ICAO ENVIRONMENT

ACT-SAF #17 SERIES

Country examples in SAF development – From Vision to Reality
Sweden

ACT SAF
Assistance, Capacity-building and Training for SAF

1. Opening

Mrs. Jane Hupe
Deputy Director
ICAO Environment

Objectives

ACT-SAF #17 SERIES

To learn from the perspectives and experiences of ACT-SAF Partner States and their stakeholders, of how SAF development can be transformed from Vision to Reality

ACT-SAF Series #17 Speakers

Kajsa Lindström

Head of Section for Environment

Swedish Transport Agency

Christian Janssen

Head of Business Development Aviation

Chairman of the Board AFSN

St1

Sofia Lagerkvist

Head of Strategic Business Development

PREEM

Agenda

- Opening remarks by ICAO
- ICAO update on ACT-SAF activities
- SAF development – From Vision to Reality
  - Sweden Policy Framework
  - Presentation by St1
  - Presentation by Preem
- Questions and answers with the audience
- Closing remarks by ICAO

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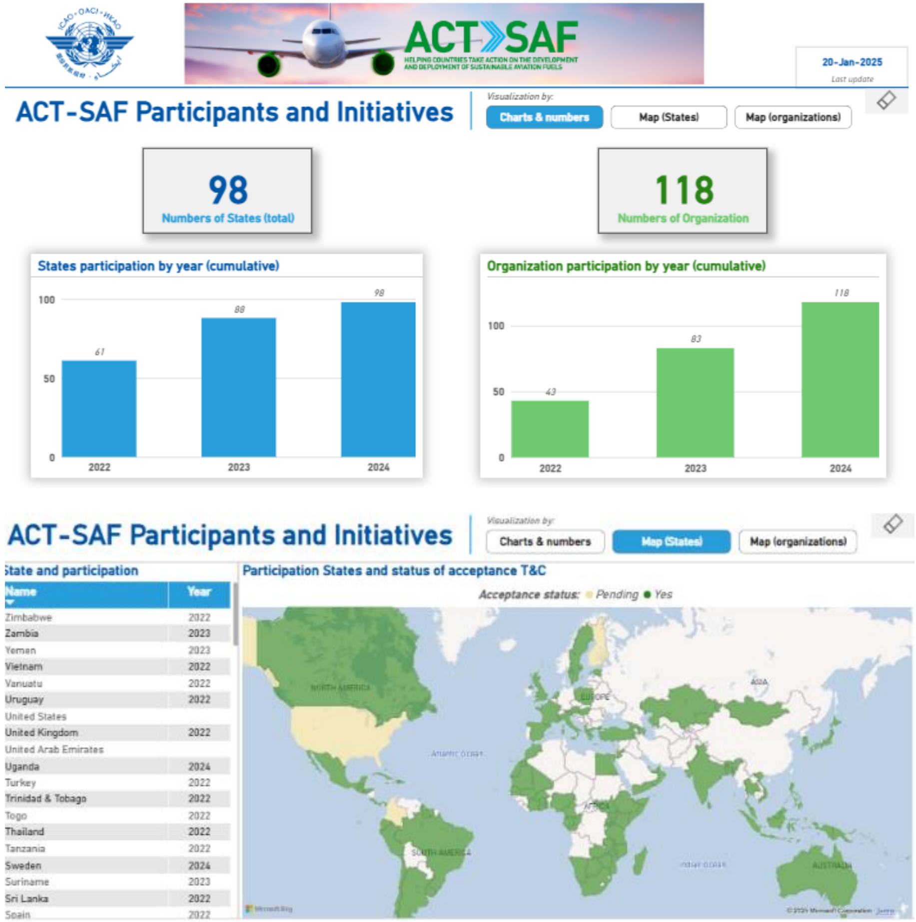
ACT SAF

Assistance, Capacity-building and Training for SAF

ICAO update on ACT-SAF programme

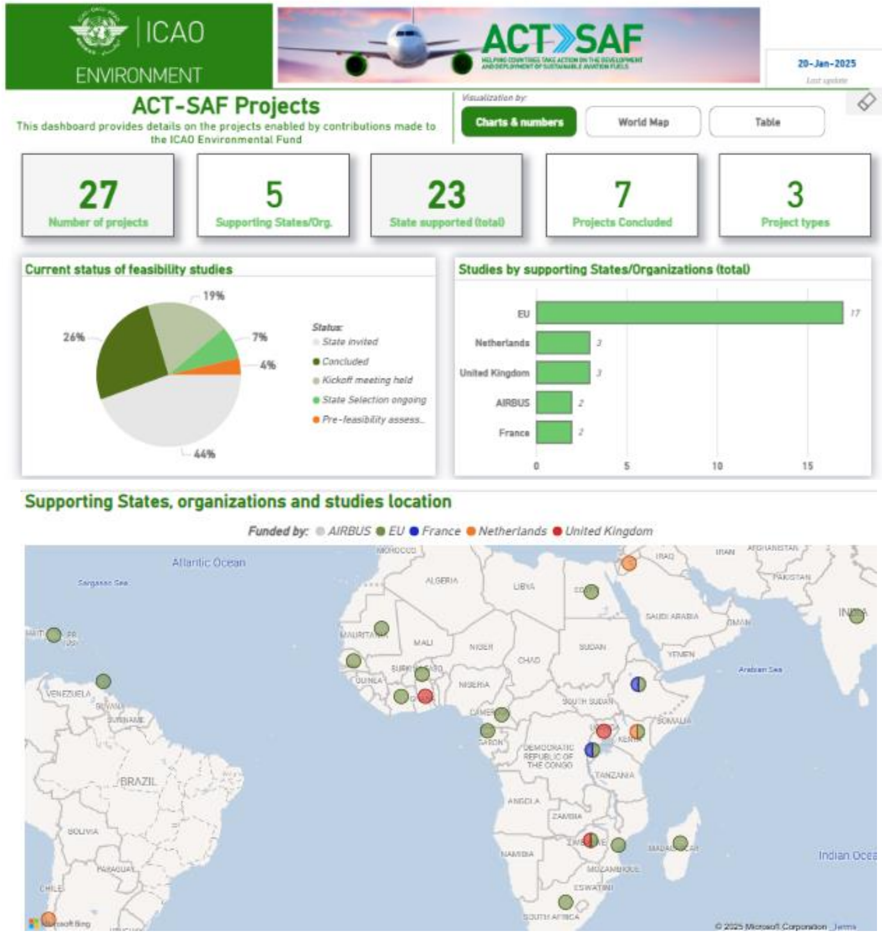
Marked increase in number of ACT-SAF partner States/Organizations

- **Increased opportunities for expert contributions towards training, feasibility studies, etc.**
  - More than 200 ACT-SAF Partner States and Organizations
  - Supports further outreach of SAF development and deployment initiatives



New dashboard provides status updates for ongoing ACT-SAF projects (SAF feasibility studies / business implementation reports)

- 7 SAF feasibility studies already conducted with the contributions provided by the EU
- 20 more being implemented or planned, operationalizing contributions by France, the Netherlands, United Kingdom, and EU
- Planned contributions by Airbus
- As of December 2024, consultants to commence studies for Chile, Ethiopia, India, Jordan, South Africa, Zimbabwe.
- Projects in Kenya and Rwanda to commence in early 2025
- Additional support in planning stages

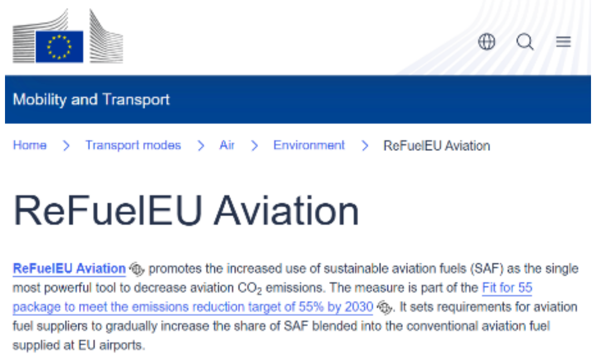


Additional support provided to ACT-SAF partners

- ✓ **Côte d’Ivoire** – Inclusion of SAF on a national bioenergy code. Further support on regulatory framework being evaluated
- ✓ **Mexico** – ACT-SAF workshop delivered in coordination with the ICAO North American, Central American and Caribbean (NACC) Regional Office
- ✓ Ongoing coordination to identify other potential assistance needs and projects

Recent SAF policy developments by ACT-SAF partner States

- **RefuelEU Aviation Regulation**
  - 2% of fuel provided in Union airports from 2025 to be SAF
  - To increase over time towards at least 70% by 2050
  - Provisions for inclusion of synthetic aviation fuels
- **UK SAF Mandate**
  - Starts in 2025 at 2% of total UK jet fuel demand, increasing linearly to 10% in 2030, 22% in 2040
  - Could deliver up to 6.3 Mt of carbon savings per year by 2040



Mobility and Transport

Home > Transport modes > Air > Environment > ReFuelEU Aviation

ReFuelEU Aviation

ReFuelEU Aviation promotes the increased use of sustainable aviation fuels (SAF) as the single most powerful tool to decrease aviation CO_2 emissions. The measure is part of the Fit for 55 package to meet the emissions reduction target of 55% by 2030. It sets requirements for aviation fuel suppliers to gradually increase the share of SAF blended into the conventional aviation fuel supplied at EU airports.

GOV.UK Menu

Home > Transport > Aviation > Aviation and the environment

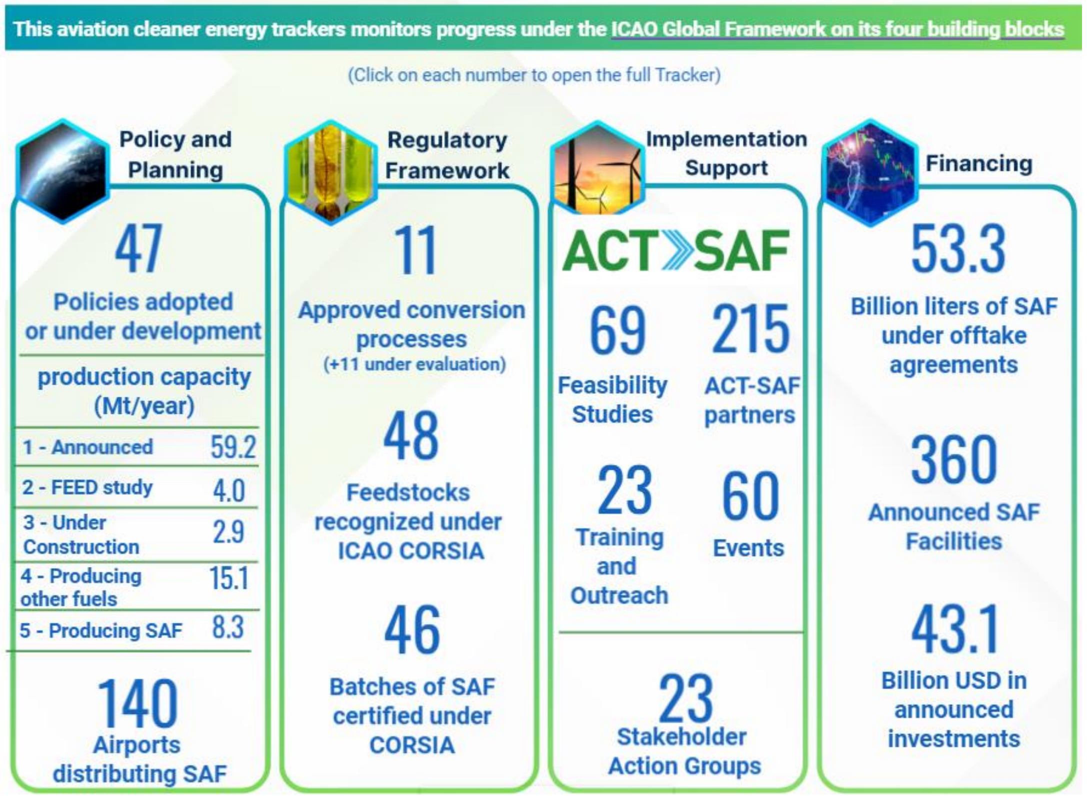
Collection

Sustainable Aviation Fuel (SAF) Mandate

The SAF Mandate is the UK's key policy to decarbonise aviation fuel by encouraging the supply of sustainable aviation fuels.

ICAO Cleaner Energy Tracker Tools

- Layout to reflect four building blocks of the Global Framework
- SAF-related indicators in airports distributing SAF, policies adopted/under development, SAF volumes/offtake agreements, approved conversion processes, etc.
- Please reach out to officeenv@icao.int to have your initiatives updated



SAF related events taking place in 2050

- Close to 40 upcoming SAF related events
  - 10-12 February 2025: Sustainable Aviation Futures – MENA
  - 20 February 2025: Annual ISCC Global Sustainability Conference
- Please reach out to officeenv@icao.int to have your initiatives updated

SAF Events

Events on Aviation and Cleaner Energies

Visualization by: World Map | Table

60	36	40
Total of events	Upcoming events	Numbers of locations

Status selection: Future

Location and status of SAF events

Status: ● Future

Name of event: All | Location: All | Status: Future | Hosted by: All

Date	Name of event	Location	Status	Hosted by (States/Organizations)	Reference
02-Sep-2025	SAF Global Summit 2025	London, UK	Future	Leader Associates	
03-Jun-2025	2025 CAAFI Biennial General Meeting (CBGM)	Cambridge, US	Future	Volpe National Transportation Systems/ US DOT/CAAFI	
05-Nov-2025	European E-Fuels Conference	Hamburg, Germany	Future	Axens/EDL Porner Gruppe	
05-Nov-2025	ISCC Regional Stakeholder Committee – Latin America	Mexico City, Mexico	Future	ISCC	
06-May-2025	Sustainable Aviation Futures Congress (EU)	Amsterdam, Netherlands	Future	Sustainable Aviation Futures	
09-Jul-2025	1st International Conference on Sustainable Aviation Research	Dublin, Ireland	Future	ICSAR	
09-Jun-2025	Carbon Capture & Storage Summit	Omaha, US	Future	Biodiesel Magazine/SAF Magazine	
09-Jun-2025	Sustainable Fuels Summit: SAF, Renewable Diesel, and Biodiesel	Omaha, US	Future	Biodiesel Magazine/SAF Magazine	
10-Feb-2025	Global Sustainable Aviation Marketplace (GSAM) + Sustainable Aviation Futures (MENA)	Abu Dhabi, United Arab Emirates	Future	Sustainable Aviation Futures	
10-Mar-2025	CERA Week	Houston, US	Future	S&P Global	
11-Jun-2025	China Sustainable Aviation Fuel Summit 2025	Shanghai, China	Future	ECV	
11-Jun-2025	Sustainable Aviation Fuels (SAF) Engineering &	Houston, US	Future	EPC (Energy Projects Conference)	

Sweden
Policy framework

Climate framework adopted by the Swedish Parliament

- Climate Act
- Emission goals
  - By 2045 Sweden shall have no net greenhouse gas emissions
- Climate Policy Council

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Pathways to net zero

Reduction of greenhouse gas emissions in the transport sector

- ✓ Transport efficiency
- ✓ Energy efficiency
- ✓ Electrification
- ✓ Sustainable fuels

Bioenergy is crucial

- Research and innovation
- Triple helix cooperation

The industry is proactive

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ACT SAF

Assistance, Capacity-building and Training for SAF

Presentation from St1

St1 Vision

St1 Vision

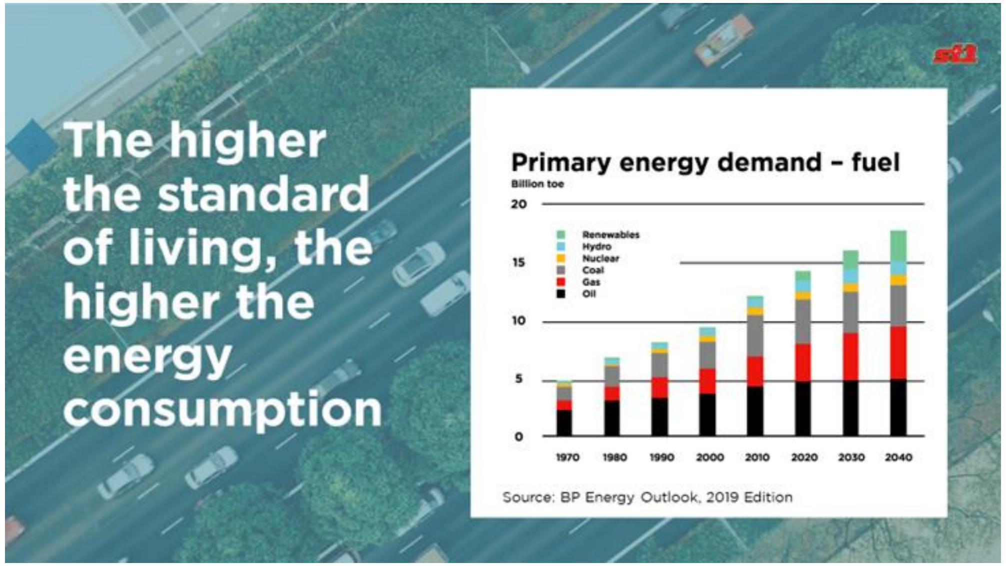
St1 Vision is to be the leading producer and seller of CO_2-aware energy

In the spirit of our vision, we research, develop, produce and invest in the energy transition to be able to provide our customers with CO_2-aware energy while creating positive societal impact

Our operations are strengthened by strategic long-term partnerships in various areas

The Context

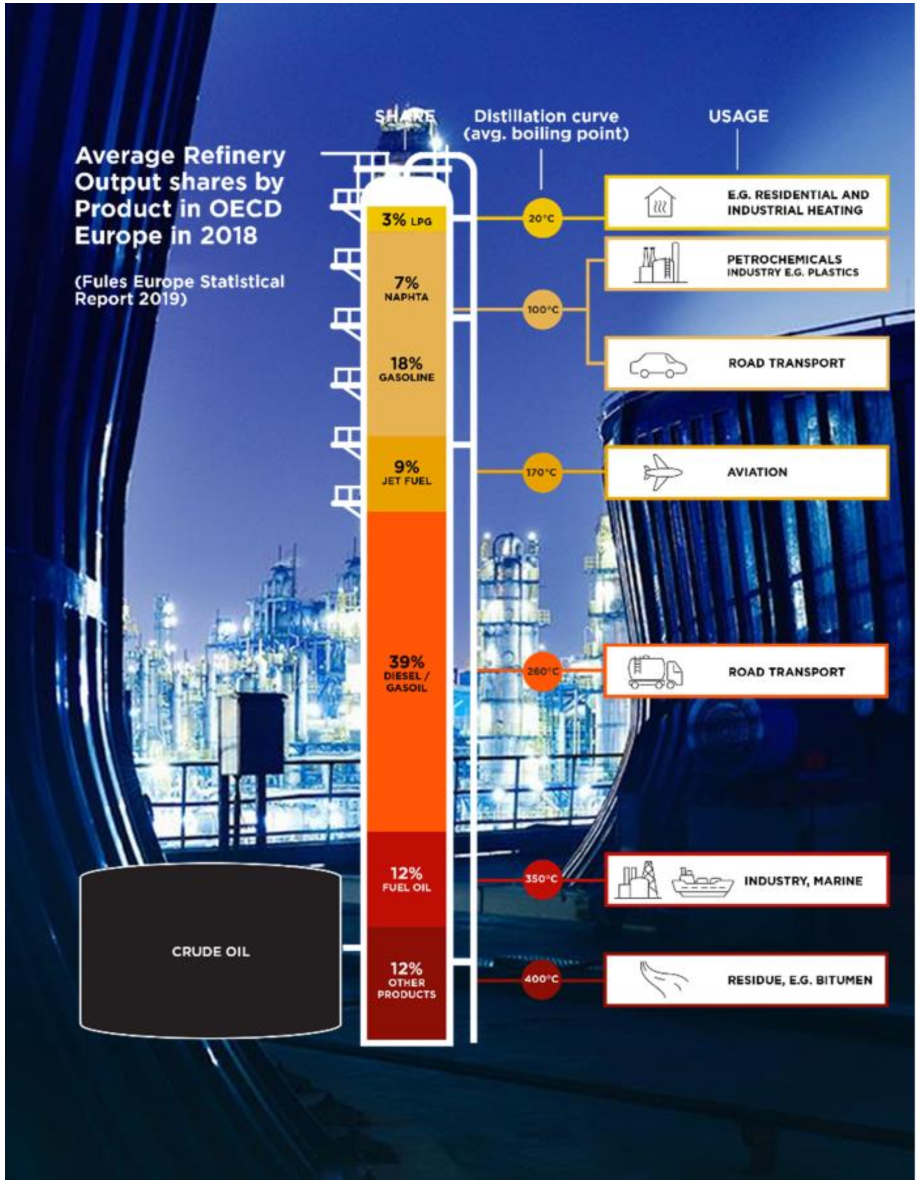
The global population is growing...
World Population
Billion
12
10
8
6
4
2
0
2010
2022
2030
2040
2050
Oceania
Northern America
Latin America and the Caribbean
Europe
Asia
Africa
United Nations, World Population Prospects 2022, Medium variant



The higher the standard of living, the higher the energy consumption
Primary energy demand – fuel
Billion toe
20
15
10
5
0
Renewables
Hydro
Nuclear
Coal
Gas
Oil
1970
1980
1990
2000
2010
2020
2030
2040
Source: BP Energy Outlook, 2019 Edition

And so is the standard of living
World GDP
Trillion USD
250
200
150
100
50
0
2010
2020
2030
2040
2050
OECD
Other
OECD (2022) Real GDP long-term forecast

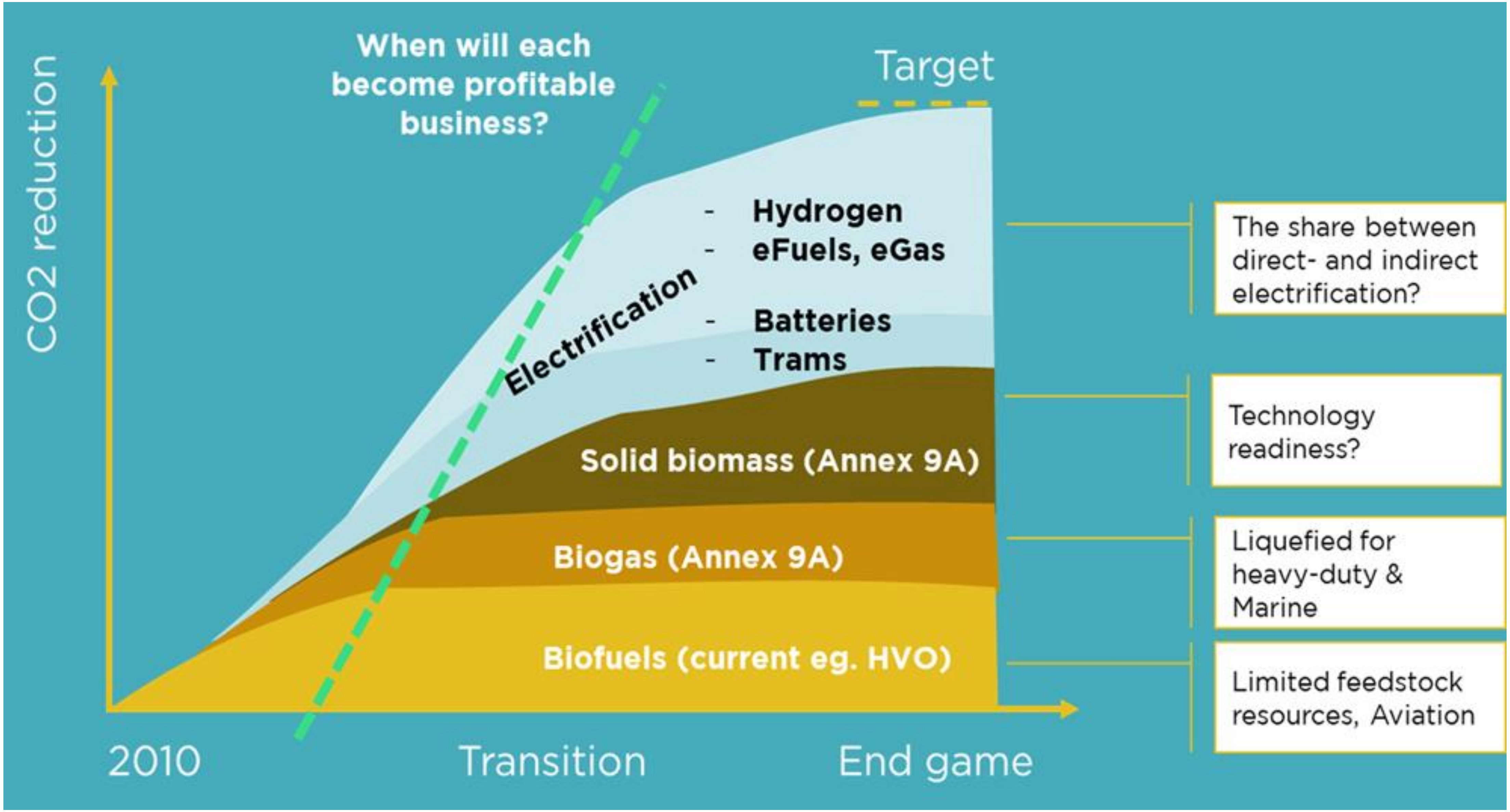
Distillation Curve Challenge



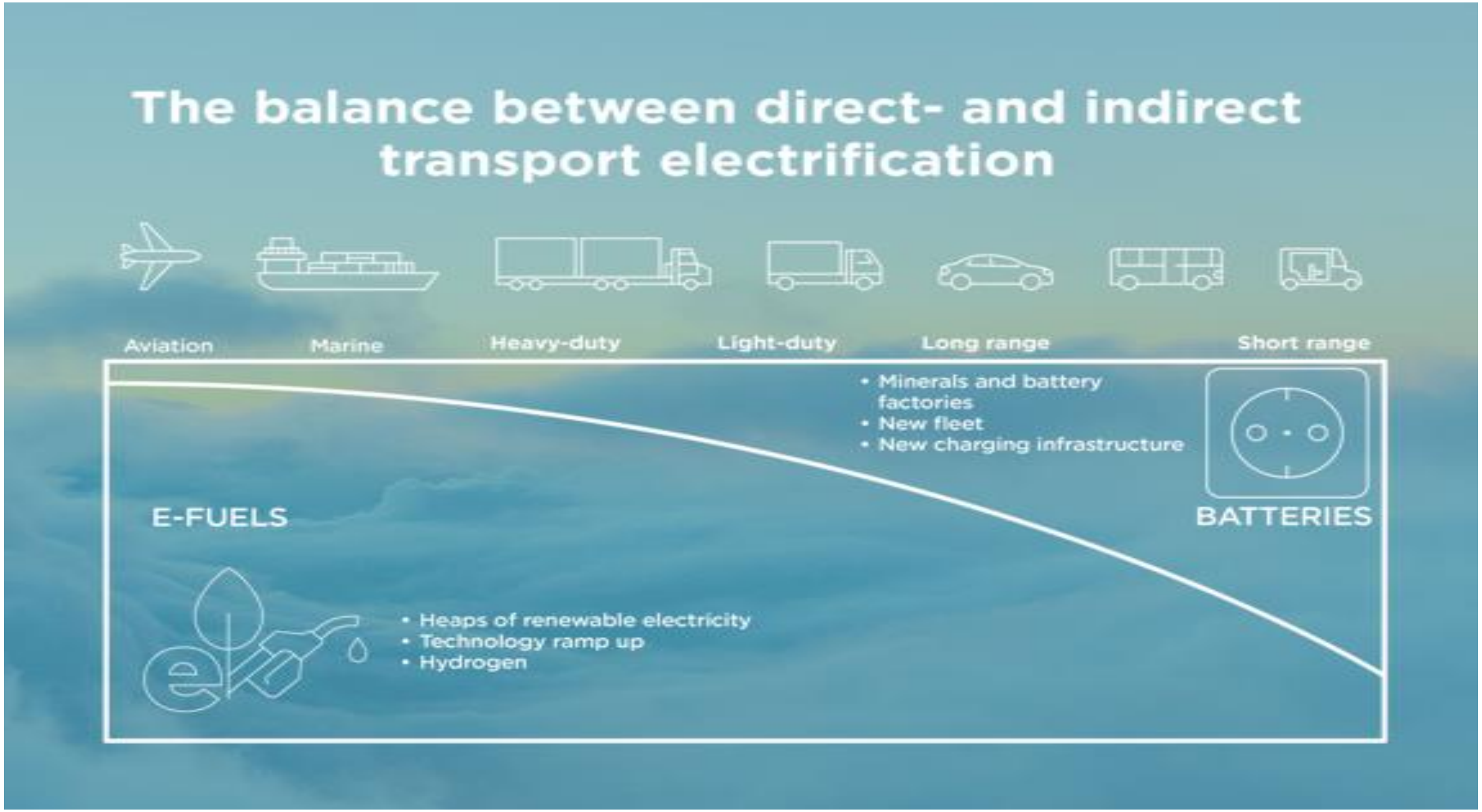
As an example: The Distillation Curve Challenge

The demand on one oil product cannot be met without producing the others

Transport Energy Mix



Transport Energy Mix Electrification



St1 Biorefinery Gothenburg

- SCA shareholder
- Capacity 200 kt
- Bio Jet 80 – 90 kt
- Feedstock
  - Talloil (partnership SCA)
  - UCO (Brocklesby UK - 100% St1)
  - Various global market

St1 Biorefinery – Business Case & Challenges

- **Business Case**
  - Mandated and voluntary markets
  - Feedstock availability
- **Feedstock**
  - Availability – meeting sustainability criteria
  - “Political / regulatory availability
- **Regulation – mandates and feedstock**
  - Long term robustness mandates – see Swedish case
  - Long term eligibility feedstock
- **Technology**
  - New to industry and immature
  - Flexibility to meet feedstock uncertainty
- **Partnerships**
  - Mitigate financial risk
  - Secure value chain (feedstock primarily)
- **Public Affairs**
  - Greenwashing / Swedish “flight shame”
- **Other / The Unknown**
  - Pandemic

Biorefinery Östrand

- Biorefinery Östrand is St1 and SCA JV
- Intention to produce SAF (bio and RFNBO) from forest industrial residues and by-products (sawdust, bark and pellets) and renewable electricity
- The JV has signed a CINEA* agreement which entitles to an innovation grant of appr. MEUR 167 in the event of a future investment decision
- The project has been singled out as one of Europe’s most important projects for creating climate benefits

- *European Climate, Infrastructure and Environment Executive Agency

ACT SAF Assistance, Capacity-building and Training for SAF

Presentation from PREEM

ICAO 23 January 2025

SAF production plans at Preem in Sweden

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This is Preem

We make the journey to a better future possible

Sofia Lagerkvist, Strategic Business Development

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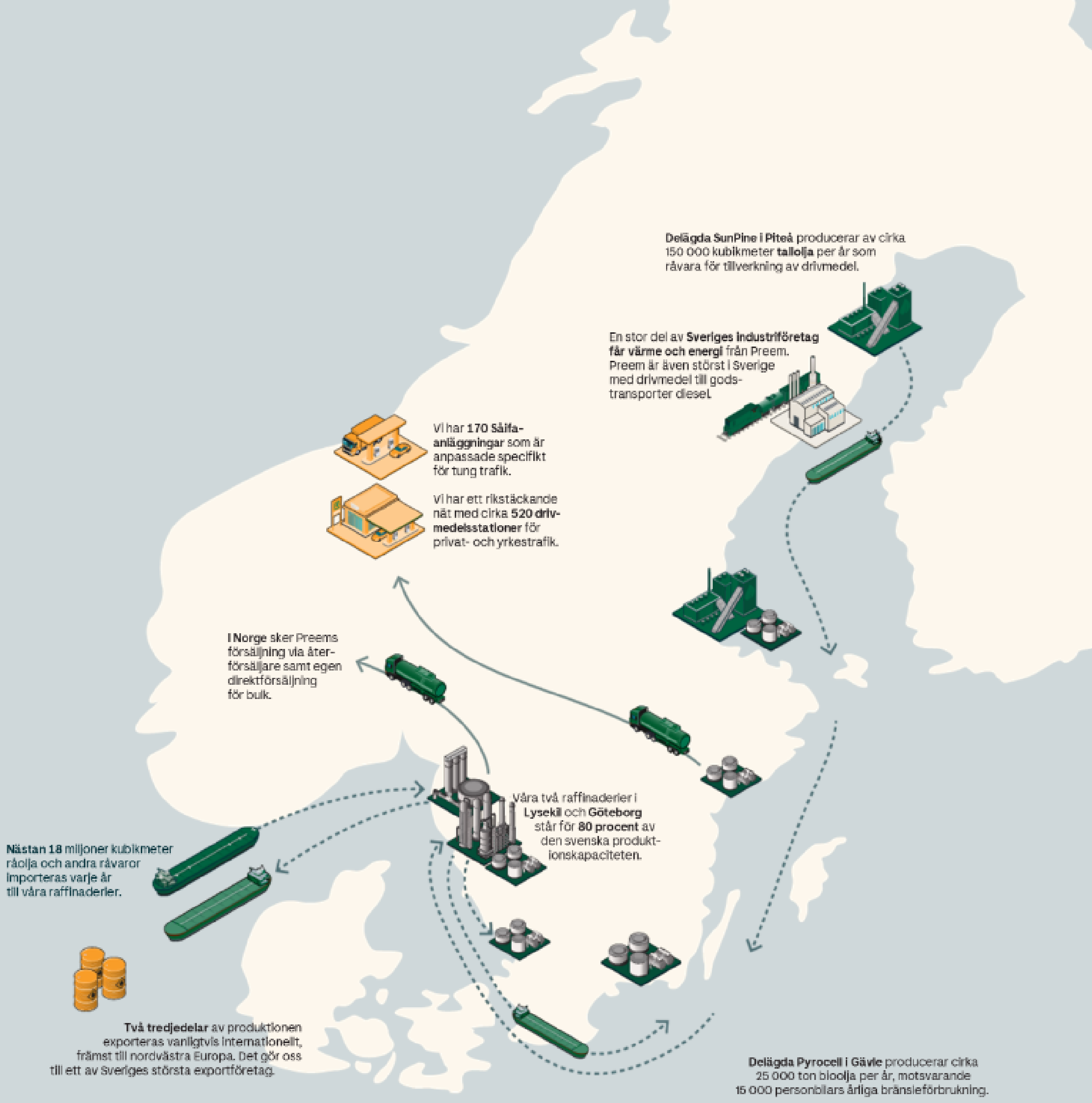
Sweden's largest fuel company

- Founded in 1996
- 1,500 employees
- Full-year revenue for 2023 – 137 billion SEK
- Own production in two refineries in Lysekil and Gothenburg, with a capacity of over 18 million cubic meters per year. Headquarters in Stockholm.
- One of Sweden's largest producers of renewable fuels
- One of Sweden's largest export companies
- Two-thirds of production is sold to international customers
- Nationwide service network with almost 500 stations



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Two refineries, both on the Swedish west-coast

Gothenburg
350
employees

Lysekil
800
employees

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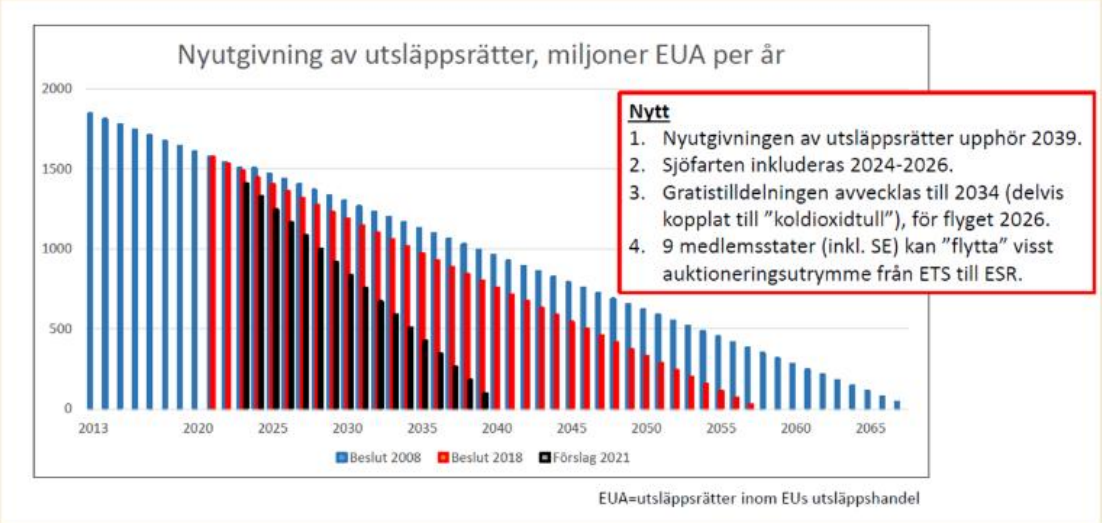
EU regulations demand change and clarifiy the need for renewable fuels

New emission rights will cease 2039



Några av EU:s klimatstyrande regelverk

EU ETS (EU ETS1)
Utsläppshandel för den tyngre industrin och flyg, samt för sjöfart med gradvis infasning.

EU ETS2
Utsläppshandel för vägtransporter, byggnader och mindre industrier. Gäller från 2027.

Refuel EU Aviation
Ska öka efterfrågan och tillgången på förnybara flygbränslen. Från 2025 krävs en över tid ökande inblandning av biobaserat flygbränsle och från 2030 även av elektrobränsle.

Fuel EU Maritime
Ska minska utsläppen från sjöfartssektorn. Växthusgasintensiteten hos de använda bränslena ska gradvis minska från 2025 och framåt.

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Our mission & strategy
Climate nautral by 2035 in the whole value chain
2025-01-21
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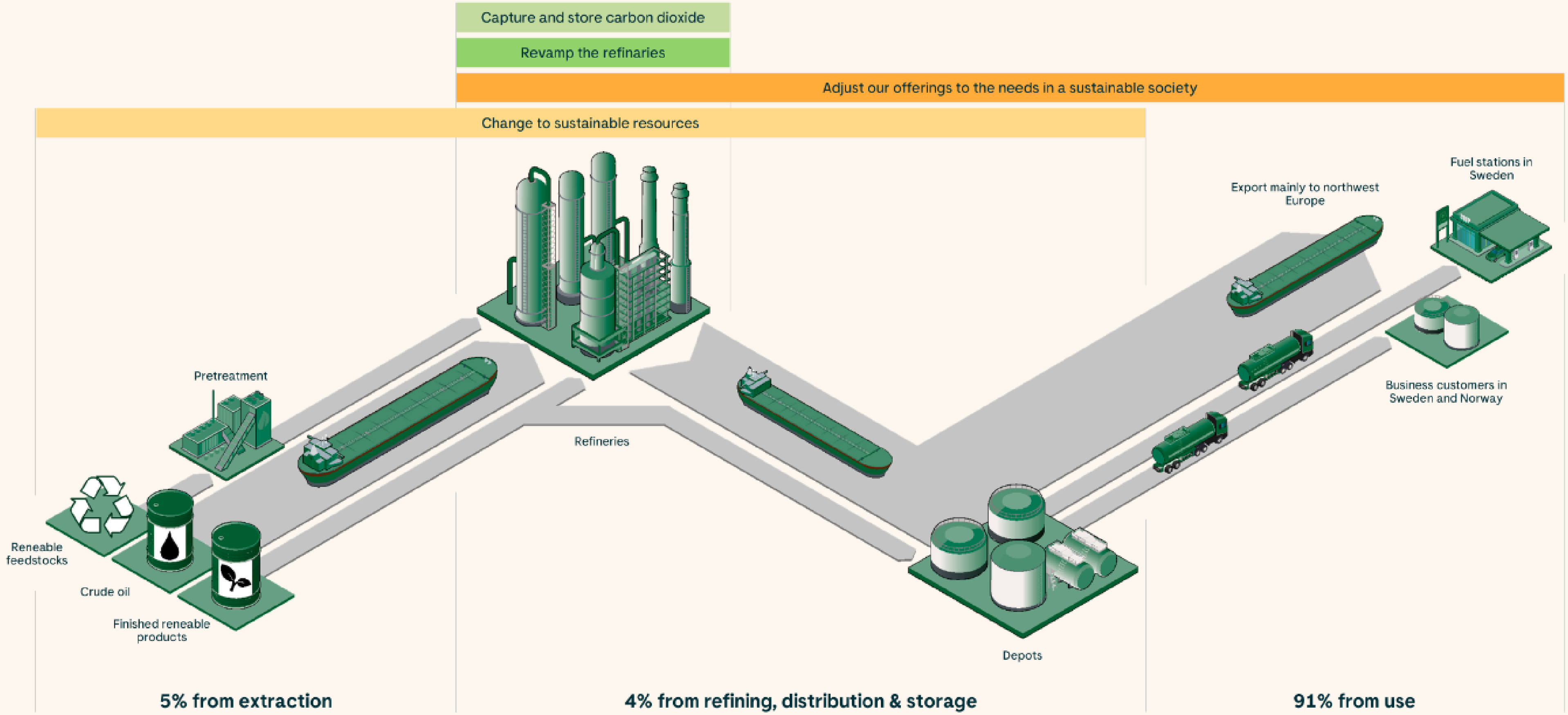
Our focus areas towards climate neutrality



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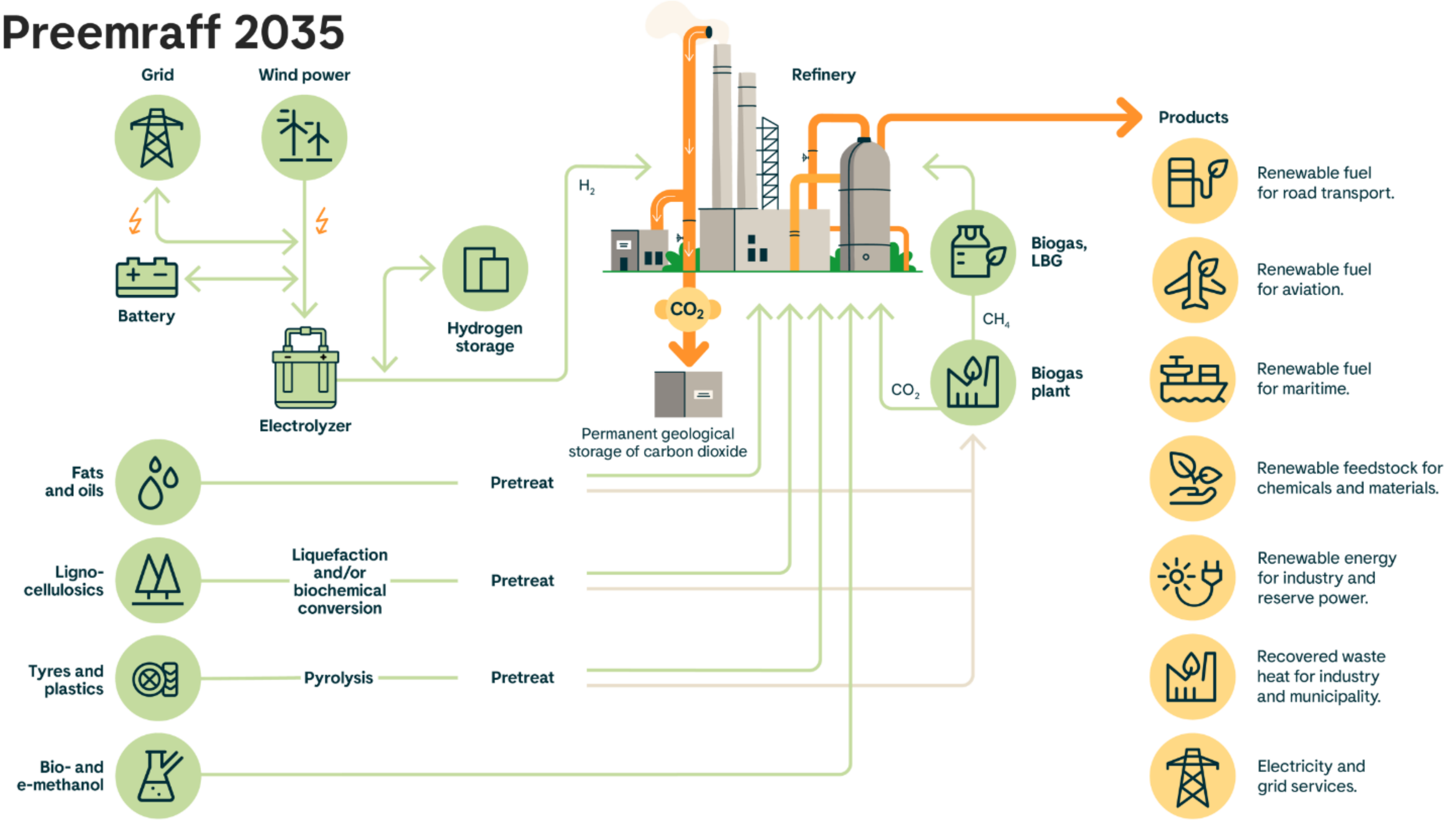
Exemplifiering av fördelning av CO2 över värdekedjan under 2023

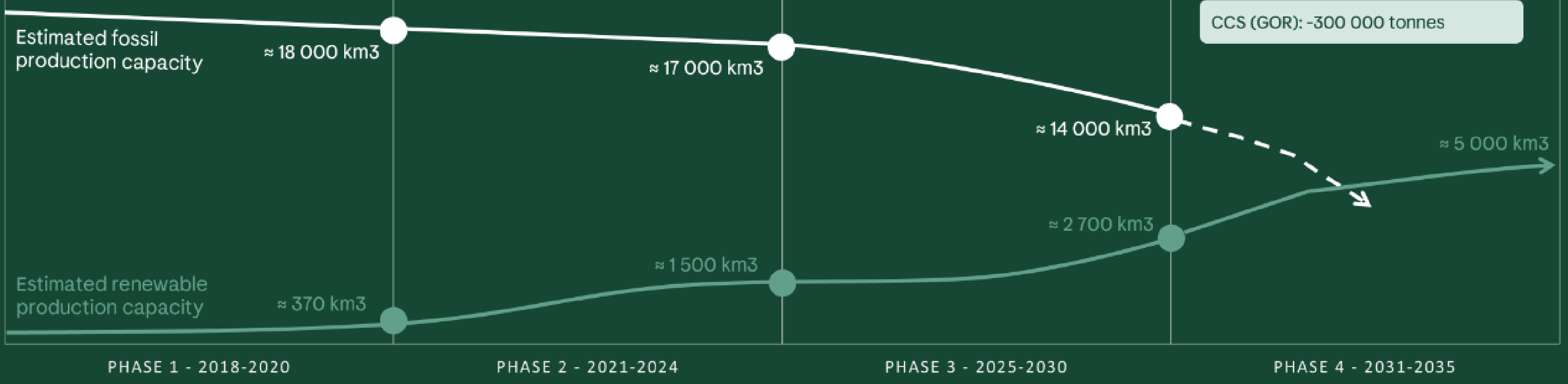
Preemraff 2035



Master transition plan 2024

Scope e-fuels

PHASE 1 - 2018-2020	PHASE 2 - 2021-2024	PHASE 3 - 2025-2030	PHASE 4 - 2031-2035
Climate Emissions	Climate Emissions	Climate goals	Climate goals
≈60 Mton	**≈50-60 Mton**	**-30%* (<42 Mton)**	**-90%* (<6 Mton)**
Scope 1 and 2: ≈2 Mton	**Scope 1 and 2: ≈2 Mton**	**Scope 1 and 2: ≈1 Mton (-50%*)**	**Scope 1 and 2: 0 Mton (-100%*)**
GHT (GOR): 320 000 m3	FCC low (LYR): 25 000 m3	ICR (LYR): +1 200 000 m3	MHC-FCC (LYR)
Synsat low (LYR): 50 000 m3	ICR/MHC low (LYR): +100 000 m3	Biogas	E-fuels
	Synsat low (GOR): +50 000 m3	CCS (LYR): -600 000 tonnes	Fossil exit
	Synsat (LYR): +900 000 m3		GFU (GOR): +1 000 000 m3
			CCS (GOR): -300 000 tonnes



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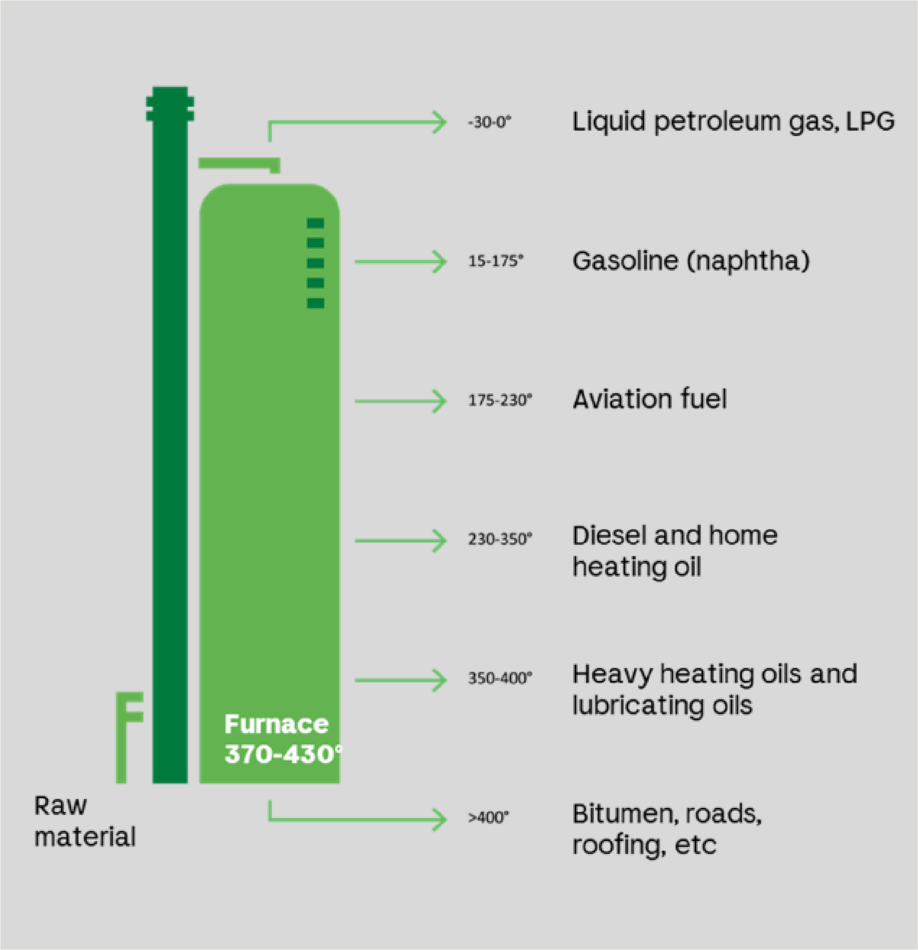
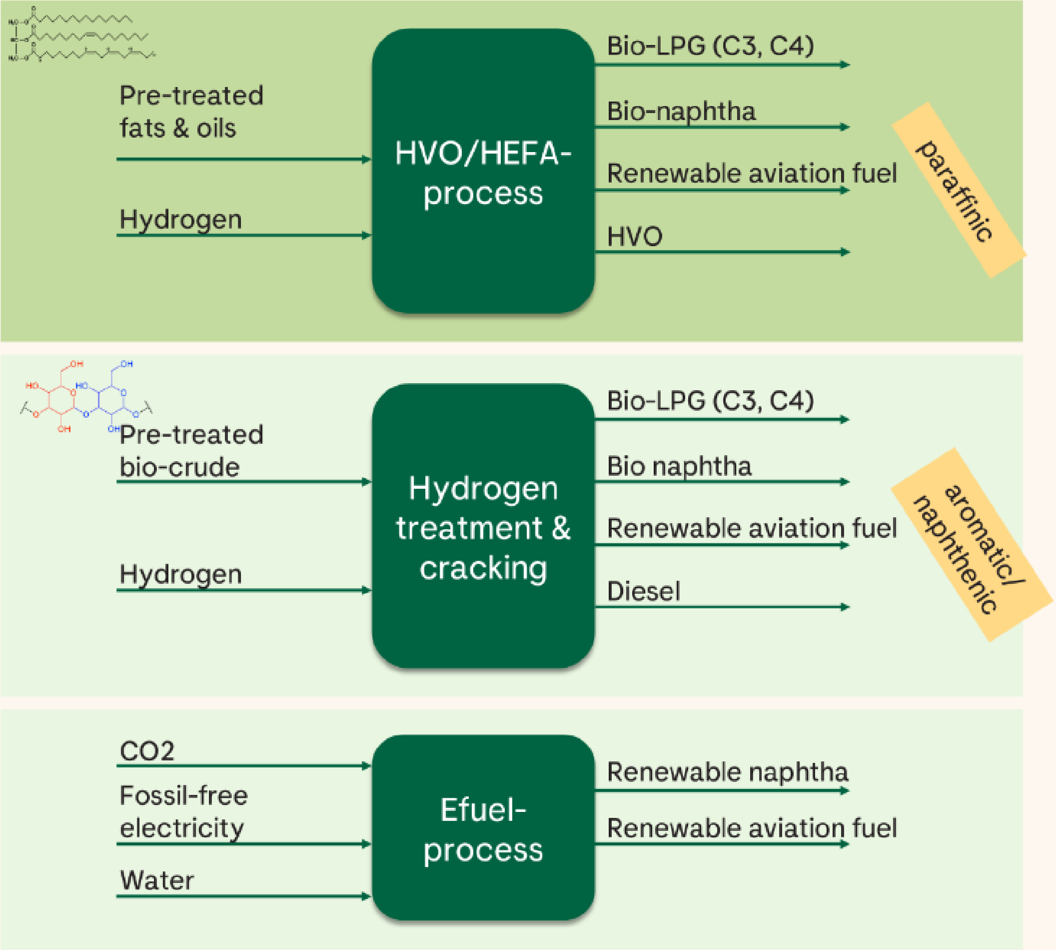
* In comparison to base year (2018)

Publik

What do refineries produce today and in the future?





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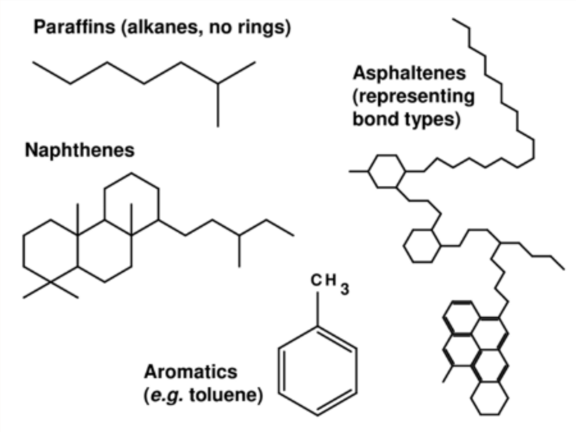
Crude oil vs biomass

Crude oil

Pure hydrocarbons,
low levels of impurities,
very low water content

Energy content: 42-44 MJ/kg



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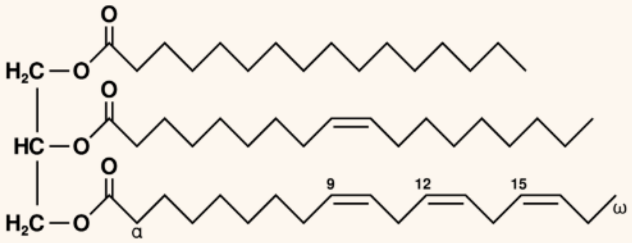
Biomass

Fats & oils

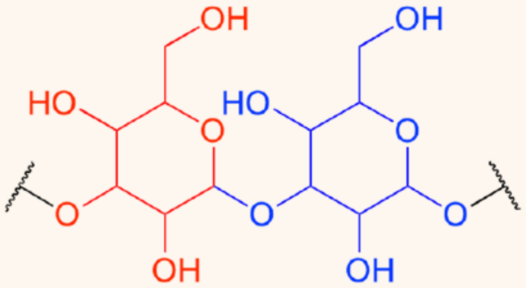
Elevated levels of oxygen, water, and heteroatoms (metals, S, N, Cl)

Energy content: 36-38 MJ/kg



Lignocellulose
High levels of oxygen, water, and impurities (metals, S, N, Cl)

Energy content: 15-18 MJ/kg (dry)



What differentiates renewable production from fossil?

Technology maturity

- Fossil: Licensable technology available, well proven for many decades. Issues identified and solved.
- Renewable:
  - "HVO type of feedstocks": Starting to become proven and commercially available technology (hydroprocessing). Still more technical uncertainties, e.g. deactivation, pressure drop build-up, corrosion issues.
  - Other feedstocks: Research/pilot test/test run stage. ("Learning by doing")
  - IP and patent issues.

=> Increased technical (and financial) risk

Operational scale & Feedstock and products standardization

- Fossil: Global, large-scale commodities readily available. Global/regional standards well established.
- Renewable:
  - Small scale, large diversity, difficult and work intensive logistics and storage.
  - Lack of (harmonized) standards.
  - Higher cost – both feedstock and Opex => Dependent on uncertain incentives/price premiums.

=> Increased financial risk/uncertainty for required large investments.

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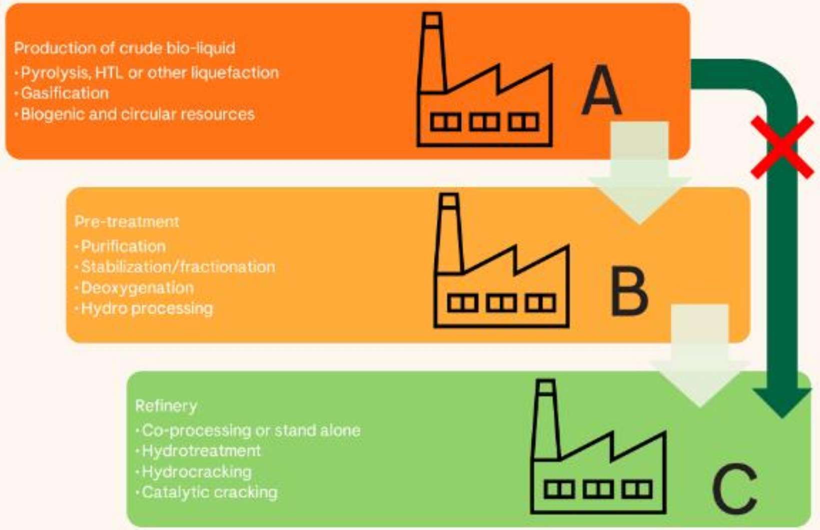
What differentiates renewable from renewables?

"HVO feedstock" (tri-glycerides, fatty acids, FAME) – The easy ones

- ❑Corrosive when heated => Need for separate feed system, reactor metallurgy upgrade
- ❑Oxygen content => High hydrogen consumption, high exotherms, reaction by-products (H20, CO2, CO)
- ❑Impurities content (metals, phosphorus, nitrogen, chlorides) => Catalyst deactivation, reactor pressure drop, salt formation and corrosion issues downstream reactor
- ❑Form paraffins after HDO => Need to isomerize (dewax) to meet diesel winter property specifications

Pyrolysis oils / HTL oils / Lignin feedstocks - Much harder!

- Solid lignocellulosic biomass (sawdust, bark, lignin etc.) needs to be liquefied, but what often has been neglected is that **those liquids usually need pre-treatment** before being suitable for refinery processing.
- Various forms of liquefaction processes:
  - **Fast pyrolysis** - rapid heating of dry biomass to 500 °C at atmospheric pressure without oxygen addition, followed by condensation of vapors thus forming a pyrolysis liquid (example Pyrocell). Alternative pyrolysis processes with catalyst and/or hydrogen present.
  - **Hydrothermal liquefaction (HTL)** – wet biomass, water and KOH fed to heated reactor at 350 bar and 400 °C. Treatment at sub and supercritical conditions results in HTL biocrude.
- Common challenges of the advanced biocrudes: **corrosive, unstable during storage and heating, impurities that cause catalyst deactivation, low miscibility with refinery streams and coking during hydrotreatment**. Co-processing or stand-alone and what process conditions should be used?



New fats & oils (VAFOs)

We **look for and continuously evaluate new** renewable fats and oils that could work as feedstock and complement existing **feedstock to our refineries**.

- Field cress – a new local oil crop
- Pongamia
- RBFAD – Rice bran fatty acid distillate
- CFAD – Coconut fatty acid distillate
- Fish fat
- CNSL – Cashew nut shell liquid

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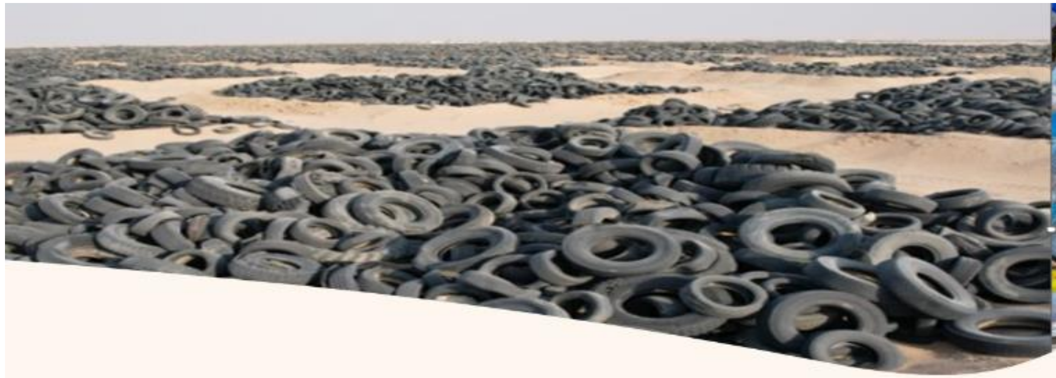

Tyre- and plastic pyrolysis oil

- Chemical recirculation of used tyres through pyrolysis
- Reused fossil oil / renewable oil – 50/50 %
- 7500 t/yr 2026

- High sulphur content

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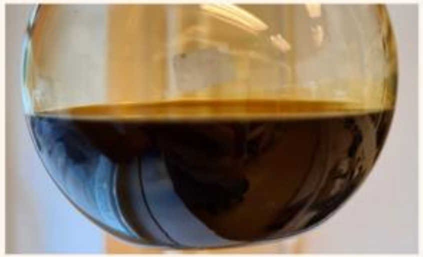
- Chemical recirculation of plastic through pyrolysis
- Reused fossil oil
- Many contaminants in relatively high contents
  - Clorine 100 - 1000 ppm
  - Metals 50 - 100 ppm (sum except Silica)
    - Silica 20 - 100 ppm

BioCrude

Raw material from lignocellulosic (straw, sawdust, branches, bark, lignin)



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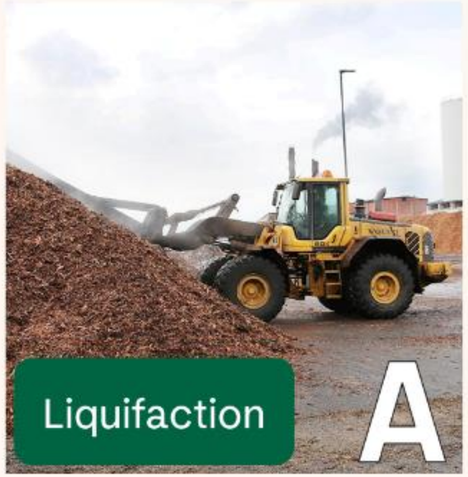

How Preem converts to more renewables

- the Synsat plant revamp

The revamp enables 40% of the feedstock to be renewable instead of fossil.

Production of 900 000 m3/yr renewable product

Carbondioxide emissions at the user level can be reduced by 1,7- 2 million tonnes/yr. This is without increasing the emissions at the refinery.

Start up is ongoing now 2024/2025

- the ICR plant revamp

Convert the hydrocracker to 100% renewable feedstock

Production of 1,2 million m3/yr renewable products whereof **600 000 m3/yr bio-SAF**

Start up 2029

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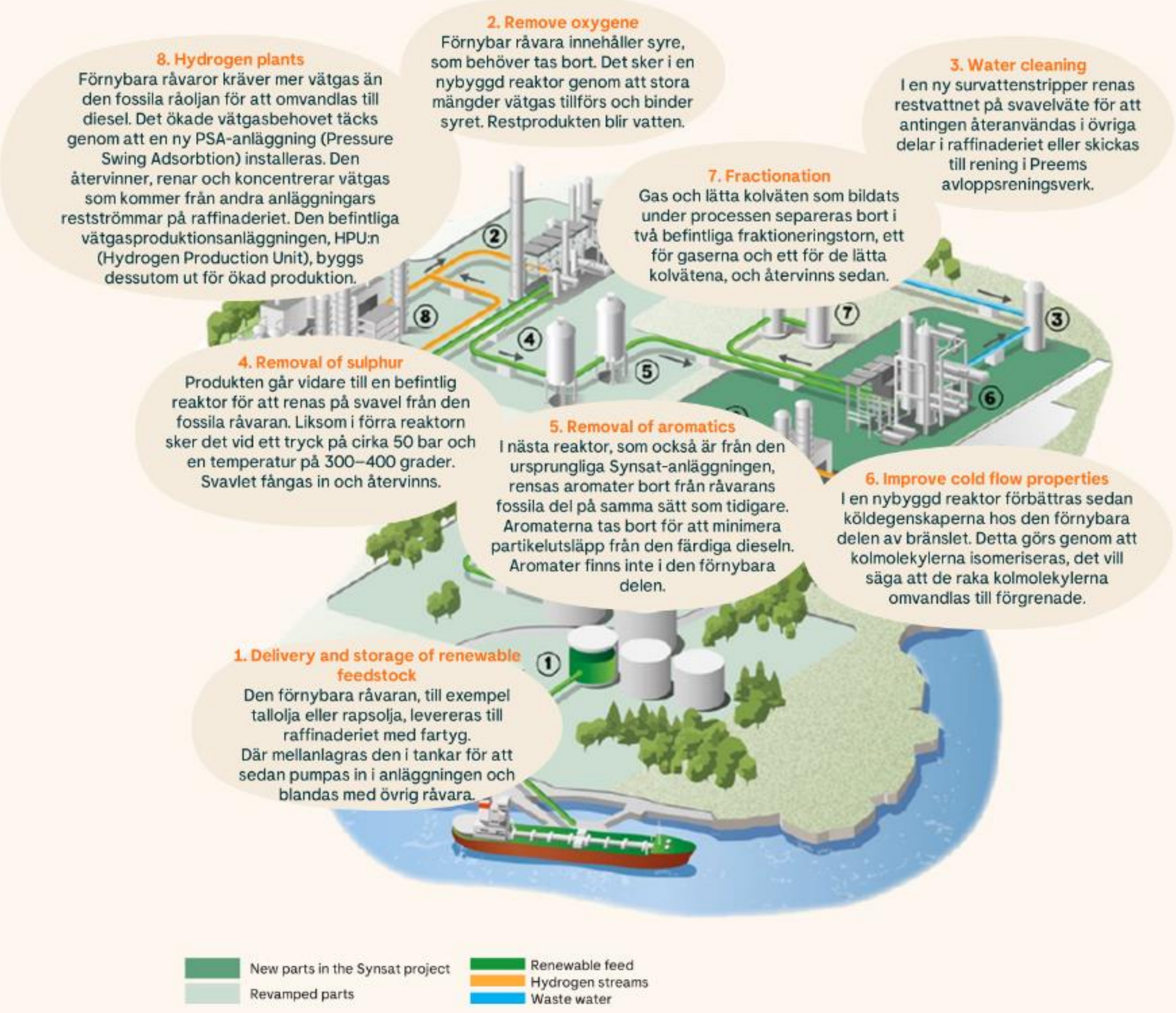
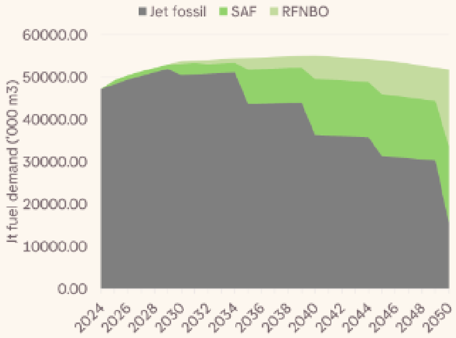
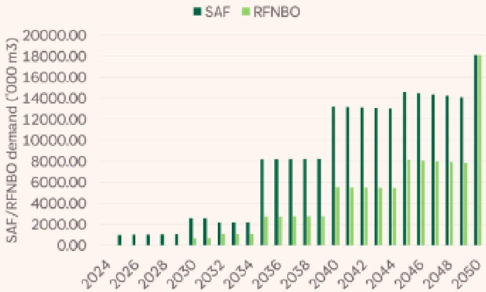


Clear demand for RFNBO in air transport – but not in maritime – confirms the conclusion to focus on eSAF

Liquid fuels NWE 2024-2050 Air transport





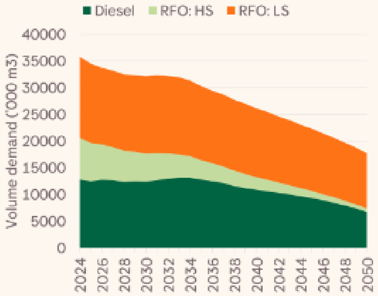
ReFuelEU Aviation volume mandate	
SAF	of which e-Jet
2025 - 2 % 2030 - 6 % 2035 - 20 % 2040 - 34 % 2045 - 42 % 2050 - 70 %	2025 - 0 % 2030 - 1,2 % 2032 - 2 % 2035 - 5 % 2040 - 10 % 2045 - 15 % 2050 - 35 %

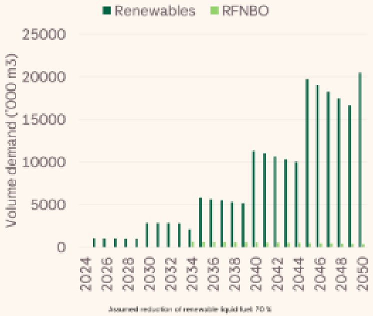
- The ReFuelEU Aviation Regulation sets volume mandates for Sustainable Aviation Fuel (SAF) and e-Jet (RFNBO) in the EU. As penalties are very high for failing to comply with the mandates, this regulation will drive significant demand for non-fossil jet fuel in the years to come.

preem

Source: S&P Global reference case feb 24, ReFuelEU Aviation

Liquid fuels NWE 2024-2050 Shipping





FuelEU Maritime reduction mandate	
GHG reduction	RFNBO subtarget (volume)
2025 - 2 % 2030 - 6 % 2035 - 14,5 % 2040 - 31 % 2045 - 62 % 2050 - 80 %	2025 - 0 % 2034 - 2 %

- The FuelEU Maritime Regulation sets a reduction target for marine vessels. Part of the reduction can be accomplished with other measures such as reducing cruise speed, but as the mandate increases, demand for low-emission marine fuels will rise.
- The sharp decrease in demand for liquid bunker fuel seen in this forecast is due to a projected increase in the LNG share of total bunker demand

preem

Source: S&P Global reference case feb 24, FuelEU Maritime

preem

Actions and way forward

- Multi-discipline eSAF project team is formed and have started its work with the aim to finalise the concept scope during Q3 2024 and a feasibility study in Q2 2025.
- Project team handles all external contacts relating to electrofuels;
  - Work with power producers and potential hydrogen producers,
  - Offtake talks with bio- & e-methanol producers,
  - Offtake talks with eSAF customers,
  - Electrolyzer suppliers
  - Process licensors for methanol synthesis and methanol-to-jet, as well as Fischer-Tropsch
- Start work with business model drafting and sensitivity analysis
- Start work to optimise project scope to be cost-competitive

Concept Q3 2024
- Optimised system is modelled, evaluated and selected
- Intensified work with electricity producers

Feasibility Q2 2025
- MTJ process feasibility studies with process licensors

Basic engineering & design 2026
- After feasibility, a preferred process licensor is selected, and work is started to perform BED phase

preem

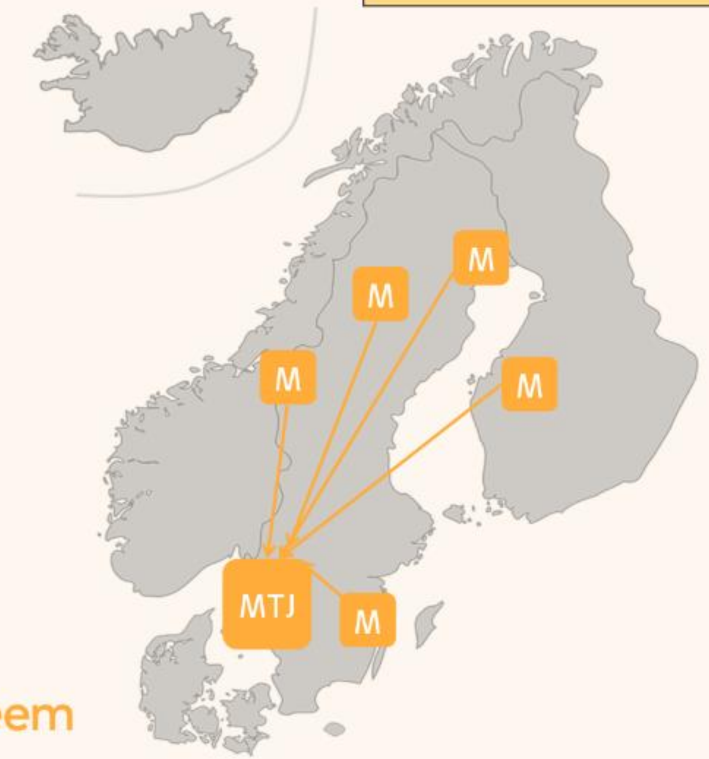
Power to X scale-up preliminary plan

Earliest possible production

2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2040	2050

Phase 1: Grid-connected eH2
Investment 1: Grid-connected electrolyzer (10-60 MW)
Investment 2: MtJ
Production: eSAF 200 kt per year (50% of plant capacity)

Phase 2: eH2 from Off shore wind
Offtake: off shore wind
Investment 3: Big elektrolyzer (500-800 MW)
Investment 4: Methanol production plant
Investment 5: H2 storage
Produktion: eSAF 400 kt per year (100% of plant capacity)



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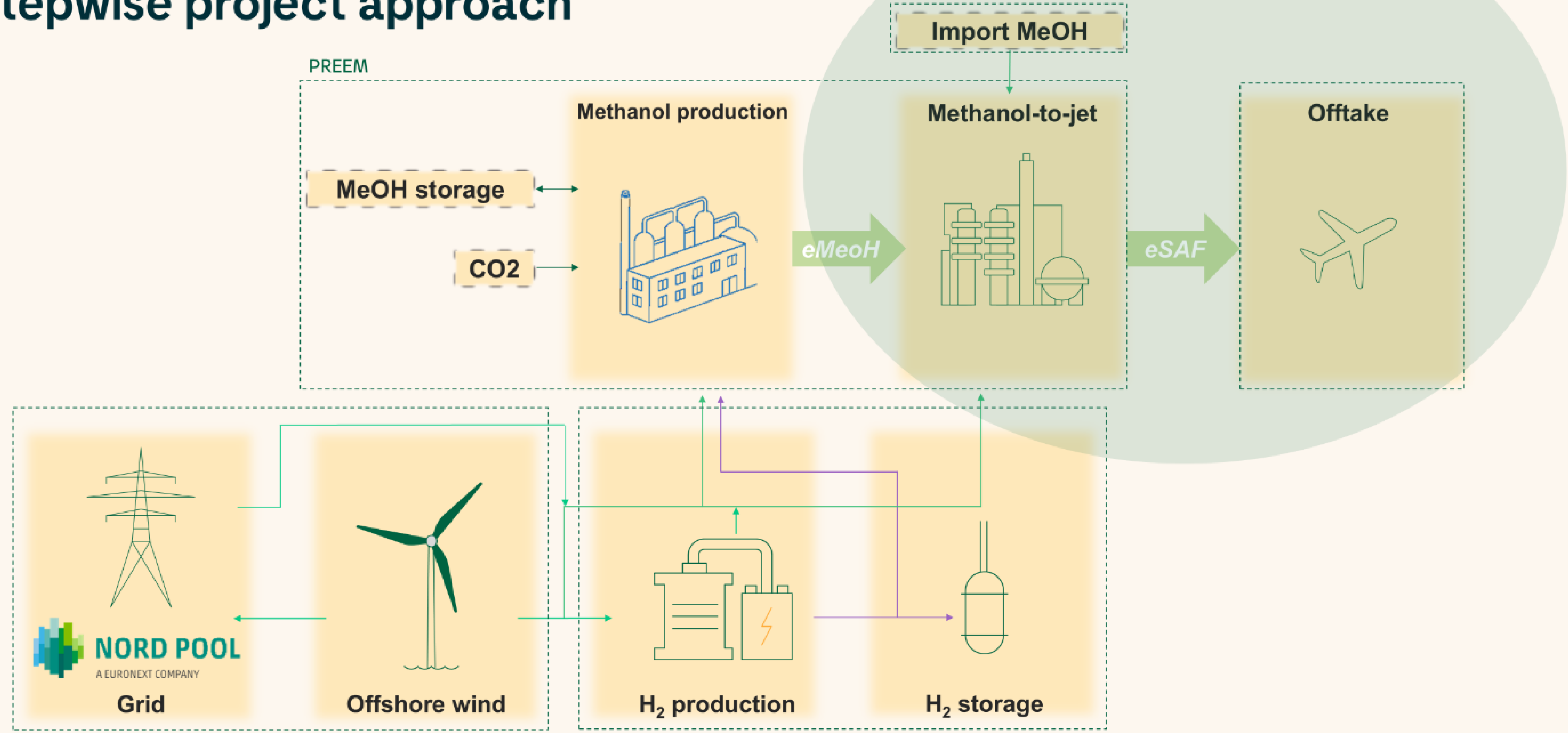
Preem eSAF value chain – stepwise project approach



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Questions & Answers

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Closing Remarks

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THANK YOU