CONCAWE'S INPUT TO THE EU LONG-TERM STRATEGY - EII INITIATIVE

Preliminary figures based on on-going Concawe work

1. Historical Figures on emissions and electricity consumption

Historical Figures (i)	**1990**	**2005**	**2008**	**2009**	**2015**	**Comment**
Direct Emissions (Mt CO$_2$/a) - EU-28 (ii)	122	143	138	134	137	*European Environment Agency* (2015 corrected value)
Total electricity consumption (GWh/y) (iii)	26,000	33,000	37,000	34,000	32,000	Estimated numbers based on Concawe internal data (iv)
Fuel Mix	**(v)**	**(v)**	**(v)**		N/A	Concawe internal database

Note:

N/A (Not available)

(i) Based on the definition of mainstream refineries excluding atypical refineries: Mainstream refinery is a refinery where a mix of refinery products with more than 40 % light products (motor spirit (gasoline) [...], kerosene including kerosene type jet fuel, gas oils) is produced. *Source:* Commission Decision of 27 April 2011 determining transitional Union-wide rules for harmonized free allocation of emission allowances pursuant to Article 10a of Directive 2003/87/EC of the European Parliament and of the Council (notified under document C(2011) 2772) (2011/278/EU).

(ii) **Including emissions associated to electricity generation directly linked to the refining system (direct emissions).** Changes in emissions include the impact of the complexity increase of the refining scheme to meet market demand (quality and quantity).

(iii) **The total electricity consumption includes purchased plus auto-produced electricity** (around half of that historically produced internally). The total electricity consumption included in the table is based on Concawe's best estimate of the historical trend (internal data). It shows that electricity consumption increases throughout the period despite the reduction in total oil demand.

(iv) Two potential external sources could be referred to but we do not consider them as "sufficiently accurate":

- *DG GROW energy costs study 2016:* based on a sample of +/- 15 refineries (~20%). The extrapolation to the full sector will not lead to a sufficiently precise number.
- *DG CLIMA data collection 2017/2018:* DG CLIMA has collected electricity consumption (2013-2016) from mid-December 2017 to mid-January 2018 from MS with a view to calculate the indirect CO$_2$ emissions (carbon leakage exposure assessment). However most MS are re-using data which they submit to Eurostat categorized according to NACE code 4 digits (1920 for refining). That means that the total (provided that all countries where refining is operated have submitted data) is not limited to mainstream refineries, hence overestimated.

(v) **(1992):** 2% imported natural gas, 57% internal fuel gas, 28% liquid fuels, 13% coke (process related internal energy carrier).

(2005): 2% Imported natural gas, 56% internal fuel gas, 24% liquid fuels, 18% coke.

2. Key mitigation technologies

Technology	Description	TRL (*)	Timeframe for industrial application
1. Energy Efficiency	**Including (but not restricted to):** ■ **Refinery process efficiency:** ❑ Continuous improvement: through implementation of a combination of measures and projects involving some capital expenditure. Examples include fouling mitigation, catalyst improvements and hardware improvements such as new motors, heat-exchangers, etc.	6-8	Progressive uptake from now until 2040
	❑ Major capital projects: Larger efficiency improvements reflecting changes to the technical configuration of individual refineries (e.g. extensive revamps of existing facilities, new process plants).	3-8	By 2040
	❑ Inter-unit heat integration.	6-8	Progressive uptake from now until 2040
	■ **Energy Management Systems** combining equipment (e.g. energy measurement and control systems) with strategic planning, organization and culture.	6-8	
	■ **Increased recovery of refinery low-grade heat** for export and electricity production.	3-6	2025-2030
2. Use of Low-Carbon Energy sources	■ Improved recovery of Hydrogen and LPG from fuel gas.	4-8	By 2040
	■ Increased use of imported low-carbon electricity: ❑ Use of electricity for general operations a/o rotating machines.	8	As grid becomes decarbonized, progressive uptake from now until 2050
	❑ Substitution of fired heaters by electric heaters.	4-8	
	❑ Production of hydrogen with electrolysers using imported renewable electricity.	4-6	
3. Carbon capture	Capture of a portion of the total CO_2 emitted by refineries The potential role of a CCS scheme together with steam reforming plants (SMR) to produce a low-carbon intensity Hydrogen is explicitly explored.	6-7	Major deployment in the 2030-2050 timeframe
4. Bio-processes	Progressive integration of sustainable bio-feedstocks, Power-to-Fuels and bio-blendstocks into the refinery. Negative emissions could potentially be achieved when combined with CCS.	3-7	2020+

(*) Technology Readiness Level

3. Abatement potential

a) Demand Scenarios

The Association is currently exploring different scenarios considering the evolution of future demand, potential changes in product ratio and the impact of future prices of energy and CO_2 reductions. The scenarios considered can be summarized as follows:

Demand Scenarios	**Evolution of demand for refining products (oil & bio based) EU refining system. (Key considerations)**	**Oil intake potential reduction due to changes in demand** (*)
2030 Reference Scenario	Scenario assuming similar complexity in the sites and no changes in total demand ratio of refining products. Energy efficiency measures continuing the historical rate of improvement.	
A. 2050 Oil-based Scenario	Moderate energy efficiency improvement in vehicles and limited electrification in passenger cars. Total demand for jet increase. Small decrease in demand for petrochemicals.	≈20% vs 2030 Ref
B. 2050 Sustainable Scenario	High energy efficiency improvement in vehicles and increased penetration of electric vehicles in the passenger car segment. Total demand for jet increase. Small decrease in petrochemicals demand. Major reduction in non-road diesel & heavy fuel oil.	≈30%. vs 2030 Ref
C. 2050 Highly electrified Scenario	Passenger car heavily electrified (remaining consumption due to PHEV). Demand for diesel is reduced due to substitution with non-liquid fuel products. Demand for jet increases in the same levels as scenarios A/B. Major reduction in non-road diesel and no domestic demand for heavy fuel oil. Due to these changes in product ratios (fuels and non-fuel product ratio), serious unbalances are expected in the refining system to fully fulfil the domestic demand.	≈45% vs 2030 Ref

(*) First estimate based on on-going Concawe work

b) Preliminary figures

The abatement potential identified is the results of a work conducted within the Association to demonstrate that the effective deployment of different technologies has the potential to achieve a significant reduction of the CO_2 emissions associated with oil refining by 2050. Two different stages are being explored:

Stage 1. CO_2 efficiency improvement measures combined with the impact of demand scenarios

The following table summarizes the potential of the mitigation technologies identified in section 2, taken the 2030 Reference Scenario as the basis for the example below:

#	Technology (CO_2 efficiency)	Demand Scenario: 2030 Reference Scenario (Example) Max abatement potential % CO_2 savings EU refining system (Scope 1 & 2)		
		2030 improved	2040 (interpolation)	2050
1	Energy Efficiency	≈15%	≈20%	≈20%
2	Use of Low-Carbon Energy sources	≈10%	≈15%	≈25%
3	Carbon capture (and storage) (CCS)	≈1-2%	≈10%	≈25%
Total (1+2+3)		≈ 25%	≈ 45%	≈ 70% (*)

(*) This 70% is a preliminary figure estimating the maximum mitigation potential when Technologies 1, 2 & 3 are exercised

Note:

1. The 2030 scenario is based on electricity to gas ratios published by external sources (IEA / EU Reference Scenario). The 2050 scenario represents a high uptake scenario where all the measures are incentivized by a lower electricity to natural gas price ratio. The basic assumption for the 2050 horizon is that the maximum level of realistic deployment will be achieved for each identified opportunity at the EU level, assuming no change in the activity level of the sector.
2. The results of the potential abatement are interrelated and depend on the order they are implemented. E.g. Technology 2 assumes that all energy efficiency measures (Tec 1) were exercised first. As a result of that, potential abatement associated to technologies 2 and 3 could be higher when individually considered.

Stage 2. Low-Carbon Feedstocks

Whilst the scope of this High Level group is to explore opportunities to improve the CO_2 efficiency of the EU Refining system (direct and indirect emissions only, i.e. Scope 1 and 2), other Concawe's studies are underway which examine the potential for integrating different, non-petroleum derived feedstocks within the refinery (examples of low-carbon feedstocks include vegetable oils (HVO, algae), biomass, pyrolysis/HTL oil and Power-to-Fuels to meet final demand for refining products). When these low-carbon pathways are exercised together with the mitigation technologies mentioned in Stage 1, additional CO_2 savings (even negative emissions) could be achieved within scope 1 and 2. However, the major benefit of these routes would be associated to the final use of products and fuels contributing to reduce significantly their Well-to-Wheels CO_2 intensity (Scope 3 out of the scope of this HLG EII exercise).

It is important to highlight that the combination of these technologies shows different potential pathways based on a range of key assumptions such as energy and CO_2 prices and the realistic development of novel technologies across the EU refining system. Therefore, the results presented in this document:

- Are not representing the maximum technical potential for all the technologies identified.
- Shall be considered as **initial figures** to enable further discussion with the COM on transport issues.
- Are not intended to be considered **as a roadmap** for the whole EU refining industry but **pathways**.
  Factors such as the CO_2 efficiency of existing facilities coupled with local and structural constraints will determine individual refineries' route to contribute to mitigate climate change.

As a result of the preliminary assessment conducted by Concawe, the figure below shows a walk into the potential evolution of the CO_2 emissions associated with the EU refining system. This **long-term vision** is the result of the combination of measures identified in **Stage 1 and 2** as described above:

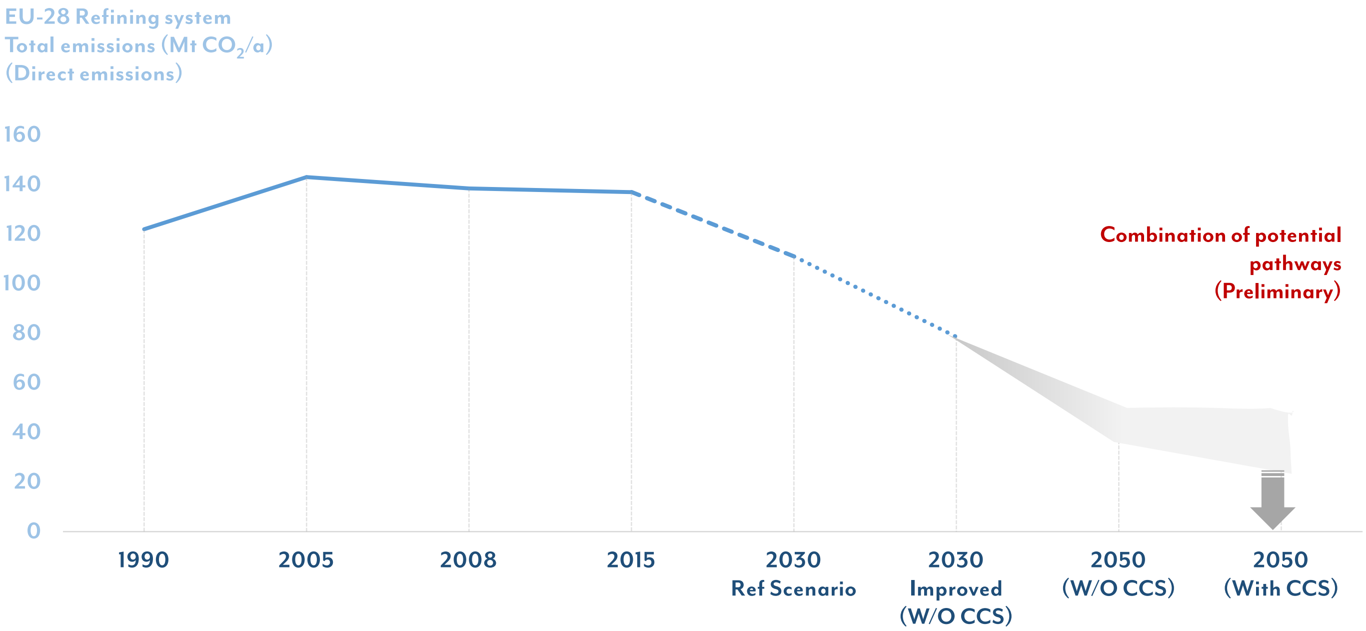

Figure 1. A walk into the CO_2 emission reduction pathways for the whole EU refining system (2030/2050). Concawe's initial view based on on-going work.

The discontinued blue line represents a potential pathway down to 2030 Reference Scenario with an increasing uncertainty when moving along the way down to 2050. At this stage, no significant low-carbon feedstocks are considered to replace crude oil intake by 2030 (EU level). The grey area (**bandwidth**) shows the uncertainty associated with different potential pathways: the effective deployment of CO_2 efficiency measures and the potential uptake of low-carbon feedstocks. The arrow indicates the potential negative emissions that could be achieved when CCS is applied to a heavily low-carbon feedstock based refinery.

The degree to which the available options will be deployed will depend on several factors such as external market conditions, evolution of energy and CO_2 prices and future regulatory framework. These factors will influence technology improvements and the effective commercial viability and deployment of the opportunities identified.

4. Investment costs

The on-going Concawe's work on Low-Carbon Pathways is currently investigating into the potential investment (Capex) and associated operational costs (Opex) that may be required to implement these technologies into the **2030 Reference Scenario**. The (very) preliminary estimate are summarized below:

2050	Investment costs (Preliminary figures)	2030 improved
Stage 1	Minimum 45,000 M€	Profitable projects across the whole EU refining system.
Stage 2	About 600,000 M€ for maximum uptake (*)	Based on Concawe's preliminary modelling work (potential future demand) complemented with external references[1]. (In terms of costs for alternative low-carbon feedstock and their associated conversion technologies).

(*) The preliminary capex estimate varies depending on the combination of different low-carbon feedstocks (availability) and technologies considered (different pathways chosen by individual refineries). This capex assumes the co-processing or co-location of new conversion technologies within or close to the refinery, maximizing the synergies and utilization of the existing refining units.

[1] SGAB (2017-1) "Final report - Building up the Future", Mar-2017. || SGAB(2017-2) "Building up the Future - Cost of Biofuel", Rev1 Sep-2017. || IRENA(2016) "Advanced Liquid Biofuels", Nov-2016. || NETL 2013-1597, "Analysis of Natural Gas GTL using FT".

These investments refer to the generic cost of the different technologies and opportunities identified, **excluding investment out of the refining system**. The actual cost of implementation could be much higher determined by the specific conditions of each individual asset which may have a significant impact on the final capex required.

5. Energy, feedstock and infrastructure needs

The scenarios analysed will require a different amount of energy, alternative feedstocks and infrastructure needs. As a preliminary assessment focused on some illustrative pathways, the results of the ongoing Concawe's modelling work show the following potential needs by 2050:

Timeframe	2030 improved	2050	
Potential needs (Preliminary estimate)	**Stage 1 CO_2 eff**	**Stage 1 (CO_2 eff + Demand)**	**Stage 2 (i) (Low-carbon feedstock) Max uptake**
Total electricity consumption (GWh/y)	≈ 30,000	≈ Up to 85,000	≈ From 5 (ii) up to 20/50 times (iii) vs 2030
Total H_2 consumption (Mt/y)	≈ 3.0	≈ 2.5	≈ From 2 (ii) up to 5/10 times (iii) vs 2030
Low-carbon feedstocks. *1. Biomass (Mt/a)*	-	-	Up to ≈ 200 - 300
Low-carbon feedstocks. *2. Vegetable oils (Mt/a)*	-	-	Up to ≈ 150 - 250
Low-carbon feedstocks. *3. Pyrolysis / HTL oil (Mt/a)*	-	-	Up to ≈ 70

Notes:

(i) Electricity and Hydrogen requirements associated with Power-to-Fuel technologies (efuels) included in the total electricity consumption reported in the table.

(ii) Preliminary estimate for bio-feedstock pathways.

(iii) Preliminary estimate for combined Low-Carbon Pathways: bio-feedstock uptake + Power-to-Liquid production (Imported electricity + CO_2).

6. Regulatory framework

In our Vision, the Refinery of the Future, capitalising on its technological know-how and flexible infrastructures, will increasingly use new feedstocks, such as renewables, waste and captured CO_2, in a very efficient manufacturing centre, integrated in a cluster of industries, in synergy with other sectors.

We call on the EU and its Member States to help the EU refining sector make our 2050 Refining Vision a reality through the following:

- Integrate this Vision into the EU industrial and technology strategy and research and development programmes for Europe to strongly support the development and deployment of the enabling technologies for low-carbon liquids and products, and of the deep industrial collaboration necessary to deliver these at scale.
- Implement a policy framework that provides investors with stability and predictability and preserves technology neutrality for the success of this transitional strategy, with long term (20+ year) consistency.
- Based on current technologies and anticipated learning curves, the cost for implementing low-carbon solutions is likely to be high. Therefore, appropriate measures will be needed to safeguard the international competitiveness of EU industries and avoid off-shoring of manufacturing activities to countries with lower climate ambitions, resulting in the increase of product imports and lower security of supply.

For more information visit **www.concawe.eu**

Disclaimer

Considerable efforts have been made to assure the accuracy and reliability of the information contained in this publication. However, neither Concawe nor any company participating in Concawe can accept liability for any loss, damage or injury whatsoever resulting from the use of this information. This report is the preliminary outcome of a Concawe on-going work. The information included is subject to change and does not necessarily represent the views of any company participating in Concawe.

About Concawe

The scope of Concawe's activities has gradually expanded in line with the development of societal concerns over environmental, health and safety issues. These now cover areas such as fuels quality and emissions, air quality, water quality, soil contamination, waste, occupational health and safety, petroleum product stewardship and cross-country pipeline performance.

Our mission is to conduct research programmes to provide impartial scientific information in order to:

- Improve scientific understanding of the environmental health, safety and economic performance aspects of both petroleum refining and the distribution and sustainable use of refined products;
- Assist the development of cost-effective policies and legislation by EU institutions and Member States;
- Allow informed decision making and cost-effective legislative compliance by Association members.

Concawe endeavours to conduct its activities with objectivity and scientific integrity. In the complex world of environmental and health science, Concawe seeks to uphold three key principles: sound science, transparency and cost-effectiveness.