Concawe

Environmental Science for European Fuel Manufacturing

Report

Report no.2/26

REFHYNE II Project: assessing the evolution of renewable hydrogen demand for EU27+3 fuel manufacturing up to 2050 under net-zero scenarios

ISBN 978-2-87567-209-4

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REFHYNE II Project: assessing the evolution of renewable hydrogen demand for EU27+3 fuel manufacturing up to 2050 under net-zero scenarios

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SUMMARY

REFHYNE II is a Horizon 2020 sponsored investment project to install a 100 MW PEM electrolyser to produce renewable hydrogen from 2027 at the Shell Rheinland refinery in Germany. At the request of Shell, Concawe joined the project consortium to help with hydrogen demand studies and dissemination of the project learnings.

The REFHYNE II project targets the production of approximately 15,000 tonnes[1] of renewable hydrogen per year and the main justification of this project comes from the increasing need of such a valuable feedstock in the context of REPowerEU Strategy[2] and the forecasted evolution of European fuel manufacturing legislation.

'Renewable hydrogen' is hydrogen produced through the electrolysis of water (in an electrolyser, powered by electricity), and with the electricity stemming from renewable sources.[3] This process ensures a significant improvement in terms of emissions savings since its GHG emissions are almost zero.

This report provides an estimation of the need for renewable hydrogen production by assessing the hydrogen demand originated by different fuel sources (traditional fossil, co-processing, biofuels and e-fuels) and the contribution from traditional solutions (naphtha catalytic reformers and steam methane reformers), all done using the framework and the data provided by two alternative long-term scenarios developed by S&P Global Commodity Insights (later referred as SPGCI) for Concawe in 2025 in which the European fuel manufacturing industry achieves net-zero by 2050[4]. It's important to highlight that this report does not assess or quantify the investments needed to meet such demand nor their financial feasibility.

Regarding the different sources of demand, the hydrogen needed by fossil fuels decreases from 4,4 Mton in 2024 to 0,6-0,7 Mton in 2050 mainly due to a significant asset rationalization. In the same period, co-processing, that is strongly linked to the same assets, drops by 50% from 0,2 Mton in 2024 to 0,1 Mton despite an intermediate period in which it rises up to 0,4 Mton. The hydrogen needed to produce biofuels, defined as advanced products of biorefineries (so excluding ethanol and FAME), grows significantly from 0,2 Mton to 3,4-5,3 Mton. E-fuels-related hydrogen need, from almost no demand in 2024, reaches 1 Mton in 2040 but grows exponentially to 4,8-7,5 Mton by 2050. In the last two cases the scenarios ("Max Electron" vs "More Molecule") highly influence the trajectory of development and consequently the end point. In total the hydrogen demand stays relatively stable until 2040 and then doubles in the last decade to reach 9,0-13,5 Mton in 2050.

Both traditional sources of hydrogen, naphtha reformers and steam methane reformers (SMR), follow the trend seen for the hydrogen of traditional fossil fuels. Naphtha reformers' hydrogen production decreases from 1,5 Mton to 0,2 Mton. SMRs however drop significantly by 2030 (minus 65%) as they are the easiest to replace with alternative sources with lower CO2 emissions and reach almost zero production in 2050.

[1] https://www.refhyne.eu/refhyne-2/
[2] https://energy.ec.europa.eu/topics/eus-energy-system/hydrogen_en
[3] Document 52020DC0301 A hydrogen strategy for a climate-neutral Europe COM/2020/301 final
[4] https://www.concawe.eu/publication/study-on-the-potential-evolution-of-refining-and-liquid-fuels-production-in-europe/

The gap between decreasing traditional sources and increasing hydrogen demand is to be closed by renewable hydrogen: this implies a production that will account for 1,6-1,9 Mton in 2030 and will double/triple every decade to practically become the only source in 2050.

1. INTRODUCTION

The REFHYNE project consisted in the installation of a state-of-the-art 10 MW PEM electrolyser at the Shell Rheinland Energy and Chemicals Plant in Germany to provide renewable hydrogen to the refinery to decarbonize its operations.

REFHYNE II, relying on this successful experience, targets the expansion of the electrolyser capacity to reach 100 MW by 2027. This project is funded by the European Commission's European Climate, Infrastructure and Environment Executive Agency (CINEA) via Horizon 2020 research and innovation programme under grant agreement number 101036970[1].

The Horizon 2020 Refhyne II project consortium consists of following partners:

Within the project's framework, Concawe has two roles: modelling and dissemination.

The first, that is the main objective of this report, is to provide an estimation of the potential evolution of the renewable hydrogen demand in the context of future European fuel manufacturing legislation under net-zero scenarios towards 2050.

By doing so, there will be the possibility to contextualize the relevancy of REFHYNE II project compared to current needs and also to a longer-term perspective that would account for those changes needed by the fuel manufacturing industry to achieve net-zero targets.

Despite the intrinsic uncertainty of long-term projections, the provided estimation should be considered a conservative approach since it doesn't account for the expected growing demand for renewable hydrogen in the whole society or, even more simply, in hard-to-abate sectors.

The second role of Concawe, dissemination, will consist in the organisation of three international workshop events dedicated to sharing the project aims, key characteristics and progress with industry and commercial players, policymakers, scientific community and civil society. This activity will take place in 2026.The workshops will be held at three EU27 refineries of which two will be in the East of Europe (EU13 countries= expansion of the EU after 2004)

[1] https://cordis.europa.eu/project/id/101036970

2. MACRO SCENARIOS AND LONG-TERM TRENDS

To develop estimations linked to long-term trends, REFHYNE II project team decided to adopt as reference two net-zero scenarios recently developed by SPGCI for the Concawe study on the “Potential Evolution of Refining and Liquid Fuels production in Europe”.

The scope of this study is to outline the potential evolution of the refining complex and the fuel manufacturing industry as a whole necessary to achieve net zero GHG emission by 2050. The study considers EU27 plus three additional European countries (United Kingdom, Norway and Switzerland).

To provide a more comprehensive picture, two different scenarios were examined: “Max Electron” and “More Molecules”. The transition in most economic sectors is considered in the same way and both comply with all requirements of Fit-for-55 initiative, however they differ substantially in the evolution of the transport sector and in the approach adopted for its decarbonization.

“Max Electron” scenario

The main assumption is to consider electrification as the preferred solution in all possible applications, in particular by ensuring zero sales of ICE vehicles after 2035 and accelerate rate of transition across modes of transportation.

“More Molecule” Scenario

The most important difference with the previous is to assume a less strict approach on requirements of ICE vehicle standards by keeping open the possibility of sales of some new internal combustion engines vehicles even after 2035 and by postponing the electrification in the aviation and marine sectors to after 2050. As a consequence, this allows low carbon fuels to have a more important role in the transition.

Obviously, these two theoretical scenarios do not cover all possible future evolutions of the transportation sector and its transition to net zero. Additional technological solutions could be further developed and exploited like those connected to carbon capture and storage (including blue hydrogen) that would extend the lifetime of “traditional” solutions.

It’s important to highlight that the scenarios rely on a wide set of assumptions (like availability of renewable energy and hydrogen and progress of electrification efforts) that would allow to meet net zero emission targets but they are not designed to validate the probability or feasibility of each of them nor their affordability and the consequences on competitiveness of European economy.

Moreover, the representation of refineries and new assets (biorefineries and e-fuel plants) does not take into account specificities like individual energy efficiency and potential improvement programs or interactions with other assets like petrochemical integration (H2 from Steam Cracker is still not low carbon unless bionaphtha is used), therefore the conclusions on the asset rationalization are not indications at the level of any individual European refinery.

3. HYDROGEN DEMAND AND SUPPLY

To estimate the demand for renewable H2, the most effective way is to follow three logical steps:

1. From the data included in the SPGCI study, estimate the overall H2 demand by adding the volume needed by each different origin of fuel:
    1. Traditional fossil (crude-derived streams)
    2. Co-processing (bio-originated feedstock processed together with crude-derived streams in refinery units)
    3. Biofuel (bio-originated feedstock processed in dedicated units or facilities like biorefineries)
    4. E-fuel (derived from combining captured biogenic CO2 and renewable H2)
2. Calculate the contribution of traditional sources of H2
    1. Naphtha catalytic reformers (units designed to produce high-octane gasoline components but that also produce H2 as side-product)
    2. Steam methane reformers (dedicated unit for H2 production from natural gas)
3. Estimate the amount of renewable hydrogen needed on top of traditional sources to match the total H2 demand

It is important to mention that, despite relying on the net-zero scenarios' data, this approach require assumptions and additional data besides what is already included in the SPGCI study.

3.1. OVERALL HYDROGEN DEMAND

In the following four subchapters, each different fuel origin is assessed to provide an estimation of the related renewable hydrogen demand.

3.1.1. Traditional fossil: assumptions, data and estimation

The SPGCI study forecasts a gradual decrease in refinery utilization driven by reduction in traditional fossil fuel demand. This reduction is caused by many factors from more general phenomena like demographic trends to transportation-specific drivers like the growing spread of e-mobility, the incentivised switch to alternative transportations (i.e. rail) and the mandated increase of low carbon fuels.

An important disclaimer is the fact that the results of the SPGCI study in terms of the decrease of traditional refining processing and integration and/or substitution by biorefineries and e-fuels plants comes from an optimisation exercise. The decrease is not automatic: thanks to complex optimization models, each individual refinery's profitability is assessed and challenged by the estimated decrease in traditional fuel demand therefore providing clear indications on traditional assets' utilization and their long-term economic sustainability. To be precise the study for each scenario displays fact data for 2024 and optimised results for 2030, 2040 and 2050.

For the specific scope of this project, looking at refinery's overall capacity utilisation, that basically means the effective processing of crude oil, was not the most accurate choice but it was preferred to focus on the reduction in the throughput of some secondary units. In modern refineries hydrogen has an essential role in two main families of processes/units: hydrocracking and hydrotreating. In hydrocracking units, hydrogen is used to break down heavy and long hydrocarbons into smaller and lighter molecules: these can be then used in fuel production, improving the profitability of the refinery. In hydrotreating units, hydrogen is utilised to remove sulphur and impurities and to improve some of the properties of the processed streams: this is required to meet the regulatory standards on fuel quality.

Although it was not explicitly included in the report of SPGCI study, the utilization of hydrocrackers and hydrotreaters was properly calculated during the optimization and made available to Concawe. In SPGCI study, the throughput of the refining process units is reported in kbbl/day, however the conversion unit factors (barrel/ton) reported in the same study have been used to transform into kton/day units. An operational factor of 365 days/year was also assumed in order to arrive to kton/year.

To then estimate the "conventional" refineries hydrogen demand the following formula was used:

Process unit throughput (ton feedstock) * Hydrogen consumption coefficient (ton H2 / ton feedstock) = Hydrogen consumption (ton H2)

For the specific hydrogen consumption coefficients of those processing units, the data used came from literature[2] [3] [4] [5]. It is important to mention that those used are by definition "reference values" and they are not precisely representing any individual unit. In normal operations there are many factors that would influence the specific hydrogen consumption of a unit like the characteristics of the feedstock, the unit design and operative parameters, the desired quality of the product, the efficiency of the chemical reactions, etc. however they were disregarded in this calculation.

The figures that would derive from the specific consumptions of secondary units do not consider inefficiencies due to the nature of the process and hydrogen recovery measures. To account for this effect and to estimate a more realistic hydrogen demand, the results are adjusted by applying a correction factor as an extra consumption. According to Solomon's study on refinery benchmarking[6], 14% of the hydrogen produced ends up in the fuel gas network due to process inefficiencies and purges so this value was assumed as correction factor.

[2] https://www.sintef.no/globalassets/project/recap/d2_bd0839a-pr-0000-re-001_revf02.pdf
[3] Parkash S. (2003) "Refining processes Handbook", Elsevier
[4] Meyers R.A. (2004), "Handbook of Petroleum Refining Processes" 3rd Edition, McGraw-Hill Handbooks
[5] Hart Energy and MathPro Inc. (2012), "Technical and Economic Analysis of the Transition to Ultra-Low Sulfur Fuels in Brazil, China, India and Mexico", ICCT
[6] Solomon Associates (2018), "Worldwide Fuels Refinery Performance Analysis"

Table 1 - Evolution of hydrogen consumption (and therefore demand) by traditional refinery units in Max Electron scenario

MAX ELECTRON	Utilized Capacity (Mton)				Spec Cons	H2 consumption (Mton)			
Unit	2024	2030	2040	2050	wt% on feed	2024	2030	2040	2050
Residue Hydrocracker	0,97	0,32	0,00	0,00	4,07	0,04	0,01	0,00	0,00
VGO Hydrocracker	71,60	54,50	27,86	12,36	2,90	2,08	1,58	0,81	0,36
Resid Hydrotreater	0,12	0,01	0,00	0,00	1,43	0,00	0,00	0,00	0,00
VGO Hydrotreater	29,63	22,53	4,03	0,00	1,20	0,36	0,27	0,05	0,00
Diesel Hydrotreater	149,70	92,65	38,05	15,00	0,80	1,20	0,74	0,30	0,12
FCC Gasoline Hydrotreater	10,49	5,32	4,80	1,21	0,24	0,03	0,01	0,01	0,00
Kero Hydrotreater	11,02	11,94	5,84	2,84	0,20	0,02	0,02	0,01	0,01
Naphtha Hydrotreater	76,67	51,76	13,61	3,34	0,12	0,09	0,06	0,02	0,00
Naphtha Isomerization	18,38	14,19	2,72	0,14	0,09	0,02	0,01	0,00	0,00
				Total	(Mton)	3,83	2,72	1,20	0,49
				Total with inefficiencies (14%)	(Mton)	4,36	3,10	1,37	0,56

Table 2 - Evolution of hydrogen consumption (and therefore demand) by traditional refinery units in More Molecule scenario

MORE MOLECULE	Utilized Capacity (Mton)				Spec Cons	H2 consumption (Mton)			
Unit	2024	2030	2040	2050	wt% on feed	2024	2030	2040	2050
Residue Hydrocracker	0,97	0,71	0,00	0,81	4,07	0,04	0,03	0,00	0,03
VGO Hydrocracker	71,60	55,27	29,69	15,20	2,90	2,08	1,60	0,86	0,44
Resid Hydrotreater	0,12	0,01	0,00	0,00	1,43	0,00	0,00	0,00	0,00
VGO Hydrotreater	29,63	12,48	3,99	0,19	1,20	0,36	0,15	0,05	0,00
Diesel Hydrotreater	149,70	94,35	38,99	13,15	0,80	1,20	0,75	0,31	0,11
FCC Gasoline Hydrotreater	10,49	5,18	5,26	1,14	0,24	0,03	0,01	0,01	0,00
Kero Hydrotreater	11,02	13,13	6,23	2,99	0,20	0,02	0,03	0,01	0,01
Naphtha Hydrotreater	76,67	52,97	14,52	3,78	0,12	0,09	0,06	0,02	0,00
Naphtha Isomerization	18,38	14,99	2,86	0,51	0,09	0,02	0,01	0,00	0,00
				Total	(Mton)	3,83	2,65	1,27	0,59
				Total with inefficiencies (14%)	(Mton)	4,36	3,02	1,44	0,68

3.1.2. Co-processing: assumptions, data and estimation

Hydrogen needed for co-processing is linked to the utilization of diesel hydrotreaters because this is the unit in which vegetable oils are added to integrate the fuel production with bio-feedstock. Other co-processing solutions, like the use of bio feedstocks in FCC units, do not require hydrogen therefore are disregarded in this study.

Despite the common processing with high sulphur gasoil, vegetable oils require a significantly higher amount of hydrogen, roughly four-five times more than the fossil feedstock[7], therefore using the same specific consumption would lead to a serious underestimation.

The SPGCI report gives an idea of the co-processing capacity in 2024 amounting to ~2% of the aggregated hydrotreater capacity in the EU but it projected to be ~30% of total capacity (including spare capacity) in 2050.

[7] Calderon O.R. et al. (2024), "Sustainable Aviation Fuel State-of-Industry Report: Hydroprocessed Esters and Fatty Acids Pathway", NREL

Similarly to what was done in case of traditional processes, also for co-processing an extra consumption of 14% was added to the total to account for process inefficiencies.

Table 3 - Evolution of hydrogen consumption (and therefore demand) due to co-processing in Max Electron scenario

MAX ELECTRON	Utilized Capacity (Mton)				Spec Cons	H2 consumption (Mton)			
Unit	2024	2030	2040	2050	wt% on feed	2024	2030	2040	2050
Diesel Hydrotreater	154,03	101,27	43,42	17,20					
fossil feed	149,70	92,65	38,05	15,00					
bio-feed (co-processing)	4,33	8,62	5,38	2,20	4,00	0,17	0,34	0,22	0,09
				Total	(Mton)	0,17	0,34	0,22	0,09
				Total with inefficiencies (14%)	(Mton)	0,20	0,39	0,25	0,10

Table 4 - Evolution of hydrogen consumption (and therefore demand) due to co-processing in More Molecule scenario

MORE MOLECULE	Utilized Capacity (Mton)				Spec Cons	H2 consumption (Mton)			
Unit	2024	2030	2040	2050	wt% on feed	2024	2030	2040	2050
Diesel Hydrotreater	154,03	104,38	44,80	16,03					
fossil feed	149,70	94,35	38,99	13,15					
bio-feed (co-processing)	4,33	10,03	5,81	2,88	4,00	0,17	0,40	0,23	0,12
				Total	(Mton)	0,17	0,40	0,23	0,12
				Total with inefficiencies (14%)	(Mton)	0,20	0,46	0,26	0,13

3.1.3. Biofuels: assumptions, data and estimation

The hydrogen demand in the bio/renewable pathways relies heavily on the SPGCI data and the assumptions made. From the product supply and demand balance available in the study, it is possible to obtain the production of bio-fuels (and e-fuels) separately per product (i.e. gasoline, diesel, kerosene).

The amount of bio-fuels produced by each technological pathway is then required to estimate the hydrogen demand coming from bio-fuel production.

The first step needed is to determine the net bio-fuel demand. In the EU27+3 bio-fuel balance of the SPGCI study, the demand is equal to the production because no import or export is assumed. Bio-fuels are broken down by fuel type: bio-gasoline, bio-diesel and bio-jet. Other streams like bio-LPG and bio-naphtha are considered by-products therefore they will not require additional hydrogen consumption. The demand of first-generation biofuels, ethanol and FAME, is also reported and this allows to calculate the net demand of bio-gasoline and bio-diesel. Co-processed product is discounted fully from bio-diesel demand and production as it assumed all to be HVO.

SPGCI study assessed the bio-refinery capacity in 2024 and 2030 but not further on, so for 2040 and 2050 it has been assumed that:

Bio-refinery capacity utilised = Bio-fuel demand (w/o ethanol and FAME) – bio-fuel co-processed.

Once estimated the overall bio-refinery capacity, it is necessary to allocate it to the different technology pathways envisioned in the SPGCI study:

- Alcohol-to-Jet Synthetic Paraffinic Kerosene (ATJ-SPK),
- Biomass-to-liquids (BtL)
- Catalytic esterification
- Biomass Gasification Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK),
- Hydrotreated Esters and Fatty Acids (HEFA),
- Hydrotreated Esters and Fatty Acids Synthetic Paraffinic Kerosene (HEFA-SPK)
- Biomass Hydrothermal Liquefaction (HTL).

The allocation of technology pathways has been extracted from a 2024 study commissioned for the European Commission[8].

As mentioned before, co-processing is deducted from the figures related to 2040 and 2050, more specifically from those of HEFA (closest technology, also fully dedicated to diesel components production).

Table 5 - Evolution of bio-refinery capacity by pathway in both net-zero scenarios

ME = Maximum Electron MM = More Molecule		2024		2030		2040		2050	
		ME	*MM*	*ME*	*MM*	*ME*	*MM*	*ME*	*MM*
ATJ-SPK	Mton	0,0	0,0	0,0	0,3	4,7	6,6	14,6	22,2
Biomass-to-Liquids	Mton	0,0	0,0	0,0	0,0	0,9	1,4	1,9	2,8
Catalytic esterification	Mton	0,0	0,0	0,0	0,1	0,0	0,1	0,0	0,1
FT-SPK	Mton	0,0	0,0	0,0	0,6	2,8	4,7	10,0	15,2
HEFA	Mton	4,4	4,4	4,4	7,3	5,2	11,6	9,9	16,4
HEFA-SPK	Mton	0,7	0,7	2,4	2,8	10,9	16,1	11,9	19,0
HTL	Mton	0,0	0,0	0,0	0,2	0,9	1,4	3,3	4,7
Total	**Mton**	**5,0**	**5,0**	**6,8**	**11,2**	**25,6**	**42,0**	**51,5**	**80,5**

For the specific hydrogen consumption coefficients of these technologies, the used data came from several literature sources[9] [10] [11] [12].

[8] European Commission, Directorate-General for Research and Innovation, BEST, Georgiadou, M., Goumas, T., Chiaramonti, D. (2024) "Development of outlook for the necessary means to build industrial capacity for drop-in advanced biofuels Annex 3 Report on Task 3", Publications Office of the European Union
[9] Van Dyk, S.; Saddler, J. (2024), "Progress in Commercialization of Biojet/Sustainable Aviation Fuels (SAF): Technologies and Policies", IEA Bioenergy
[10] https://www.concawe.eu/publication/sustainable-biomass-availability-in-the-eu-to-2050/
[11] Calderon O.R. et al. (2024), "Sustainable Aviation Fuel State-of-Industry Report: Hydroprocessed Esters and Fatty Acids Pathway", NREL
[12] Konstantinos F.T., Posada J.A., Ramirez A. (2017), "Analysis of biomass hydrothermal liquefaction and biocrude-oil upgrading for renewable jet fuel production: The impact of reaction conditions on production costs and GHG emissions performance", Renewable Energy, Volume 113

Table 6 - Evolution of hydrogen consumption (and therefore demand) due to biofuels' production in Max Electron scenario

MAX ELECTRON	Utilized Capacity (Mton)				Spec Cons	H2 consumption (Mton)			
Unit	2024	2030	2040	2050	wt% on feed	2024	2030	2040	2050
ATJ-SPK	0,00	0,00	4,72	14,63	1,07	0,00	0,00	0,05	0,16
Biomass-to-Liquids	0,00	0,00	0,95	1,89	16,96	0,00	0,00	0,16	0,32
Catalytic esterification	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
FT-SPK	0,00	0,00	2,85	9,96	16,25	0,00	0,00	0,46	1,62
HEFA	4,36	4,38	5,24	9,86	4,62	0,20	0,20	0,24	0,46
HEFA-SPK	0,67	2,41	10,92	11,87	5,35	0,04	0,13	0,58	0,64
HTL	0,00	0,00	0,95	3,32	7,05	0,00	0,00	0,07	0,23
				Total	(Mton)	0,24	0,33	1,57	3,42

Table 7 - Evolution of hydrogen consumption (and therefore demand) due to biofuels' production in More Molecule scenario

MORE MOLECULE	Utilized Capacity (Mton)				Spec Cons	H2 consumption (Mton)			
Unit	2024	2030	2040	2050	wt% on feed	2024	2030	2040	2050
ATJ-SPK	0,00	0,26	6,61	22,18	1,07	0,00	0,00	0,07	0,24
Biomass-to-Liquids	0,00	0,00	1,42	2,84	16,96	0,00	0,00	0,24	0,48
Catalytic esterification	0,00	0,10	0,11	0,11	0,00	0,00	0,00	0,00	0,00
FT-SPK	0,00	0,57	4,74	15,18	16,25	0,00	0,09	0,77	2,47
HEFA	4,36	7,29	11,56	16,43	4,62	0,20	0,34	0,53	0,76
HEFA-SPK	0,67	2,79	16,14	18,99	5,35	0,04	0,15	0,86	1,02
HTL	0,00	0,15	1,42	4,75	7,05	0,00	0,01	0,10	0,33
				Total	(Mton)	0,24	0,59	2,58	5,30

3.1.4. E-fuels: assumptions, data and estimation

E-gasoline, e-diesel and e-jet demand and production are reported in the SPGCI study. It is worth to mention that e-fuels are the only subset of fuels where the SPGCI study assumes a significant contribution of Extra-EU imports to fulfil the future demand. The reason behind this choice is linked to the allocation of renewable electricity and renewable hydrogen to the transport sector in fact the basic assumption is that all e-fuel production will be based on renewable (low carbon) hydrogen supply.

We can take the hydrogen consumption coefficients for the e-fuels pathways from the Concawe e-fuels study[13] that was published in 2024 and is available on the Concawe website. Two main technologies were analysed: one is going via Methanol as an intermediate and the other is via Fischer-Tropsch with syngas as an intermediate. In the calculations the first technology will be used for e-gasoline, while the second will be used for e-diesel and e-jet.

[13] https://www.concawe.eu/publication/e-fuels-a-techno-economic-assessment-of-european-domestic-production-and-imports-towards-2050-update/

Table 8 - Evolution of hydrogen consumption (and therefore demand) due to e-fuels' production in Max Electron scenario

MAX ELECTRON	Utilized Capacity (Mton)				Spec Cons	H2 consumption (Mton)			
Unit	2024	2030	2040	2050	wt% on feed	2024	2030	2040	2050
E-Gasoline	0,00	0,01	0,08	1,25	44,30	0,00	0,00	0,04	0,55
E-Diesel	0,00	0,11	0,28	1,29	49,30	0,00	0,05	0,14	0,63
E-Jet	0,00	0,16	1,27	7,33	49,30	0,00	0,08	0,63	3,61
				Total	(Mton)	0,00	0,13	0,80	4,80

Table 9 - Evolution of hydrogen consumption (and therefore demand) due to e-fuels' production in More Molecule scenario

MORE MOLECULE	Utilized Capacity (Mton)				Spec Cons	H2 consumption (Mton)			
Unit	2024	2030	2040	2050	wt% on feed	2024	2030	2040	2050
E-Gasoline	0,00	0,01	0,09	1,53	44,30	0,00	0,00	0,04	0,68
E-Diesel	0,00	0,15	0,78	5,90	49,30	0,00	0,08	0,39	2,91
E-Jet	0,00	0,11	1,17	7,83	49,30	0,00	0,06	0,58	3,86
				Total	(Mton)	0,00	0,13	1,00	7,45

3.2. CONTRIBUTION OF TRADITIONAL SOURCES OF H2

In the same way as it was done in subchapter 3.1.1 for refinery units' consumptions, the SPGCI study provides an estimation of those two technologies that in a traditional refinery produce hydrogen. The first one is the catalytic reformer: here the main scope is to transform naphtha into a high-octane gasoline component called reformate but, as a valuable secondary product, in this reaction there is also generation of hydrogen. The second technology is the steam methane reformer that is actually uniquely devoted to the production of hydrogen.

For the Catalytic Reformer, it has been assumed a hydrogen yield of 2,4%wt taking as literature reference "Refining Processes Handbook, Surinder Parkash, 2003, Elsevier" [QUOTE] and considering that the majority of the units in EU27+3 is a continuous catalytic reformer (Concawe internal database). In the SPGCI study, it is assumed that on-purpose hydrogen production through SMR (Steam Methane Reforming) will be replaced by renewable hydrogen by 50% in 2030 and almost 100% in 2050. In that estimation it has not been considered the potential impact of the blue hydrogen (SMR + Carbon Capture) or the utilisation of biomethane.

Table 10 - Forecasted contribution from traditional H2 production sources in Max Electron scenario

MAX ELECTRON	Utilized Capacity (Mton)				Spec Prod	H2 production (Mton)			
Unit	2024	2030	2040	2050	wt%	2024	2030	2040	2050
Catalytic reforming	63,64	50,73	18,99	7,32	2,40	1,53	1,22	0,46	0,18
SMR (*)	3,07	1,10	0,54	0,01	100,00	3,07	1,10	0,54	0,01
				Total	(Mton)	4,60	2,32	1,00	0,18

(*) SMR capacity is not indicated as total feedstock but as H2 production (therefore 100% specific value)

Table 11 - Forecasted contribution from traditional H2 production sources in More Molecule scenario

MORE MOLECULE	Utilized Capacity (Mton)				Spec Prod	H2 production (Mton)			
Unit	2024	2030	2040	2050	wt%	2024	2030	2040	2050
Catalytic reforming	63,64	50,27	19,82	8,36	2,40	1,53	1,21	0,48	0,20
SMR (*)	3,07	1,11	0,56	0,01	100,00	3,07	1,11	0,56	0,01
				Total	(Mton)	4,60	2,32	1,04	0,21

(*) SMR capacity is not indicated as total feedstock but as H2 production (therefore 100% specific value)

4. CONCLUSIONS

The combination of all the above calculations provides the overall hydrogen demand under each of the two net-zero scenarios, aggregated over the different technology pathways.

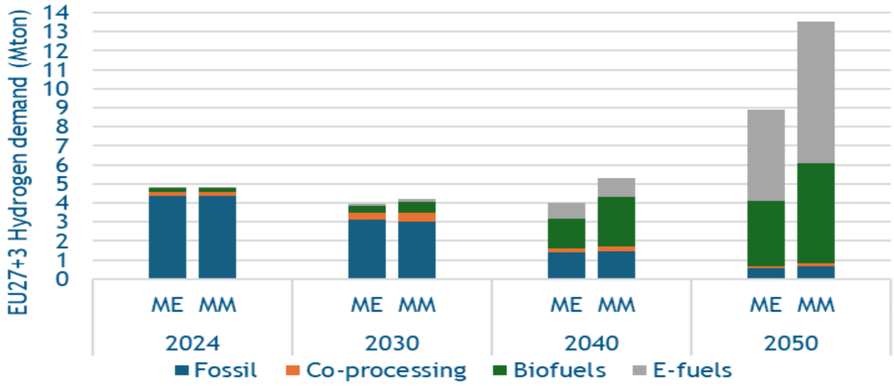

Figure 1 - EU27+3 Hydrogen demand estimation for fuel production by fuel origin

The differences between the two scenarios appear to be significant only from 2040, when the "More Molecule" scenario shows 33% higher hydrogen demand compared to the "Max Electron" scenario. This delta increases further reaching a 50% in 2050.

Examining each individual scenario separately, despite both scenarios assume a reduction in the overall market for liquid fuels, it is not surprising the rise in hydrogen demand given the switch to more hydrogen-intensive production pathways. Just as basic comparison, for diesel moving from a traditional fossil feedstock processed in a hydrotreater to a bio-feedstock co-processed or through HEFA implies four-five times increase in hydrogen need and, if the switch is with e-diesel, the hydrogen need increases by ten times.

Given the estimations on overall demand and the contribution of the traditional sources, it is then possible to identify the expected hydrogen demand covered by renewable H2 production.

Table 12 - Hydrogen supply and demand balance and estimated contribution of renewable hydrogen

ME = Maximum Electron MM = More Molecule		2024 ME	2024 MM	2030 ME	2030 MM	2040 ME	2040 MM	2050 ME	2050 MM
Fossil	Mton	4,36	4,36	3,10	3,02	1,37	1,44	0,56	0,68
Co-processing	Mton	0,20	0,20	0,39	0,46	0,25	0,26	0,10	0,13
Biofuels	Mton	0,24	0,24	0,33	0,59	1,57	2,58	3,42	5,30
E-fuels	Mton	0,00	0,00	0,13	0,13	0,80	1,00	4,80	7,45
Total demand	***Mton***	***4,80***	***4,80***	***3,96***	***4,21***	***3,99***	***5,29***	***8,88***	***13,55***
Catalytic reforming	Mton	1,53	1,53	1,22	1,21	0,46	0,48	0,18	0,20
SMR	Mton	3,07	3,07	1,10	1,11	0,54	0,56	0,01	0,01
Total "traditional" production	***Mton***	***4,60***	***4,60***	***2,32***	***2,32***	***1,00***	***1,04***	***0,18***	***0,21***
Renewable H2	**Mton**	**0,20**	**0,20**	**1,64**	**1,89**	**2,99**	**4,25**	**8,70**	**13,34**
Total production	***Mton***	***4,80***	***4,80***	***3,96***	***4,21***	***3,99***	***5,29***	***8,88***	***13,55***

Regarding the production sources, there are some important elements to be highlighted.

SMR's decrease is significantly faster than reformers' one particular in the early years: the reason behind is simply that SMRs are the ideal targets for a substitution with water electrolysers. A substitution will maximise the benefits from an ETS perspective and will not impact any other refinery process or product. Moreover, decarbonising hydrogen production from catalytic reforming is theoretically possible but practically extremely difficult, except if the reformer is switched to processing a LOHC (liquid organic hydrogen carrier) which was hydrogenated overseas with low carbon hydrogen. This option is disregarded in this report.

The SMR's fast reduction doesn't continue in the 2030-2040 decade because the dominant driver of the reduction becomes asset rationalisation: if a site ceases to operate, both traditional sources are reduced to zero simultaneously.

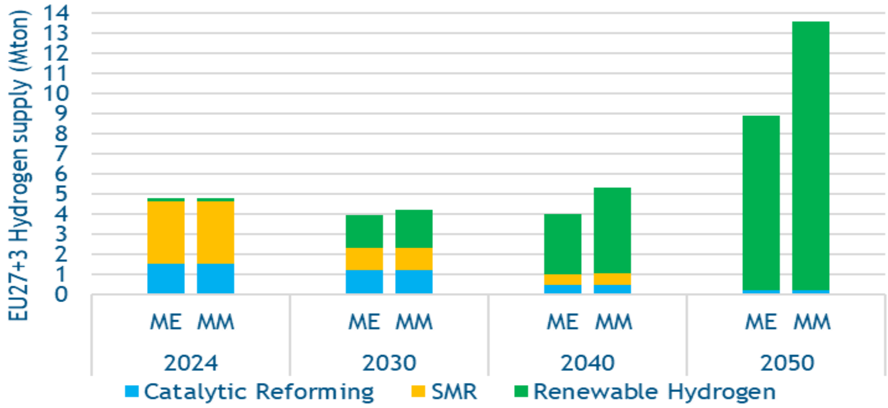

Figure 2 - EU27+3 Hydrogen demand estimation for fuel production by technology source

As visible from the data, renewable H2 importance is expected to grow significantly over the next two decades: from the very limited contribution of today, by 2030 it is expected to cover more than one third of the total hydrogen need, by 2040 it will be by far the primary source (75%-80%) and by 2050 it will become de facto the only hydrogen source.

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ISBN 978-2-87567-209-4