BERGHOF MEMBRANE TECHNOLOGY GmbH

Berghof Membranes

AnMBR

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Membranes
Think outside the box

AnMBR - *Table of contents*

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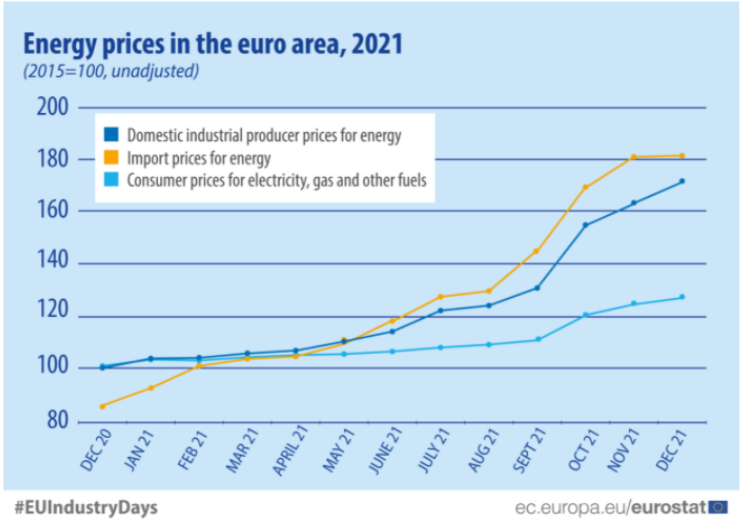
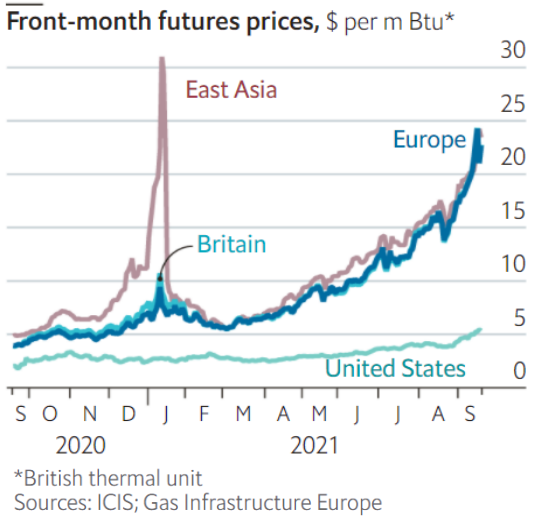
Drivers for AnMBR

Pushed by the energy context:

- Unprecedented rising **prices** for **energy and gas**
- Increased CO2 pricing to fulfill **decarbonization targets**
- **Energy dependency** in a global unstable scenario
- Some facilities even at risk of becoming **unprofitable**



Natural gas



*British thermal unit
Sources: ICIS; Gas Infrastructure Europe

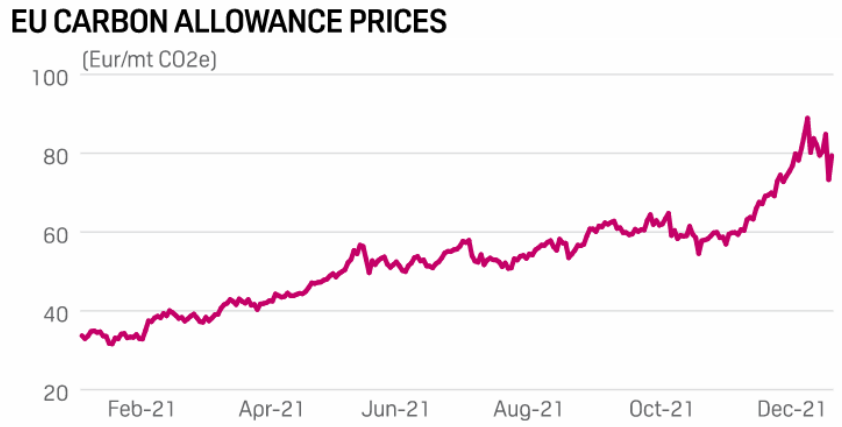
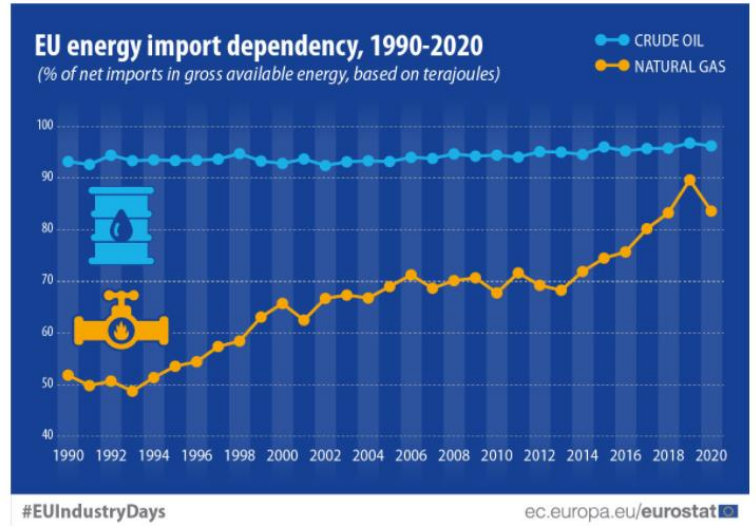


Chart shows EU Allowance futures contracts for Dec. 2021 delivery (daily close)
Source: ICE Endex



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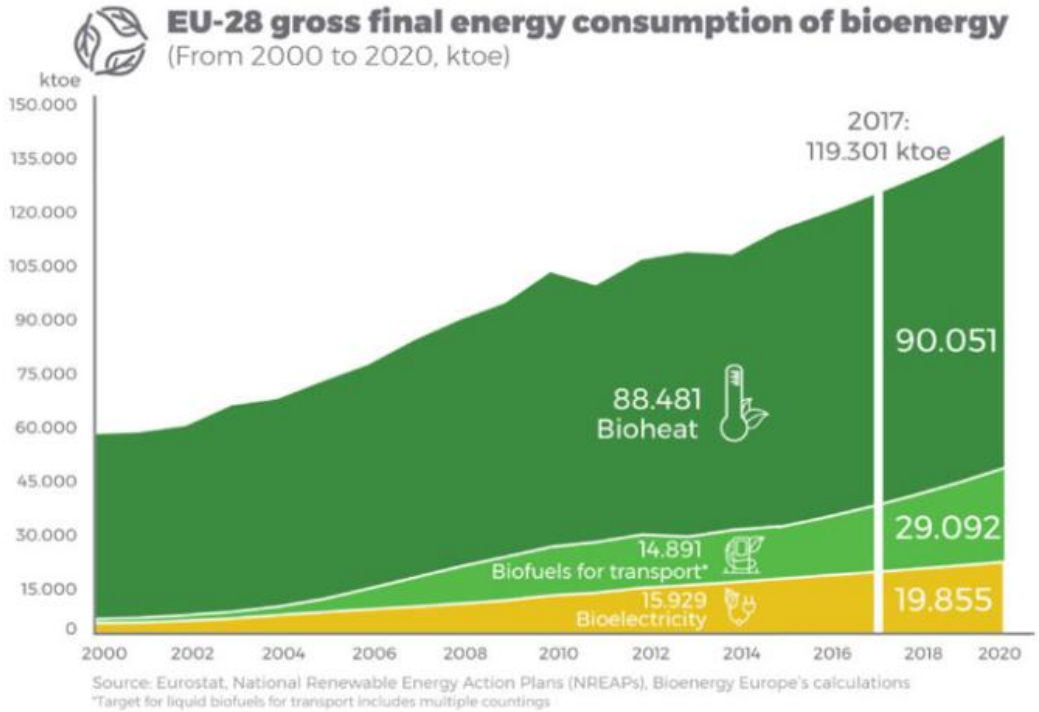
Drivers for AnMBR

Clear trend for bioenergy production:

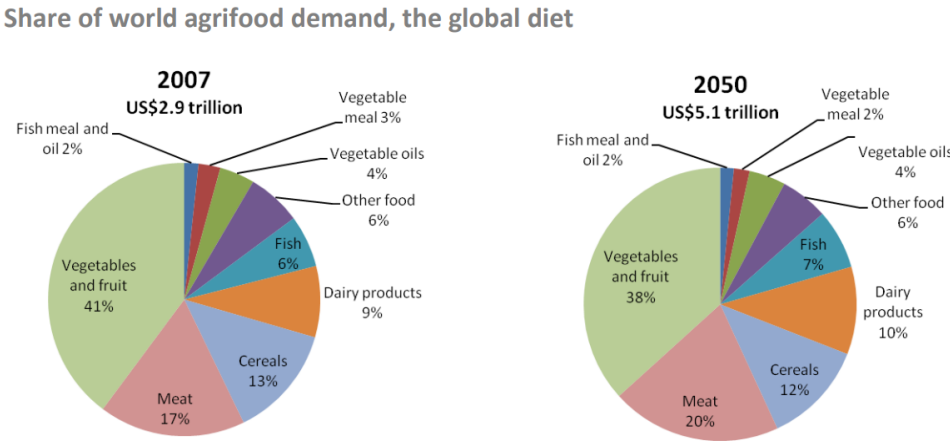
- Increased **environmental** awareness about fossil fuels
- Targets for reducing the **primary energy** consumption *(Energy Efficiency Directive - EED)*
- **Economic** incentives for green energy production *(REPowerEU)*
- **Sustainable practices** as a tool for improving public perception
- Development and **consolidation** of advanced technologies such as **AnMBR** during the last decade

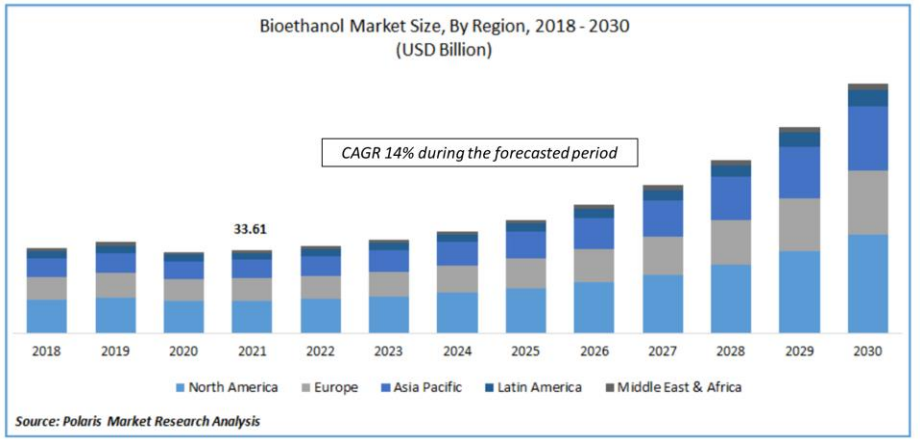


Global challenges

Why the need for AnMBR technology?

- Rise in the production of **high-strength industrial** wastewater: population growth vs. **food & beverage demand**.
- **Biofuel** production (e.g. bioethanol): source of complex high-loaded wastewater.
- Growing **concern** about water consumption and pollution, stringent regulations.
- Industries' target on reducing **water** and **energy footprint**.
- Need for effective & efficient technologies: maximize organics turned into **biogas** + produce high-quality **treated water**.
- AnMBR technology increasingly **cost effective** and even **profitable**.





Membranes
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The Solution

- Do you need to treat **high-loaded** wastewater?
- Do you want to reduce your **water** footprint by applying **reuse** strategies?
- Or do you need to improve your **effluent quality** for reducing your discharge costs?
- For any of these purposes… Are you looking for a **low OPEX** technology?
- And what if this solution allows you to even obtain **profit from your waste**?

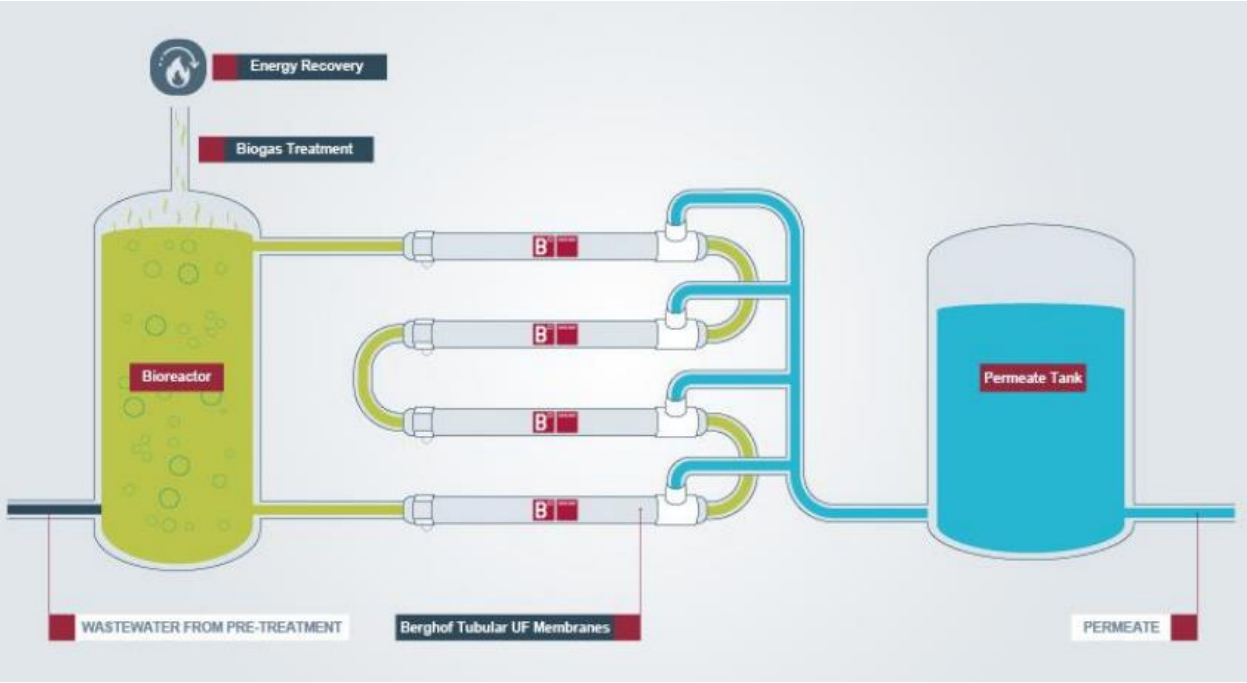
Then, your solution is the anaerobic membrane bioreactor:

AnMBR

Interested in learning more about AnMBR?

How can Berghof Membranes support you?
Tubular AnMBR

- **External** tubular UF system coupled to a simple complete-mix digester.
- For **high-strength** wastewater, achieving maximum conversions of organics into **biogas.**
- Superior effluent quality, for direct **discharge** or **RO post-treatment** for reuse.
- Limited **footprint**: high OLRs, compact UF skid. Pre- and post-treatment minimized or avoided.



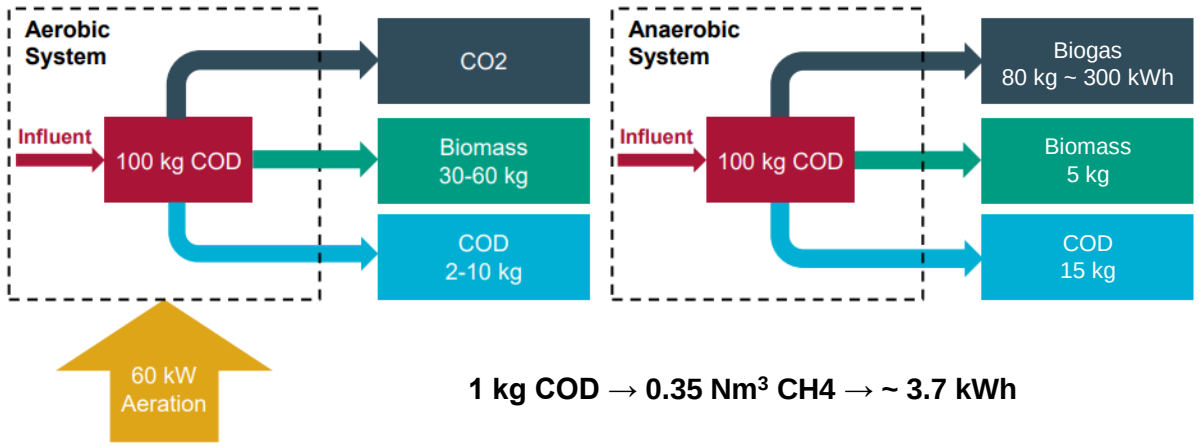
The best solution **for high-strength and high-solid wastewaters:**

- food&beverage,
- dairy,
- bioethanol production,
- distilleries,
- slaughterhouses,
- confectionery,
- fish processing,
- …

Tubular AnMBR

Why an anaerobic process for high-strength wastewater?

Feature	Aerobic	Anaerobic
Energy	Higher, due to aeration	Minimum, positive net **energy generation**
Organic load	Low – medium (COD < 10 g/L)	Medium - high (**COD > 10 g/L**)
Effluent quality	Very good (COD < 100 mg/L achievable). No SS.	Good, higher COD (~ 3 - 5x). No SS.
Nutrient removal	N and P removed (with the appropriate reactor configuration)	Limited N removal and moderate P removal, depending on technology
Sludge production	High (30-40% of the inlet COD)	**Low** (8% of the inlet COD)
Biokinetics	Simple, generally stable	Control required (pH, T…)



1 kg COD → 0.35 Nm³ CH4 → ~ 3.7 kWh

Instead of consuming huge amounts of energy for aeration, the AnMBR generates electricity from the organic material.

Additionally, anaerobic processes can produce up to 75% less excess sludge, significantly reducing the solids handling costs.

Tubular AnMBR vs. other known methods

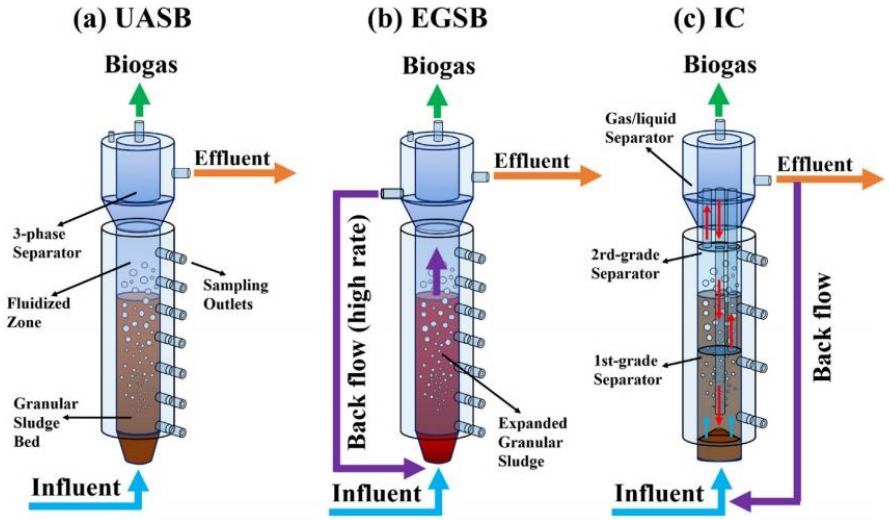
The success of high-rate anaerobic treatment depends on the retention of slow growing methanogenic bacteria (efficient **decoupling of SRT and HRT**).

3 methods are conventionally applied for **biomass retention**: settling, attachment and granulation.

For industrial wastewater, several **granular sludge technologies** are available: UASB, EGSB, IC.

These technologies can be feasible and efficient, but under certain conditions they present certain **limitations**:

- Deterioration of effluent quality (degranulation, biomass wash-out…)
- Partial/uncomplete COD removal – reduced biogas production
- Long and complex start-up period (granular seed required)
- Complex internal design of the digester (vs. completely stirred digester)

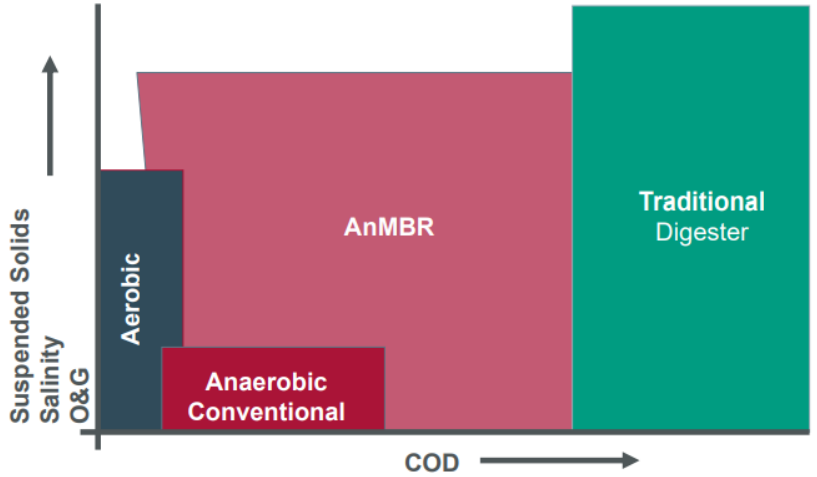


Z. Kong et al. Journal of cleaner production. 2019. https://doi.org/10.1016/j.jclepro.2019.05.233

Tubular AnMBR
Advantages over conventional anaerobic technologies

Conventional anaerobic technologies such as granular sludge are hampered by the fats, oil and grease (**FOG**), suspended matter (**TSS**) and **salinity**. AnMBR overcomes these issues and provides major benefits:

- Effluent quality: the highest **COD removal** (up to 99%, vs 75-90%) - allowing discharge or RO for reuse.
- Improved **energy balance** due to increased biogas production (+25%)
- Ability to handle **high TSS and FOG**, simplifying the pretreatment and maximizing the conversion of organics into biogas.
- **No DAF** pretreatment, reducing chemical consumption and avoiding big amounts of sludge.
- No washout of biomass: rapid **start-ups**, specialized microbial communities and **robustness** against organic or toxic shocks.



Tubular AnMBR
The external principle - Benefits

External filtration system provides distinct advantages over submerged membranes:

- **Stable filtration**: the most suitable for anaerobic sludge, characterized by poorer filterability (vs. aerobic).
- **Flexibility** and **adaptability**: cross-flow operation effectively deals with influent variability or process fluctuations.
- **No** need for gas **scouring** (e.g. nitrogen, biogas) for fouling control.
- ´**Out of tank**' service and maintenance. Fully accessible membranes.
- Completely **automated CIP** cleaning, minimum system downtime.
- Robust membranes, less susceptible to breakage. **Long lifespan**.

➢ <u>External membranes are the most proven in industrial scale AnMBR projects</u>

Tubular AnMBR
Operational conditions and performance

- Uncoupled hydraulic and solids retention times. Complete solids retention and control of a long sludge age.
- Operational **conditions**:

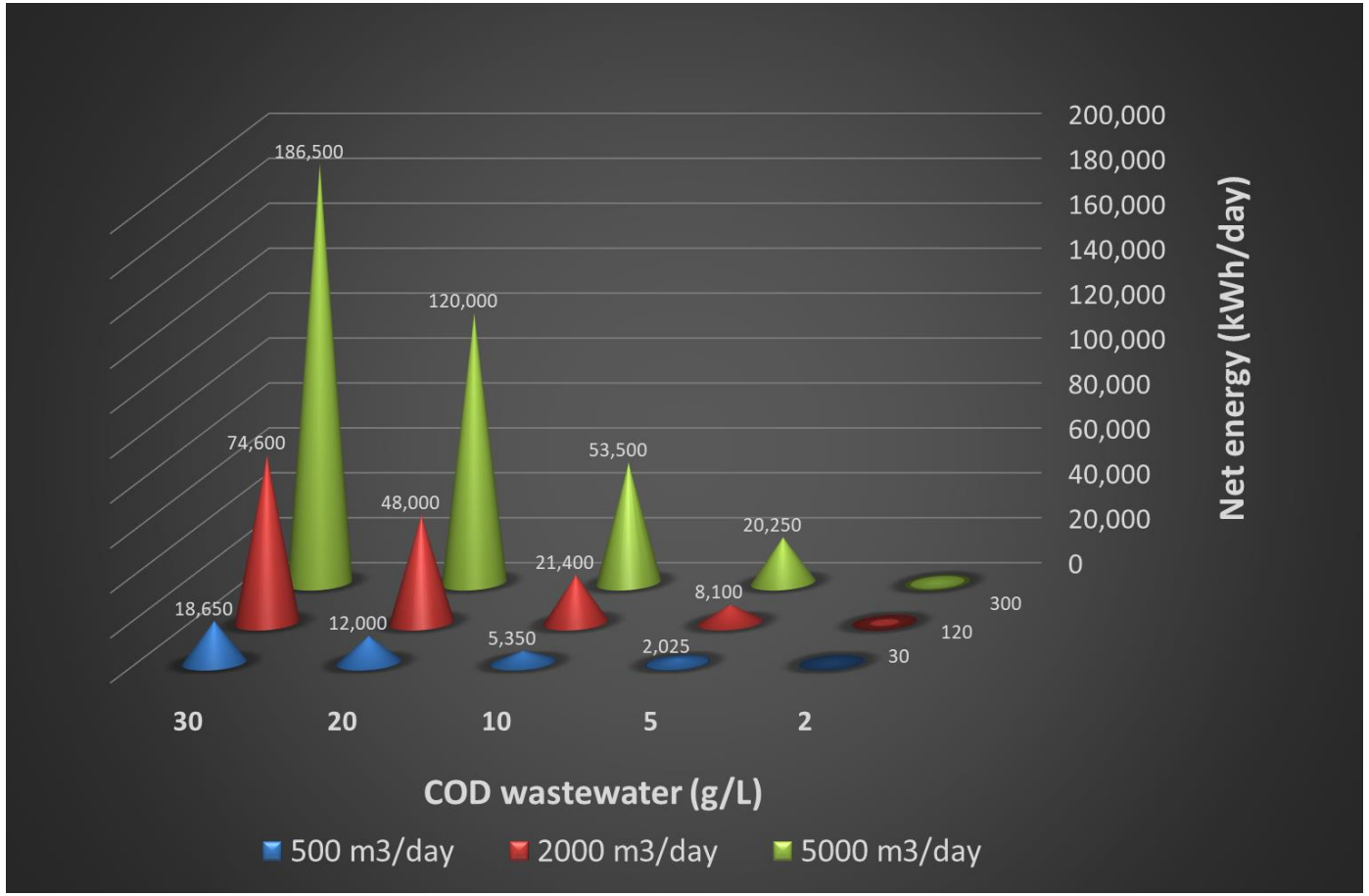
Anaerobic digester	
MLSS	20 g/L (standard)
OLR	6 – 10 kgCOD/m^3·day
Temperature	Meso and thermophilic

Tubular UF	
Flux	25 – 55 LMH
CFV	2 – 4 m/s *(Performance vs. Eco)*
Energy	1.8 – 4 kWh/m^3

- **Membrane**: PVDF, 30 nm cut-off, 8mm diameter, backwashable and non-backwashable.
- Standard **permeate** quality:

Parameter	**Value**
TSS	< 3 mg/L (not detectable)
Turbidity	< 1 NTU
SDI	< 3
COD	Depends on WW, often < 300 mg/L

Tubular AnMBR
Positive net energy balance



In this graph, the difference between the energy generated from the biogas and the energy consumed by the UF is displayed.

Different capacities and inlet CODs are considered.

Conclusion: for high-load wastewater, the net **energy balance** is **positive:** energy obtained from biogas is higher the energy consumed by the UF.

Note: the following calculation basis has been applied:

- Only UF consumption has been considered (digester and ancillaries not included).
- Specific UF energy consumption: 2.6 kWh/m^3.
- 95% COD removal, 0.35 Nm^3CH_4/kg COD removed.
- 65% CH_4 biogas, 6.5 kWh/Nm^3 biogas
- 40% Efficiency biogas transformation

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Reference cases

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AnMBR Installation – Dairy

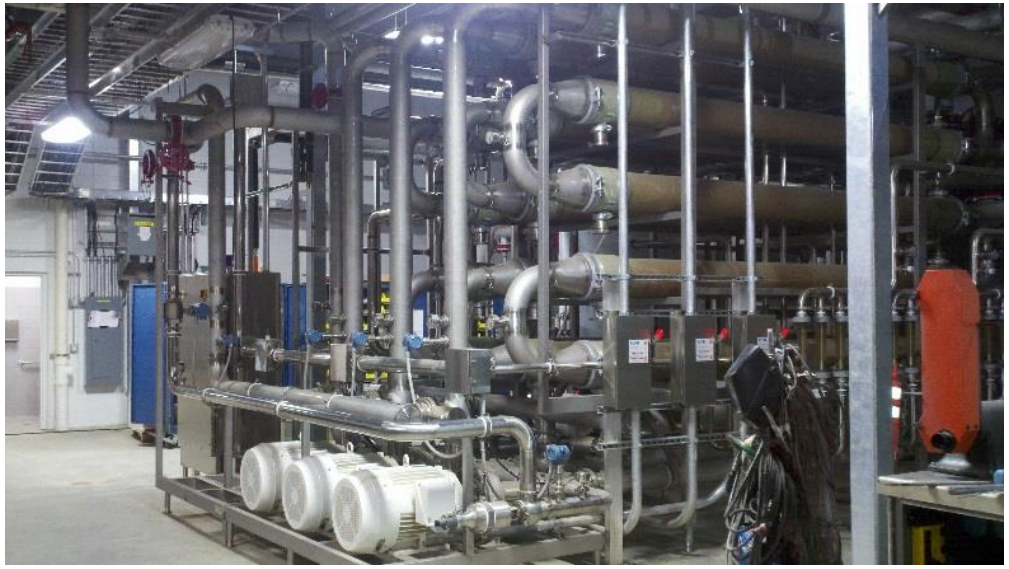
Dairy Industry

The dairy industry is considered to produce one of the largest **quantities** of wastewater and one of the highest **organic** pollutants loads.

Wastewater **variability** is often high (due to individual processes, cleaning operations…).

As a result, **robust** and **flexible** technologies are required.

Location:	**USA. Wisconsin**
Capacity:	**2,160 m^3/day**
Industry:	**Cheese and yogurt**
Solution:	**External AnMBR**
COD influent:	**25,000 – 50,000 mg/L**



- 99% COD removal
- Significant phosphorus removal
- Biogas utilized for generating electrical **power and heat**.

AnMBR Installation – Beverage industry

Distillery

Liquor production requires large **amounts of water** (as raw material and for cleaning operations).

Distillery WW is acidic and presents **huge COD** values – even > 100,000 mg/L.

Waste-to-energy plants provide low-cost energy to **heat the stills** and meet compliance and sustainability targets.

Location:	**Northern UK**
Capacity:	**467 m^3/day**
Industry:	**Distillery**
Solution:	**External AnMBR**
COD influent:	**31,000 mg/L**

- > 95% COD removal
- ~ 8,000 Nm^3/day biogas generation
- Treated biogas is burned in a biogas boiler (gases produced are scrubbed)
- Treated effluent is safely discharged into the northern UK coast.

MBR + AnMBR Installation – Dairy

Dairy industry

Phase I: Conversion of CASP to aerobic MBR (effluent reused after RO for cooling towers and steam generation)

Phase II: **AnMBR** + segregation (low/high COD)

Tubular UF coupled to a 3800 m^3 anaerobic digester

40% flow and 70% organic load treated in the AnMBR

Location:	**USA. Wisconsin**
Capacity:	**1900 m^3/day**
Industry:	**Butter products**
Solution:	**External AnMBR**
COD influent:	**20,000 – 40,000 mg/L**

- AnMBR effluent COD < 300 mg/L
- 60% reduction chemicals for P removal
- Biogas: 9,000 kW per day of electricity

Feed

Aerobic MBR

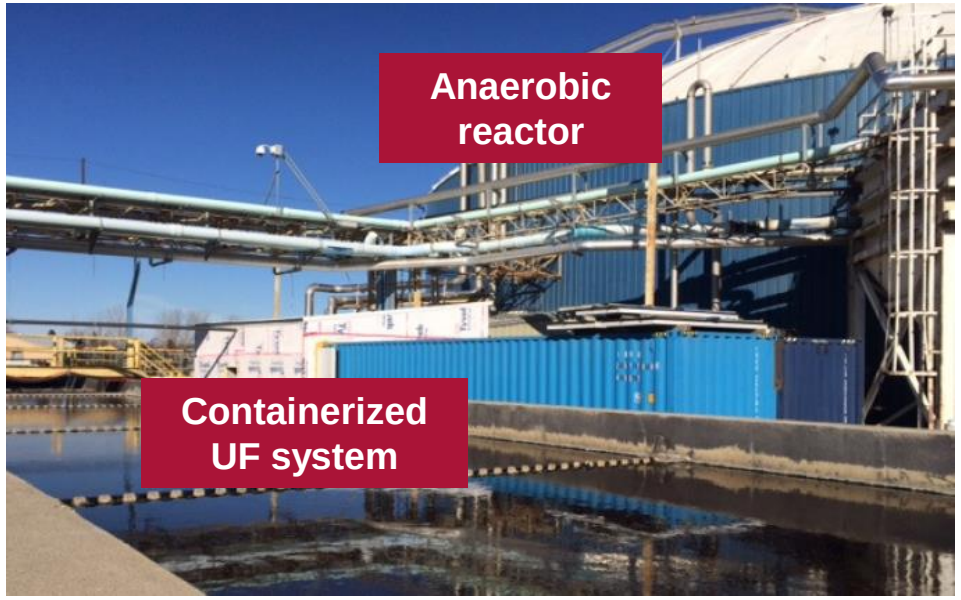
Anaerobic MBR

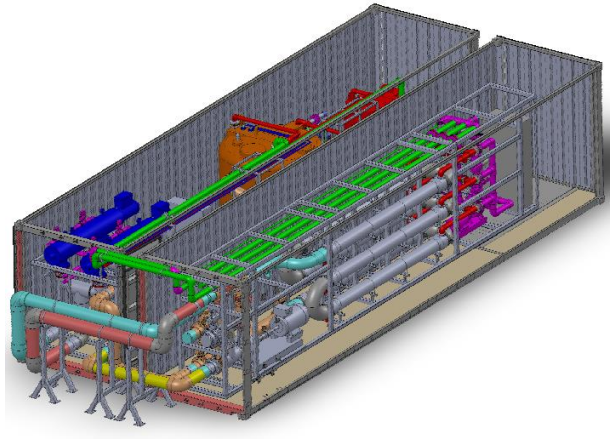
AnMBR Installation – Sugar production

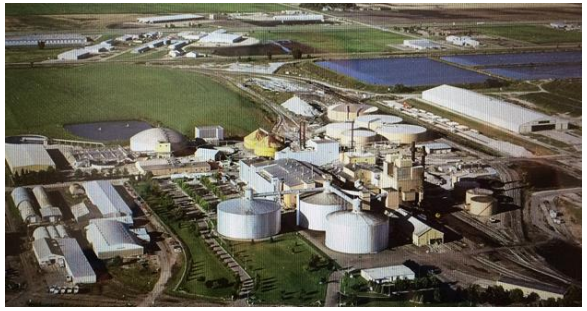
Food Industry – Sugar beet processing plant

Sugar production is a **water intensive** process that produces a large amount of wastewater with **high COD** and **BOD**, mostly consisting of **organic carbon** compounds.

Location:	**USA. Wisconsin**
Capacity:	**768 – max. 800 m³/day**
Industry:	**Sugar beet**
Solution:	**External AnMBR**
MLSS:	**20 – 25 g/L**
CFV:	**1.5 – 4 m/s (B-Smart Eco)**







Company / corporate info

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Berghof Group

Your Innovation Hub

As an adaptive, growing company and strong partnership network, we integrate expertise, technologies and resources into a first-class service.

- 8 Business Units
- 400 Employees Worldwide
- Offices in Europe and Asia
- 50+ year history

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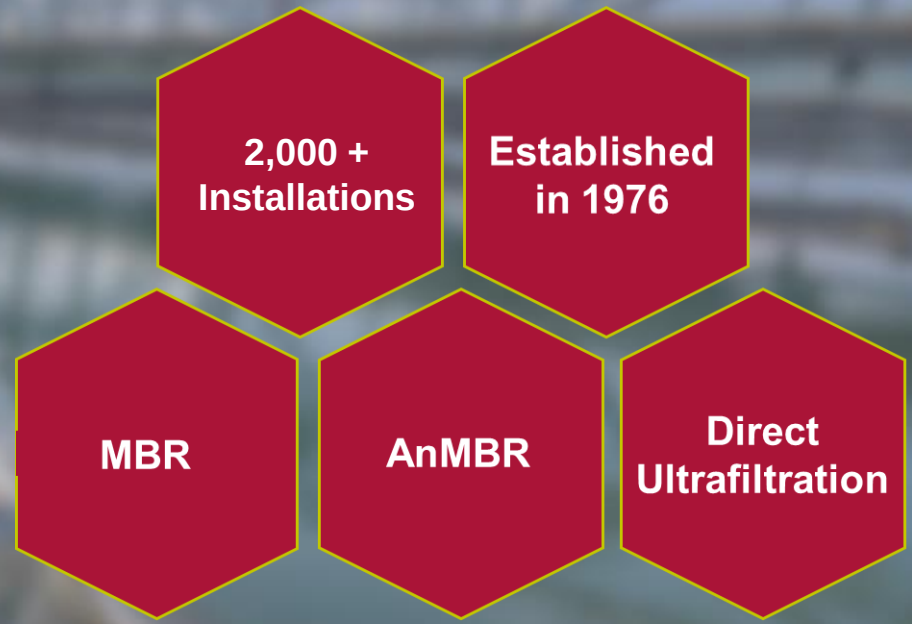
Berghof Membrane Technology GmbH (BMT) is the leading manufacturer of tubular membranes for the filtration and separation of process streams and wastewater for industrial applications including Dairy, Food&Beverage, Landfills, Chemical, Pharmaceutical, and Oil&Gas.

With more than 50 years of experience and over 2,000 installed systems across the globe, Berghof Membranes prides itself on the robustness, flexibility, energy-efficiency and superior quality of its external filtration membranes and solutions.



4 Sites
(Germany, The Netherlands, Singapore, Spain)

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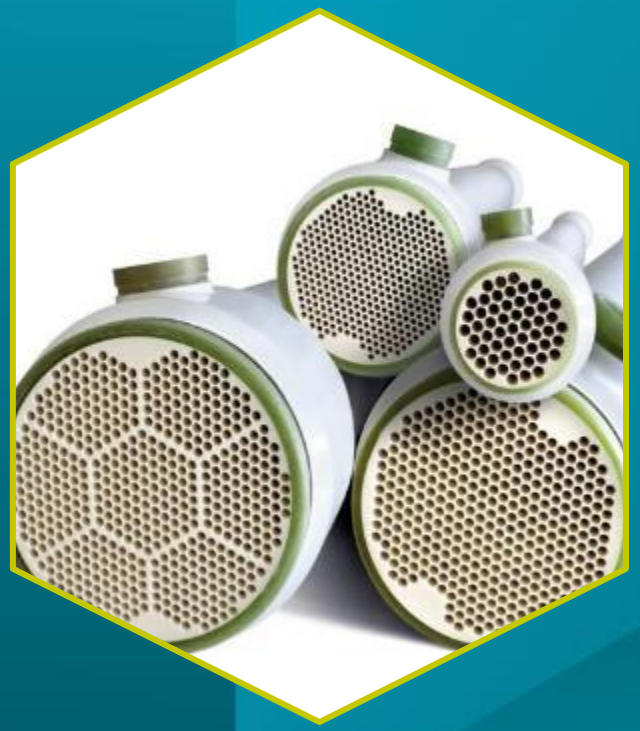
More than just a membrane supplier

Tubular UF

Membrane Modules



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Service and Support Programs

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Questions?

Feel free to contact us via
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Thank you very much

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