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Environmental Science for European Refining

Refinery 2050:

Opportunities and challenges for the refining industry

Biofit Project meeting - External presentation

Virtual, 24 March 2021

Marta Yugo - Science Executive (Refining Transition)

Agenda

01 Setting the scene

02 A vision for manufacturing: Refinery 2050

03 A Clean Fuels For All - Scenarios towards 2050

01

Setting the scene

Concawe – Environmental Science for European Refining

Concawe Membership

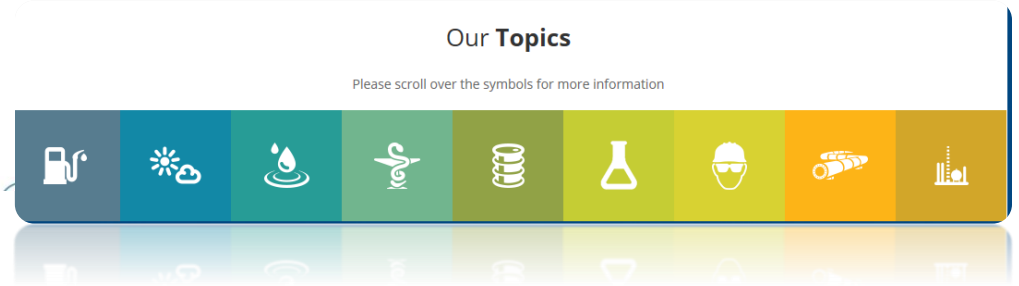
Concawe represents 41 Member Companies ≈ 100% of EU Refining

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.



Role of Concawe

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Science Executive Refining

Roland Dauphin
Science Executive Fuels Quality and Emissions

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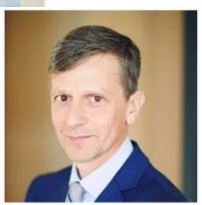
MCs experts

Concawe

FuelsEurope

https://www.concawe.eu/low-carbon-pathways/

John Cooper
Director General



Alessandro Bartelloni
FuelsEurope Director

Alain Mathuren
Communication Director

Emanuela Sardellitti
Advocacy Strategy Manager

Jean-Pierre Debruxelles
Policy Executive

Daniel Leuckx
Policy Executive

https://www.fuelseurope.eu/vision-2050/

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The Commission strategy for 2050

1.5C Tech scenario of "Clean Planet for All" / 2030 Impact Assessment

Towards energy efficiency and a more diversified low GHG transport sector

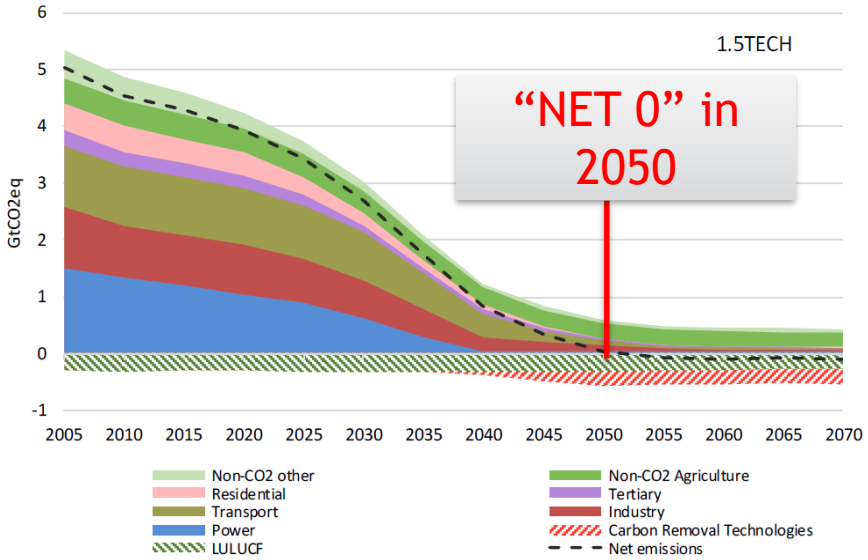
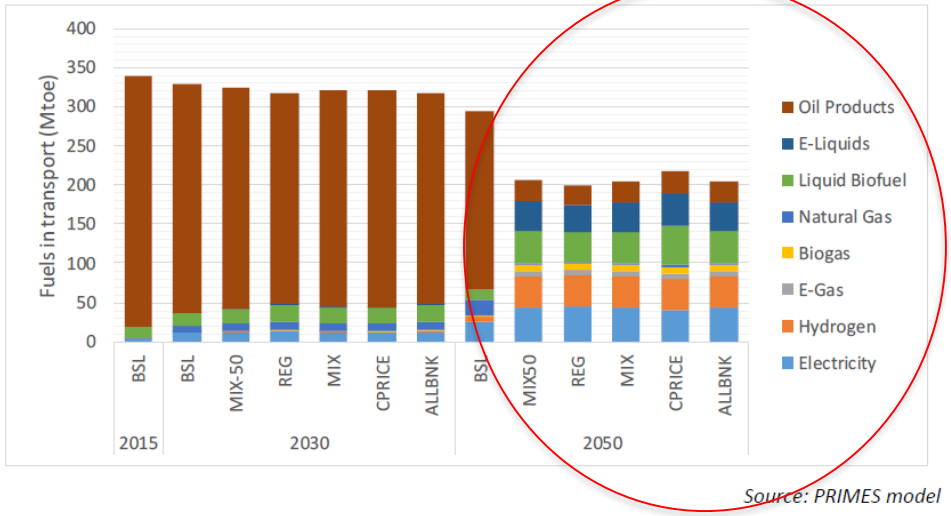


Figure 63: Fuels in transport (including aviation and maritime navigation)



Source: PRIMES model

* »Clean Planet for All - A strategic vision»: European Commission, November 2018

* 2030 Impact Assessment, Nov 2020

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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 CO_2 intensive sites

Low Carbon fuels

Low Carbon feedstocks to chemicals

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Not just one single solution

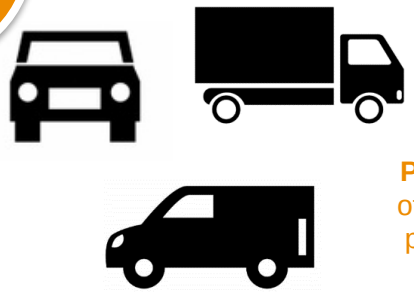
Collaboration is key: JEC Well-To-Wheels (WTW) v5

WTT
fuel
gCO2 / MJ

> **250** Resource to fuel pathways

TTW
Powertrain efficiency
MJ / km

FLEET



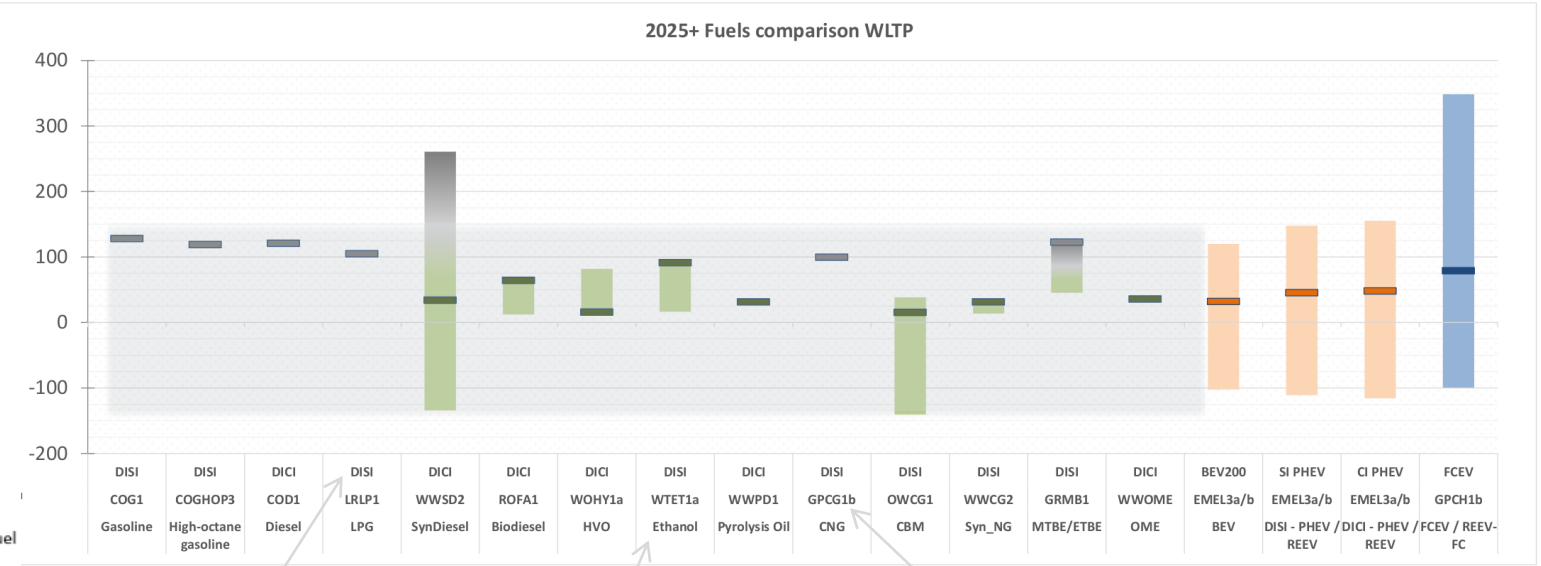
Penetration of alternative powertrains

>60 powertrains combinations

> 1500 possible combinations!

Not just one single solution

Multiple solutions: feedstock / technology / powertrains towards low GHG future



Legend:

- Fuel - Representative pathway
- ICE (DISI/DICI) + fossil based fuel
- ICE (DISI/DICI) + bio/low-CO_2 syn fuel
- xEV (Electricity)
- FCEV (H_2)

Alternative fuels and powertrain combinations offer similar GHG reduction as BEVs depending on the electricity source used. Moving to low carbon fuels (biofuels and e-fuels) offer compelling options / multiple routes to achieve low GHG intensity WTW

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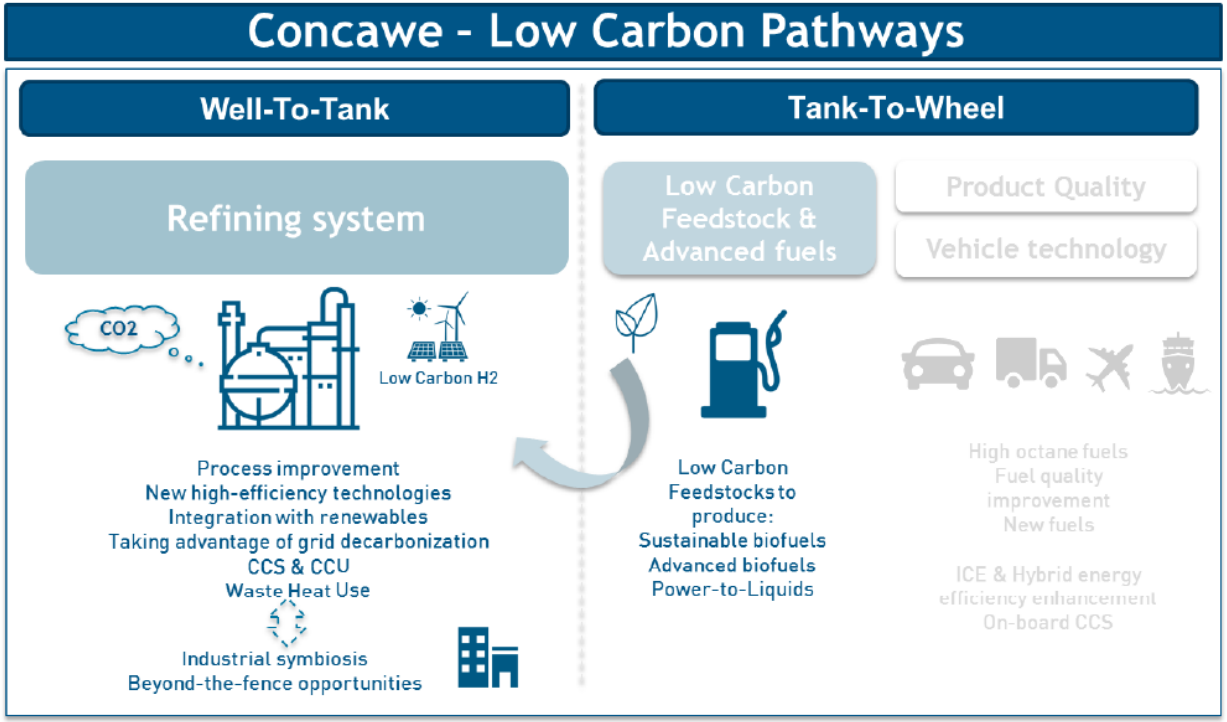
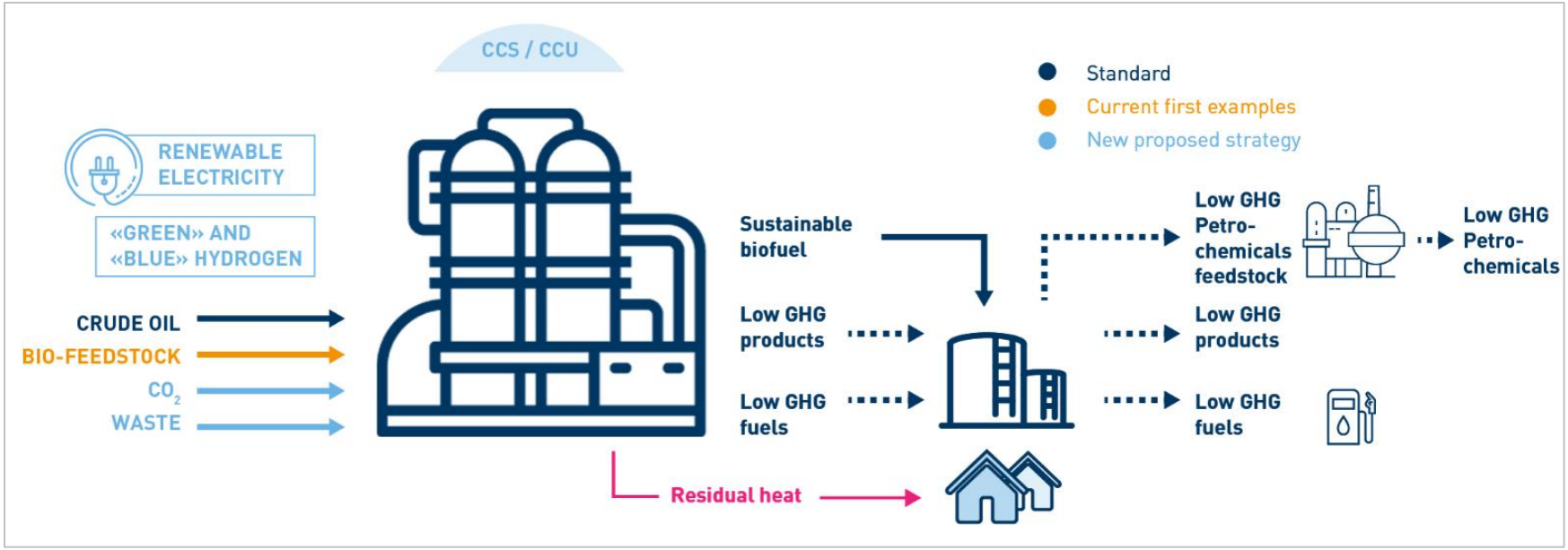
Our approach towards a low GHG future

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



Vision 2050: The refinery as an ENERGY HUB…

… within an INDUSTRIAL CLUSTER

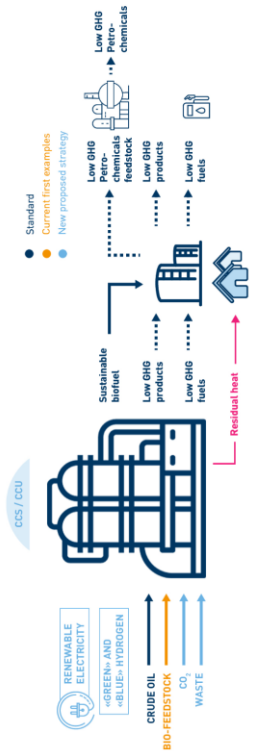


Reducing emissions within the site + the final use of our products

02

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

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Report

Report

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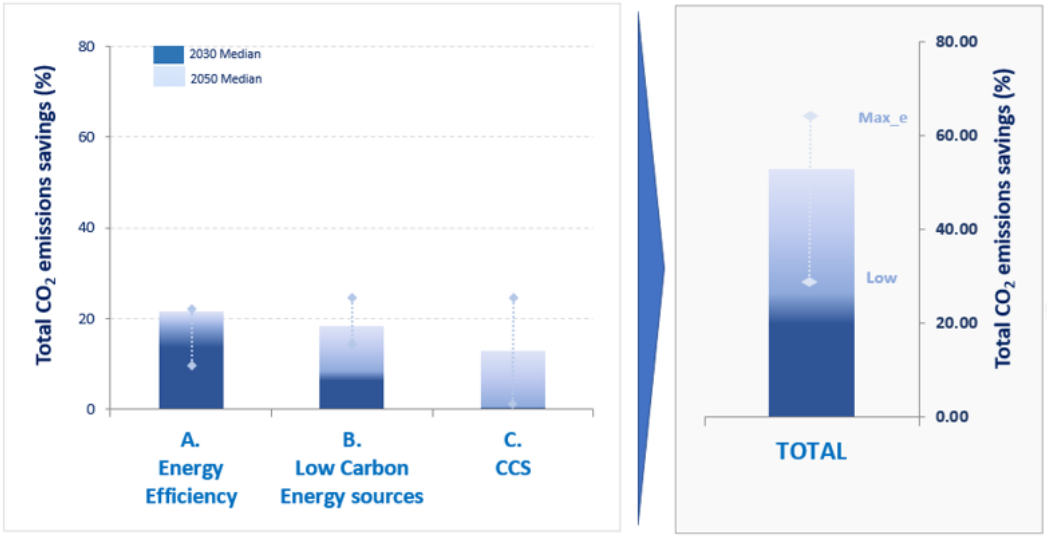
1 Early-stage
High efficiency operation

Potential CO_2 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

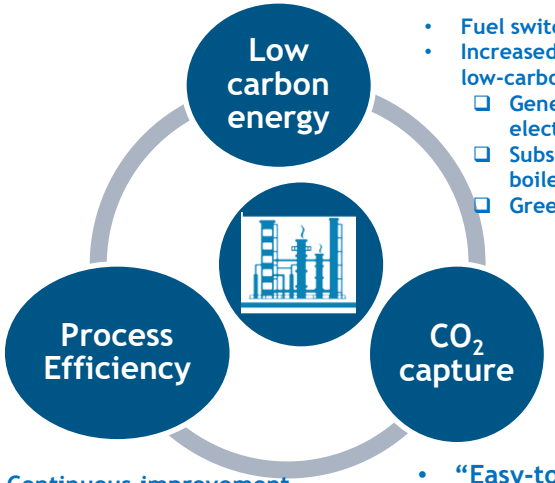
Total electricity consumption: 130 TWh/y in 2050
(4% of the electricity currently in EU).

Minimum CAPEX 30 B€



Note: Electrification may account for up to ~23% of the CO_2 reduction in the 2050 High electrification sensitivity case. This incurs significant additional capex outside the refinery not included in the scope of this assessment.

CO_2 reduction technologies



- Fuel switch
- Increased use of imported low-carbon electricity
  - ❑ General electrification
  - ❑ Substitution of fired boilers and heaters
  - ❑ Green H_2

- Continuous improvement
- Energy Management
- Major capital projects

- "Easy-to-capture" (H_2 production)
- Other plants

No additional OPEX associated to ad-hoc turn-arounds considered

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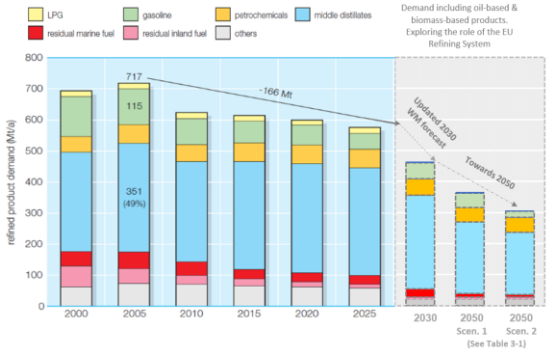
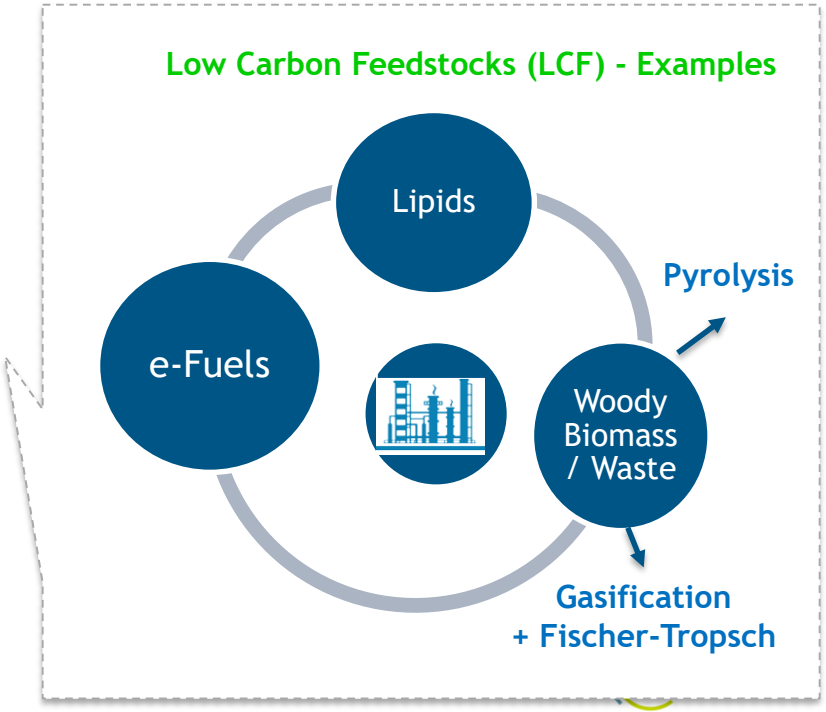
2 **Evolution**
Progressive introduction of low-emission components and low-carbon feedstocks

LCF examples within an average refinery (160 kbl/d)



For both demand scenarios, 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.

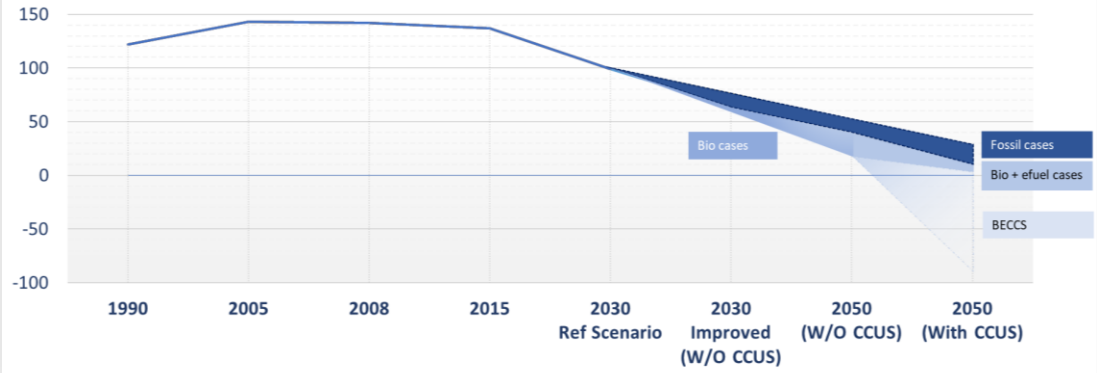


2 **Evolution**
Progressive introduction of low-emission components and low-carbon feedstocks

Results 2050 (EU wide)

EU-wide

EU-28 Refining system
Total emissions (Mt CO_2/a)
(Direct fossil emissions)



- Potential **CO_2 savings** range from **50 to 90% vs 1990**
  and 85% vs 2030 improved scenario
  (-70% Optimized oil-based cases)

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

- Total **electricity** consumption from **150 to 550 TWh/y** in 2050

Multiplied by **5-18 times** vs 2030 improved scenario

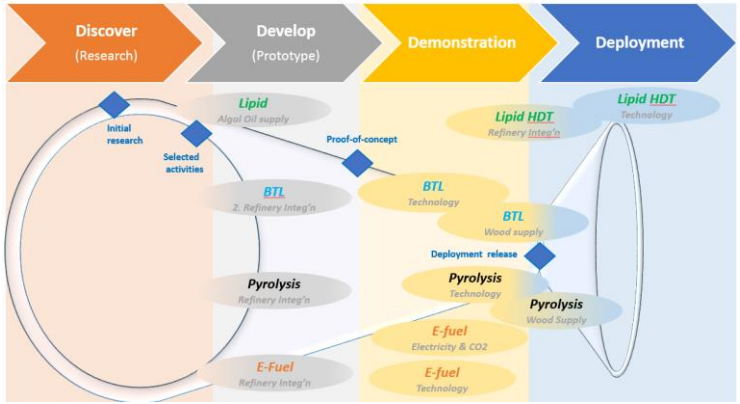
- Total **Hydrogen** consumption (from 7 to 15 Mtoe/y) multiplied by **2-5 times** vs 2030 improved scenario

- 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.

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.**

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



Some of the key R&D(&I) 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 CO_2 capture ratio → cost reduction

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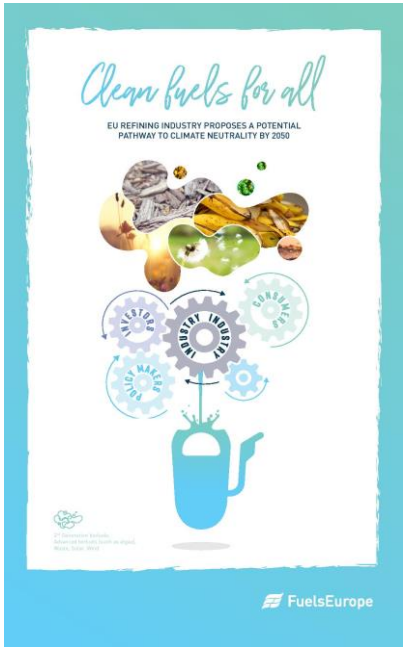
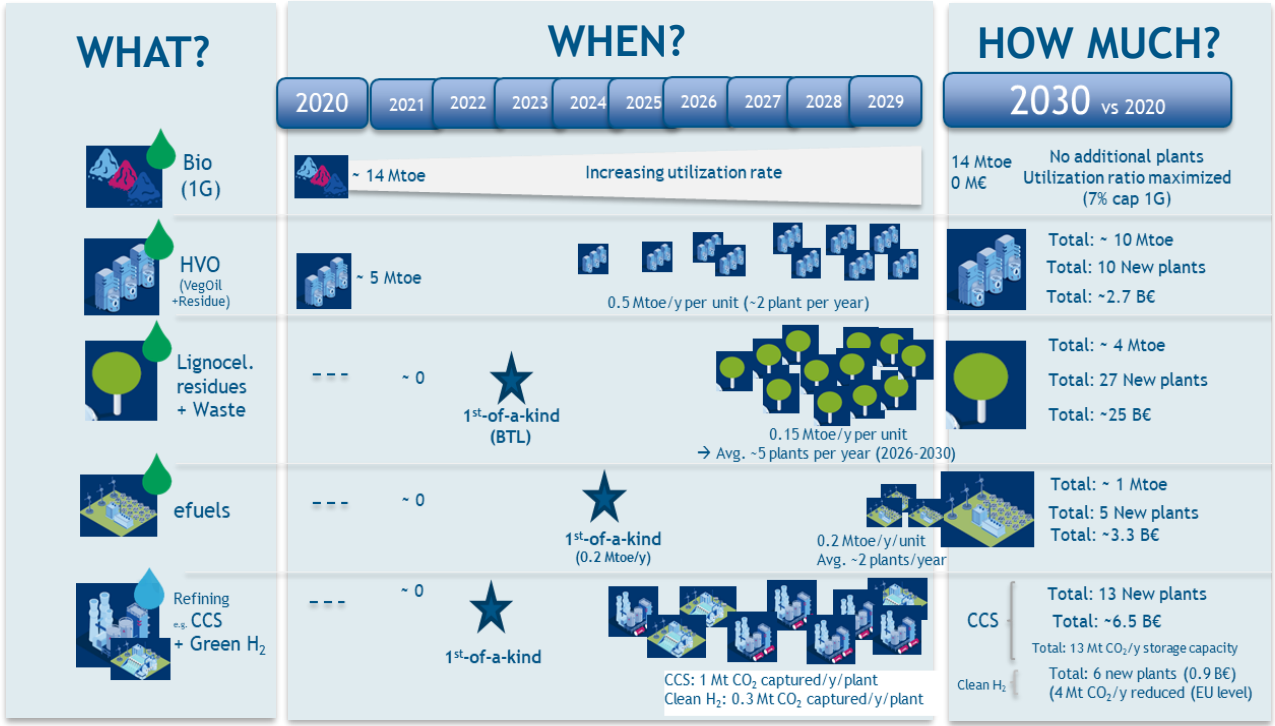
03

A Clean Fuels For All Scenarios towards 2050



The Clean Fuels for All Strategy

Demo and Scale-up is needed!



Accelerating
the pace
towards
1st-of-a-kind
in parallel to
supply chain
+ market creation!

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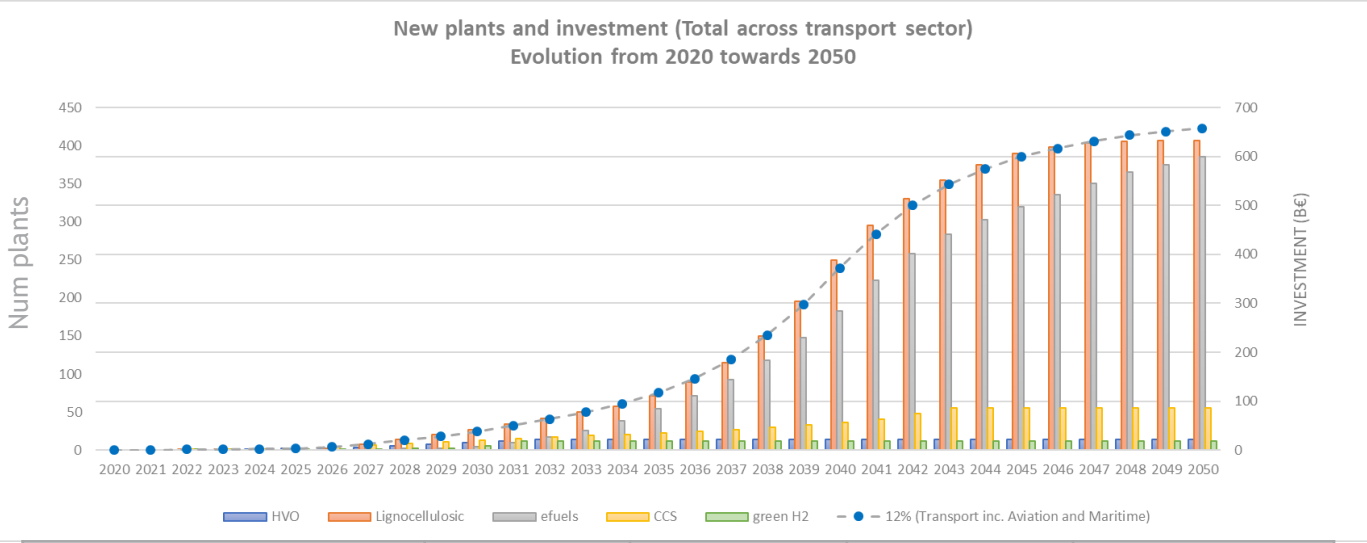
The Clean Fuels for All Strategy

A challenging techno-economic trajectory in numbers – One Scenario



Cumulative (Transport)	2020-2030	2020-2035	2030-2040	2020-2050
Total volume LCF (Mtoe)*	~30	~40	~90	~150
Total investment, B€*	~30-40	~75-110	~240-350	~420-630
Total new plants (bio+efuels)	~40	~130	~420	~760

~150 Mtoe/y

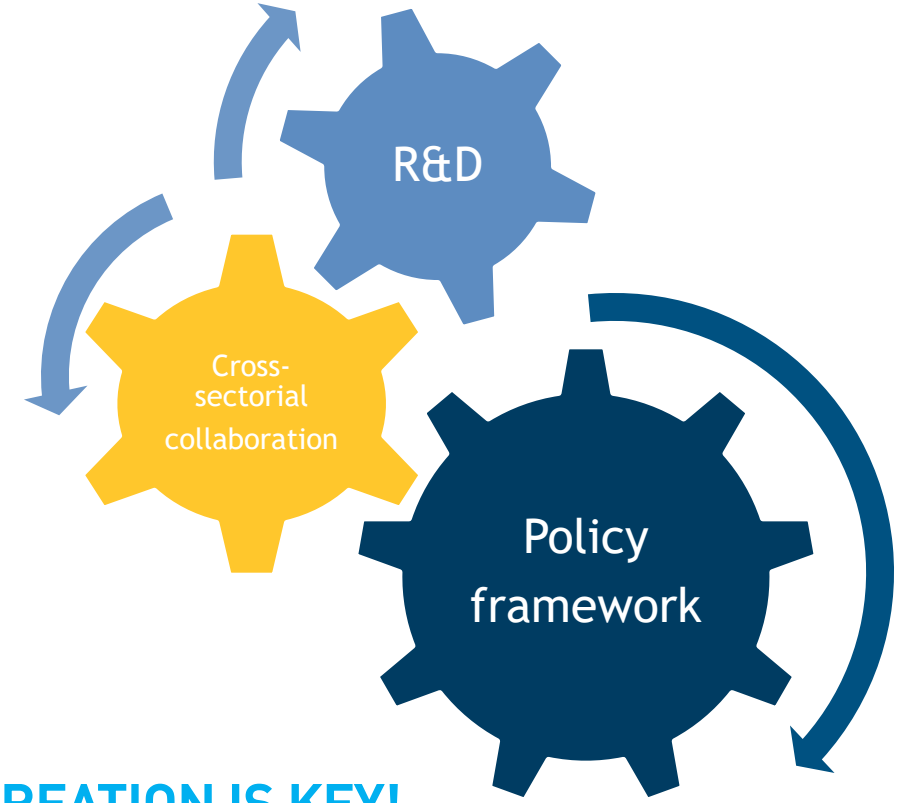
t/y Low Carbon Liquid fuels

~400-650 B€

Investment needed

~100 Mt CO2/y

GHG savings in transport by 2035 <> 50 M BEVs



...CO-CREATION IS KEY!