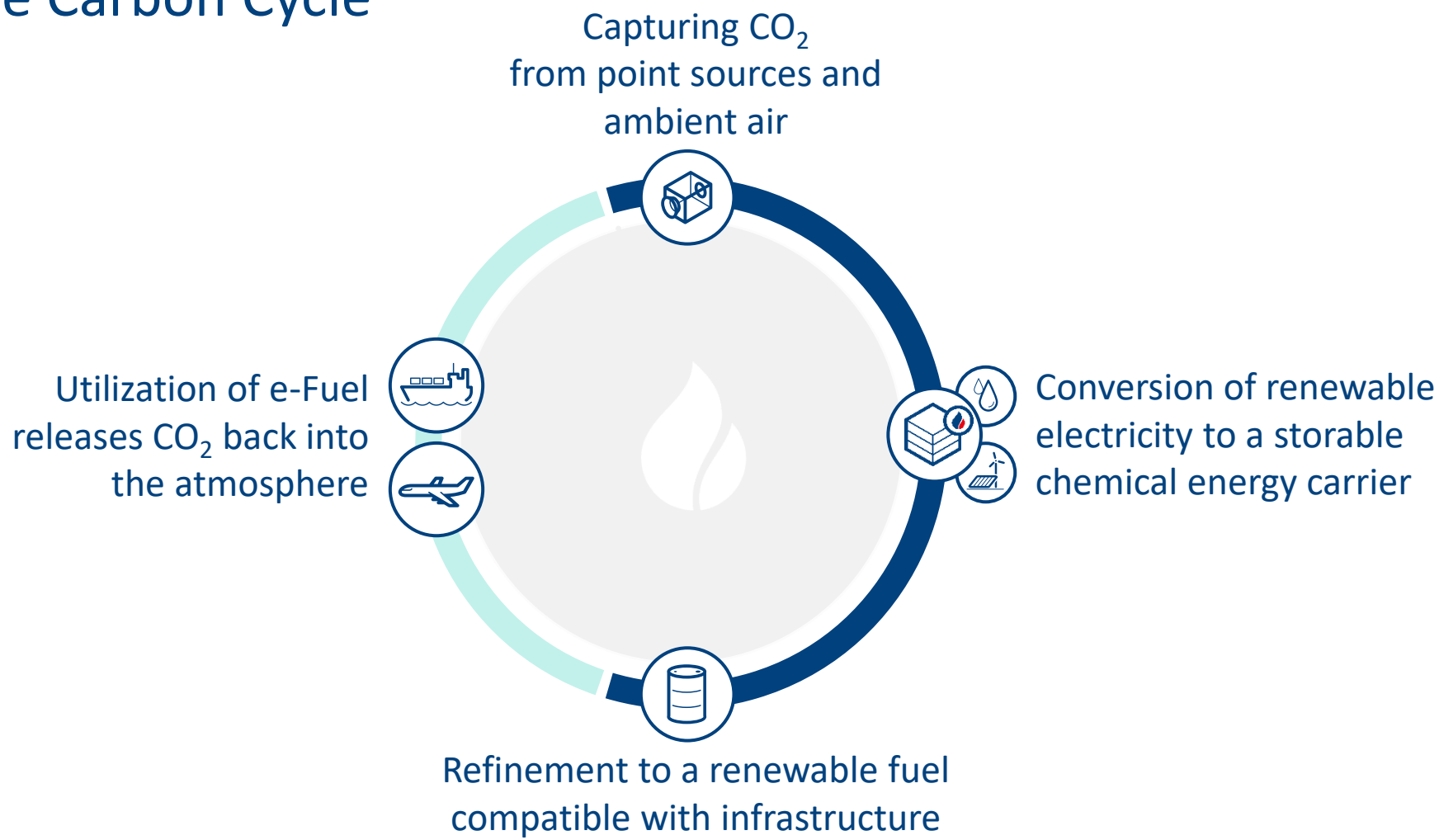
# Norsk e-Fuel
# Developing e-fuel projects

## Accelerating the transition to aviation with renewable energies

2023 Karl Hauptemier

norsk e-fuel

# Closing the Carbon Cycle



# Quotes from AR6

- "**Land-based**, long-range, heavy-duty trucks **can be decarbonized through battery electric haulage** (including the use of electric road systems), complemented by hydrogen- and biofuelbased fuels in some contexts (medium confidence). These same technologies and expanded use of available electric rail systems can support rail decarbonisation (medium confidence)." (p 1052)
- "Decarbonisation options for shipping and aviation still require R&D, though **advanced biofuels, ammonia, and synthetic fuels** are emerging as viable options (medium confidence)." (p. 1052)
- **"Given these high costs** and limited scales, the **adoption** of synthetic fuels **will likely focus on the aviation, shipping, and long-distance** road transport segments, where decarbonisation by electrification is more challenging. **In particular, synthetic fuels are considered promising as an aviation fuel** (Section 10.5)." (p 1068)

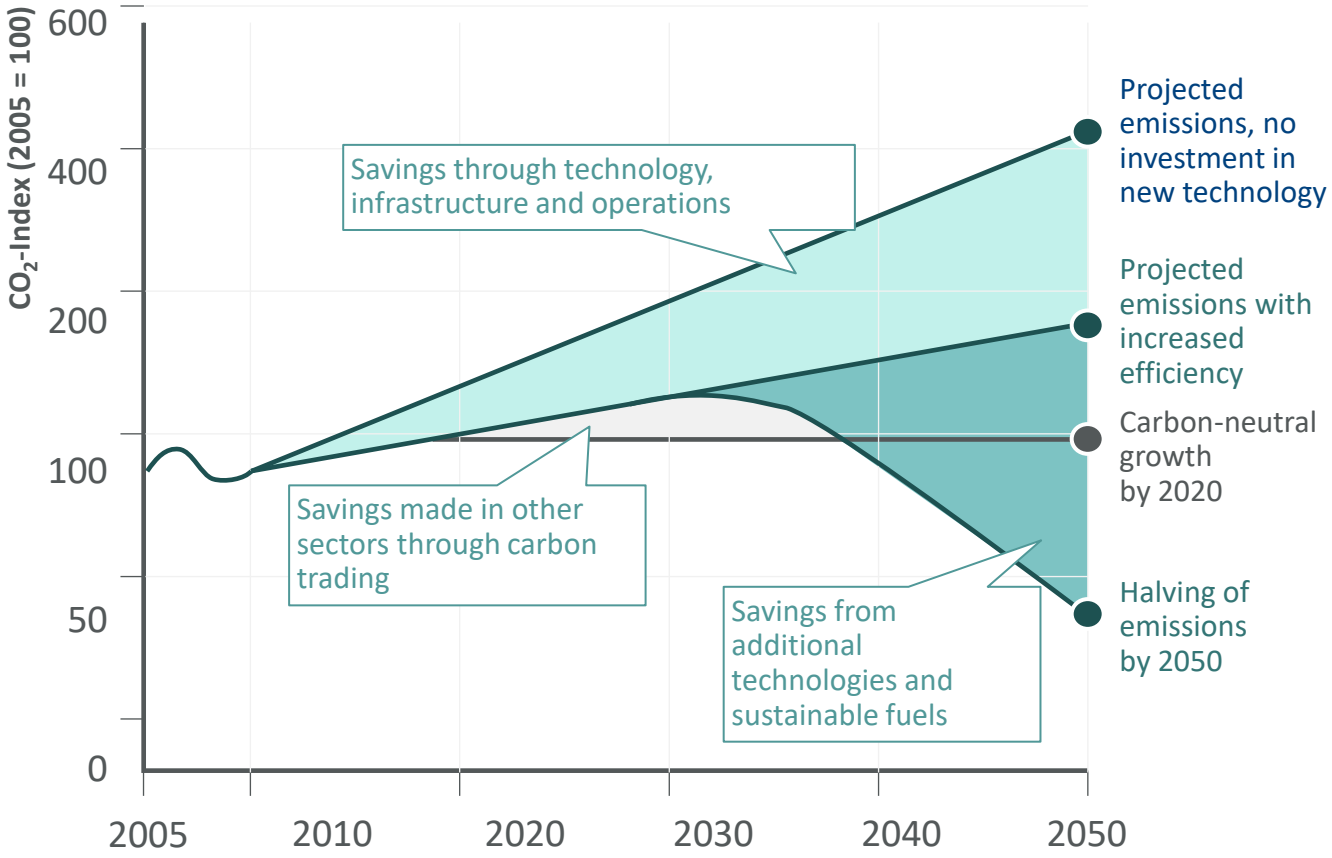
IPCC
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_Chapter10.pdf

80% of fuel needs to be sustainable by 2050

# Fast ramp-up of e-Fuel industry required




ICAO 2013

# Is there a political movement?

# ETS regulation for aviation: 2024 - 2030

- Trilog negotiations on ETS rules for aviation (“CORSIA proposal”) completed on the 9th of December.


## What was agreed:

- Free ETS allowances for aviation will be fully phased out by 2026.
- 20 million ETS allowances to be dedicated to support the up-take of SAF for commercial flights from **2024 to 2030**. About **1.8 billion EUR** at todays ETS prices.
- To cover **95% of the price differential for RFNBOs**, 70% for advanced biofuels, and 50% for other eligible fuels compared to fossil kerosene.

Trialog Discussions are ongoing, but a sub-target for e-Fuel seems certain

# ReFuelEU Aviation: 2030 - 2050

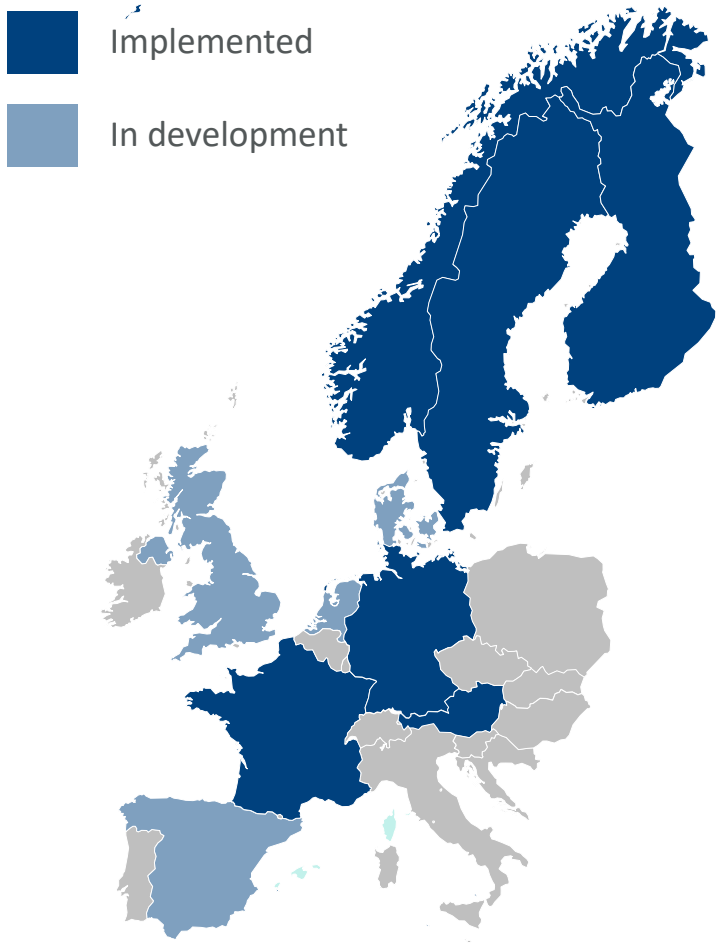
*Next trilogue discussion April 25th*

| Year | Original European Commission proposal | | European Parliament amendments | | Council of the European Union amendments | |
|---|---|---|---|---|---|---|
| | Overall SAF target | Synthetic sub-target | Overall SAF target | Synthetic sub-target | Overall SAF target | Synthetic sub-target |
| 2025 | 2% | – | 2% | 0.04% | 2% | – |
| 2030 | 5% | 0.7% | 6% | 2% | 6% | 0.7% |
| 2035 | 20% | 5% | 20% | 5% | 20% | 5% |
| 2040 | 32% | 8% | 37% | 13% | 32% | 8% |
| 2045 | 38% | 11% | 54% | 27% | 38% | 11% |
| 2050 | 63% | 28% | 85% | 50% | 63% | 28% |

*Note:* Shaded cells denote where the ambition in the Parliament or Council amendments is the same as the Commission proposal.

Source: ICCT Briefing - Considerations for the ReFuelEU aviation trilogue – Sept. 2022

# EU regulatory framework on SAF




## ReFuelEU Aviation

Draft available

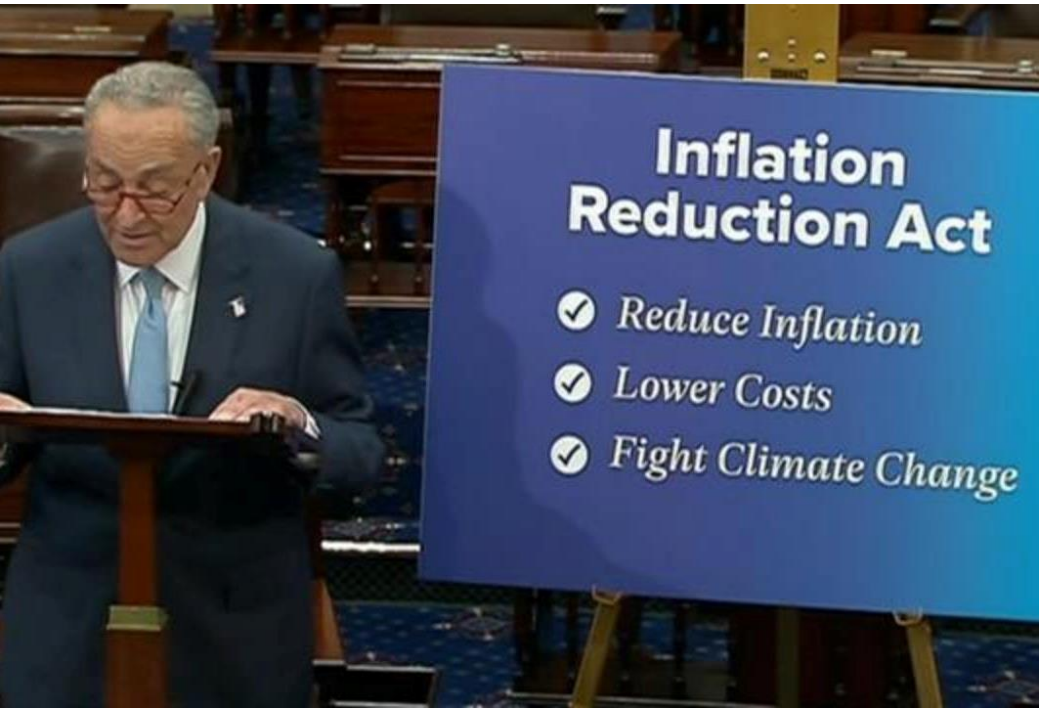
- Current draft proposes a blending mandate for hydrogen-based aviation fuels of **0.7 % (2030);** potentially up to **2 %.**
- Up to 1 mio ton of e-Fuel jet-fuel required by 2030, based on total EU Jet-Fuel demand of around 56 mio ton p.a.

## e.g. of national implementation of RED II: BImSchV

In effect

- Fuel suppliers must ensure a minimum share of sustainable aviation fuel produced via electrolysis: **0.5 % (2026), 1 % (2028) and 2 % (2030).**
- Penalty of 70 EUR/GJ in place for non-fueled e-Fuel SAF

National implementation of SAF strategies might very well exceed the targets as set out within the ReFuelEU Aviation.




Europe is not alone in promoting e-Fuels

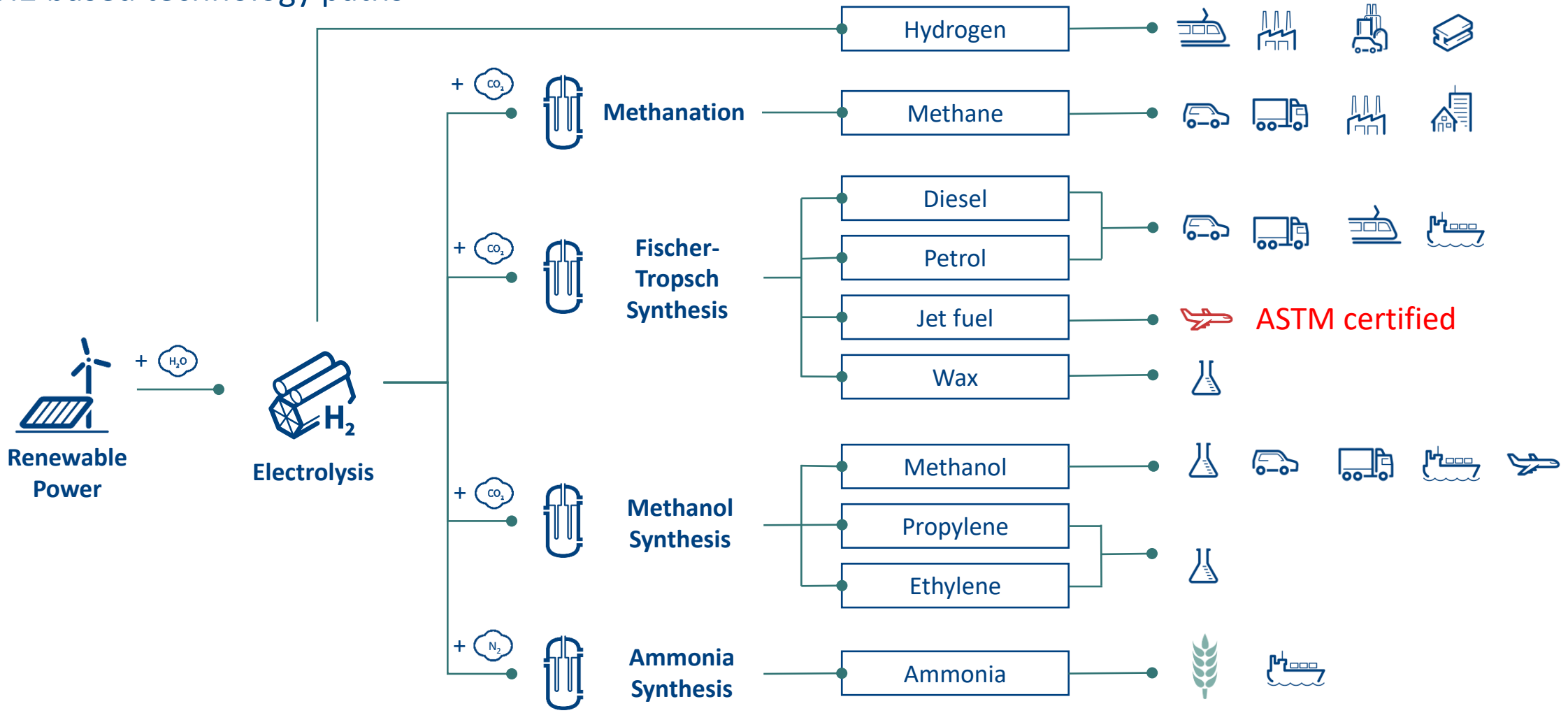
# Rest of the World: e.g. USA

- Inflation reduction act adopted by US government in July 2022
- Many provisions which will facilitate project development and the creation of an e-Fuel industry
  - $60 billion to accelerate RE deployment
  - Grants/credits to support zero-emission fuels, including infrastructure
  - $180 per ton tax credit for DAC CO2 techologies
  - $0.35 - $1.75 per gallon for SAF, based on CO2 reduction potential

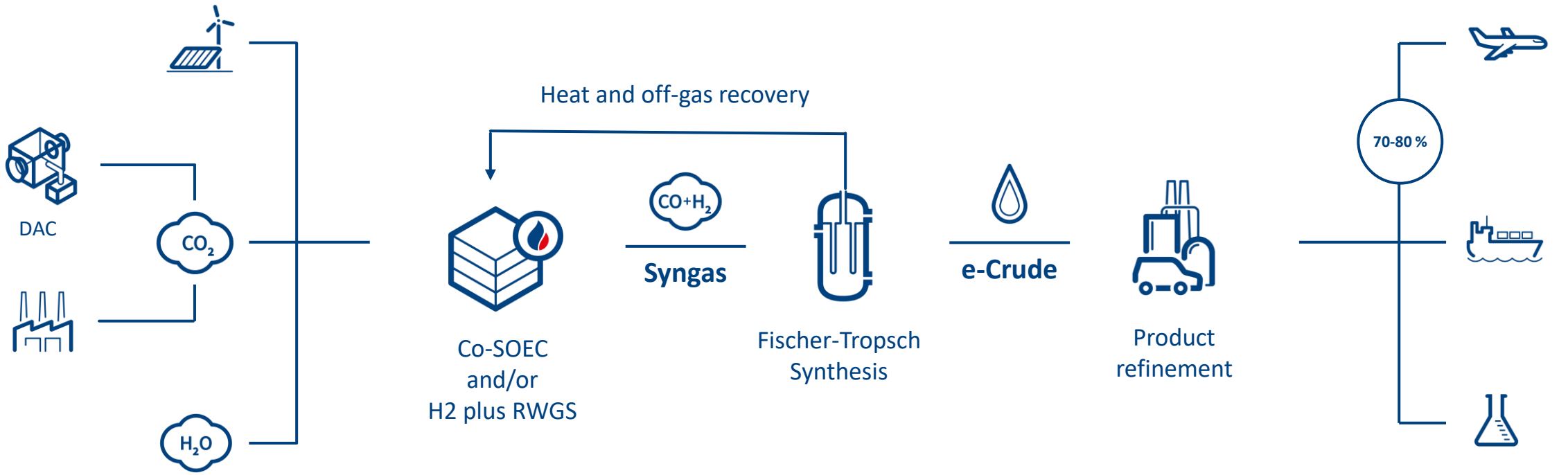
# Is the technology ready?

# Multiple technical pathways can be taken to provide fuels to hard to abate sectors

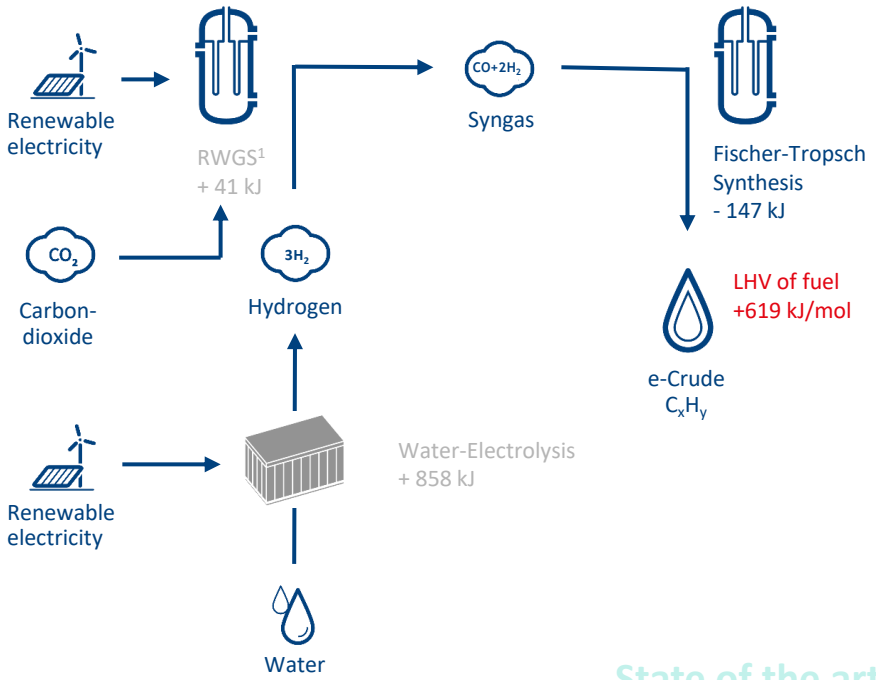
## H2 based technology paths



# ASTM certifiable technology path

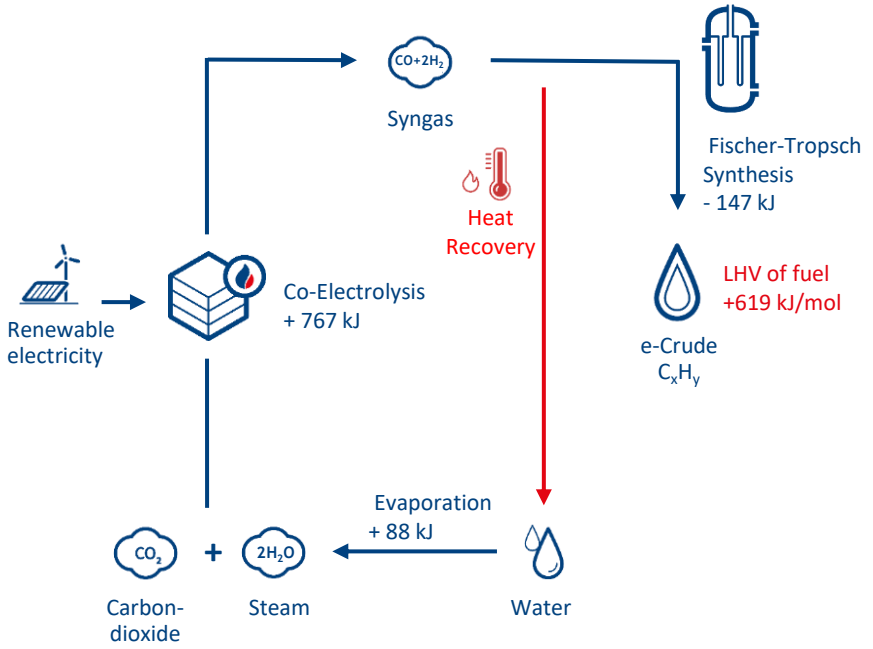


# Technical outlook




## State of the art

$\eta_{max, theor}$ = 69 %
$\eta_{max, real}$ = 38 - 48 % BENCHMARK




## Outlook

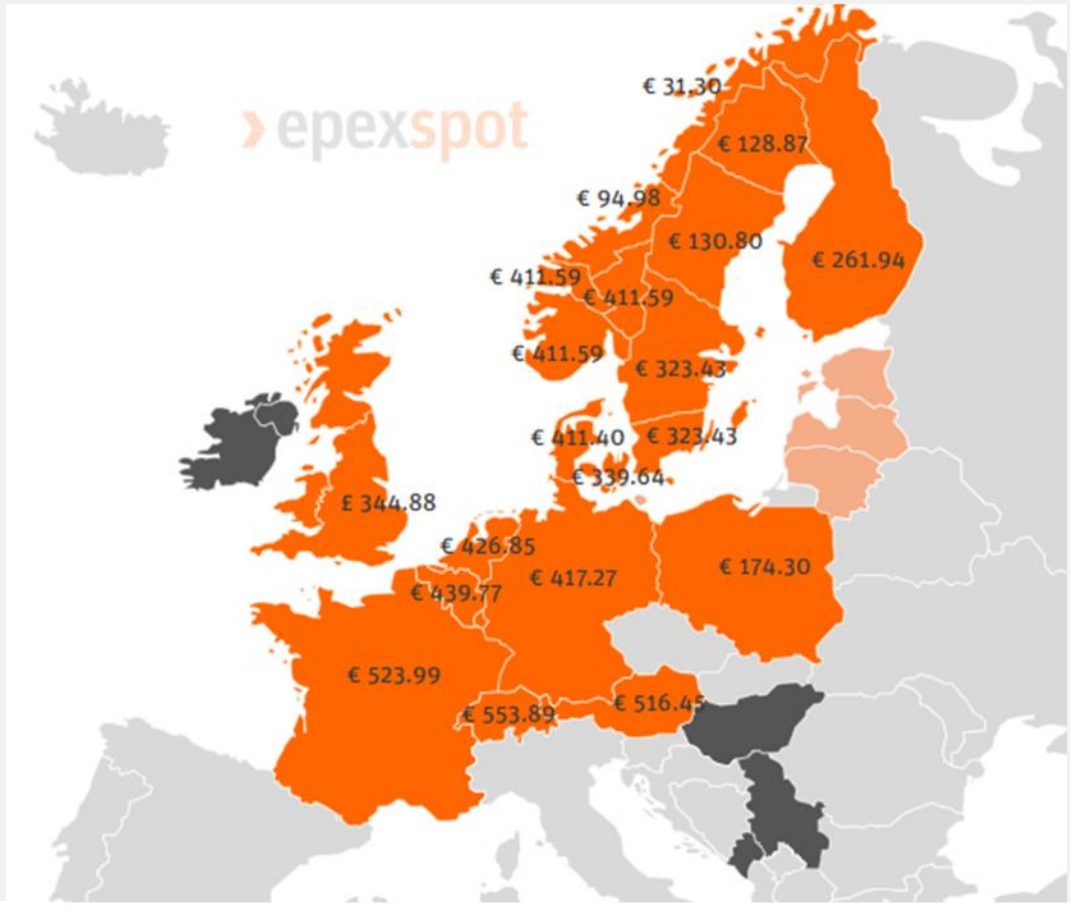
$\eta_{max, theor}$ = 81 %
$\eta_{max, real}$ = BENCHMARK + 15 % points

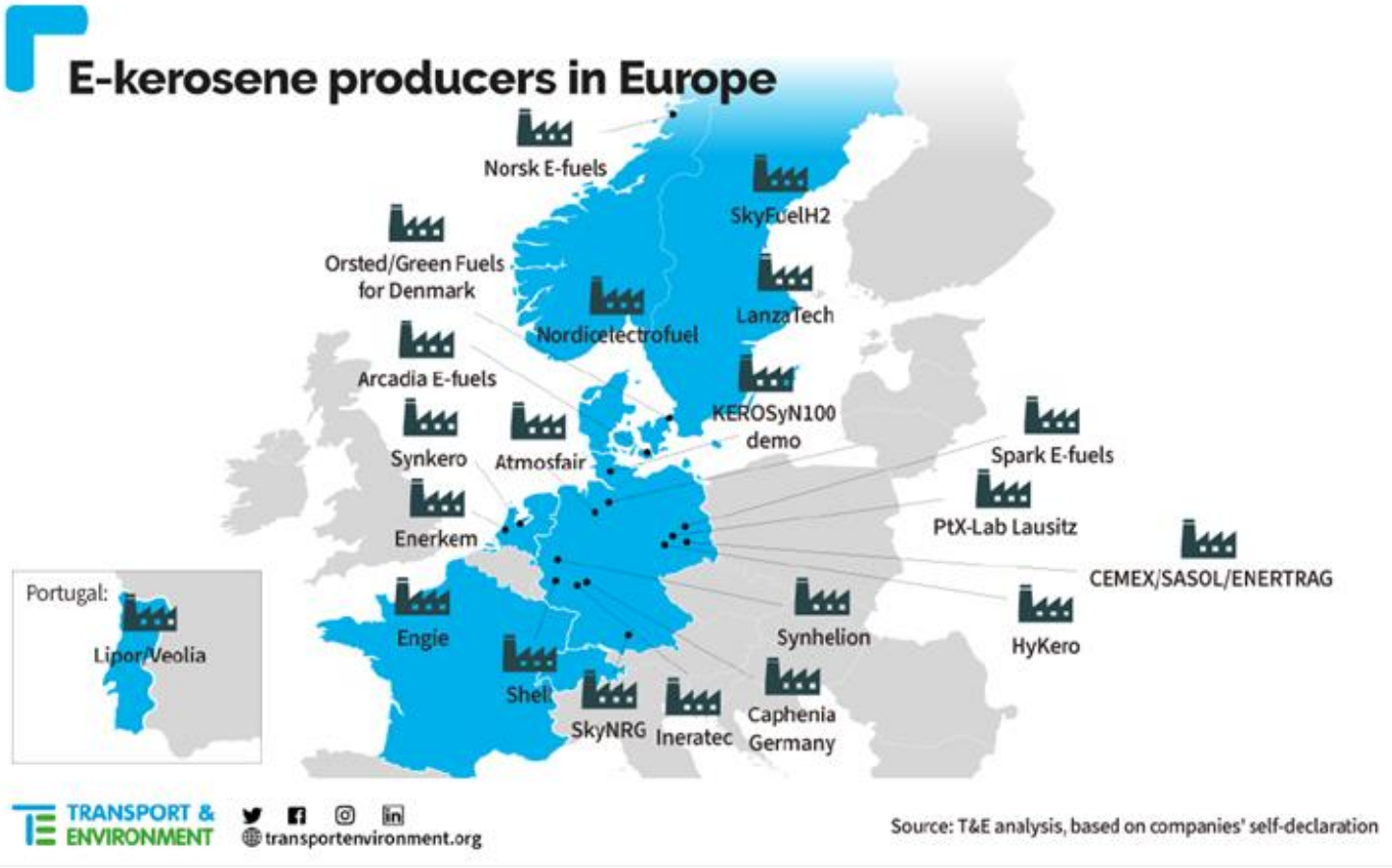
Theoretical efficiency is calculated as lower heating value of the fuel (620 kJ/kmol) compared to the electrical energy without any parasitic losses.
All values refer to energy conversion necessary for the production of 1 mol of -CxHy- hydrocarbons
[1] RWGS = Reverse Water-Gas-Shift

# How to make it commerical?

# Price Sensitivity

| | | | |
|---|---|---|---|
| **A cost increase of** |  ±5-10 €/MWh in Electricity |  ±400 Mio.€ in CAPEX |  ±75 €/t in $CO_2$ |
| **Results in cost increase of** |  ± 250 €/ton for Renewable Fuel | | |



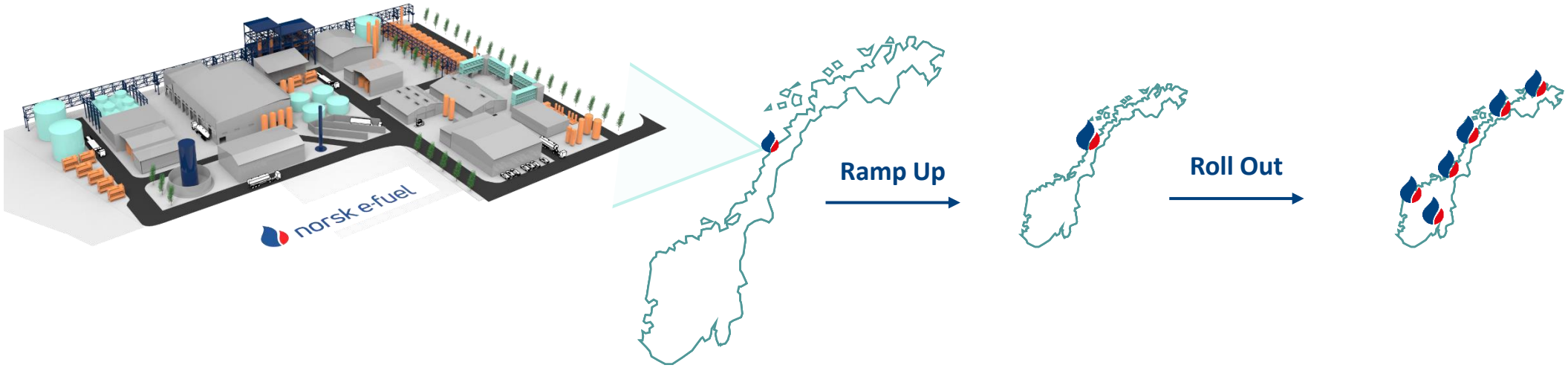

# Developments in energy market und outlook on PtL projects

- **Facing** the dramatically and rapidly changing energy markets which also **influences the SAF landscape**

Sources: T&E 2022, EPEXSPOT spot market analysis, retrieved: 05.08.2022

Cutting emissions of the top 5 most frequently serviced flight routes by 50%

# Commercially viable - scaling from Mosjøen to the world

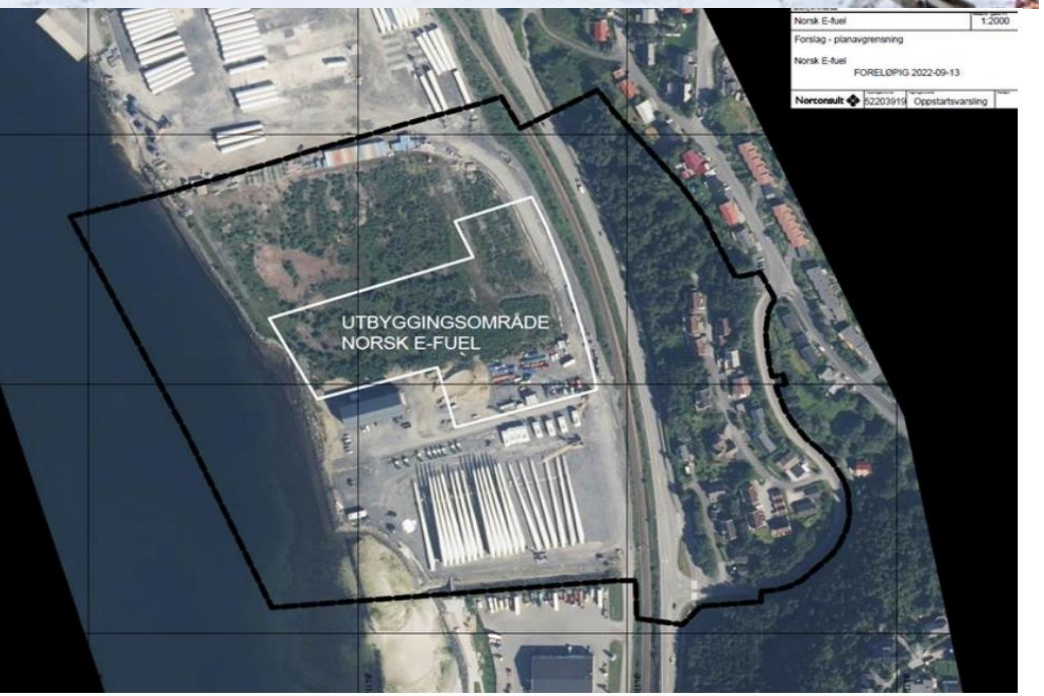



Norsk e-Fuel *Alpha plant*
25 to **50 Mltr of e-crude** annual production volume

Norsk e-Fuel *Beta plant*
**100 Mltr** annual production volume

Norsk e-Fuel *Gamma, Delta ….*
x **100 Mltr**

2025 → 2028 → 2029…




Utbyggingsområde vist med hvit strek, forslag til planområde vist med sort strek.

# Current status of project

- **Site** is secured via Option Agreement
- **Grid** capacity on site is sufficient and concession for a new substation is submitted
- **Power prices** are favourable due to NO4 bidding zone. LoI for long term PPA signed.
- External **CO2 supply** from biogenic source. MoU signed.
- **Engineering** ongoing.

# Summary

Every project developer needs to tackle four major aspects

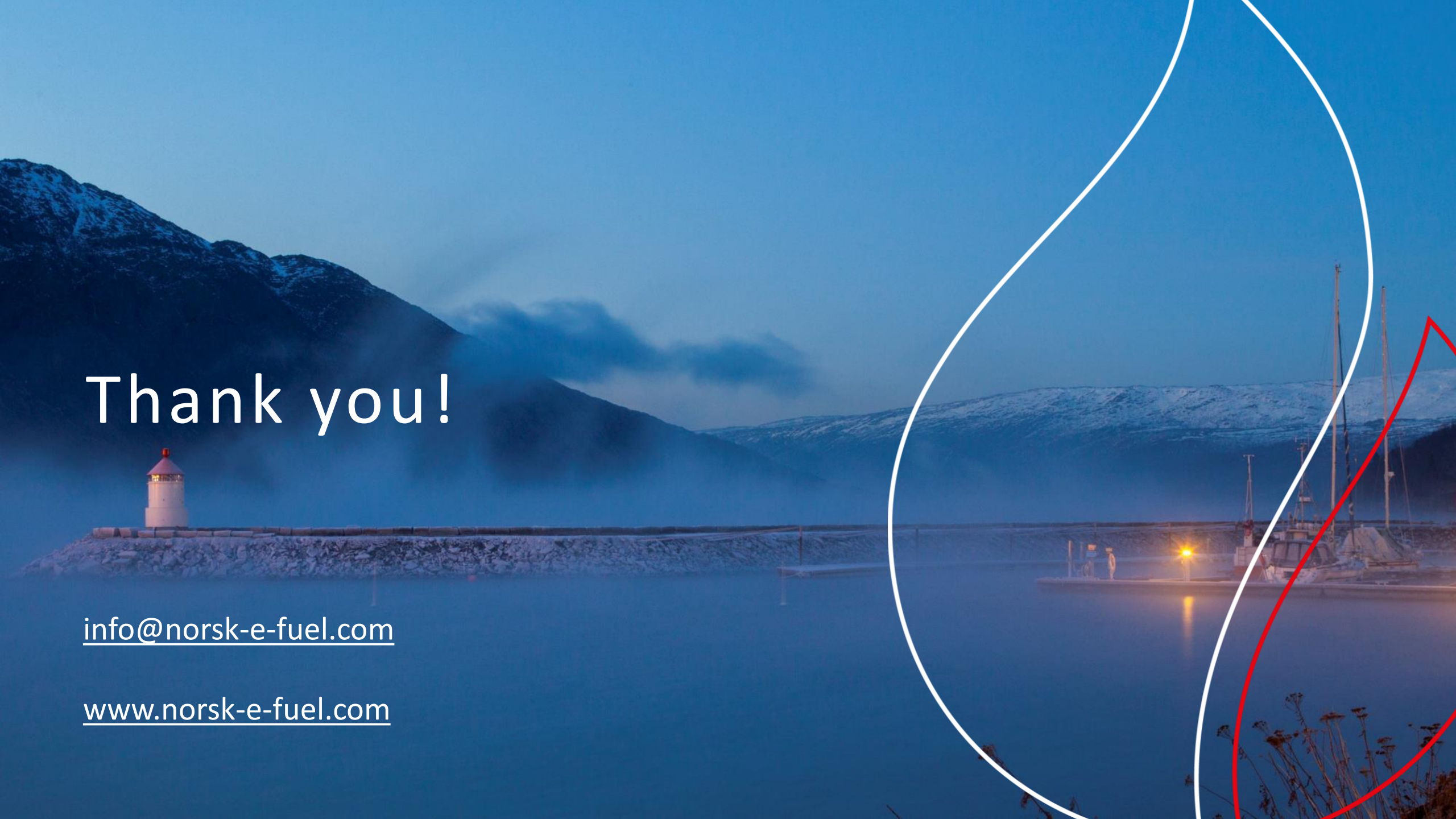
# 4 dimensions of an e-fuel value chain

Technical

Commercial

Financial

Political


Thank you!
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