# Pioneering Carbon Capture Solutions for Sustainable Transportation and Chemical Industries

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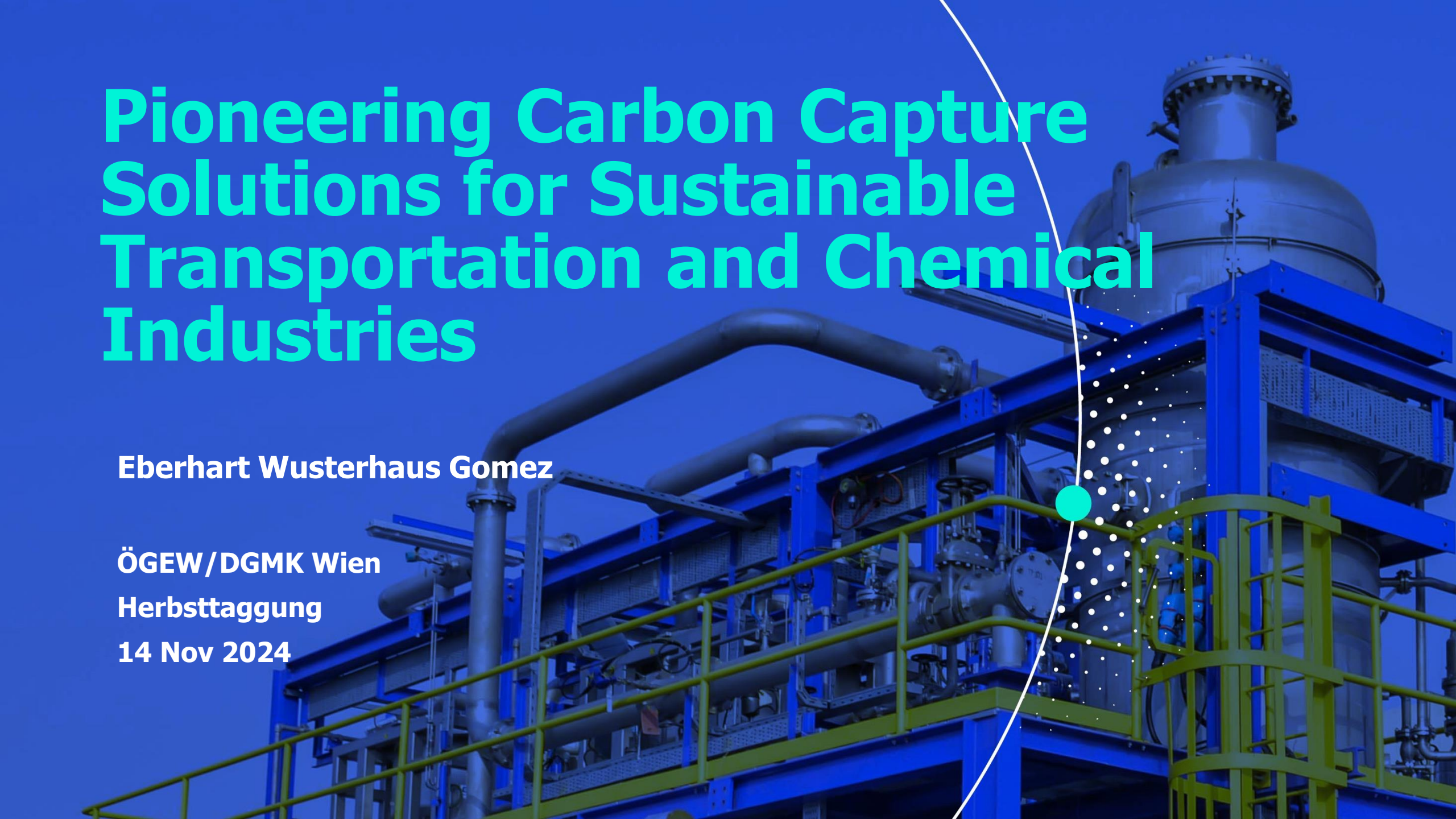


# Agenda

Pioneering Carbon Capture Solutions

## 1. Introduction to eFuels

- Overview of Aviation Fuels and Methanol Markets.
- Efuels in the EU
- eFuels economic challenges.

## 2. Integrating Advanced Systems for Efficiency

- Analysis of integrating PEM electrolyzers, carbon capture, and methanol production.
- Opportunities for heat integration, utility sharing, and operational synergies.

## 3. CCSL's Role in eFuel Sector

- Partnerships for a Design Performance Centre
- Intensification of the Carbon Capture technology
- Vision for the future of eFuel projects and an accelerated deployment.

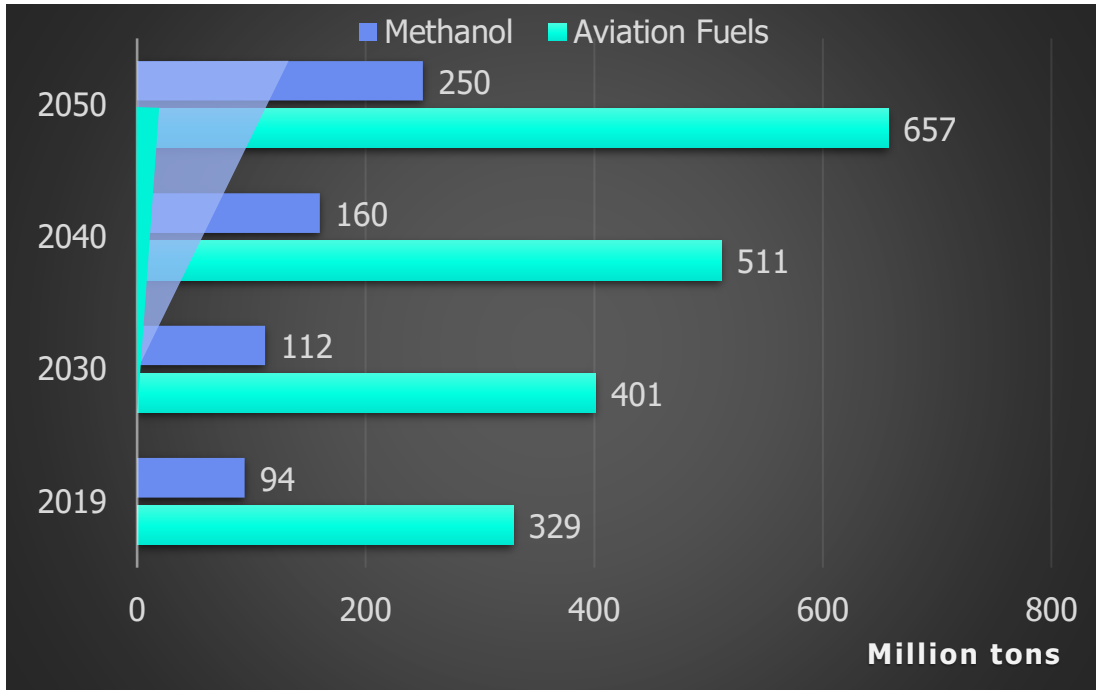
# E Fuels

## A Promising Solution with Economic Challenges

# Markets in Focus

**Aviation Fuel and Methanol**

Growth Outlook expected during Energy Transition 2019 - 2050




***Demand combined of fossil / renewable sources***

Methanol Institute

**eMethanol**

- 2050: 112MM TPY

**CAGR ≈ 26%**

- 2030: 1.1 MM TPY

***It is expected that Marine Applications to drive up the eMethanol demand.***

***Challenges: price and on-board logistic.***

ReFuelEU

**SAF**

- 2050: 21MM TPY

**CAGR ≈ 19%**

- 2030: 0.6MM TPY

***Considering EU consumes 15% of the global Aviation Fuel demand, ReFuel EU will allow 20 – 25% of SAF to replace EU's jet fuel consumption by 2050.***

*Source: Bloomberg terminal JODI< GO>, BloombergNEF*

*Source: S&P Global*

*Source: Methanol Institute / DNV*

# eFuel EU Regulations

**SAF and eMethanol** **From 1st January 2025**

Penalties under the ReFuelEU Aviation regulation for not meeting the Quotas.

- **Fuel Suppliers**: If SAF Supply Quota not met
  2x Missing quota (Jet fuel €/ton – SAF €/ton).

- **Airlines**: If SAF Uplift Quota not met
  2x Missing Quota (Jet fuel €/ton)

***ReFuelEU Aviation***
***SAF Quota at EU Airports:***

***2025 – 2%***

***2030 – 6%***

***2040 – 32%***

***2050 – 70%***

Penalties under FuelEU Maritime for not meeting the GHG intensity:

- **Ships**:
  If GHG intensity exceed the allowed:

  €2400(/ton VLFSOeq) x Energy Used x (GHG actual – GHG req)

- GHG Intensity 100% within EU/EEA and 50% in/out EU/EEA

***FuelEU Maritime***
***GHG Intensity Reduction:***

***2025 – 2%***

***2030 – 6%***

***2040 – 31%***

***2050 – 80%***

***GHG Intensity: 91.16 gCO2re/MJ)***

# eMethanol

**Cost to replace 1 ton of LSFO equivalent.**

carbon clean

## 2030

Cost breakdown (USD/Ton LSFO eq)

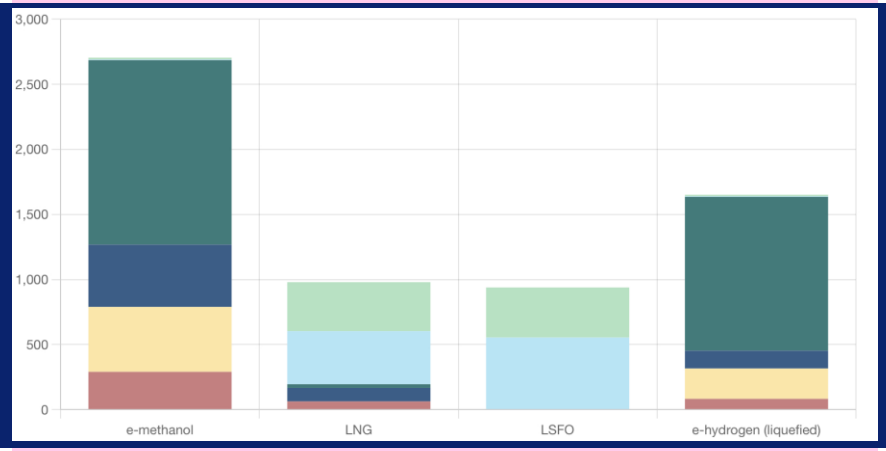
**100 USD carbon tax**

## 2050

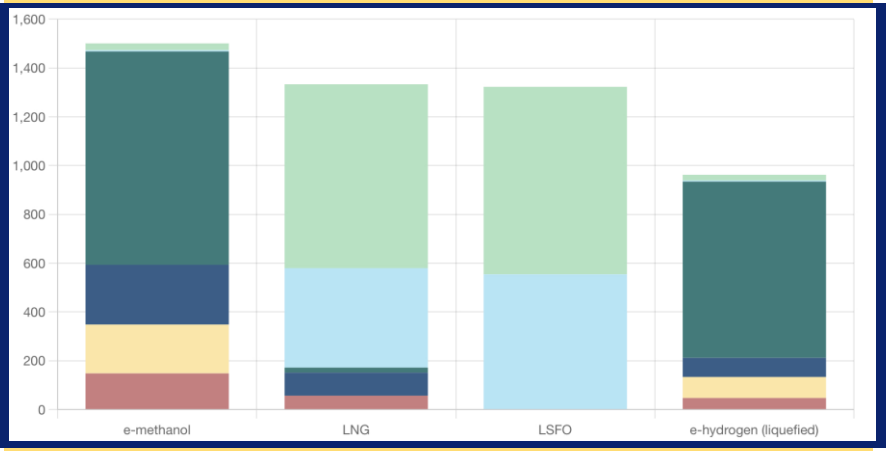
Cost breakdown (USD/Ton LSFO eq)

**200 USD carbon tax**

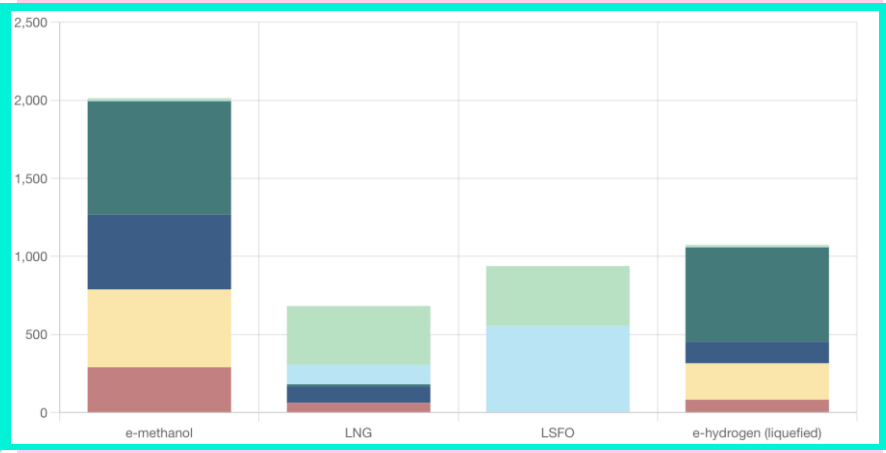
**Europe**



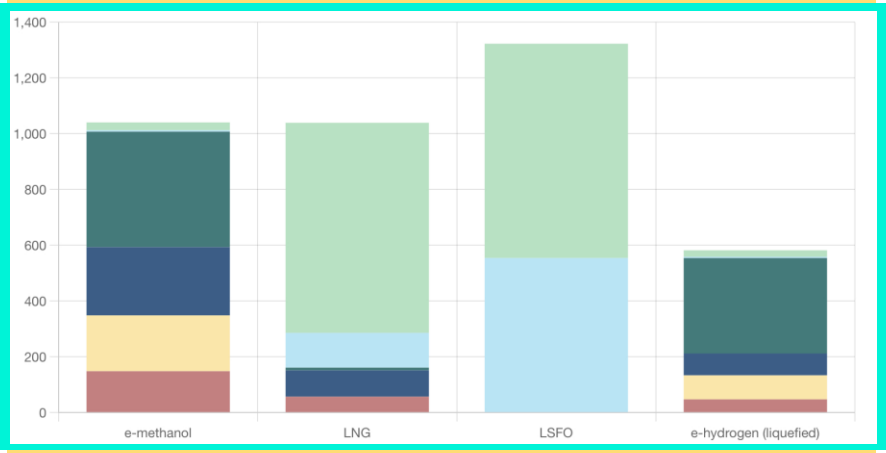

**High Power Prices**




**Middle East**




**Low Power Prices**



# E Fuels

## Integrating Advanced Systems for Efficiency

# eFuel Main Elements

**SAF and eMethanol**

Liquid Wind

carbon clean

TOPSOE

carbon clean

ALFA LAVAL

SIEMENS energy

Renewable Electricity

Green Hydrogen

Green Oxygen

Dual Compressor $H_2/CO_2$

Emission Source

Green CO2

MeOH Synthesis $H_2/CO_2$

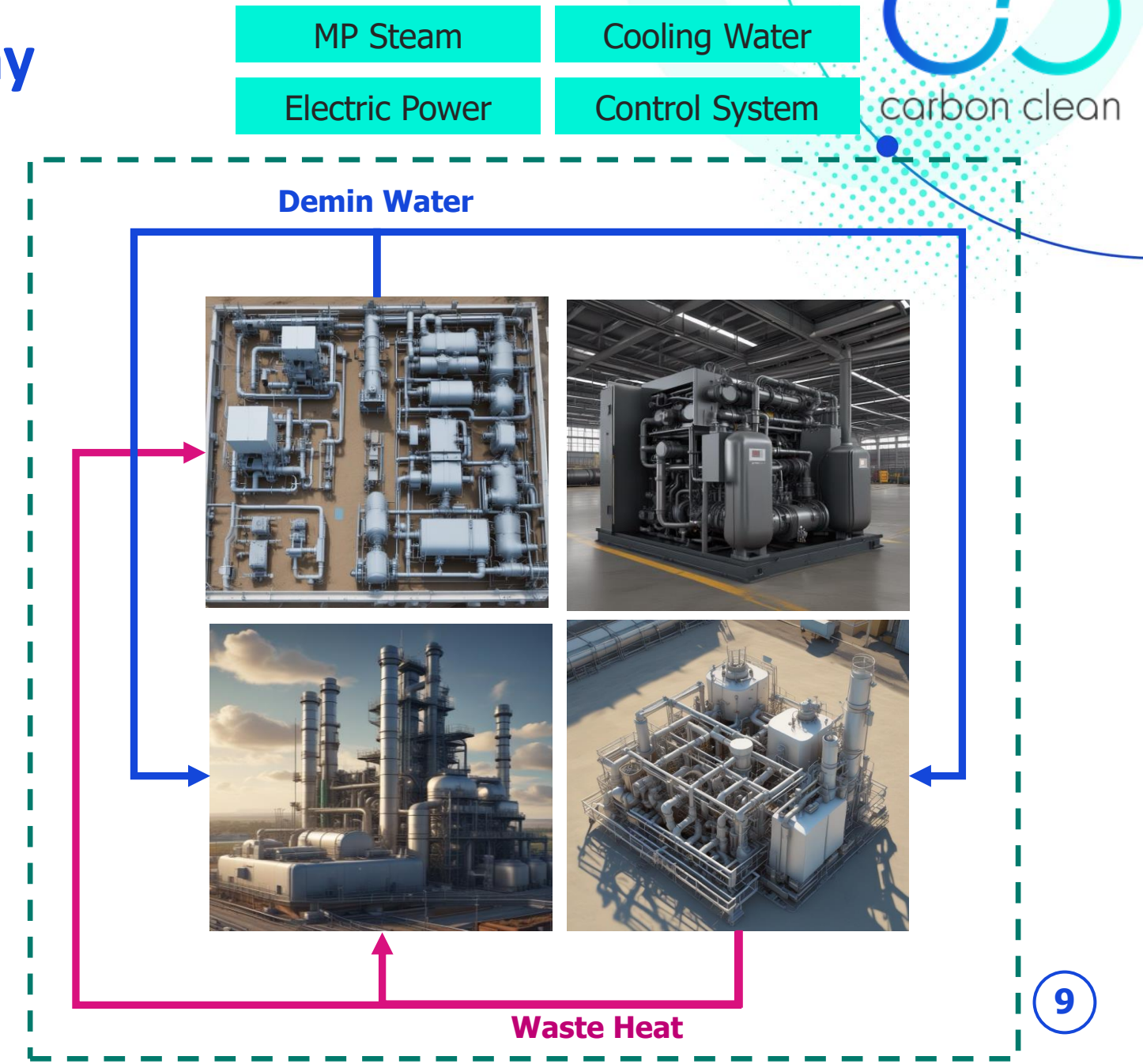
Storage MeOH

# eFuel One-System Philosophy

**SAF and eMethanol**

## How Integrated Systems Can Enhance Efficiency and Reduce Costs

- **CAPEX**: Compact design and shared equipment lead to lower infrastructure costs.
- **Operational Flexibility**: Dynamic operation of electrolyzers and CycloneCC allows for optimization based on renewable energy availability and CO2.
- **Lower Energy Consumption:** Heat integration and utility sharing reduce overall energy requirements and costs.
- **By-Product Utilization:** Oxygen from electrolysis can be sold or used internally, creating additional revenue streams.
- **Regulatory Benefits:** Improved emissions profile and potential eligibility for carbon credits enhance financial viability.



# First of its kind:
# eFuel design and performance centre

Alfa Laval · carbon clean · Liquid Wind · Siemens Energy · Topsoe

## Design Performance Centre (DPC)

In Hørsholm, Denmark will drive technological progress, strengthen production capacity and bring in-demand eFuels to market at scale.

## KPIs

- Modularization >85%
- Digital Twin Philosophy and OS Integration
- Utilization and Storage (CCUS) Services
- >95% Heat Process Integration CCP – MeOH
- AI support for O&M
- Product Generations
- One System Philosophy


**Resulted Optimization**
**25 – 45% less TCO**

# eFuel Projects under Development

## Liquid Wind Partnership


**Umeå Energi**

CO2 biogenic Dåva CHP

230 k TPA CO2 Captured CCUS

Production of 130 k TPA eMeOH

Off taker: Shipping industry

Umeå City's climate neutral 2030

Dåva Eco-Industrial Park

Construction 2024

eMeOH Production 2027

CO2 avoidance 271 k TPA


**Sundsvall Energi**

CO2 biogenic Korstaverket CHP

140 k TPA CO2 Captured CCU

Production of 130 k TPA eMeOH

Off taker: Shipping industry

Construction 2025

eMeOH Production 2028

CO2 avoidance 283 k TPA


**Kanteleen Voima**

CO2 biogenic NordFuel Oy

140 k TPA CO2 Captured CCU

Production of 130 k TPA eMeOH

Off taker: Chemical Industry

Construction 2026

eMeOH Production 2028

CO2 avoidance 295 k TPA


**Sweden**

100k TPA eMeOH

# CycloneCC

## Redefining Carbon Capture

# Four pillars for Optimization of TCO

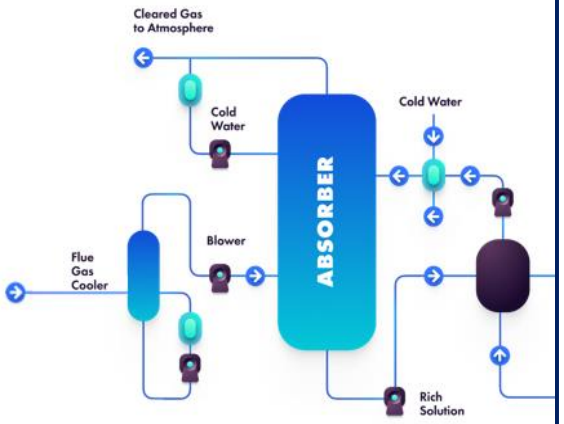
## RPBs

- 10x higher mass transfer vs standard column
- Proven at 1 TPD and 10 TPD

**Impact**

**Up to 50% footprint and 75% height reduction**

## Process




- Heat integration process
- Low grade heat utilization
- Standard skids for mass production

**Impact**

**Up to 35% skid cost reduction + shorter delivery times**

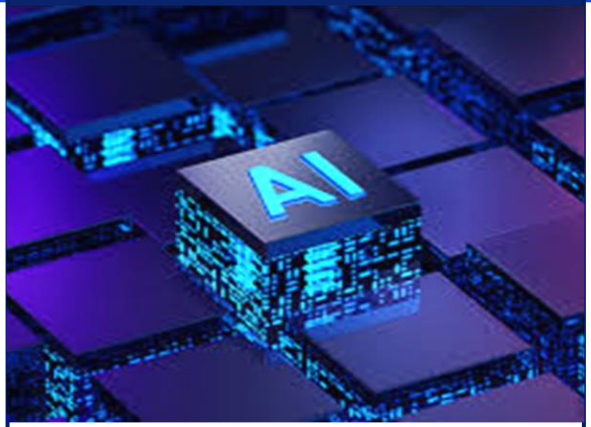
## Solvent

- Proven at 49 sites
- 2.5 million hours of operating data with CDRMax
- Advanced next generation solvents under development

**Impact**

**Up to 30% OpEx reduction compared to MEA**

## Software AI product




- AI embedded CycloneCC plant operation
- Real time process efficiency and uptime improvement
- Installed at one site

**Impact**

**Up to 25% OpEx reduction from 2023 benchmark**

**Solid patent protection 100 active patents, across 16 patent families covering 40 countries**

# Next Generation Carbon Capture 100 k TPA $CO_2$

carbon clean

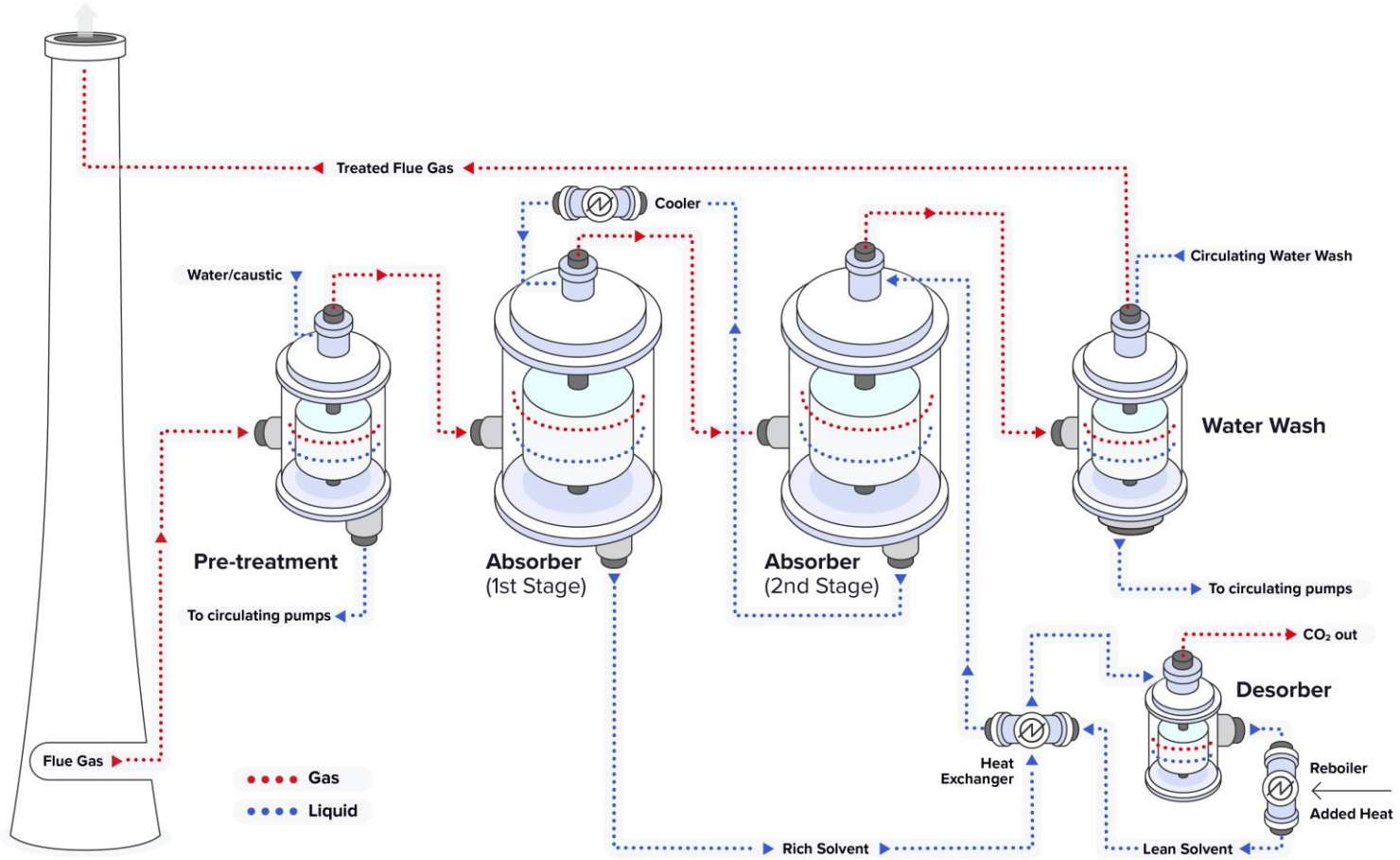
## CycloneCC

**Height:** 12 m
**Length:** 28 m
**Width:** 15 m

## CaptureX

**Height:** 38 m
**Length:** 50 m
**Width:** 40 m

# CycloneCC process




Carbon Clean has expertise in process design and engineering that, when integrated with existing industrial plants or new projects, **enables optimised carbon capture.**

- **20x** less corrosion
- **10x** less degradation
- **10-25%** lower energy demand
- **5x** longer solvent life

# CycloneCC product vision

| KEY SUCCESS FACTOR | RESULT |
|---|---|
| **Compact Unit** | Fits limited plot space at legacy sites |
| **Short lead-time** | Improve ROI by compressing project schedule |
| **Low OPEX** | Improve return on investment<br>• PPB Solvent Emissions<br>• Negligible Ammonia Emissions<br>• LP Steam replaced with low grade heat<br>• No Corrosion<br>• Solvent Make-up 90% less than MEA |
| **High Capture Rate** | Meet regulatory requirements & maximise revenue<br>95% $CO_2$ capture rate |
| **High Availability** | Maximize annual $CO_2$ capture rate<br>Design to >95% availability |
| **Simple Operation** | Reduce skilled manpower requirements (use AI automation) |
| **Easy to Maintain** | Reduce OPEX and increase availability (use AI automation) |

# Conclusion and Future Outlook

**SAF and eMethanol**

## Integration of technologies for E fuel Production

- Successful production of eFuels hinges on the **seamless integration** of various technologies, including PEM electrolyzers, carbon capture, advanced catalyst and distillation processes.
- By emphasizing **circular economy**, principles, we can recycle waste streams across processes, minimize in the need for utilities and reducing environmental impact.

## Leveraging digital twin and AI technologies

- Implementing digital technology and AI can streamline operations **minimize redundancies** and enhance real time, monitoring and control.
- These innovations will reduce the reliance on highly skilled operators by **automating routine tasks** and optimizing system performance.

# Conclusion and Future Outlook

**SAF and eMethanol**

## Advancements in carbon captured technology

- Intensification and modularisation of carbon capture technologies to facilitate integration into existing industrial processes.
- Ongoing technology partnerships between key players in this industry, will drive innovation and ensure the rapid deployment of effective carbon capture, and eFuel production solutions.

## Europe Supporting E Fuels Development

- Infrastructure development for hydrogen production storage and distribution is essential. Including eFuel pipelines and refueling stations to facilitate widespread in transportation and chemical industry.
- Clear and supportive regulatory framework to provide certainty needed for investment. Recognizing eFuels as a viable alternative in energy policies and chemical feedstock across the heavy industry.

# The time is now.

Let’s create a carbon clean future