INNOVATIVE H_2 TECHNOLOGY -eREACT



ABLC Next

San Francisco

October 2026

TOPSOE

Steve Eckhoff

Sr. Licensing Manager, Hydroprocessing Technology

TOPSOE AT A GLANCE

Topsoe is a leading developer and provider of solutions and technologies to produce fuels and chemicals essential to the energy transition.

For more than 80 years, we've been perfecting chemistry to help industries produce more efficiently. Today, it's our ambition to lead the global transition of hard-to-abate sectors to a zero-carbon future.

Guided by our purpose, 'Perfecting chemistry for a better world', we work to deliver solutions that will leave the world in better shape for future generations.

#1
In renewable fuels

#1
In hydrogen

#1
In ammonia



+600
Patent families

8.6%
Of revenue invested in R&D

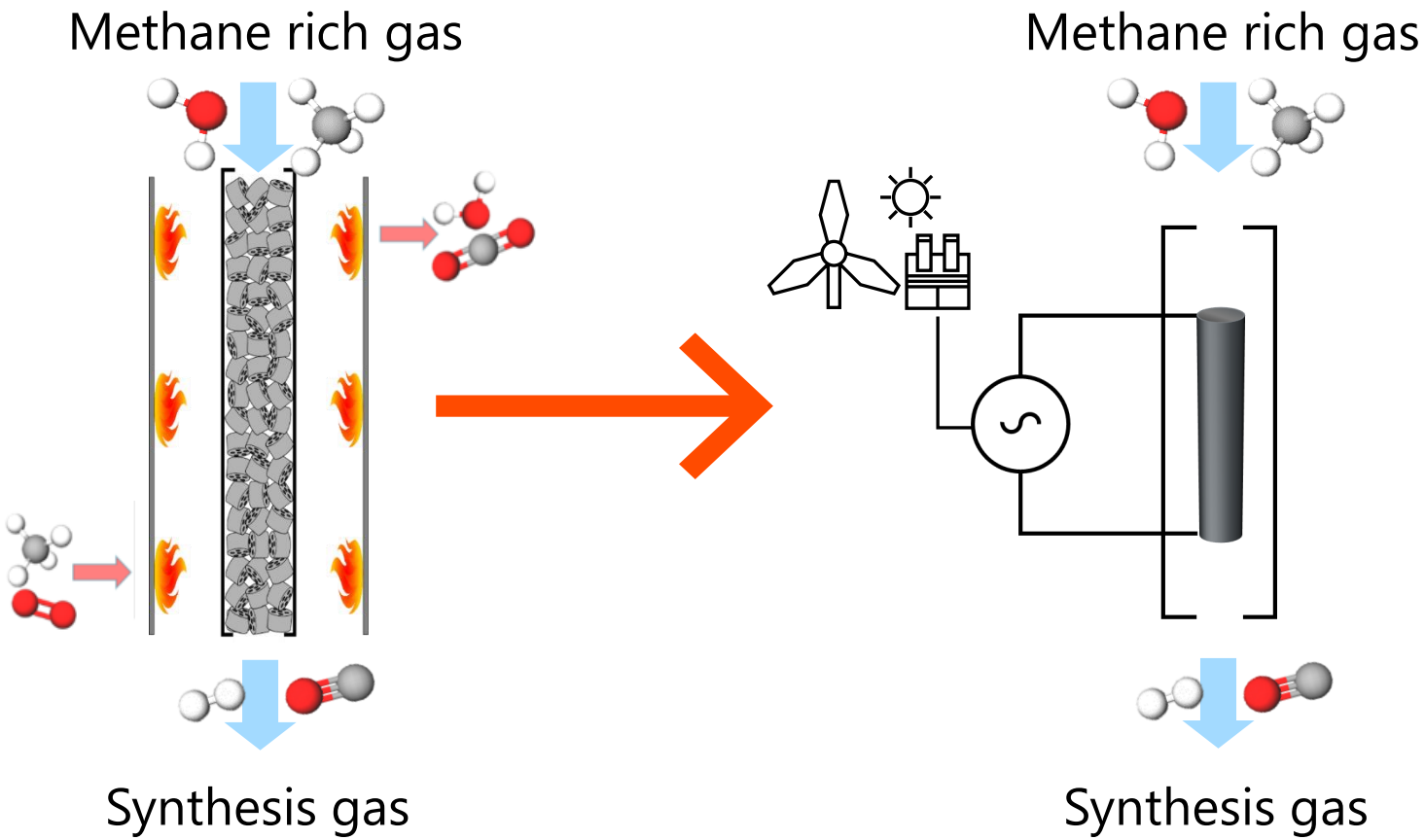
2,800
Employees

AGENDA

#	SECTION
1	**WHAT IS eREACT™?**
2	**BENEFITS OF eREACT™**
3	**eREACT™ TECHNOLOGY MATURITY**

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THE FRONT-RUNNER ELECTRIFIED REFORMING TECHNOLOGY | eREACT™ REMOVES THE FIRED SECTION OF CHEMICAL REACTORS THROUGH ELECTRIFICATION



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ELECTRIFIED METHANE REFORMING – eREACT 2019 *Science* Article

INDUSTRIAL CATALYSIS

Electrified methane reforming: A compact approach to greener industrial hydrogen production

Sebastian T. Wismann[1], Jakob S. Engbæk[2], Søren B. Vendelbo[2], Flemming B. Bendixen[3], Winnie L. Eriksen[3], Kim Aasberg-Petersen[4], Cathrine Frandsen[1], Ib Chorkendorff[1]*, Peter M. Mortensen[4]*

Electrification of conventionally fired chemical reactors has the potential to reduce CO_2 emissions and provide flexible and compact heat generation. Here, we describe a disruptive approach to a fundamental process by integrating an electrically heated catalytic structure directly into a steam-methane–reforming (SMR) reactor for hydrogen production. Intimate contact between the electric heat source and the reaction site drives the reaction close to thermal equilibrium, increases catalyst utilization, and limits unwanted byproduct formation. The integrated design with small characteristic length scales allows compact reactor designs, potentially 100 times smaller than current reformer platforms. Electrification of SMR offers a strong platform for new reactor design, scale, and implementation opportunities. Implemented on a global scale, this could correspond to a reduction of nearly 1% of all CO_2 emissions.

The synthesis of important chemicals such as hydrogen and ammonia has a substantial CO_2 footprint because the heating of the processes often relies on the combustion of hydrocarbons. One of the largest endothermic processes is the production of hydrogen by steam-methane reforming (SMR), which accounts for ~50% of the global hydrogen supply, where all hydrogen production is estimated to account for 3% of global CO_2 emissions (*1*, *2*). In this strongly endothermic reaction, natural gas reacts with steam according to the following equations:

$$CH_4 + H_2O \rightleftharpoons CO + 3H_2 \quad (\Delta H_r^\circ = +206\ \mathrm{kJ/mol}) \qquad (1)$$

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \quad (\Delta H_r^\circ = -41\ \mathrm{kJ/mol}) \qquad (2)$$

Where ΔH_r° is standard reaction enthalpy. Heat is typically supplied to the reaction by combustion of a mixture of natural gas and potential offgases from the synthesis. In total, conventional SMR produces 6.6 to 9.3 metric tons of CO_2 per metric ton of H_2, of which 17 to 41% is the direct product of hydrocarbon combustion (*2*, *3*).

Today, a large-scale industrial SMR reformer consists of an array of more than 100 10- to 14-m-long tubular reactors in a large furnace, with gas burners positioned for an optimal distribution of heat among the reactor tubes (*4*–*6*). The combustion must occur considerably above the reaction temperature to generate the necessary inward heat flux, as illustrated by the temperature profile in Fig. 1A (*5*, *7*). Because of limited thermal conductivity across the SMR catalyst and reactor walls, transporting the heat necessary to drive the reaction is a natural limitation (Fig. 1A), and typically less than 2% of the furnace volume contains catalyst (*5*, *8*). Intrinsic catalytic activity is typically not a limiting factor for industrial reforming (*9*). Instead, the low thermal conductivity combined with a strongly endothermic reaction creates steep temperature gradients across the catalyst, leading to poor catalyst utilization and increasing the risk of detrimental carbon formation (*10*–*12*).

For decades, thermal conductivity of SMR has been the subject of research. Efforts include using catalysts with higher thermal conductivity (*13*), lowering the temperature of SMR by shifting the equilibrium (*14*–*17*), obtaining shorter characteristic length scales through μ-reactors (*18*, *19*), performing room-temperature reactions using plasma (*20*), or employing direct heating of magnetic catalysts by induction (*21*). Alternatively, electrical heating of an integrated catalytically coated heating element enables reactor temperatures exceeding what is feasible in conventional reactors (*22*), and allows substantially improved temporal response, pushing start-up times to within minutes (*23*). However, despite decades of research, no alternatives with lower CO_2 emissions have been implemented at the industrial scale.

This work describes a high-performing, fully electrically driven reformer based on direct resistive (ohmic) heating (Fig. 1B), which is scalable to industrial conditions and capacities. The intimate contact between the electric heat source and the catalyst enables energy to be supplied directly to the catalytic sites, removing thermal limitations and providing well-defined control of the reaction front. Electrification removes the fired section, substantially reducing reactor volume, CO_2 emissions, and waste-heat streams. This provides a disruptive advantage to existing industrial reformers, enabling the production of "greener" hydrogen for the large-scale synthesis of indispensable chemicals such as methanol, ammonia, and biofuels (*24*, *25*).

For this work, we prepared a laboratory-scale reactor based on an FeCrAl-alloy tube, which was

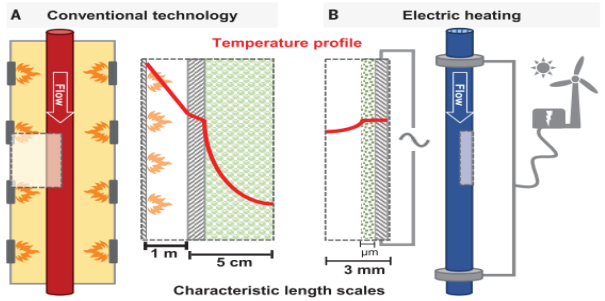


Fig. 1. Heating principles. (**A**) Conventional fired reactor. (**B**) Electric resistance–heated reactor. Characteristic radial length scales and temperature profiles are shown across the heat source, reactor wall (gray), and catalyst material (green). In (B), the heat source and reactor wall are one. Illustrations are not to scale.

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Electrified methane reforming: A compact approach to greener industrial hydrogen production | Science

First-of a kind paper in ***Science*** published by Topsoe in 2019

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eREACT™ IS ADDING A TECHNOLOGY TO THE WIDEST PORTFOLIO OF REFORMING TECHNOLOGIES

SynCOR™
ADVANCED AUTOTHERMAL REFORMING
100,000 - 820,000 Nm³/h
90 – 735 MMSCFD

- → 99%+ Carbon recovery
- → Lowest LCOH



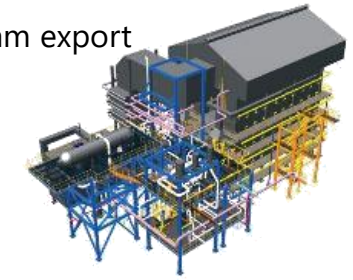
SMR
RADIANT WALL TUBULAR REFORMER
20,000-200,000 Nm³/h
18 – 180 MMSCFD

- → Steam export flexibility
- → Medium range capacity



SMR-B
SMR WITH BAYONET TUBES
20,000-200,000 Nm³/h
18 – 180 MMSCFD

- → SMR with Bayonet tubes
- → Low / zero steam export



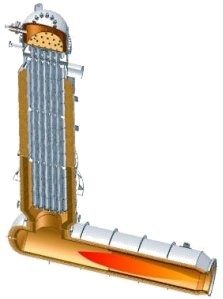
HTER
HALDOR TOPSOE EXCHANGE REFORMER
50,000- 250,000 Nm³/h
45 – 225 MMSCFD

- → Reduced steam export
- → Option for plant revamp to increase capacity



HTCR™
CONVECTION REFORMER
5,000-60,000 Nm³/h
4.5 – 54 MMSCFD

- → Zero steam export
- → Compact plot



eREACT™
ELECTRIFIED REFORMER
3,000 -100,000+ Nm³/h
2.7 – 90 MMSCFD

- → Zero flue gas emissions
- → Rapid start-up



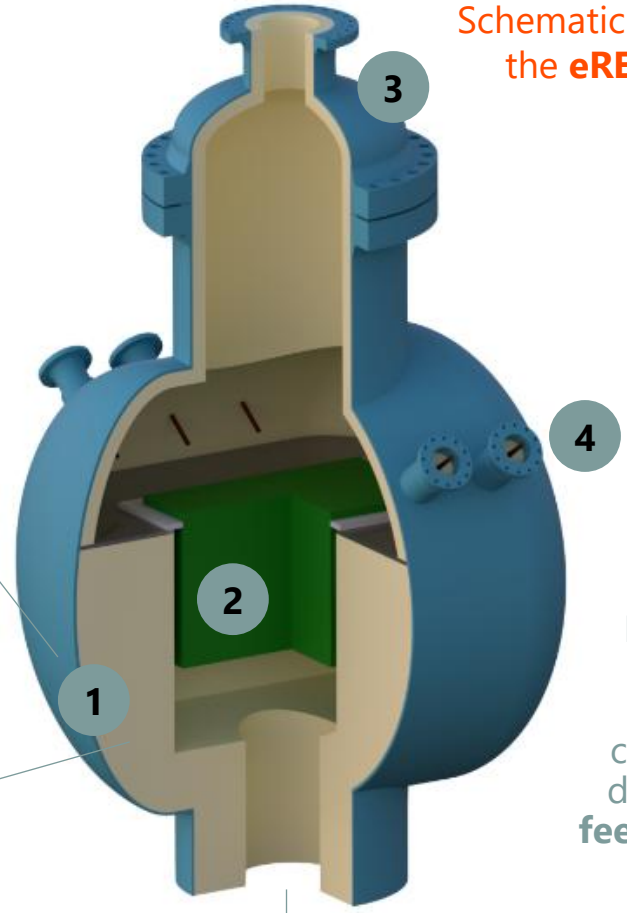
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eREACT™ DESIGNED FOR OPTIMAL PERFORMANCE AND SAFETY

eREACT™ reactor basics

- Refractory-lined pressure shell (1)
- Feed gas enters the reactor from the top, and product gas exits at the bottom at the desired stoichiometry
- Catalyzed hardware (2) installed in the reactor via the removable top dome (3)
- Feedthroughs (4) provide the power from outside the reactor to the catalyzed hardware

Schematic representation of the **eREACT™ reactor**



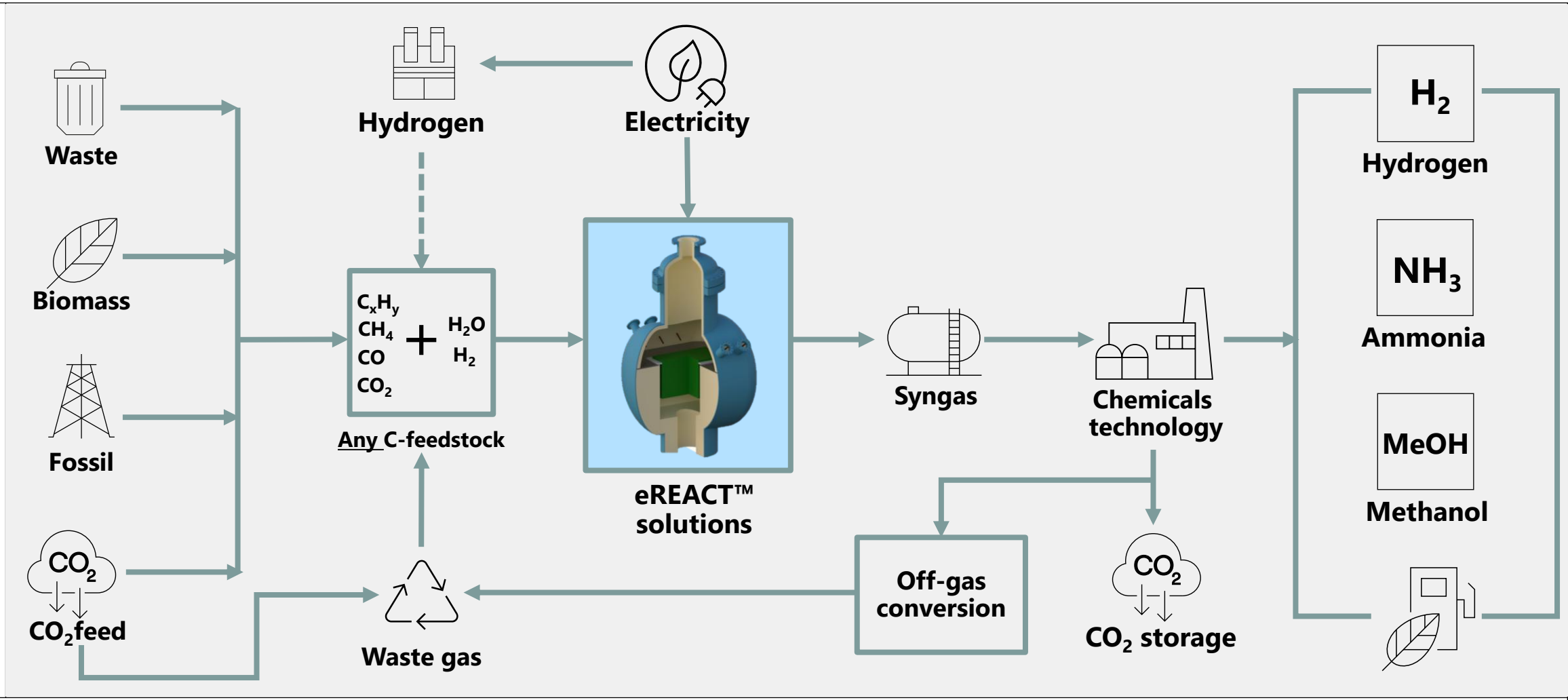
Pressure vessel for integration in **known syngas process schemes** with low alloy steel

Refractory lining provides **safe proven** method of housing 1000°C reaction environment and allows **99% energy efficiency**

High single pass conversion and stochiometric chemicals process design with **>95% feedstock utilization**

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eREACT™ A PLATFORM TECHNOLOGY WITH MULTIPLE APPLICATIONS



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eREACT™ REFORMING LAYOUT REDUCES COMPLEXITY - LEADING TO LESS EQUIPMENT AND EASIER OPERATION

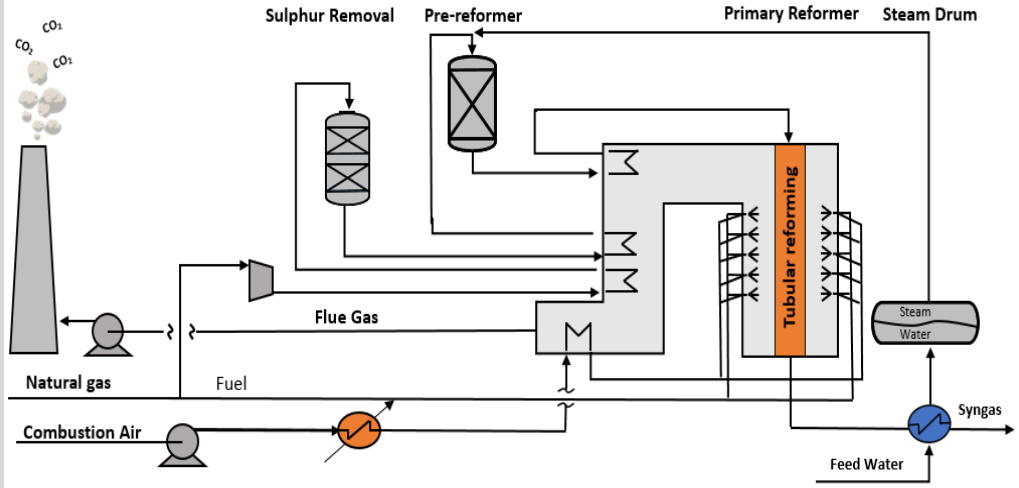
Equipment removed in eREACT™compared to SMR

Tubular reformer with:
÷ Fire Box/furnace
÷ Burners
÷ Flue gas duct
÷ Convection coils
÷ Air blower
÷ Air preheater
÷ Fuel preheater
÷ Stack

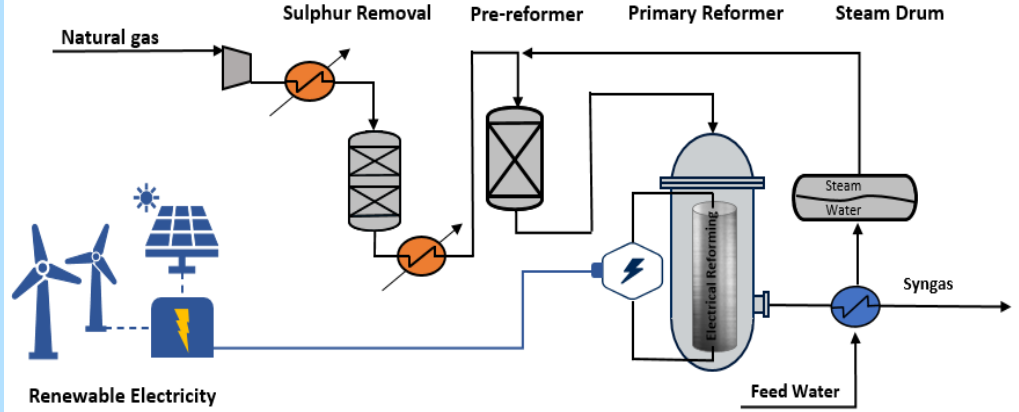
Equipment added in eREACT compared to SMR

- ✓ eREACT™ reactor (pressure vessel)
- ✓ Preheater(s)
- ✓ Power supply unit

Steam methane reforming (SMR)



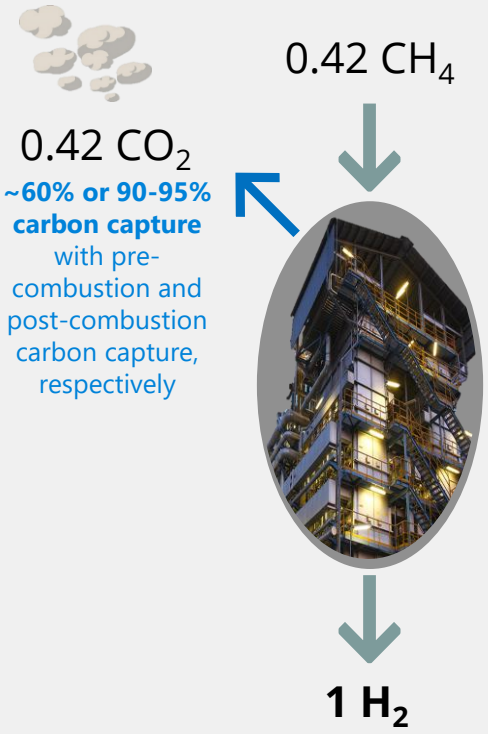
eREACT™



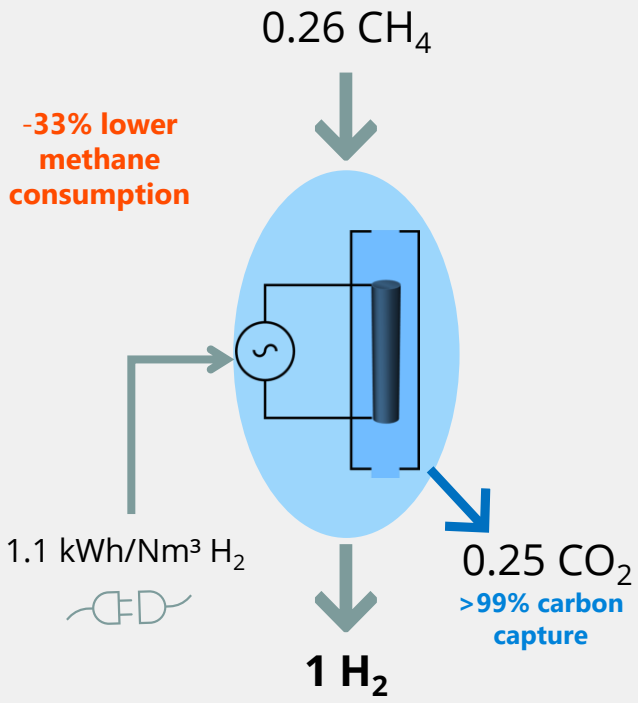
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HYDROGEN PRODUCTION | COMPARISON OF DIFFERENT ROUTES

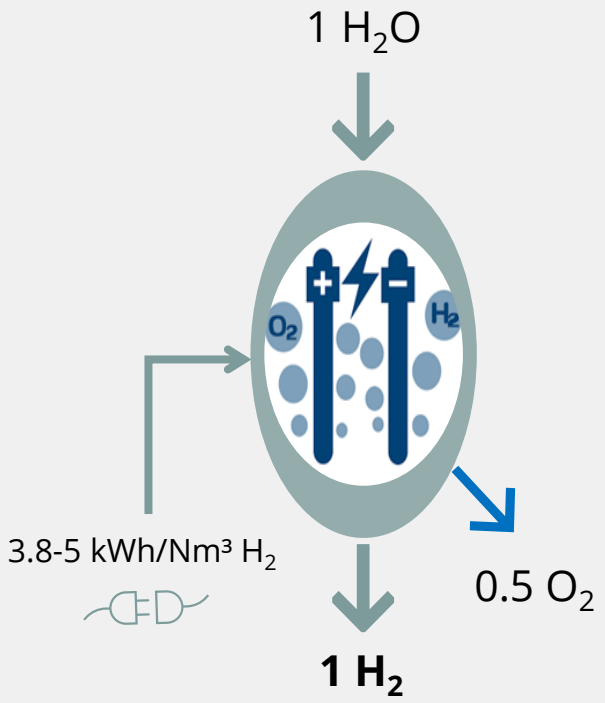
Fired reformer



Topsoe eREACT™



Electrolysis



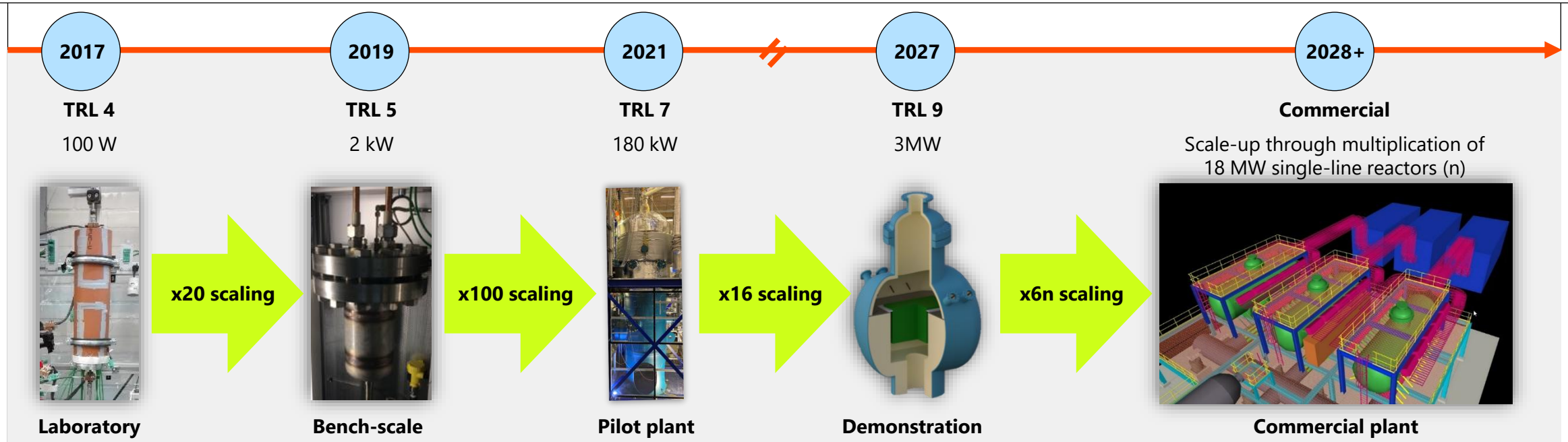
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EXTENSIVELY TESTED TECHNOLOGY READY FOR COMMERCIAL DEPLOYMENT



→ **Majority of eREACT™ technology constituents are already at TRL 9** and have been utilized in other commercial Topsoe technologies. Current overall TRL rating based on the eREACT™ novel catalytic system which is only constituent at TRL 7[1]

1: Actual catalyst and carrier are well known in industrial operation

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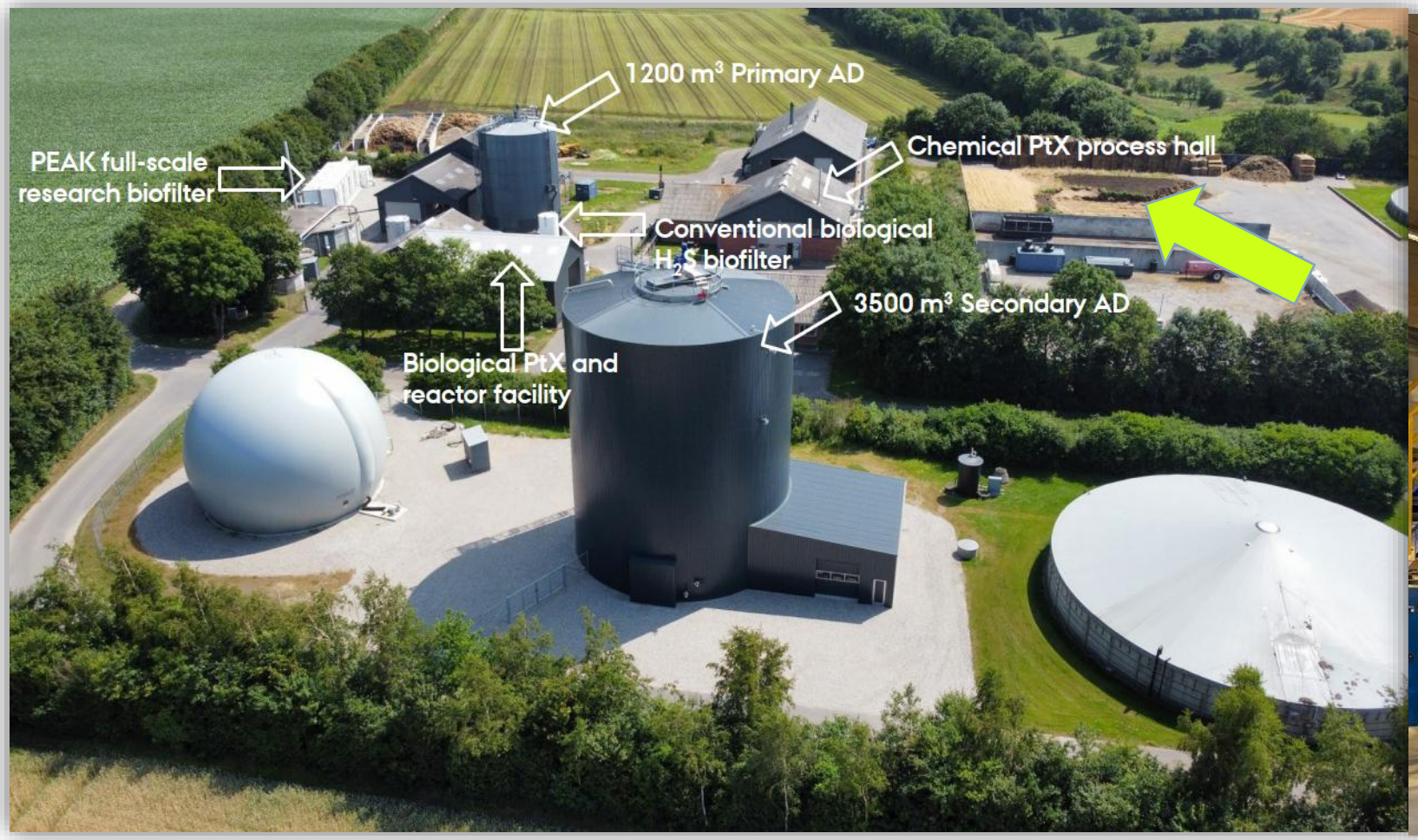
eREACT™ PILOT PLANT IN FOULUM DENMARK HAS BEEN OPERATING SINCE AUGUST 2021





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eREACT™ PILOT PLANT IN FOULUM DENMARK HAS BEEN OPERATING SINCE AUGUST 2021





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eREACT™ PILOT PLANT IN FOULUM DENMARK HAS BEEN OPERATING SINCE AUGUST 2021

Extensive experiments conducted in the pilot plant to:

- → Verify all key elements in the novel reactor
- → Demonstrate the performance at varying operating conditions
- → Demonstrate catalyst stability
- → Test transients and upset situations including trips
- → Test feed variations



Pilot plant has run for >15,000 hours
(and counting)

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eREACT™ EXTENSIVELY TESTED AND PROVEN IN PILOT PLANT OPERATION

Stable operation
for >15,000 hours (and counting)

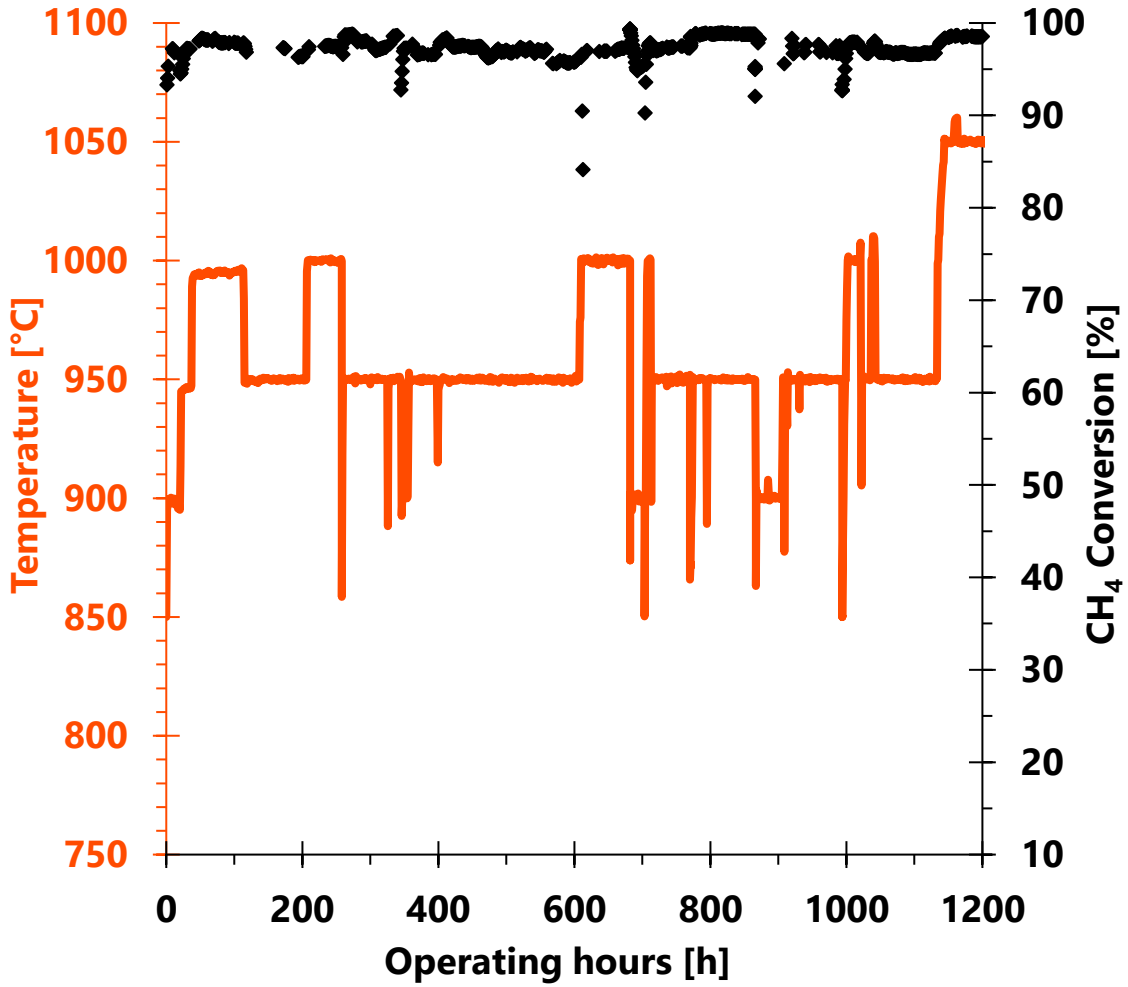
> 95%
CH_4 conversion

SOR = EOR
eREACT™ performance

> 99%
Energy efficiency in industrial scale

Fast
Start-up & turndown

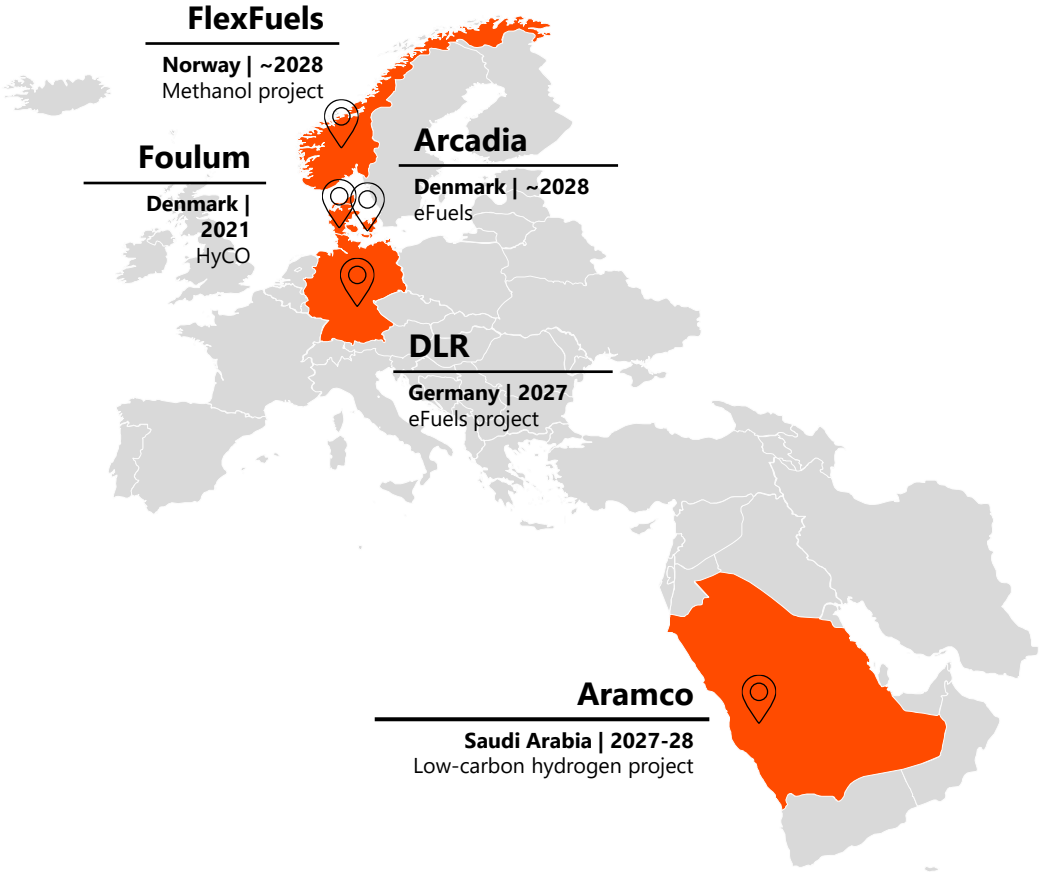
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Trips due to eREACT™



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*T.N. From, et.al. Electrified steam methane reforming of biogas for sustainable syngas manufacturing and next-generation of plant design: A pilot plant study, *Chem. Eng. J.* **276** (2024)

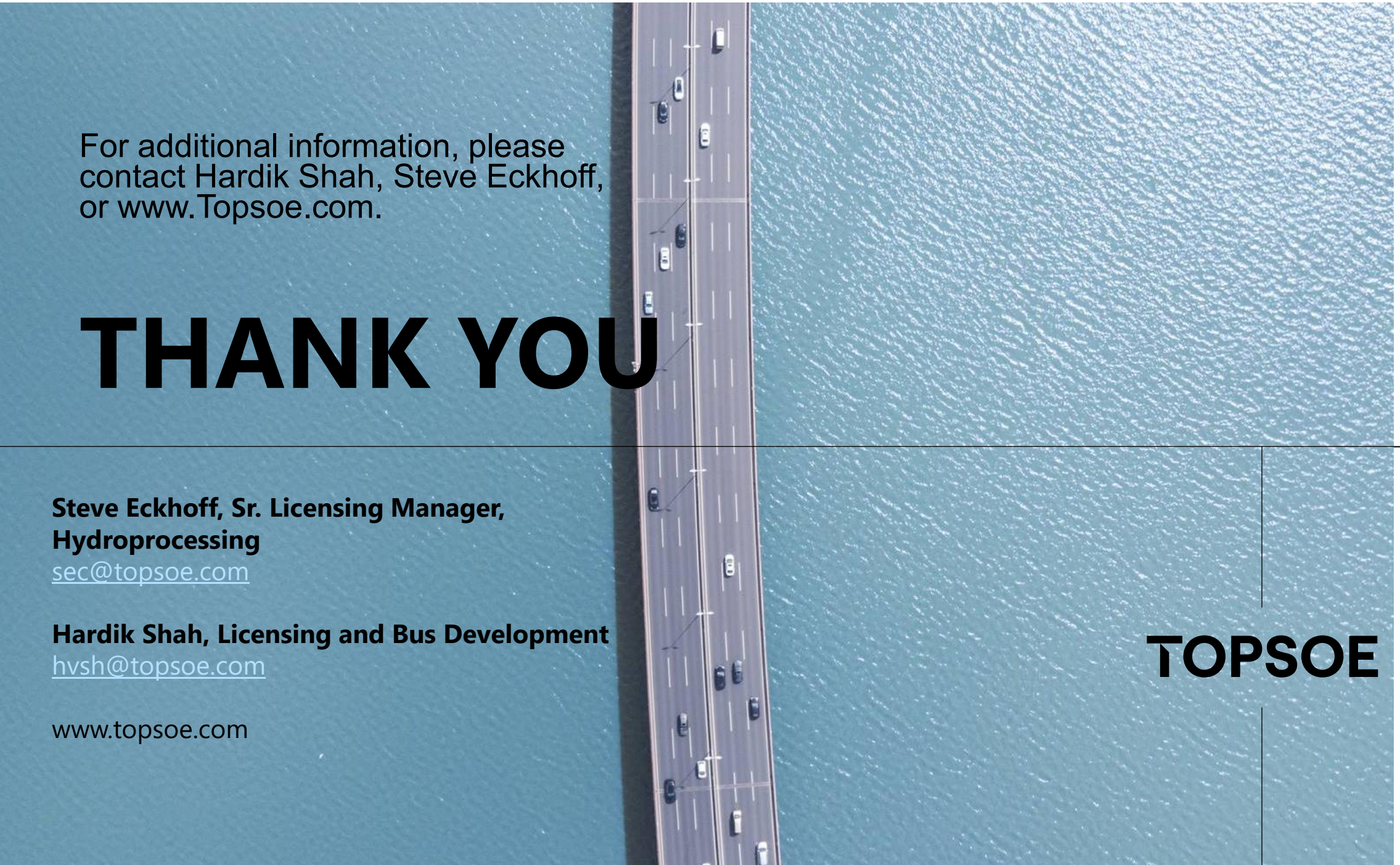
COMMERCIALIZATION OF eREACT™ SUPPORTED BY STRONG PORTFOLIO OF ACTIVE PROJECTS



Selected eREACT™ related projects

Owner	Scale	Product	Stage	Expected start-up
Topsoe	Pilot	HyCO	Operational	In operation from 2021
Aramco	Demo/JDA	Hydrogen	BEDP complete	2027-28
DLR	Demo	eSAF (FT route)	Under construction	2027
FlexFuels	Commercial	Methanol	FEED complete	Awaiting FID
Arcadia	Commercial	eFuels (FT route)	BEDP complete	Awaiting FID

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For additional information, please contact Hardik Shah, Steve Eckhoff, or www.Topsoe.com.

THANK YOU

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