Hydrogen use in Dutch industry

Inventory of small- and medium-sized users in the context of the RFNBO industry obligation in the REDIII

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Summary

In this report we provide an updated overview of industrial hydrogen users in the Netherlands, with a particular focus on relatively small to medium-sized industrial hydrogen users, with a consumption in the range of 0.1-10 kilotonne per annum (ktpa). The goal of the study has been to identify existing industrial hydrogen users with a hydrogen use of more than 0.1 ktpa, the intended lower limit for industrial hydrogen users to be subject to a consumption obligation for *Renewable Fuels of Non-Biological Origin* (RFNBO), that the Ministry of Climate Policy and Green Growth is preparing as part of the REDIII implementation. While large hydrogen users, such as refineries and ammonia producers, were already wellknown, a better overview of smaller hydrogen users was desired – in particular industrial parties with a use of 0.1 ktpa or more.

Through desk research, interviews and contact with companies we have identified 36 industrial hydrogen users that have a hydrogen consumption of at least 0.1 ktpa. Our estimate is that around 10 of these hydrogen users will not be subject to the RFNBO obligation as some sectors (e.g. (bio)refineries) and some hydrogen use (e.g. byproduct) will not fall under the obligation. Over half of the identified users fall within the range of 0.1-10 ktpa (see Table s.1). The majority of identified users either produce hydrogen on-site or receive hydrogen via pipeline. A small number receive hydrogen via truck.

Table S.1 Overview of identified number of plants where hydrogen is currently used and the method of hydrogen production or delivery. The list of identified plants is not considered to be complete, there are likely more hydrogen using plants that were not identified during this study – especially for smaller hydrogen users (up to 0.1 ktpa).

Category	Split	Number of plants
Annual hydrogen use	>100 ktpa	6
	10-100 ktpa	9
	1-10 ktpa	8
	0.1-1 ktpa	13
	0.01-0.1 ktpa	4
	<0.01 ktpa	3
	Total	43
	Total above 0.1 ktpa	36
Method of production or delivery	Own or on-site production	20
	Pipeline	16
	Tube trailer	5
	Gas cylinders	2

A set of questions on the effects of the RFNBO obligation and the willingness of their clients to pay more for products that are produced using green hydrogen was prepared for the identified smaller hydrogen users (0.1-10 ktpa). Our assumption was that small- to medium-sized hydrogen users already pay relatively higher prices for hydrogen than large users and that the hydrogen costs would only form a smaller portion of the overall product costs.

Because of this, we assumed that the smaller hydrogen users could potentially absorb the higher cost of green hydrogen more easily than the larger hydrogen users. During the first years of the RFNBO obligation, these parties could then potentially be in a position to use more green hydrogen in their process than required by the obligation and trade their surplus of HWIs[1]. The HWIs could then be sold to companies that cannot meet their own obligation due to practical or cost constraints.

A simplified analysis of the impact of the RFNBO obligation on product costs confirms that the increase in total product costs as a results of higher green hydrogen production costs are limited for companies with 1) a limited share of hydrogen costs in total costs and 2) that currently pay a relatively higher price for hydrogen. On the other hand, companies that currently have low hydrogen costs – for example because they have their own production – will feel a higher impact of the increase in hydrogen production costs.

While the observed interest in green products is high, the willigness to pay more for products made with green hydrogen was considered low by the respondents. The results of the inquiry indicate that it is highly uncertain to which extent companies can pass on the higher green hydrogen costs to their clients. It is therefore uncertain whether the ability to pass on costs to clients will serve as an incentive for companies to use more green hydrogen to trade their surplus of HWIs with other companies that have more difficulty meeting the RFNBO obligation.

[1] In Dutch: *Hernieuwbare Waterstofeenheid voor de Industrie* (Renewable Hydrogen Unit for Industry).

Contents

1 Introduction

1.1 Background

Based on the revised EU Renewable Energy Directive (REDIII) that entered into force on 21 November 2023, EU Member States have an obligation to ensure that the share of 'renewable fuels of non-biological origin' (RFNBO) used for energetic and non-energetic final energy consumption in industry is at least 42% of the hydrogen used in industry in 2030 and 60% in 2035. For the Netherlands – the second largest industrial hydrogen user in Europe after Germany – this is a challenging target. RFNBO includes hydrogen produced via water-electrolysis with renewable electricity and (chemical) derivatives produced using this hydrogen like methanol and ammonia. In this report RFNBO will generally be referred to as green hydrogen. Green hydrogen still comes at a relatively high cost of production today. It might therefore be necessary to provide significant financial support to stimulate companies to use green hydrogen. The Ministry of Climate Policy and Green Growth (KGG) intends to, at least partially, pass on the national RFNBO obligation to industrial companies using hydrogen. The Ministry is developing a regulation for an annual obligation for industry starting in 2026 and ramping up to 2030 (see Table 1.1).[2] The obligation is also meant to stimulate the creation of a green hydrogen market.

Table 1.1: Draft regulation of annual RFNBO obligation for industry, expressed in percentages of the hydrogen use in industry and in required kilotonnes of green hydrogen per year (ktpa) to meet the industry obligation (based on 70 PJ/year total denominator for the obligation) (Leguijt, et al., 2023).

Year	2026	2027	2028	2029	2030
Indicative percentage annual obligation	0.2%	1%	8%	16%	24%
Total amount of green hydrogen for the annual obligation for the Dutch industry (ktpa)	1.2	5.8	47	93	140

It is proposed that the obligation would apply to industrial companies with a hydrogen consumption of at least 0.1 kilotonne per year (ktpa). Based on an earlier survey by the Netherlands Enterprise Agency (RVO) it was estimated that around forty companies would fall under such an obligation. But while the large hydrogen users are well-known based on previous research[3], e.g. the ammonia producers and the refineries, there is not a complete overview of the smaller hydrogen users. In particular industrial companies with a hydrogen consumption of 0.1 to 1 ktpa, and possibly up to 10 ktpa are not well documented. Based on previous analyses, there is a difference of about 6 petajoules (PJ) of hydrogen consumption compared to the estimated yearly production by the ammonia producers, refineries, and by the industrial gases producers. This equals about 50 ktpa of hydrogen consumption. It is expected that this hydrogen is mostly distributed as merchant hydrogen, but an overview of the users of the hydrogen is missing.

[2] An alternative ramping up to 8% in 2030 is also being considered by the Ministry.
[3] Including, but not limited to: MIDDEN (PBL, 2024), Weeda & Segers (2020) , Weeda & Lamboo (2022), CE Delft & TNO (Leguijt, et al., 2022) (Leguijt, et al., 2023).

When using green hydrogen so-called HWIs[4] can be generated. Companies need these HWIs to be able to prove compliance with their annual obligation. When using more green hydrogen than needed to comply with the obligation, companies will have a surplus of HWIs that can be sold to companies that do not use sufficient green hydrogen to meet their obligation. While large hydrogen users generally make bulk products with limited margins, it is assumed that some of the smaller industrial users produce more specialized products where higher green hydrogen prices could more easily be passed on to clients in the product prices. The smaller industrial companies could therefore play an important role in the starting phase of the annual obligation. In addition, the scale of hydrogen use seems to fit with the total amount of green hydrogen required in the first years (see Table 1.1). The Ministry of KGG therefore would like to have a better overview of the smaller industrial hydrogen users and their potential role in the annual RFNBO obligation and HWI market.

1.2 Research questions and method

The two research questions for this project are:

- What industrial processes and applications with an annual hydrogen use of at least 0.1 ktonne exist in the Netherlands, outside the already known large users of hydrogen like the ammonia producers and refineries? Which of these companies have own hydrogen production facilities and which get hydrogen delivered via pipeline or trucks?
- What is the willingness to pay for green hydrogen by these industrial companies and to what extent can they fulfil the annual RFNBO obligation?

The research method consisted of creating an overview of relevant industrial processes, applications and companies that use hydrogen based on literature (e.g. the MIDDEN database (PBL, 2024)). In addition to publicly available sources, both relevant internal and external contacts were consulted to add to the overview. In the first stage of the project interviews were conducted with industrial gas producers Air Liquide and Air Products, hydrogen technology provider HyGear, consulting and engineering firm Ekinetix, engineering services firm ON2Quest and chemical industry sector association VNCI. Following this, the nearly 40 industrial companies identified were approached and asked about whether they use hydrogen and if yes, how much and how the hydrogen is delivered to them.

In the second phase of the study, the companies that had indicated to use between 0.1 and 1 ktpa of hydrogen were approached with several follow-up questions. These questions targeted information about the share of hydrogen costs in the total costs of products and the possibilities of passing on higher costs to customers due to green hydrogen use. Several interviews were held to discuss the questions in more detail.

1.3 Reading guide

The results of the first phase of the study, the survey among the identified small- to medium-sized industrial hydrogen users in the Netherlands are presented in Chapter 2. An overview of identified industrial ammonia and methanol users is also provided in Chapter 2. Although it is not foreseen that these companies are subject to the RFNBO obligation if they only use ammonia or methanol, they could play a role in meeting the obligation if they use green ammonia or methanol as these are also RFNBO. The results of the second phase of the study are presented in Chapter 3. In this chapter the results have been aggregated and anonymised so that the results are not traceable to individual companies. Finally, Chapter 4 contains our conclusions based on the findings of this study.

[4] In Dutch: *Hernieuwbare Waterstofeenheid voor de Industrie* (Renewable Hydrogen Unit for Industry).

2 Overview industrial hydrogen users

2.1 Industrial hydrogen users

The largest industrial hydrogen users (>100 ktpa) consist of the 3 largest refineries and the production of methanol and ammonia (see Table 2.1). It should be noted that refineries will be largely or entirely exempted from the industry RFNBO obligation as the hydrogen used to produce conventional transport fuels and biofuels will be exempted from the obligation as it will fall under the scope of a separate RFNBO obligation for the transport sector. Only the hydrogen that is attributed to the production of industrial products, such as products made for the chemical sector, will be part of the industry obligation.

In the category of 10-100 ktpa (see Table 2.2) there are the BP and Gunvor Refineries, which both produce hydrogen as a byproduct from catalytic reforming (Oliveira & Schure, 2020). The category also includes two chemical production locations from ExxonMobil and Shell that use hydrogen from the ExxonMobil and Shell refineries. In addition, there are three locations where hydrogen is produced as a byproduct from steam cracking: DOW Chemicals, SABIC Geleen and Shell Moerdijk. Part of the hydrogen is sold externally, but our estimate is that more than 10 ktpa is used on the sites of the steam crackers. In this group there is also the Neste biofuels facility, where hydrogen is delivered by pipeline. Like the refineries, it is expected that the hydrogen used by Neste to produce biofuels will be exempt from the industry RFNBO obligation. Fibrant, located at the Chemelot cluster, also receives more than 10 ktpa hydrogen by pipeline from SABIC (and OCI if necessary).

The category 1-10 ktpa mainly consists of companies in the chemical sector (see Table 2.3). The only exception is Wilmar International, where hydrogen is used for the hydrogenation of vegetable oils and fats. This is considered to be the oleochemistry sector. In this group of companies, hydrogen is produced on-site through *Steam Methane Reforming* (SMR) (Evonik and SABIC Bergen op Zoom), byproduct hydrogen is used (Nobian) and/or hydrogen is supplied via pipeline.

The category 0.1-1 ktpa is also a mix of on-site production, supply via pipeline, and supply via tubetrailers (see Table 2.4). In this category there are also companies from the metal sector, next to the chemical and oleochemical sectors.

In the category 0.01-0.1 ktpa hydrogen is supplied via pipelines or tubetrailers (see Table 2.5). This group contains the only identified hydrogen user in the glass industry in the Netherlands.

In this study into industrial hydrogen users, we have identified 3 (oleo)chemical companies that use a small amount of hydrogen per year (<0.01 ktpa, see Table 2.6). The hydrogen is not necessarily used for production processes, but for example for tests in labs. It is possible that there are many more companies that use such small amounts of hydrogen, but that have not been identified during this study.

Table 2.1: Overview industrial hydrogen users in the Netherlands with a use of >100 ktpa

Company	Location	Sector	Products/process	Delivery method
ExxonMobil Refinery	Botlek, Rotterdam	Refinery	Oil products	Own production/ production Air Products based on residual gas ExxonMobil refinery
OCI Methanol[5]	Delfzijl	Chemical	Methanol	Own production
OCI Nitrogen	Chemelot, Geleen	Chemical	Ammonia	Own production
Shell Pernis Refinery	Pernis, Rotterdam	Refinery	Oil products	Own production
Yara	Sluiskil	Chemical	Ammonia	Own production
Zeeland Refinery	Vlissingen	Refinery	Oil products	Own production

Table 2.2: Overview industrial hydrogen users in the Netherlands with a use of 10-100 ktpa.

Company	Location	Sector	Products/process	Delivery method
BP Refinery	Europoort, Rotterdam	Refinery	Oil products	Own production (by-product)
DOW Chemicals	Terneuzen	Chemical	High value chemicals. Multiple hydrogenation processes	Co-product steam crackers
ExxonMobil Chemical Holland (Rotterdam Aromatics Plant)	Botlek, Rotterdam	Chemical	Cyclohexane, benzene, orthoxylene and paraxylene	From own refinery
Fibrant	Chemelot, Geleen	Chemical	Caprolactam	Pipeline
Gunvor Refinery	Europoort, Rotterdam	Refinery	Oil products	Own production (by-product)
Neste	Maasvlakte, Rotterdam	Chemical	Biofuels	Pipeline
SABIC	Chemelot, Geleen	Chemical	High value chemicals. Multiple hydrogenation processes	Co-product steam crackers
Shell Chemicals Park Moerdijk	Moerdijk	Chemical	High value chemicals. Multiple hydrogenation processes	Co-product steam crackers
Shell Energy and Chemicals Park	Pernis, Rotterdam	Chemical	Multiple products (incl. HCS, MIBK, DIBK, MIBC)[6] and processes (e.g. hydrogenation)	Shell Pernis refinery and dehydrogenation processes

[5] The OCI Methanol plant is non-operational since 2021. As of September 2024, the plant has been sold to Methanex (OCI Global, 2024).

[6] HCS = hydrocarbon solvents, MIBK = Methyl Isobutyl Ketone, DIBK = Di-Isobutyl Ketone, MIBC = Methyl Isobutyl Carbinol

Table 2.3: Overview industrial hydrogen users in the Netherlands with a use of 1-10 ktpa.

Company	Location	Sector	Products/process	Delivery method
AnQore[7]	Chemelot, Geleen	Chemical	Diaminobutane via hydrogenation	Pipeline
Evonik	Delfzijl	Chemical	Hydrogen peroxide	Own production
Kemira Chemicals	Europoort, Rotterdam	Chemical	Hydrogen peroxide	Pipeline
LyondellBasell Botlek	Botlek, Rotterdam	Chemical	Propylene glycol; butanediol; tert-butyl alcohol (TBA); MTBE; ETBE and isobutylene	Pipeline
Nobian	Botlek, Rotterdam	Chemical	Hydrogen is used as a fuel	By-product
Nobian	Delfzijl	Chemical	Hydrogen is used as a fuel	By-product
SABIC Bergen op Zoom	Bergen op Zoom	Chemical	NORYL (PPE blends)	Production syngas on location by Air Liquide
Wilmar International	Botlek, Rotterdam	Oleochemistry	Hydrogenation of oils and fats	Pipeline

Table 2.4: Overview industrial hydrogen users in the Netherlands with a use of 0.1-1 ktpa.

Company	Location	Sector	Products/process	Delivery method
ASML	Veldhoven	Electronics	Extreme Ultraviolet (EUV) lithography	Tubetrailer
Cargill Refined Oils Europe	Botlek, Rotterdam	Oleochemistry	Hydrogenation of oils and fats	Pipeline
Cargill Bioindustrial	Gouda	Oleochemistry	Stearin, oleic acid, and glycerine products	Tubetrailer
ICL-IP	Terneuzen	Chemical	Hydrogen bromide	Tubetrailer
LyondellBasell Maasvlakte (50% Covestro)	Maasvlakte, Rotterdam	Chemical	Propylene oxide and styrene	Pipeline
Nouryon Metal Alkyl	Botlek, Rotterdam	Chemical	Metal alkyls	Pipeline
Nouryon MCA	Delfzijl	Chemical	Monochloroacetic Acid (MCA)	Pipeline
Nyrstar	Budel	Metal	Industrial water purification	Own production
SD Guthrie International Zwijndrecht Refinery	Zwijndrecht	Oleochemistry	Hydrogenation of oils and fats	Pipeline

[7] While Envalior does not use hydrogen themselves, they purchase hydrogen for AnQore, who operate the Evalior-owned diaminobutane plant.

Company	Location	Sector	Products/process	Delivery method
Shin-Etsu Botlek	Botlek, Rotterdam	Chemical	Ethylene dichloride (EDC) and vinyl chloride monomer (VCM)	Pipeline
Synthomer	Middelburg	Chemical	Hydrogenation for the production of resins	Own production
Tata	Velsen	Metal	Steel production	Own production
Teijin Aramid	Delfzijl	Chemical	Aromatic polyamides	Pipeline

Table 2.5: Overview industrial hydrogen users in the Netherlands with a use of 0.01-0.1 ktpa.

Company	Location	Sector	Products/process	Delivery method
Caligen	Breda	Chemical	Reticulation of PU (detonation of H2/O2 mix going from closed-celled PU to open-celled PU)	Tubetrailer
Ducor Petrochemical	Rozenburg	Chemical	Polypropylene homopolymers	Pipeline
Libbey	Leerdam	Glass industry	Finishing glass with hydrogen flame	Tubetrailer
LyondellBasell Moerdijk	Moerdijk	Chemical	Cattaloy and poly-butene polymers	Pipeline

Table 2.6: Overview industrial hydrogen users in the Netherlands with a use of <0.01 ktpa.

Company	Location	Sector	Products/process	Delivery method
ADM	Europoort, Rotterdam	Oleochemistry/ food and beverages	Process soybeans into soy meal	Gas cylinders
Arlanxeo	Chemelot, Geleen	Chemical	Synthetic elastomers; rubber	Pipeline
Shin-Etsu Pernis	Pernis, Rotterdam	Chemical	PVC. Hydrogen is only used for analysis	Gas cylinders

Table 2.7 contains a list of identified potential hydrogen users based on the company profiles and products. For a few of the companies it is highly likely that hydrogen is used, but where it was not confirmed by the companies whether more than 0.1 ktpa hydrogen is used. On the other hand, for a few companies on the list it is almost certain that there is no hydrogen used, but that remained unconfirmed as well. An example is Emery Oleochemicals, which seems to be a company more focused on the transport of oils and fats than the production of them.

Missing from the list are companies from the pharmaceutical industry. For the production of some pharmaceutical products, a hydrogenation step could be part of the production process. The pharmaceutical industry in the Netherlands is large, employing over 15.000 people in 2019 (Nordeman, 2021), spread out throughout the country and produces a large range of products. Due to the heterogeneity of the products and the large amount of pharmaceutical companies, it was not possible within this study to determine which of the companies use hydrogen in their production processes. The pharmaceutical industry is mainly located outside of the main industrial clusters (Nordeman, 2021), which means that it is less likely that hydrogen, if used, is delivered by pipeline. More likely is that hydrogen is delivered by tubetrailer, which makes it likely that if hydrogen is used by pharmaceutical companies, that they would be using smaller amounts of hydrogen (<1 ktpa).

Table 2.7: Companies where (amounts of) hydrogen use could not be confirmed during this study.

Company	Location	Sector	Products/process
Arkema/Bostik	At least 7 locations	Chemical	Multiple
Ashland	Zwijndrecht	Chemical	Natrosol - hydroxyethyl cellulose (HEC)
ChemCom Industries	Delfzijl	Chemical	Formaldehyde and resins/glues for wood processing industry
Emery Oleochemicals	Venlo	Oleochemistry	Unknown
Invista Nylon Chemicals Netherlands B.V.	Botlek, Rotterdam	Chemical	Nylon intermediate products (nylon resins) and polymers
Neste Loders Croklaan	Maasvlakte, Rotterdam	Oleochemistry/biofuels	Oils and fats; processing of palm oil
NXP	Nijmegen	Electronics	
Olenex (Joint Venture ADM and Wilmar)	Zaandam and Pernis, Rotterdam	Oleochemistry	Oils and fats
Teijin Aramid	Emmen and Arnhem	Chemical	Aromatic polyamides
Viterra	Botlek, Rotterdam	Chemical	Biodiesel and glycerine

Finally, Table 2.8 contains a list of companies that were identified as potential hydrogen users based on the sector, products, or processes, but where the identified companies have confirmed that they currently do not use hydrogen.

Table 2.8: Companies that have confirmed that currently no hydrogen is used in their facilities.

Company	Location	Sector	Products/process
AAK	Zaandijk and Botlek, Rotterdam	Oleochemistry	Oils and fats
Ardagh Glass	Dongen and Moerdijk	Glass industry	Glass containers (bottles and jars)
Bunge	Amsterdam	Oleochemistry	Oils and fats
Carbogen Amcis	Veenendaal	Oleochemistry	Pharmaceutical industry (vitamin D-analogs, vitamin D2, cholesterol and lanoline derivatives). Fat derivatives
Cargill Multiseed Amsterdam and Cargill Zaanlandse Olieraffinaderij	Amsterdam and Zaandam	Oleochemistry	Production and processing of oils and fats

Company	Location	Sector	Products/process
Cargill Cocoa & Chocolate	Deventer and Wormer	Food and beverages	Cacao and chocolate
Cargill Sweeteners	Bergen op Zoom and Sas van Gent	Food and beverages	Sweeteners
Delamine	Delfzijl	Chemical	Ethyleneamines
Dutch Glycerin Refinery B.V.	Delfzijl	Chemical	Refined glycerol
Envalior[8]	Chemelot, Geleen	Chemical	Diaminobutane and polymerization
Huntsman	Botlek, Rotterdam	Chemical	Methylene diphenyl diisocyanate (MDI)
Indorama Ventures Europe B.V.	Europoort, Rotterdam	Chemical	Purified terephthalic acid (PTA) and PET
Kemira Water Solutions	Botlek, Rotterdam	Chemical	Chemicals for water purification
Kerry Group	Zwijndrecht	Oleochemistry	Oils and fats; processing of palm, rapeseed, and sunflower oils
Lubrizol Advanced Materials Resin B.V.	Delfzijl	Chemical	Resins
Maschem	Hoek	Oleochemistry	Ethoxylates
O-I	Leerdam and Maastricht	Glass industry	Glass containers (bottles and jars)
Trinseo	Terneuzen	Chemical	Styrene
Westlake Epoxy B.V.	Pernis, Rotterdam	Chemical	Epoxy resins and advanced chemicals

2.2 Industrial methanol and ammonia users

The focus of this study was to get an overview of hydrogen users in the Netherlands because they are expected to be subject to the RFNBO obligation if they consume more than 0.1 ktpa of hydrogen. While the obligation is based on hydrogen use, the obligation can be met by using RFNBOs. That means that companies that do not use hydrogen, but do use, for instance, methanol or ammonia, could play a role in the RFNBO obligation. These companies are expected to be able to obtain HWIs that can be traded. Table 2.9 and Table 2.10 therefore list methanol and ammonia users that were identified during this study. The list is not considered to be complete.

Methanol is mainly used for the manufacturing of polymers (PTA (purified terephthalic acid), a precursor of PET (polyethylene terephthalate) plastics), MTBE (methyl tertiary – butyl ether), acetic acid, glycol ethers and formaldehyde (Block, Gamboa Palacios, & van Dril, 2020). In the Netherlands, PTA was produced by Indorama Ventures Europe B.V. In July 2024 Indorama announced it will be closing the production facilities in the Europoort (industrielinqs, 2024). MTBE is produced by refineries and chemical industry. In the

[8] Envalior owns the diaminobutane plant and buys the hydrogen for AnQore. AnQore has an agreement to operate the plant.

Netherlands BP, LyondellBasell, Shell Energy and Chemicals Park Pernis and SABIC produce MTBE. LyondellBasell also produces propylene glycol methyl ether (PGME) from methanol and propylene oxide (PO) (Yong & Keys, 2021). Shell Energy and Chemicals Park Pernis also produces PO glycol ethers (POGE's) using methanol (Block, Gamboa Palacios, & van Dril, 2020). Formaldehyde is produced by ChemCom Industries and DuPont (ChemCom industries, 2024; Rodriguez, van Dril, & Gamboa Palacios, 2021).

Methanol is also used to produce FAME (fatty acid methyl esters) biofuel for diesel engines (Khandelwal & van Dril, 2020). The FAME producing biofuel companies have not been included in the overview as they are considered to be using methanol for the transport sector and not for the industry sector.

Table 2.9: Overview of identified industrial methanol users in the Netherlands (not complete).

Company	Location	Sector	Products/process
BP Refinery	Europoort, Rotterdam	Refinery	MTBE
ChemCom Industries	Delfzijl	Chemical	Formaldehyde
DuPont	Dordrecht	Chemical	Formaldehyde
Indorama Ventures Europe B.V.	Europoort, Rotterdam	Chemical	PTA
LyondellBasell	Botlek, Rotterdam	Chemical	MTBE and PGME
Shell Energy and Chemicals Park	Pernis, Rotterdam	Chemical	MTBE and PO glycol methyl ether
SABIC Geleen	Chemelot, Geleen	Chemical	MTBE

Ammonia is known to be used for the production of fertilisers, melamine, ammonium sulfate, diaminobutane and ethyleneamines. Until recently DOW Chemicals also produced ethyleneamines in Terneuzen (Eerens & van Dam, 2022). It is unclear whether DOW Terneuzen still uses ammonia. OCI Nitrogen and Yara both use hydrogen to produce ammonia and use the ammonia to produce a variety of (fertiliser) products. They are therefore included here as well as in Table 2.1.

Table 2.10: Overview of identified industrial ammonia users in the Netherlands (not complete).

Company	Location	Sector	Products/process
AnQore	Chemelot, Geleen	Chemical	Diaminobutane
OCI Nitrogen	Chemelot, Geleen	Chemical	Fertiliser products and melamine
Delamine	Delfzijl	Chemical	Ethyleneamines
Fibrant	Chemelot, Geleen	Chemical	Ammonium sulphate
Yara	Sluiskil	Chemical	Fertiliser products

3 Willingness to pay and the role of small- and medium-sized hydrogen users in the industry RFNBO obligation

In this chapter we focus on the second research question: "What is the willingness to pay for green hydrogen at medium-sized industrial hydrogen users and what can the role of these companies be in fulfilling the RFNBO obligation?" The results are based on questions sent to the identified companies that use 0.1-10 ktpa hydrogen and to Fibrant, who uses >10 ktpa. Nobian was not asked because they use their own by-product hydrogen. The potential role of Nobian for the production of green hydrogen is reflected on in Section 3.3. Cargill, LyondellBasell and Nouryon have two production locations that fall within this range and were asked to answer separately for their two locations, but because the answers received were (nearly) identical they are treated as single answers. With 9 responses out of the 16 companies, the response rate was 56%. The low number of companies and low response means that there is no certainty that the responses are representative for the entire group of companies.

The larger hydrogen users were not approached because the assumption was that the smaller hydrogen users could play a relatively large role in the ramping up phase of the national RFNBO obligation (see Table 1.1).

The results are therefore mainly based on the self-reported input from these companies. The survey results have been supplemented with an analysis of the impact that higher hydrogen costs could have on the production costs, based on our own assumptions of the cost differential between the current situation and the use of green hydrogen (see Section 3.2).

3.1 Questionnaire results

The first question invited the companies to approximate the share of current hydrogen costs in the total product costs. The answers are mainly divided between <1% and >10% (see Figure 3.1). Responses from companies in the oleochemical and metal sectors indicated lower cost fractions (<2%) while the chemical sector indicated higher cost fractions >10%.

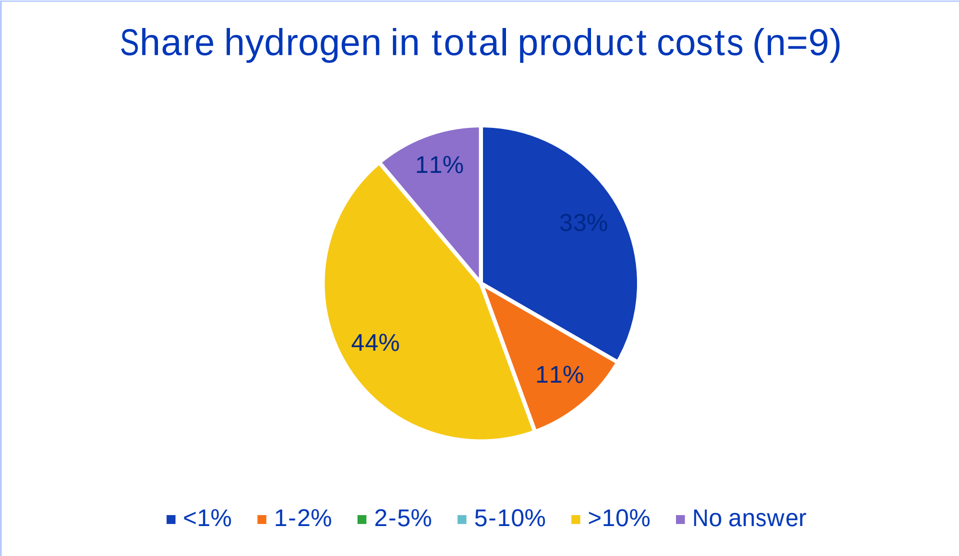

Figure 3.1: Questionnaire answers on the current share of hydrogen costs in total product costs.

The second question related to the client sensitivity to an increase in product costs as a result of higher hydrogen costs. The companies mainly mentioned a high sensitivity (see Figure 3.2). There is no trend based on sectors or amount of hydrogen used per year in these answers. It should be noted that some of the answers seem to refer more generally to product price increases and not necessarily the cost increase due to higher hydrogen costs. In case hydrogen costs are a small part of total product costs, these price increases could be limited.

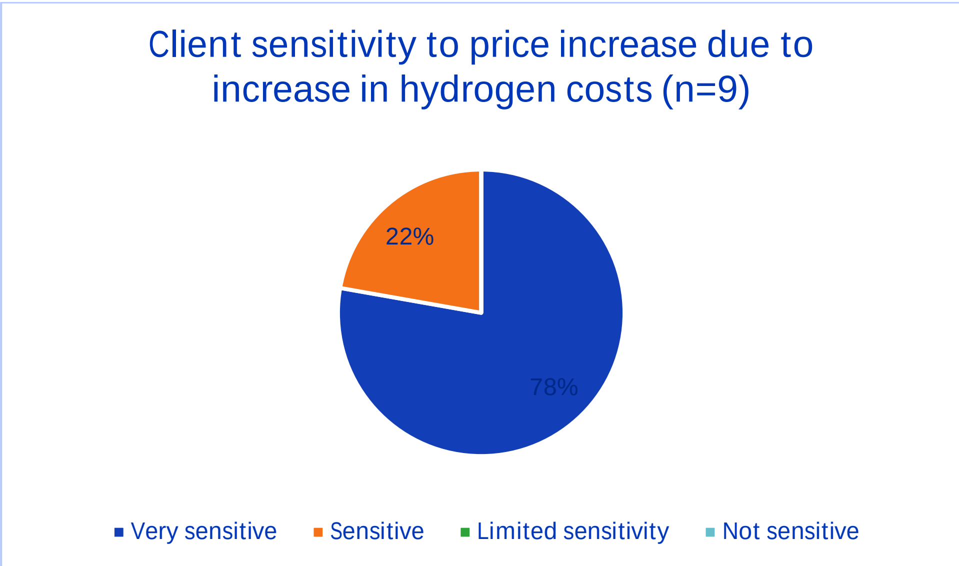

Figure 3.2: Questionnaire answers on client sensitivity to increases in product costs resulting from higher hydrogen costs due to the RFNBO obligation.

The third question was on client interest and willingness to pay more for products made with green hydrogen. The majority of answers indicated that clients were expected to show interest in greener products, but that the willingness to pay more for greener products would be limited. Multiple respondents, mostly from the chemical industry, also expected willingness to pay to be predominantly higher for end users. While the end consumer (i.e. in the consumer market) might be willing to pay more for greener products, the willingness to pay is expected to decline quickly when moving up the supply chain. Another remark made was that a product only becomes marginally greener with the use of green hydrogen if the share of hydrogen in the product is limited.

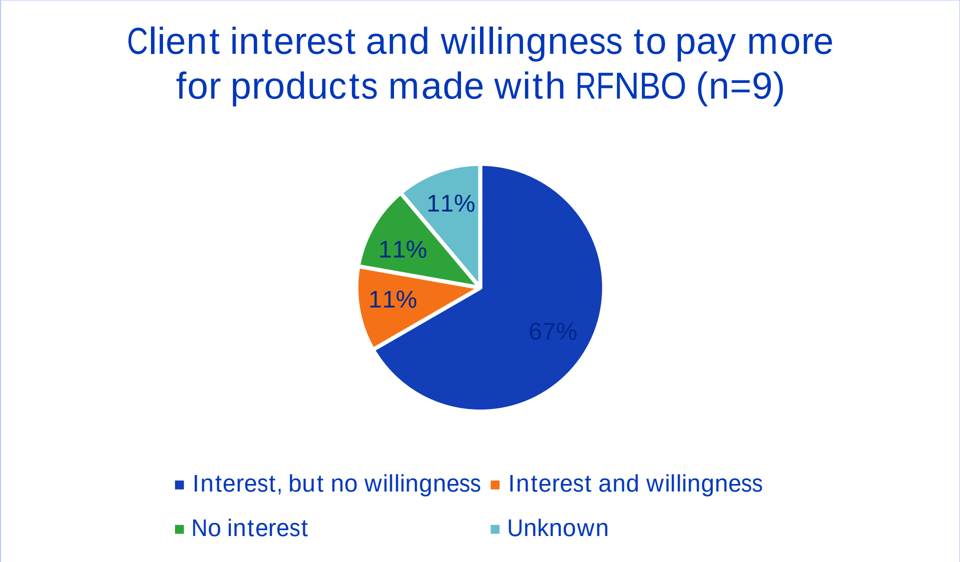

Figure 3.3: Questionnaire answers on client interest and willingness to pay.

The final question was whether companies are expecting to use more green hydrogen than strictly required to meet the RFNBO obligation and generate HWIs that can be sold to other companies. The responses were mixed (see Figure 3.4) and mainly indicated this to depend on the availability of green hydrogen and of the possibility to sell the HWIs at a high enough price to cover any additional costs of using the additional green hydrogen. Companies that responded not to expect to generate and sell HWIs indicate they expect to struggle to meet the obligation in the first place and/or that they expect the need to buy HWIs to meet their obligation. Also here, there is no discernible trend in the answers from companies based on the production or delivery method.

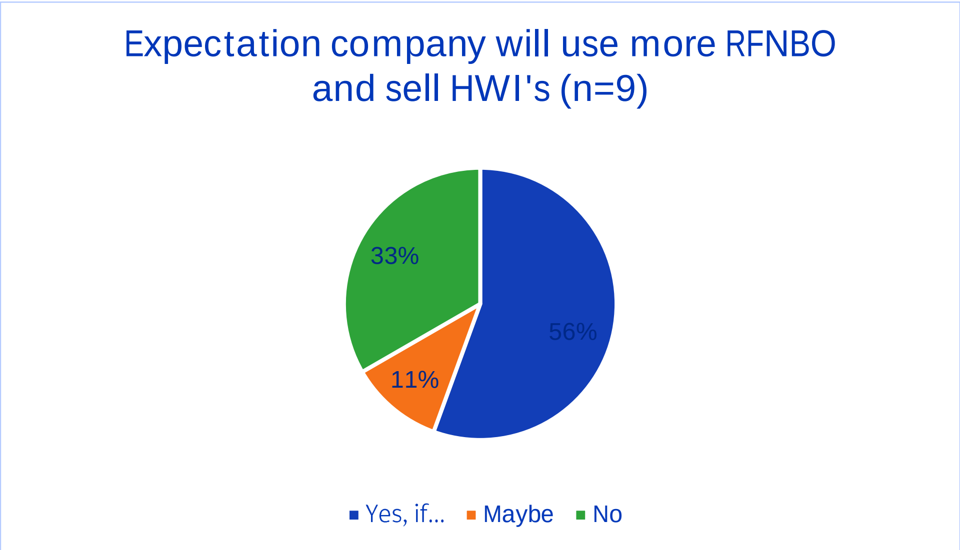

Figure 3.4: Questionnaire answers on the intention to generate and sell HWI's.

3.2 Analysis of impact higher hydrogen costs on product costs

In this section we present the results of a high-level analysis of the impact of higher hydrogen costs due to the RFNBO obligation based on four cases. For this analysis, we assume that current large-scale hydrogen production costs through *Steam Methane Reforming* are 2 €/kg. The price of hydrogen paid by companies depends on the amount of hydrogen consumed per year and the method of delivery (own production, pipeline or tubetrailer). As a simplification, it is assumed green hydrogen is delivered in the same manner and that the price paid for green hydrogen is equal to the difference between the production costs of green hydrogen and the assumed current hydrogen production costs of 2 €/kg. Here we assume a cost range of 5-10 €/kg for green hydrogen. The higher end of this range (10 €/kg) represents a high production cost scenario. The lower end (5 €/kg) represents subsidized green hydrogen production or import of RFNBO from locations with lower production costs, including reconversion to hydrogen.

The four cases are:
1. Low case of a company consuming 0.1 ktpa, with hydrogen costs being a limited part of total product costs and paying a relatively high price for current hydrogen delivered by tubetrailer. Due to the higher current cost of hydrogen, the relative increase in costs due to the higher green hydrogen production costs are lower than the other cases. Due to the low share of hydrogen cost in total costs the impact of higher hydrogen costs is also relatively low.
2. Middle case of a company consuming 1 ktpa, which is delivered by pipeline. The current price paid for hydrogen and the share of hydrogen in the total product costs are higher than the first case.
3. High case of a company using 10 ktpa from own production and where hydrogen is a relatively significant portion of the total product costs. Because the hydrogen is produced on-site, the current hydrogen costs are low. The impact of higher green hydrogen costs is therefore large.
4. A very high case of a company using 20 ktpa and where hydrogen costs make up a quarter of total product costs. Hydrogen is also produced on-site at low costs.

The assumptions used for the four cases are presented in Table 3.1.

Table 3.1: Chosen parameters for the cases to explore the effects of higher hydrogen costs as a consequence of the RFNBO obligation.

Parameter	Low case	Middle case	High case	Very high case
Hydrogen use (ktpa)	0.1	1	10	20
Method of delivery	Tubetrailer	Pipeline	On-site production	On-site production
Current hydrogen costs (€/kg)	10	5	2	2
Current share of hydrogen cost in total costs	1%	5%	10%	25%

In this analysis, we calculate the expected cost increase for each of these four cases based on the draft regulation for 2030 (see Table 1.1). Figure 3.5 illustrates the effect of an 8% and a 24% RFNBO obligation in 2030 at green hydrogen production costs of 5, 7.5 and 10 €/kg on total product costs. The analysis shows that the impact of the obligation is relatively small (0.02-0.2% higher product costs) for the case with a high current hydrogen costs and a 1% share of hydrogen costs in total product costs. For the middle case the increase in product costs is 0.2-0.6% for an 8% RFNBO obligation and 0.7-1.9% for 24% RNFBO. For the high case the increase is 1.2-3.2% for 8% RFNBO and 3.6-9.6% for 24% RFNBO. For the very high case, the effect of the RFNBO obligation is most significant ranging from 3-8% and 9-24% respectively.

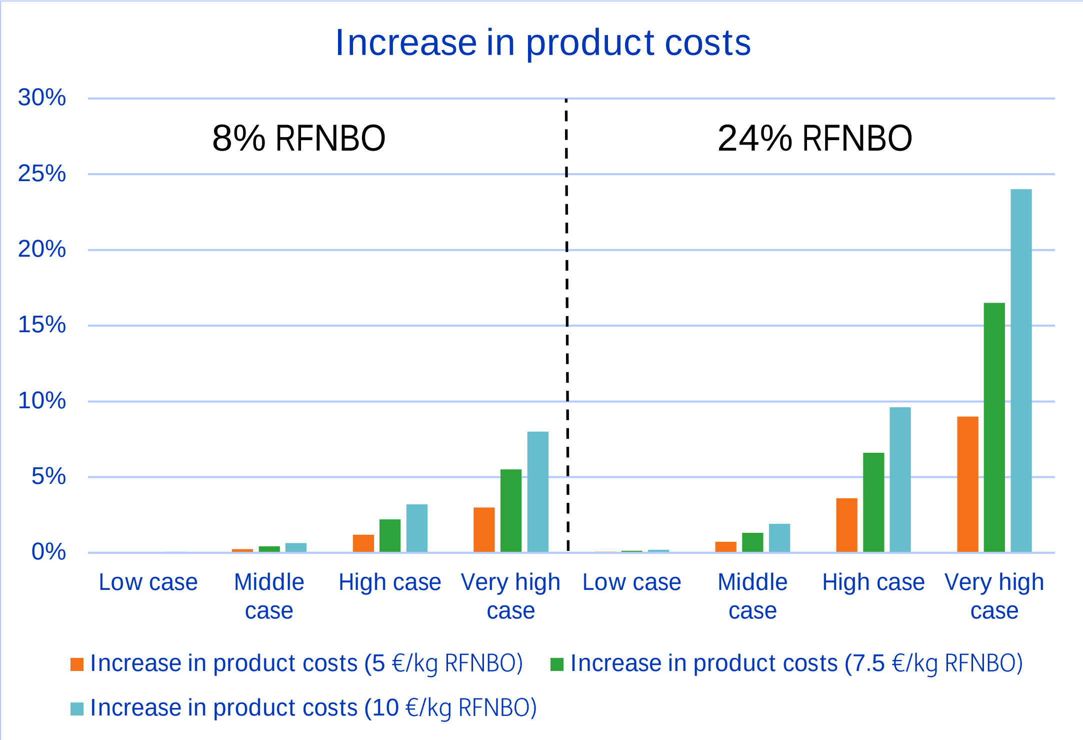

Figure 3.5: Increase in product costs for four cases with a range of 5-10 €/kg cost of RFNBO hydrogen. Left side is 8% RFNBO for all cases. Right side is 24% RFNBO for all cases.

While Figure 3.5 shows the effect of the RFNBO obligation in 2030, the effect will be smaller in the years leading up to 2030 when following the ramp-up of the draft obligation to 24% in 2030 (see Table 1.1). Figure 3.6 shows the resulting increase in product costs based on a 7.5 €/kg RFNBO production costs and the ramping of the RFNBO obligation. The effect is minor for all cases in 2026 and 2027 (<1%), whereafter it quickly increases for the high and very high cases. For the low and middle cases, the effect is small leading up to 0.1% and 1.3% respectively in 2030.

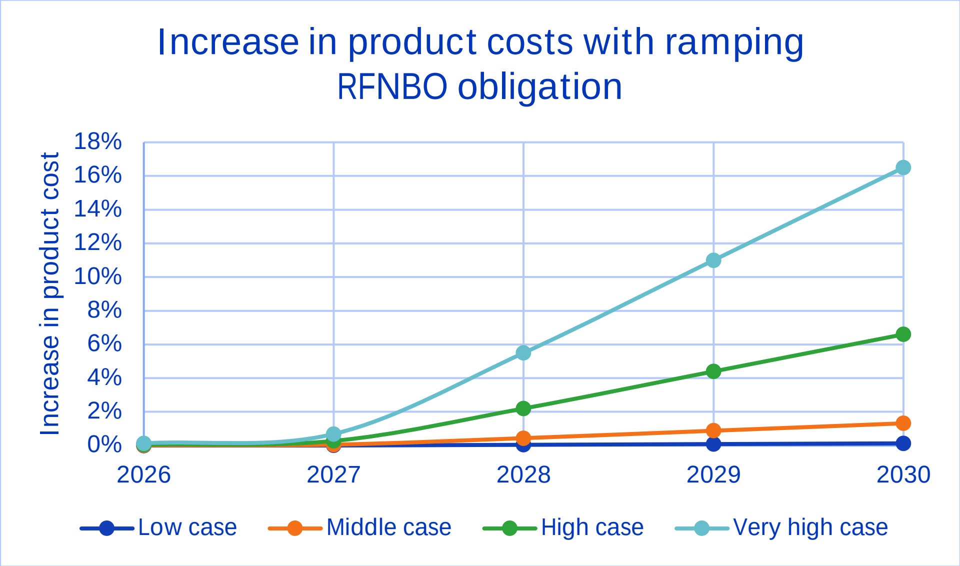

Figure 3.6: Increase in product costs over the years as a result of the RFNBO obligation ramping up to 24% in 2030, assuming a RFNBO hydrogen cost of 7.5 €/kg.

3.3 Reflection on coproducts

Some of the hydrogen users do not only use hydrogen, but also CO or CO_2 from the SMR process. While low amounts of green hydrogen can probably be mixed in, these companies will eventually face a challenge when the SMR production cannot be reduced further because of the remaining demand for CO or CO_2. These companies will then need to either find another source of CO or CO_2 to be able to increase the amount of green hydrogen used or they will become dependent on buying HWIs to meet their obligation. How much the SMR production can be scaled down differs per company, so it is uncertain when all these companies will require HWIs. But generally speaking, it is less likely that these companies will be in a position to use more green hydrogen and sell excess HWIs. Only if there is another source of CO or CO_2 available, these companies could increase their use of green hydrogen and potentially generate and sell HWIs.

On the other hand, Nobian produces hydrogen in their current chloralkali production process and partially use this themselves and partially sell to other industrial users. While the by-product hydrogen is not expected to be subject to the RFNBO obligation[9], the hydrogen could qualify as RFNBO if Nobian uses renewable electricity for their brine electrolysis. Nobian could therefore play a significant role in the starting phase of the RFNBO obligation, as they have existing production of hydrogen, and the hydrogen can be competitive compared to new electrolysis projects.

[9] Based on a recent Guidance document from the European Commission, the by-product hydrogen from chloralkali is expected to be exempted from the national RFNBO obligation (European Commission, 2024). More certainty on the implementation in the Netherlands will follow when the Dutch Government shares more information on their intentions for the national RFNBO obligation for industry.

4 Conclusions

In this study we have looked to answer the following two research questions:

- What industrial processes and applications with at least 0.1 ktpa hydrogen use exist in the Netherlands, outside the already known large users of hydrogen like the ammonia producers and refineries? Which of these companies have own hydrogen production facilities and which get hydrogen delivered via pipeline or trucks?
- What is the willingness to pay for RFNBO-hydrogen by these industrial companies and to what extent can they fulfil the annual RFNBO obligation?

Regarding the first research question, we have identified 43 industrial hydrogen users, 36 of which use over 0.1 ktpa of hydrogen during normal operation. The list includes previously known large hydrogen users like (bio)refineries, ammonia producers and naphtha steam crackers. Not all the identified hydrogen users will be subject to the industry RFNBO obligation, for instance some (bio)refineries and users of by-product hydrogen are expected to be excluded. Our estimate is that around 10 out of the 36 identified companies will not be subject to the obligation. The majority of the identified companies are in the chemical sector, of which six are (bio)refineries, four from the oleochemical sector, two from the metal sector and one from the semiconductor sector. One glass producer was identified as a hydrogen user, but the annual consumption is below 0.1 ktpa. The overview is not considered to be complete. Some companies were identified as potential hydrogen users based on their sector and/or processes and products, but these companies did not confirm to be hydrogen users during the study. In addition, there could be hydrogen users that were not identified at all during the study.

Of the identified hydrogen users, the vast majority has on-site hydrogen production or has hydrogen delivered by pipeline. A smaller number of companies receive hydrogen by truck, mainly also being smaller users of hydrogen (up to 1 ktpa).

Table 4.1: Overview of identified number of plants where hydrogen is currently used and the method of hydrogen production or delivery.

Category	Split	Number of plants
Annual hydrogen use	>100 ktpa	6
	10-100 ktpa	9
	1-10 ktpa	8
	0.1-1 ktpa	13
	0.01-0.1 ktpa	4
	<0.01 ktpa	3
	Total	43
	Total above 0.1 ktpa	36
Method of production or delivery	Own or on-site production	20
	Pipeline	16
	Tubetrailer	5
	Gas cylinders	2

Regarding the second research question, we have focused on the group of hydrogen users with an annual consumption of 0.1-10 ktpa. The assumption was that hydrogen costs could be a smaller part of the total costs when smaller amounts of hydrogen are used and that additional costs of the RFNBO obligation could therefore be more easily passed on to clients. A simplified analysis shows the sensitivity of the product costs to both the share of hydrogen costs in the total product costs and the increase in hydrogen costs due to the use of more expensive green hydrogen. For companies where the share of hydrogen costs in total costs is limited and that currently pay a relatively higher price for hydrogen, the increase in total product costs as a results of higher green hydrogen production costs are limited. On the other hand, companies that currently have low hydrogen costs – for example because they have their own production facilities – will feel a higher impact of the increase in hydrogen production costs.

While companies report to observe that their clients are interested in greener products, the observed willingness to pay is limited. Whether smaller hydrogen users can therefore use more green hydrogen than required by the obligation, pass on a part of the costs to customers and generate HWIs at an attractive price for other industries remains uncertain.

So, while the smaller hydrogen users with a relatively minor share of hydrogen in total costs might be impacted less by the RFNBO obligation, it is still uncertain which companies will position themselves as HWI sellers. Some companies have indicated their willingness to generate and sell HWIs to be dependent on sufficient returns being made on the use of additional green hydrogen. If costs are therefore not partially passed on to clients, the value of HWIs will reflect the costs of RFNBO and margins. This may make it more likely that companies will try to meet their obligation by using green hydrogen themselves, instead of buying HWIs. It would also imply that the value of HWI's will be determined by who can produce or source green hydrogen at the lowest costs. This could be the larger industrial players due to their economies of scale over the smaller players.

Companies that also use the CO or CO_2 from steam methane reforming would need to scale down the hydrogen production from the SMR to incorporate green hydrogen. While this is probably possible for limited amounts of green hydrogen, these companies would eventually become dependent on the availability of HWIs or be required to find alternative sources of CO and CO_2. That could create some demand for HWIs, but it is still uncertain who will be selling HWIs.

Nobian, with their existing hydrogen (co-)production from the electrolysis of brine for the production of chloride, could become an interesting player in the HWI market. The hydrogen is currently both consumed by Nobian and sold to third parties. While the by-product hydrogen will be exempted from the RFNBO obligation, the hydrogen could qualify as RFNBO if produced with renewable electricity. As the hydrogen is a by-product, the costs will likely be lower than the costs of green hydrogen produced with new electrolysers. Nobian, and the off takers of their hydrogen, could therefore play an interesting part in the fulfilling of the RFNBO obligation for industry and the supply of HWIs – in particular in the early years of the obligation.

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