Refrery 2050:
Opportunities and challenges for the refining industry
(Concawe Low Carbon Pathways programme)

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Agenda

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Setting the scene
Concawe - Environmental Science for European Refining

Concawe Membership

Concawe represents 41 Member Companies ≈ 100% of EU Refining
Open to companies owning refining capacity in the EU

Concawe mission

To conduct research to provide impartial scientific information, in order to:

• scientific understanding
• Assist the development of technically feasible and cost effective policies and legislation
• Allow informed decision making and cost effective legislative compliance by Association members.

Our Topics
Please scroll over the symbols for more information
Low-carbon liquid fuels and products

EU average refining production (Concawe 2018)

65% Mobility
- Diesel
- Gasoline
- Kerosene
- Heavy oil
- Liquid gas

25% Other Products
- Petrol
- Heavy oil
- Liquid gas
- Bitumen
- Lubricant
- Oil coke
- Heating oil

10% Petrochemical feedstocks
- Olefins
- Aromatics
- Other
Low-carbon liquid fuels and products

RENEWABLE HYDROCARBONS: TECHNOLOGY- OPTION IN COMPETITION WITH OTHER OPTIONS

EU refining system

25% Other Products

10% Biochemical feedstocks

RENEWABLE HYDROCARBONS NECESSARY IN THE LONG-TERM

Mobility

65%

app. 40%

HEAT

17%

38%

LIGHT DUTY VEHICLES

14%

HEAVY ROAD TRANSPORT

9%

PLANE/MARINE

22%

NON-ENERGY USE (E.G. CHEMICAL FEEDSTOCK)
The key question

How to satisfy the future need for products and fuels... ... in a low GHG intensive manner?

Multiple pathways integrated in a holistic view (Well-To-Wheels)

The triple dimension challenge for the refinery of the future

Low CO₂ intensive sites

Low Carbon fuels

Low Carbon feedstocks to chemicals

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Our approach towards a low GHG future

Multiple pathways integrated in a holistic view (Well-To-Wheels)

Concawe - Low Carbon Pathways

Well-To-Tank

- Refining system
  - CO2
  - Low Carbon H2
  - Process improvement
  - New high-efficiency technologies
  - Integration with renewables
  - Taking advantage of grid decarbonization
  - CCS & CCU
  - Waste Heat Use
  - Industrial symbiosis
  - Beyond-the-fence opportunities

Tank-To-Wheel

- Low Carbon Feedstock & Advanced fuels
- Product Quality
- Vehicle technology
  - Low Carbon Feedstocks to produce:
    - Sustainable biofuels
    - Advanced biofuels
    - Power-to-Liquids
  - High octane fuels
  - Fuel quality improvement
  - New fuels
  - ICE & Hybrid energy efficiency enhancement
  - On-board CCS
Vision 2050: The refinery as an ENERGY HUB…

… within an INDUSTRIAL CLUSTER,

Reducing emissions within the site + the final use of our products
The technologies are being developed....

... but more support on R&D&I across the whole value chain is needed to make them happen (reduce the time to development / deployment scale up)

Algae

Green H₂

Advanced bio

... from biomass

... from waste

... from plastics

E-fuels

CCUS
A vision for manufacturing: Refinery 2050
Can the EU refining industry can effectively contribute to a low CO2 economy?

1. **Early-stage**
   - High efficiency operation

2. **Evolution**
   - Progressive introduction of low-emission components and low-carbon feedstocks

3. **Future-stage**
   - Hub for production and distribution of low-emission energy products and raw materials
Potential CO₂ savings: 25% by 2030 (33 Mt) and 52% (65 Mt) by 2050 in the median scenario compared to 2030 Ref Case (125 Mt CO₂/a).
Up to ~60% (78 Mt) by 2050 in the high uptake sensitivity cases

Total electricity consumption: 130 TWh/y in 2050 (4% of the electricity currently in EU).

Minimum CAPEX 30 B€

CO₂ reduction technologies

- Fuel switch
- Increased use of imported low-carbon electricity
  - General electrification
  - Substitution of fired boilers and heaters
  - Green H₂

Low carbon energy

Process Efficiency

- Continuous improvement
- Energy Management
- Major capital projects

CO₂ capture

- “Easy-to-capture” (H₂ production)
- Other plants

No additional OPEX associated to ad-hoc turn-arounds considered
1. Early-stage
High efficiency operation

Abatement costs (€/t CO₂ avoided)

\[ \text{Abat. cost} = \frac{\text{New technologies (CAPEX/OPEX)} - \text{Fuel savings (OPEX)}}{t \text{ CO₂ avoided}} \]

Not a single value! It depends on the scenario considered!

2050 Median Case
(CO₂ abatement cost curve)

Range of CO₂ abatement cost per technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>CO₂ Price (€/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process efficiency</td>
<td>150</td>
</tr>
<tr>
<td>Low pressure heat</td>
<td>25</td>
</tr>
<tr>
<td>Electrification</td>
<td>100</td>
</tr>
<tr>
<td>Coal substitution</td>
<td>100</td>
</tr>
<tr>
<td>Gas/electric option</td>
<td>100</td>
</tr>
<tr>
<td>Electric heater (mix)</td>
<td>100</td>
</tr>
<tr>
<td>ELECTRIC power (mix)</td>
<td>100</td>
</tr>
<tr>
<td>ELECTRIC power (CO₂)</td>
<td>100</td>
</tr>
<tr>
<td>CCS (sequestration)</td>
<td>100</td>
</tr>
</tbody>
</table>

Note: the horizontal lines indicate the range of CO₂ prices considered in the different cases.
• R&D: The opportunities will require technological development to make the potential a reality at reasonable cost within the time horizons (2030 and 2050).
• Cross-sectorial and collaborative R&D key to accelerate the development.
Two series of cases in 2050:

- **Limited penetration cases** (individual pathways): production of 1 Mt/a liquid products from each of the selected pathways.
- **Maximum low carbon feedstock cases** (Combined pathways): combination of different low carbon feedstocks to provide the demand without impacting on the EU import/export balance.

**A look into 2050 demand scenarios**

Low Carbon Feedstocks (LCF) - Examples

- **Lipids**
- **e-Fuels**
- **Woody Biomass / Waste**
- **Pyrolysis**
- **Gasification + Fischer-Tropsch**
2 Evolution
Progressive introduction of low-emission components and low-carbon feedstocks

- **Potential CO₂ savings** range from 50 to 90% vs 1990 and 85% vs 2030 improved scenario (~70% Optimized oil-based cases)

- Total electricity consumption from 150 to 550 TWh/y in 2050 multiplied by 5-18 times vs 2030 improved scenario

- Total Hydrogen consumption (from 7 to 15 Mtoe/y) multiplied by 2-5 times vs 2030 improved scenario

- Estimated CAPEX for a notional refinery could range between 1 - 10 G€ for the limited penetration cases, and between 6 - 15 G€ for the extreme cases.

Pathways enabling **negative emissions** through Biomass + CCS!

**Impact beyond the refining boundary limits:**
Example. In these extreme cases the fossil **carbon intensity** of main fuels could be reduced by 60-80% (Diesel). Feedstocks to petrochemicals also benefit from the renewable carbon intake. In these extreme cases, **up to about 60% non-fossil carbon.**
Some of the key R&D&E challenges

**Lipid**
- Alternative feedstocks development (e.g. waste, algae). Biology still in early R&D

**BTL**
- Technology not commercially available yet
- How to ensure continuous operation when processing different feedstocks is still an issue
- Conversion efficiency / Increasing resource availability as key factors
- Establishment of large lignocellulosic / residue supply chain in line with new plants start-up needed!

**Pyrolisys**
- Technology needs to scale up
- Processing of pyrolysis in refineries requires further R&D

**E-fuels**
- Technology needs to scale up
- Efficiency improvement required to reduce electricity requirement and improve CO₂ capture ratio → cost reduction
04 (Our) main takeaways
Main takeaways

• The EU Commission has recently published its long-term strategy, confirming Europe's commitment to lead in global climate action
• The challenge for the refinery of the future has a triple dimension:
  • CO₂ reductions at the site are not enough and need to be accompanied by technologies/feedstocks to reduce emissions in the final use (fuels & products).
  • A Well-To-Wheel approach needs to be part of a low GHG industrial strategy
• Refineries can contribute to this long-term goal internationally:
  • Delivering low-carbon fuels (biofuels, efuels including H₂)
  • Availability of large amounts of both renewable electricity and low-carbon feedstocks (including biomass) would be required.
  • R&D in increasing resource availability and mobilization (Supply chain) & technology scale-up / efficiency improvement are key areas to enable deployment.
• Challenges go beyond the bio-industry / refining battery limits!!
  • Cross-sectorial opportunities → The challenge is so big that collaborative efforts are perceived as key enablers
I was taught that the way of progress was neither swift nor easy.

(Marie Curie)