biogas upgrading:

<u>Optional biological H_2S removal</u> (bulk removal of H_2S):
Reduction of H_2S levels from few 1000 ppm to 30-50 ppm levels

<u>Gas scrubber/chiller</u>
Removal of ammonia/water solubles (partial removal of VOC)

<u>Activated Carbon</u>
Removal down to max. 1-5 ppm of all contaminations :

- H_2S
- VOC (terpenes, ketones)

Success factors in practice

Operational training
Automated process control
Periodic 3rd party testing
SOP's: Absorbents replacement
Calibration procedure
Maintenance
Remote Process Support & SLA

Cleaning steps of raw CO_2 during liquefaction:

<u>Compression to 18 bar (g)</u>
-> Temperature increase to > 110°C -> sterilization of CO_2

<u>Regenerative activated carbon</u>
Removal of last ppm contaminations to ppb level

<u>Liquefaction, strip column</u>
Removal of all non-condensable gases: CH_4, N_2, H_2, O_2,

2016 UK MARKET BIO-CO_2 & BIO-METHANE

93 Plants

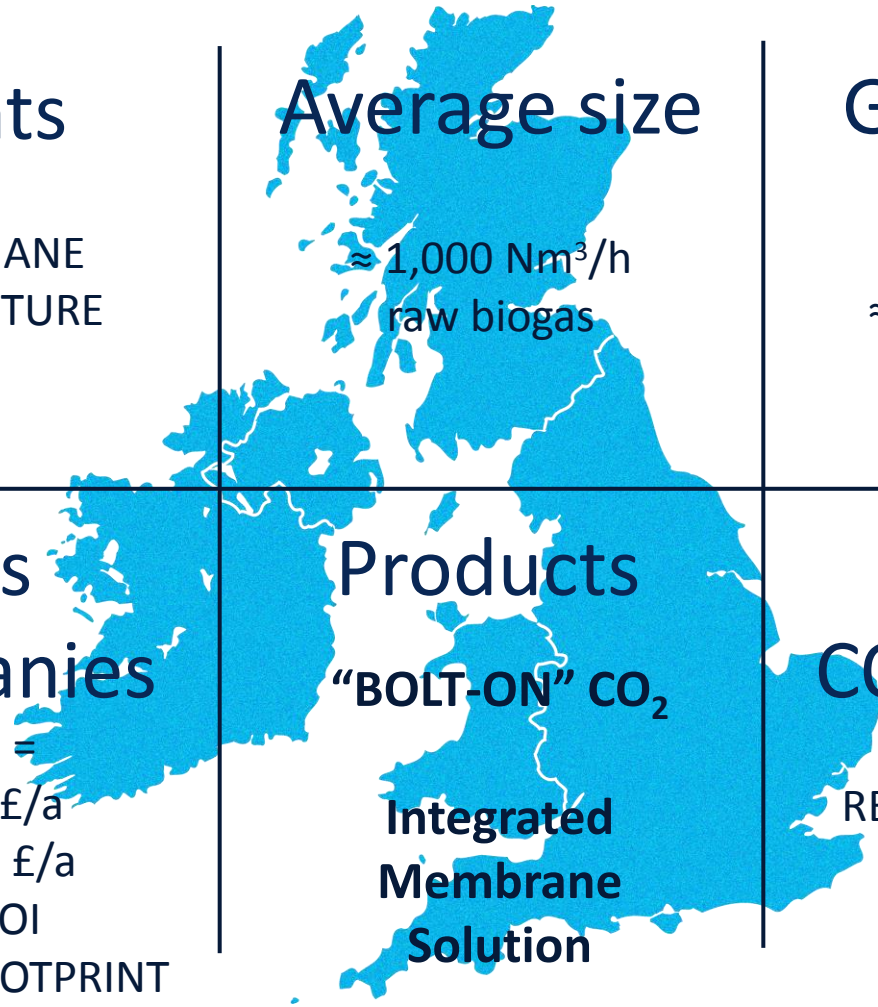
84 BIO-METHANE
EXCL. CO_2 CAPTURE

Average size

≈ 1,000 Nm^3/h
raw biogas

GHG-Emissions

≈ 1% SLIPPAGE =
≈ CH_4: 50,000 Nm^3/a
≈ CO_2: 7,000 t/a



Benefits CH_4 Companies

1% SLIPPAGE =
≈ CH_4: 50,000 £/a
≈ CO_2: 300,000 £/a
IMPROVED ROI
IMPROVED GHG FOOTPRINT

Products

"BOLT-ON" CO_2

Integrated Membrane Solution

Benefits CO_2 Companies

NO IMPORTS
REDUCED ROAD TRAFFIC
HIGH FLEXIBILTY
RELIABLE SOURCING
GHG REDUCTION

REGIONAL CO_2 DEMAND + DISTANT CO_2 SOURCE = FEASIBLE BIO-CO_2 PROJECT

CO_2 from biogas – quality & experience

FOOD SAFETY RISK ASSESSMENT WITH INDUSTRIAL GAS COMPANY

- Food safety risk assessment completed in 2016
- Inline / complete batch analysis before supply (30 vs. 9 components for industrial CO_2)
- 2000^+ EIGA samples since 2015
- CO_2 complies with food-grade requirements
- Test result: < 2 bacteria / dm^3
- Initial deviations caused by:
  - H_2S
  - Moisture
  - Hydrocarbons (propane)
- Approx. 99 % of samples now OK

NL EXPERIENCE

- First plant in operation since 2011
- Mainly bio-waste, vegetable & food waste
- Higher level of impurities -> process control
- CO_2 goes via industrial gas companies and OCAP pipeline mainly to greenhouses
- Demand driven by greenhouses

UK EXPERIENCE

- Energy crops / unprocessed vegetable matter
- High quality -> low risk
- CO_2 goes via industrial gas companies to food & beverage and industrial applications
- Shortage in conventional sources -> imports
- Regional demand & distant industrial sources

GERMANY, DK, USA, SOUTH AFRICA and PHILIPINES WILL FOLLOW

CO_2 Entscheidungungskriterien

ABNEHMER:

- Industriegasunternehmen oder lokaler Abnehmer?
- Werden die Biogas-Substrate akzeptiert?
- Regionale Nachfrage / Wettbewerb
- Mehrwert Flexibilität und Nachhaltigkeit
- Wer übernimmt: Qualitätssicherung
  Lagerung
  Transport

EINNAHMEN/KOSTEN:

- Marktpreis CO_2
- Mehrwert CH_4-Rückgewinnung
- Senkung der Treibhausgas-Emmissionen
- Investitionskosten (auch Tank/QS)
- Energiekosten
- Finanzierung
- Personal / Wartung

GRÜNES CO_2 ALS MEHRWERT

Conclusion

During summer 2018 a shortage in raw CO_2 caused serious problems for the beverage industry and other CO_2 consumers. Innovative solutions are reachable short, medium and long term:

- Low hanging fruits in solving the CO_2 shortage periods include extended storage and further utilization of biogas upgrading with the two value streams biomethane and food-grade CO_2
- Biogas represents a growing source of green CO_2 as the global biogas market grows.
- CO_2 from biogas has been approved for food & beverages by EIGA and is under review by the ISBT
- Some countries (NL, UK, ...) have started using the biogas CO_2
- As other raw gas sources are declining, decentralized investments offer the most stable CO_2 supply
- Looking ahead, new and environmental conscious solutions are coming up – however the technical and commercial feasibility is still uncertain

CO2 shortage is avoidable – the solution is individual

Thank you

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Category Leader – Gas Solutions

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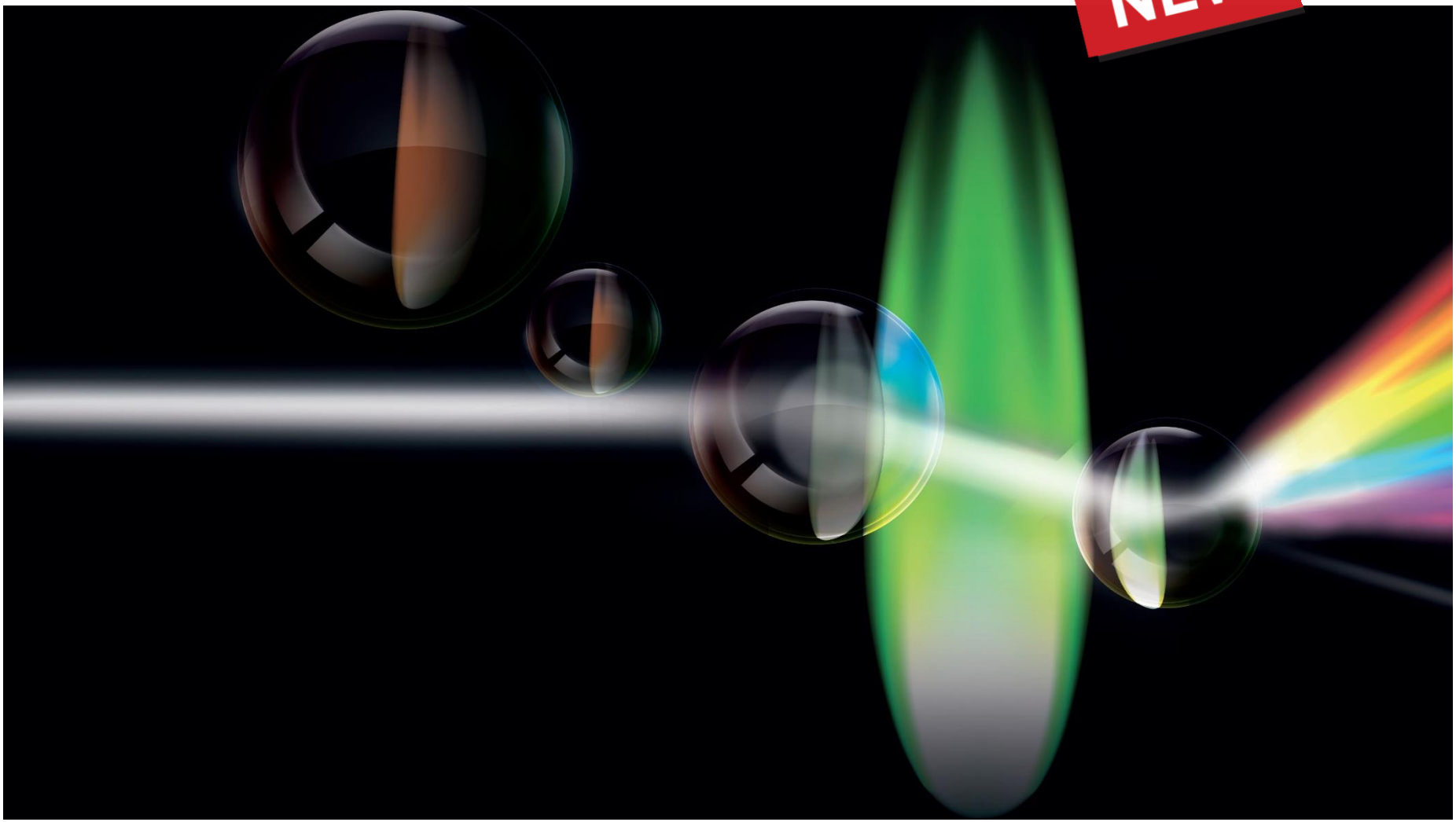
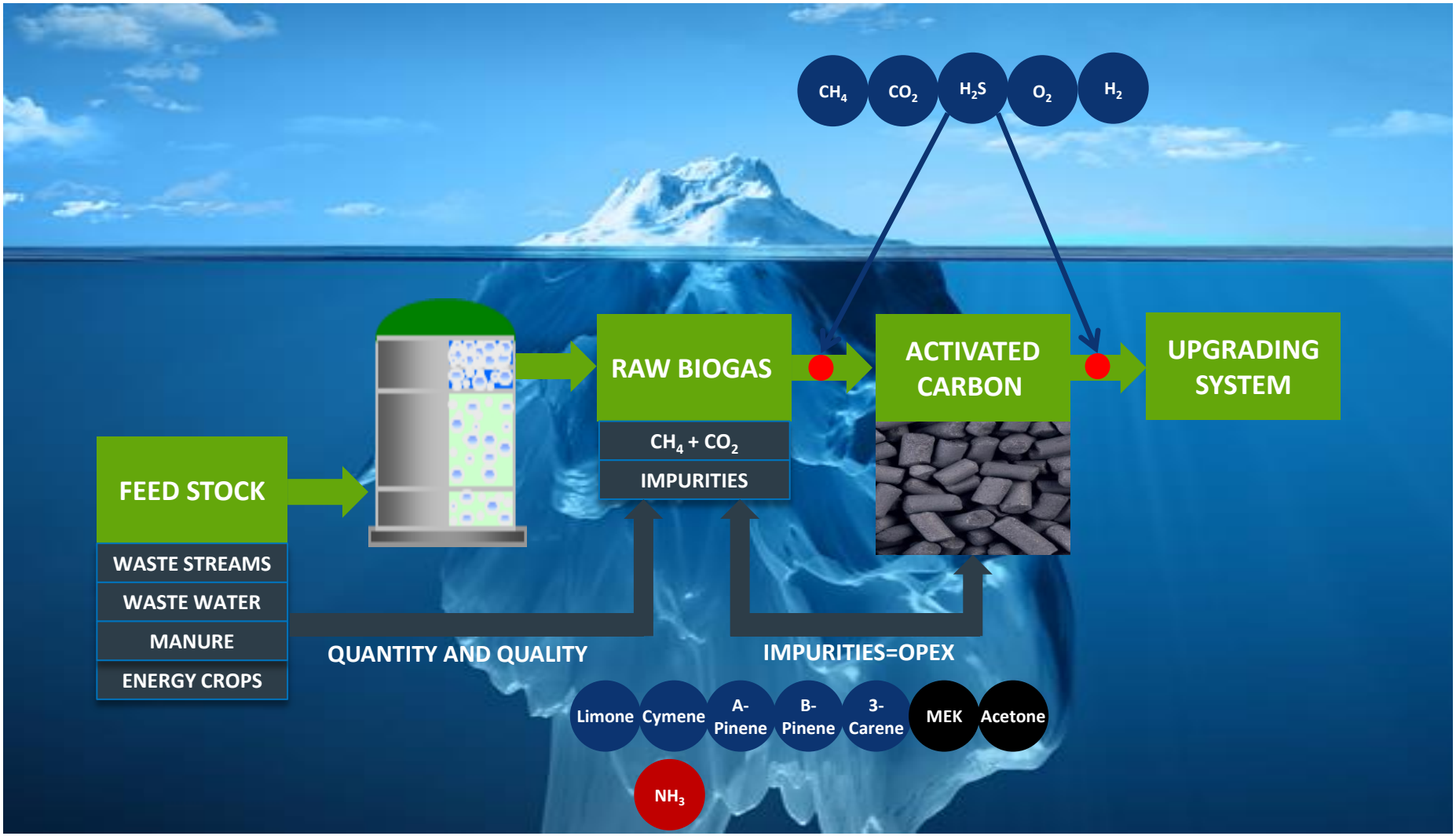
BIOSENSE – ONLINE VOC SENSOR



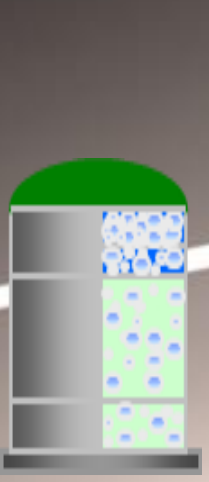
FEED STOCKS, PRE-TREATMENT & OPEX

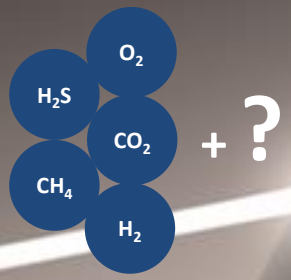


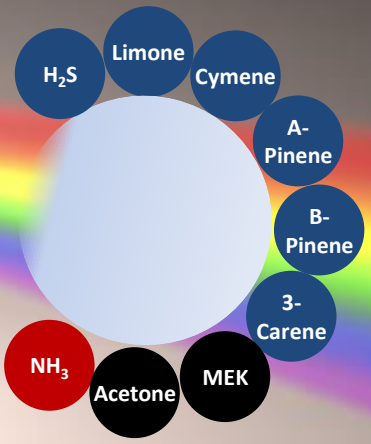
"KNOW YOUR HIDDEN COSTS"

BACK TO START

BioSENSE=>OPTICAL ABSORBTION SPECTROSCOPY







- **DETERMINE SATURATION POINT ACTIVATED CARBON**
- **OPTIMIZATION FEEDSTOCK/SUBSTRATES**

***Safeguard membrane performance and service Life**
***Reduce bio-methane production Costs**

***Reduce Operational Costs for AC**
***Increase uptime**

"OPTIMIZING THE TOTAL BIOGAS PROCESS"

BACK TO START