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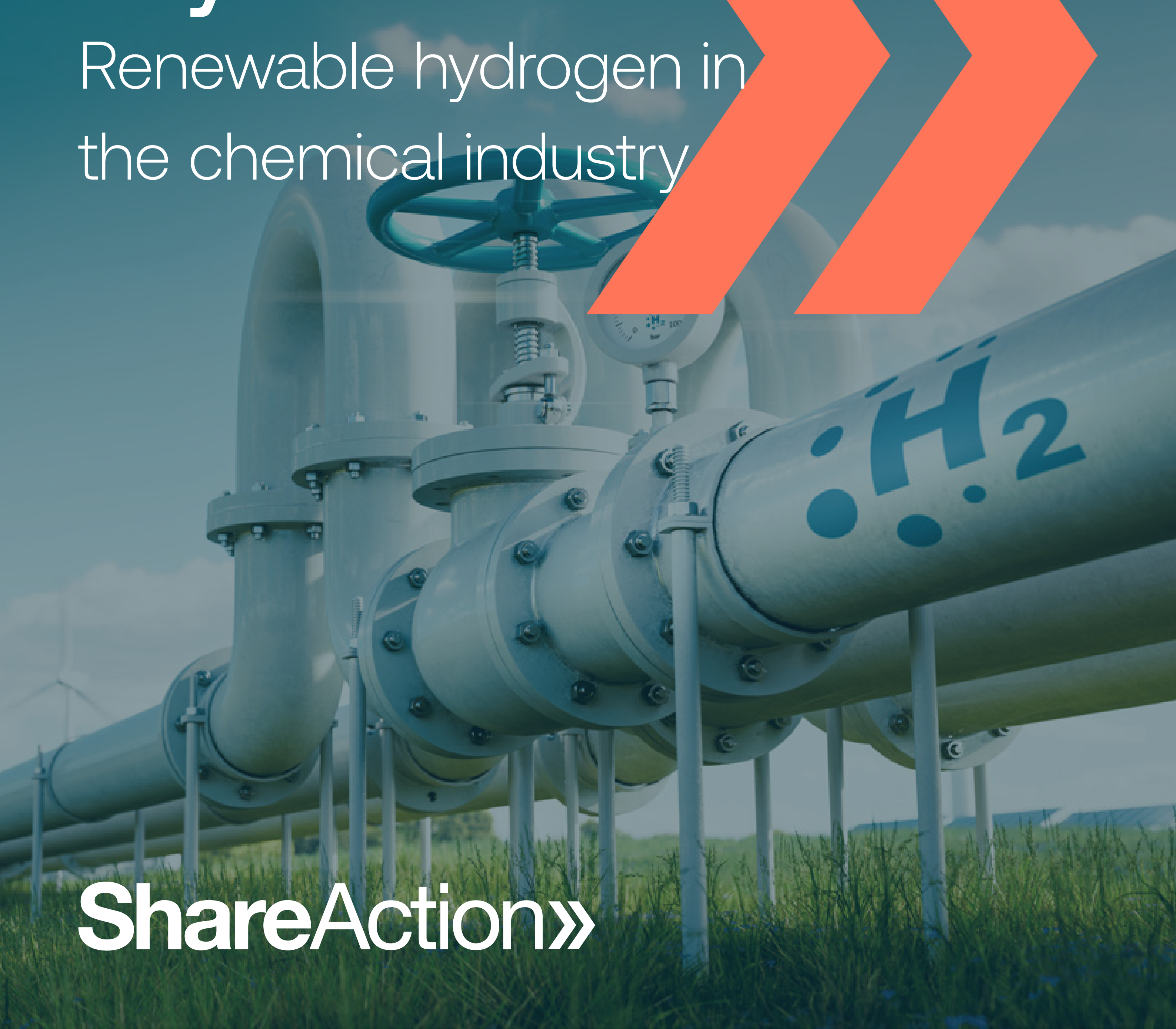
Beyond the Blue

Renewable hydrogen in the chemical industry



ShareAction»

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Contents

Executive Summary

Executive summary

The chemical sector needs to tackle feedstock emissions to reach net zero by 2050

The chemical sector is responsible for over 5.8 percent of global greenhouse gas (GHG) emissions and needs to reach net zero emissions by 2050, as set out in the Paris Climate Agreement.[i] It is technically feasible and economically viable to fully decarbonise chemical production by that date as shown in ShareAction's previous investor briefing.[ii]

About half of the emissions from primary chemicals stem from "feedstock". Feedstock is an input into the chemical production process that is needed as a component of the chemical itself.

During the chemical production process, feedstock is turned into hydrogen and other molecules. These hydrogen molecules are a key building block of primary chemicals, such as ammonia, methanol, and high-value chemicals.

Today, emissions are caused due to fossil fuels – such as natural gas – being used as feedstock. Natural gas feedstock undergoes a process that splits it into its hydrogen and carbon components. The hydrogen is used in further steps to create the desired chemical. But the carbon component is emitted into the atmosphere during the chemical reaction. In cases where the carbon is not emitted but is used in the chemical, it is nonetheless released at the end of life. These types of emissions are known as Scope 3 emissions.

This means that whichever way you look at it, fossil-based feedstock releases emissions, either during production or at the end of a product's life when it is used, burned, or scrapped (Scope 3). These emissions must be reduced to net zero by 2050.

Renewable hydrogen will play a key role in decarbonising the chemicals sector

Chemical companies can achieve net zero emissions from feedstock by transitioning their production processes to replace fossil-based feedstock with renewable hydrogen. Renewable hydrogen is produced by using 100 percent renewable energy, which makes it emission-free.

In comparison, blue hydrogen – using gas derived from fossil fuels and carbon capture – produces 200 times more emissions.[iii] These emissions are locked-in for the lifetime of the asset, which is typically around 25 years.[iv] This means that chemicals made after 2025 using blue hydrogen processes will likely contribute emissions after 2050, inhibiting the ability to reach net zero. By this logic, the chemicals industry has three years to fully transition to renewable hydrogen or analogous feedstocks if it wants to hit its net zero target.

Renewable hydrogen is the only zero emissions hydrogen option, and it will also become the cheapest one. In fact, with current gas prices (March 2022) renewable hydrogen is already cheaper than fossil-based hydrogen today.[v] This is the beginning of a broader trend where, even without an extraordinary increase in gas prices, renewable hydrogen prices will start to undercut those of grey and blue hydrogen before 2030, as per research by BNEF.[vi]

Switching feedstock to renewable hydrogen is the most economically attractive and the lowest emissions pathway for primary chemical production.

Chemical producers need to make critical decisions by 2025

The lifecycle of hydrogen investments is roughly 25 years[vii] and the lifetime of chemical production plants is around 50 years.[viii]

The risk of locking-in emissions until 2050 and beyond is high depending on the choices we make today. The risk of stranded assets is also high if we fail to act. This affects both companies and their investors.

To align with 1.5C pathways and avoid stranded assets, chemical companies should commit to retrofitting and building new plants with production processes that are compatible with renewable hydrogen.

This means that:

By 2025

- All new plants built by 2025 need to be based on renewable hydrogen.
- All retrofitted plants from 2025 onwards need to be based on renewable hydrogen.

Up until 2050

- All existing plants using fossil-based hydrogen need to be retrofitted for renewable hydrogen usage by 2050 at the latest.
- Companies need to show how non-retrofitted plants up until 2050 will still be aligned with intermediate emission reduction targets, such as a 50 percent reduction in emissions by 2030 across the company.

Recommended actions for investors

Investors can use this briefing to scrutinise chemical companies' transition plans and ensure their portfolio holdings are aligned with 1.5C pathways.

We recommend asking the following engagement question to support this process.

How does [company name] plan to transition to emissions-free/emissions-neutral feedstock by 2050?

Tracking outcome:

The company has a credible strategy for emissions-neutral feedstock by 2050 as per the decision points outlined above.

A comprehensive engagement guide can be found in Part III of this report.

Introduction

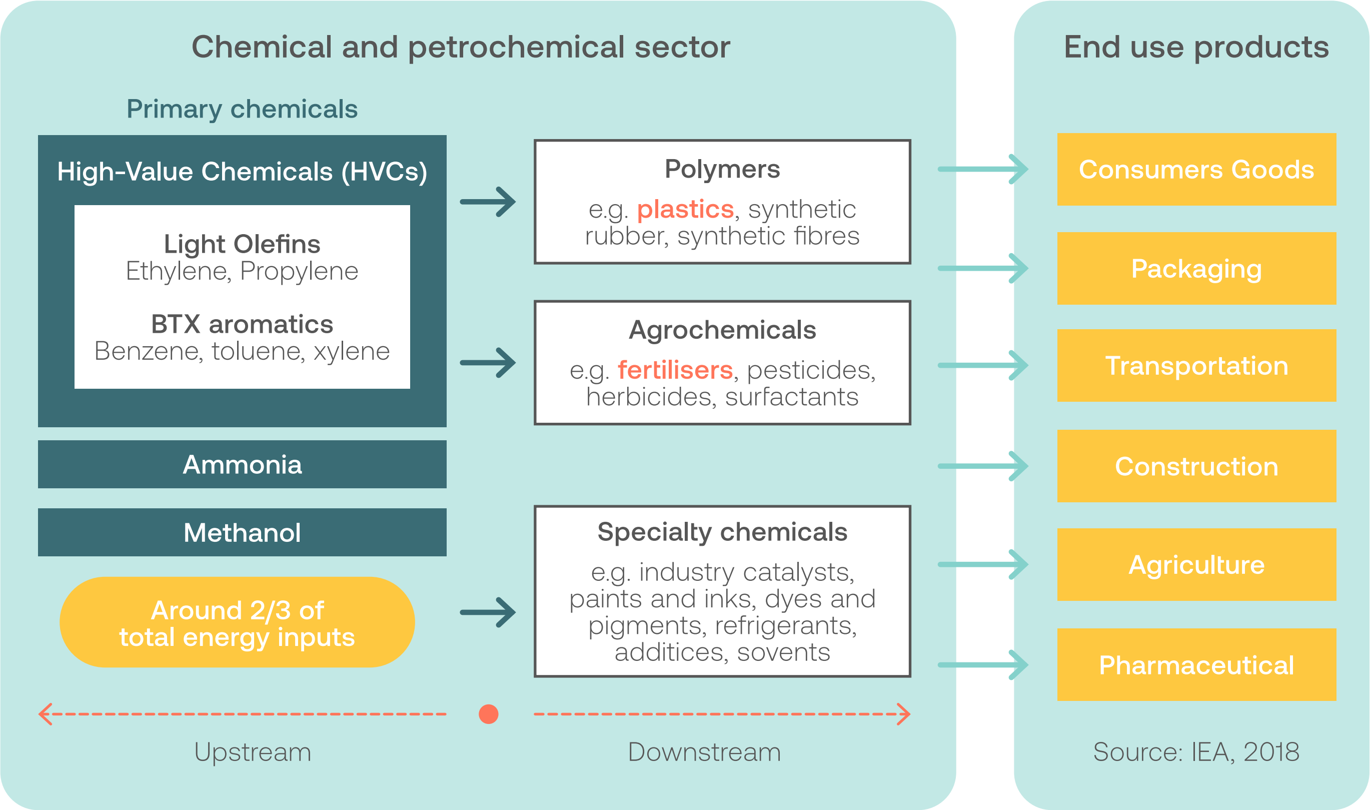
Introduction

What is the purpose of this briefing?

This briefing aims to provide investors with the information they need to confidently engage on hydrogen usage within the chemical industry.

It follows ShareAction's report "Slow Reactions: Chemical companies must transform in a low-carbon world",[ix] which outlines net zero pathways for primary chemicals (Figure 1) and the role hydrogen plays in production processes.

Figure 1: Overview of the seven primary chemicals in scope for this report (and their end products)



Source: IEA, 2018

The chemical sector is responsible for over 5.8 percent of global GHG emissions and needs to reach net zero emissions by 2050.[x] It is technically feasible and economically viable to fully decarbonise the production of chemicals by that date.[xi]

But making this transition successfully relies heavily on chemical producers transitioning away from fossil-based feedstocks to zero-emissions hydrogen.

Why is hydrogen relevant in chemical decarbonisation pathways?[xii]

About half of the emissions from primary chemicals stem from “feedstock”. Today, feedstock comes from fossil fuels such as natural gas.

Feedstock is an input into the chemical production process that is needed as a component of the chemical itself. As an analogy, timber could be burned to produce energy or heat – akin to using fossil fuels to produce energy –, but it could also be used as a construction material for buildings, akin to using fossil fuels as feedstock.

Emissions are released from fossil fuel feedstock during the chemical reaction and at the end of their lives (also known as Scope 3 emissions).

For example, let’s look at the process of creating methanol:

- First, natural gas feedstock is split into hydrogen and carbon in a process called steam reforming. Some of the carbon is released into the atmosphere at this stage, while most is needed as a building block for methanol later in the process.
- This hydrogen and carbon from the natural gas is then used in further processes, such as compression, to create methanol.
- Methanol is used to produce plastics and at the end of life. As plastic gets burned, the carbon within methanol/the plastic end-product is released into the atmosphere.

We use natural gas as a feedstock to get our building blocks, namely hydrogen and carbon, for our primary chemical (methanol). But this releases emissions during production and at the end of the product’s life (Scope 3).

Zero emission alternatives exist, are technically feasible, and increasingly economically viable.[xiii] The chemicals industry needs to transition to net zero by 2050. The good news is that there is a credible pathway to decarbonisation.

It involves replacing fossil fuel feedstock with hydrogen and carbon sources that are emission-neutral. Switching feedstock to renewable hydrogen is not just the most effective method of decarbonising primary chemical production, but it is also the most economically attractive.

Part I: An overview of hydrogen

Part I: An overview of hydrogen

What is hydrogen?

Hydrogen gas contains more energy per unit than fossil fuels. It can be used as a fuel and energy source in different industries, and even as storage within a renewable energy grid.[xiv] In the chemical industry, hydrogen is also an essential building block of many basic chemicals (read more in our report here).

Different types of hydrogen used in chemical processes:[xv][xvi]

Renewable hydrogen and **“Green hydrogen”** refer to hydrogen “produced by electrolysis, a process that uses an electrical current to split water into hydrogen and oxygen, using power generated from renewables.” Note that “[the green] label is sometimes misleadingly applied to hydrogen derived from grid electricity, which will only be as ‘renewable’ as the grid itself is”. This report refers to renewable hydrogen as hydrogen produced from 100 percent renewable energy sources, which makes it truly emissions-free. For this reason, the rest of this report will refer to the benefits of “renewable hydrogen” rather than “green hydrogen”.

Grey hydrogen refers to hydrogen produced by using natural gas as an input. The most common process for creating grey hydrogen is the steam reforming process, where steam is used to split natural gas into hydrogen and carbon components. Black and brown hydrogen stem from similar processes, but use coal and lignite, respectively, as inputs. Today, 99 percent of hydrogen production globally relies on gas and coal inputs for production.

“Low-carbon” or **“Blue hydrogen”** refer to hydrogen using natural gas as an input to production. Unlike with grey hydrogen, the carbon emitted during the production process is captured or otherwise mitigated. The two methods most frequently mentioned are carbon capture[1,xvii] or methane pyrolysis. In the case of methane pyrolysis, a high-heat chemical process is used to split natural gas into hydrogen and solid carbon instead of a CO2 gas, as in steam reforming.[xviii] This entirely omits the carbon capture process.

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[1] Carbon capture and storage (CCS) refers to technologies that capture CO2 from large point sources such as industrial processes or even directly from the air. The “captured CO2 is compressed and transported by pipeline, ship, rail or truck to be used in a range of applications or injected into deep geological formations (including depleted oil and gas reservoirs or saline formations) which trap the CO2 for permanent storage.”

How does blue hydrogen relate to chemical production processes?

Chemicals require hydrogen as an input in their production processes. Hydrogen is predominantly produced on-site by chemical companies in a steam reforming process (analogous to grey hydrogen), which is integrated into the whole production chain. A detailed explanation and illustration of this process can be found in our report here.

Consequently, CCS is relevant to the chemical industry because existing steam reforming processes can be retrofitted with carbon capture technology. This would move chemical processes from grey hydrogen to blue hydrogen processes. This also holds true for new plants already designed with CCS technology in place.

Hence, CCS and blue hydrogen can be seen as analogous in the chemical industry.

The alternative is to replace fossil fuels in chemical production. Companies can buy or produce their own renewable hydrogen and adapt their production processes, as outlined in our report here. This alternative results in zero emissions, while CCS integration does not. It would also be more economically viable in a net zero world.

While more types of hydrogen exist, they are not relevant for this report so they have not been mentioned.

Renewable hydrogen priority sectors

There is widespread demand for hydrogen, but there are only a few priority applications – including in the chemical industry

Most sectors claim that they need low-emissions hydrogen to decarbonise.

But renewable hydrogen supply should be prioritised for sectors where no other alternatives exist.

Some sectors will have to rely on carbon-neutral hydrogen to decarbonise. The industrial sectors alone will require 300 terawatt-hours of renewable hydrogen per year by 2050.[xix] However, today only about 0.1 percent of hydrogen comes from renewable sources.[xx]

Renewable hydrogen supply will remain scarce for as long as energy infrastructure and financial resources lag behind demand.[xxi] Renewable hydrogen is therefore a limited resource and supply needs to be prioritised where it is needed most.

This means that renewable hydrogen supply should also be restricted for other sectors, where better alternatives exist.

Renewable hydrogen will always be a less efficient energy source than using renewable electricity directly. About 20-40 percent of energy is lost by converting renewable power into renewable hydrogen using electrolysis.[xxii] Where it's possible for direct electrification to replace fossil fuel usage, this should generally be preferred to renewable hydrogen. This will reduce unnecessary demand for new renewable energy and reduce costs because this energy is used directly and does not undergo further processes that add costs. For example, producing renewable hydrogen for heating with boilers requires six times more renewable energy and will be six times more expensive than using a heat pump.[xxiii] A heat pump uses renewable electricity directly to produce heat instead of combusting hydrogen in a boiler.

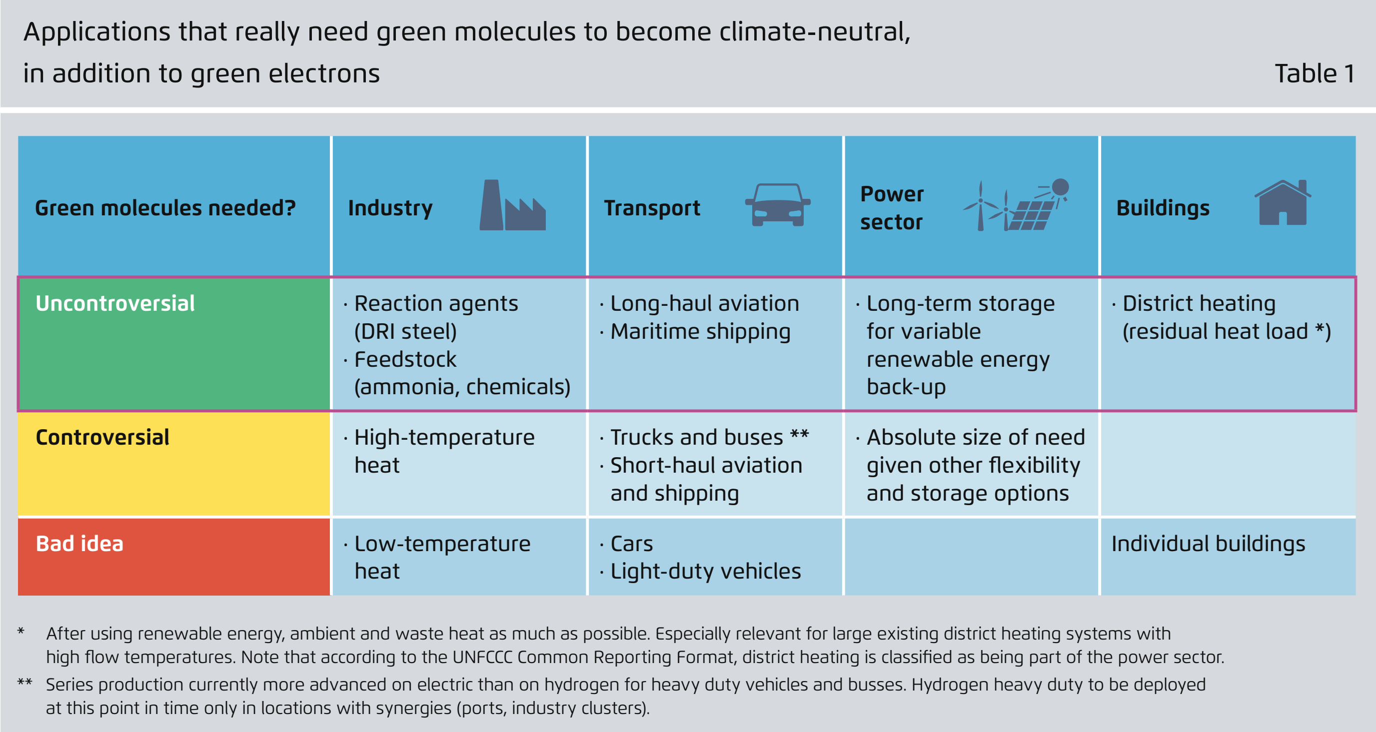
Renewable hydrogen use should be avoided as an energy and fuel source where direct electrification is possible. Instead, renewable hydrogen should only be used where no other zero emission alternatives exist, such as in the chemicals industry. For these applications, supply should be prioritised.

As laid out in ShareAction's report "Slow Reactions: Chemical companies must transform in a low-carbon world",[xxiv] there is no real alternative to renewable hydrogen that can replace existing feedstock in the chemical industry. This means the chemical industry is a top priority for renewable hydrogen supply and use.

What are the other priority sectors?

Research by Agora Energiewende breaks down all the priority sectors for hydrogen usage (Figure 2),[xxv] and where it would be a controversial and bad idea to use hydrogen.

Figure 2: Hierarchy of hydrogen prioritisation across industry by Agora Energiewende



Applications that really need green molecules to become climate-neutral, in addition to green electrons

Table 1

Green molecules needed?	Industry	Transport	Power sector	Buildings
Uncontroversial	· Reaction agents (DRI steel) · Feedstock (ammonia, chemicals)	· Long-haul aviation · Maritime shipping	· Long-term storage for variable renewable energy back-up	· District heating (residual heat load *)
Controversial	· High-temperature heat	· Trucks and buses ** · Short-haul aviation and shipping	· Absolute size of need given other flexibility and storage options	
Bad idea	· Low-temperature heat	· Cars · Light-duty vehicles		Individual buildings

* After using renewable energy, ambient and waste heat as much as possible. Especially relevant for large existing district heating systems with high flow temperatures. Note that according to the UNFCCC Common Reporting Format, district heating is classified as being part of the power sector.

** Series production currently more advanced on electric than on hydrogen for heavy duty vehicles and busses. Hydrogen heavy duty to be deployed at this point in time only in locations with synergies (ports, industry clusters).

Source: Agora Energiewende, 2021

The cost and emissions profiles of hydrogen

Regulatory support in the EU and Germany indicates accelerating supplies of renewable hydrogen

The political support for hydrogen helps shape our understanding of cost pathways and applications over time. Commitments made by governments so far give us an idea of the potential scale of the hydrogen economy and the types of hydrogen being prioritised.

The European Union (EU) and the United Kingdom (UK), as well as other key countries in Europe, such as Germany, have released policies to support the development of renewable and low-carbon hydrogen.

While Germany officially recognises that only renewable hydrogen can be sustainable,[xxvi] the UK's hydrogen strategy remains agnostic between renewable and blue hydrogen.[xxvii] The EU's strategy focuses on renewable hydrogen but leaves the door open for blue hydrogen to be used, at least for now.[xxviii]

The ambitions and financial support given to renewable hydrogen also varies, as key targets from different strategies show.

EU targets:[xxix]

- 2020 to 2024: At least six gigawatts of renewable hydrogen capacity installed.
- By 2030: Forty gigawatts of renewable hydrogen capacity installed.
- By 2050: Large-scale deployment of renewable hydrogen in hard-to-abate sectors, such as chemicals and steel.

UK targets:[xxx]

- By 2025: One gigawatt of low-carbon hydrogen capacity installed.
- By 2030: Five gigawatts of low-carbon hydrogen capacity installed.
- £240 million pound net-zero hydrogen support fund launched.

Germany targets:[xxxi]

- By 2030: Five gigawatts of renewable hydrogen capacity installed.
- By 2040: Ten gigawatts of renewable hydrogen capacity installed.
- €7 billion will be invested in new businesses and research.

The EU and Germany's targets indicate a fast transition to renewable hydrogen that will likely make blue hydrogen alternatives unattractive in the near future.

Sources of emissions from hydrogen production

Estimates of hydrogen emission profiles are heavily dependent on assumptions that pose significant risks to our climate and to investors

There are numerous studies estimating the emissions profile of different types of hydrogen. They all vary in their conclusions. This is largely due to different modelling choices and assumptions that are made in calculations, depending on whether all sources of emissions are incorporated correctly. Getting it right is critical for both our environment and for investors.

We know that investments in hydrogen have a lifecycle of about 25 years.[xxxii]

This means that the risk of locking in emissions in until 2050 is high, depending on the choices we make today. Consequently, the risk of stranded assets is also high and would negatively affect both companies and their investors.

Breaking down hydrogen emission sources

1 Upstream emissions

Methane shouldn't be ignored

All fossil-based hydrogen, including grey and blue hydrogen, creates emissions upstream during fossil fuel extraction and transportation. These emissions significantly contribute to global warming.

Fossil fuel operations are responsible for nearly one-third of all global methane emissions.[xxxiii] Methane is the second biggest contributor to global warming, having contributed 0.5C to date, compared to 0.8C by CO2.[xxxiv] Because it only has a lifetime of about ten years in our atmosphere, reducing methane emissions has an almost immediate effect in reducing global temperatures.[xxxv]

A 50 percent cut in methane emissions globally is needed to stay on track with 1.5C pathways.[xxxvi] However, methane emissions by major oil and gas companies have recently been revealed by the International Energy Agency (IEA) to be 70 percent higher than official figures.[xxxvii]

Consequently, upstream methane emissions from grey and blue hydrogen should not be ignored when assessing their 1.5C alignment.

Renewable hydrogen, in comparison, does not involve any upstream oil and gas emissions.

2 Carbon capture rates

Carbon capture is limited

Only two blue hydrogen plants are in operation as of today, in Canada and the United States.[2] Carbon capture data from these plants shows capture rates between 58 to 90 percent.[xxxviii] In addition, the carbon captured from fossil fuels used in the process (flue gases) to generate heat and steam, are generally lower with 55 to 72 percent of carbon captured.[xxxix]

In the context of the chemical industry, if fossil fuels were to be used for hydrogen production, it is likely that carbon capture would also have to be extended to emissions caused from fossil-fuel use to run chemical production processes, such as steam and heat.

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[2] One is operated by Shell in Alberta, Canada, and the other is operated by Air Products in Texas, USA.

Carbon capture rates below 100 percent, including related processes, mean that blue hydrogen usage is not aligned with net zero pathways.

Renewable hydrogen does not rely on carbon capture technology, which avoids these additional emissions.

3 Downstream emissions

A small amount of captured carbon is leaked during transport and storage

Storing captured CO2 is feasible, but approximately 2 percent of it is leaked.[xl]

CO2 can be stored in oil and gas fields, with layers of rock preventing CO2 from returning to the atmosphere.

To quote a study by researchers at the University of Oxford:

> "Firstly, you're already storing it where oil and gas has sat for millions of years undisturbed. Secondly, the CO2 dissolves in the subterranean salt water: it will stay there and even sink, but not rise. The risks of pressure, temperature and chemical changes – deep underground – allowing the CO2 to be released again are low."

Coupled with capture rates below 90 percent; at least 12 percent to nearly 50 percent of all carbon might not be captured and stored permanently.

This means that blue hydrogen, which relies on carbon capture and storage, is not a zero emissions technology.

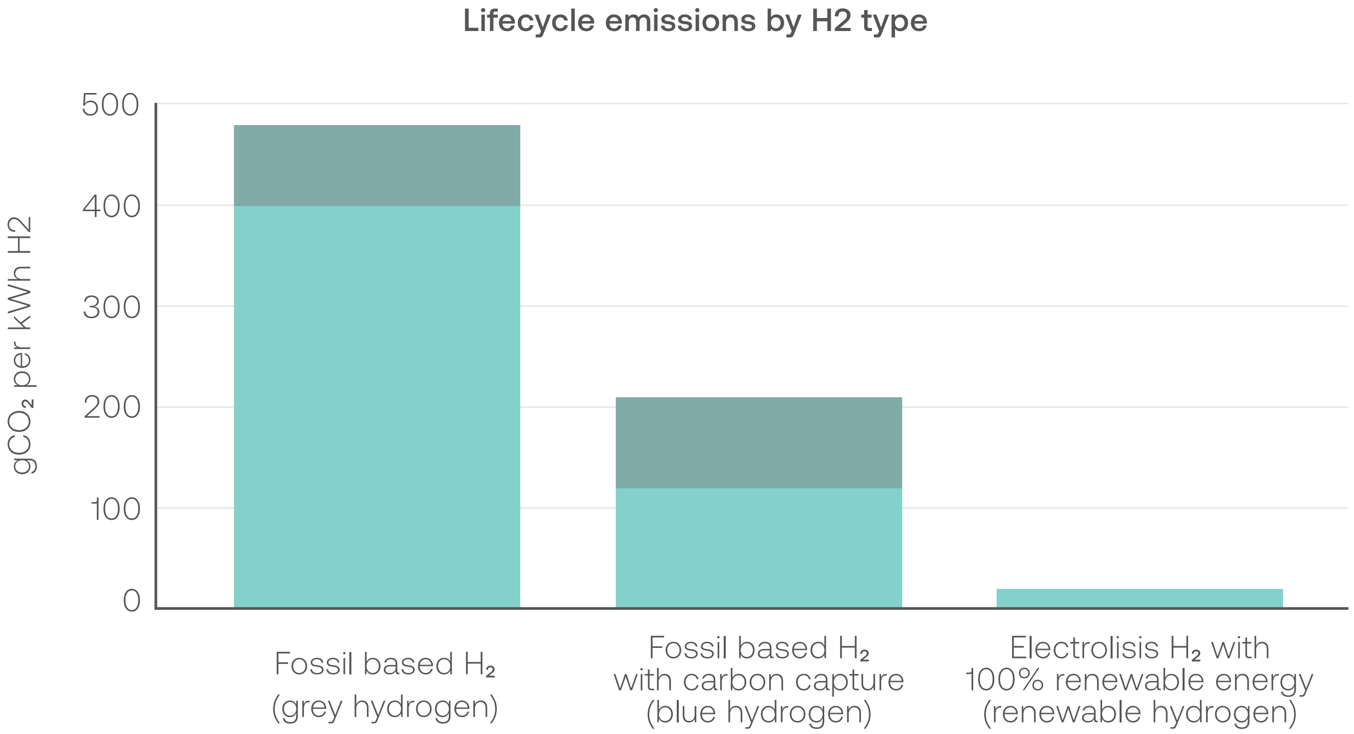
Renewable hydrogen does not face any of these risks of creating further emissions.

Renewable hydrogen will be cheaper and lower in emissions than blue hydrogen

Emissions comparison: Renewable hydrogen comes out on top

Taking all lifecycle emissions into consideration, studies show that renewable hydrogen has the lowest emissions profile by far. In fact, it is the only hydrogen type that creates near zero emissions. Blue hydrogen, on the other hand, has an emissions profile about 200 times higher than renewable hydrogen (Figure 3).[xli]

Figure 3: Blue hydrogen has emissions ~200 times higher than renewable hydrogen



Source: Agora Energiewende, 2021

Cost comparison: Renewable hydrogen undercuts the cost of fossil-based hydrogen from 2030 to 2050

Renewable hydrogen isn’t just the only zero emissions hydrogen option, but it will also become the cheapest option.

In fact, as the current gas crisis (March 2022) shows, dependent on the gas price, renewable hydrogen is already cheaper than grey hydrogen today. In the EMEA region, the levelised[3,xlii] cost of grey hydrogen has reached $6.71/kg, compared to $4.84-6.68/kg for renewable hydrogen.[xliii] This heralds a new trend that even without a significant increase in gas prices, renewable hydrogen prices will start to undercut those of grey and blue hydrogen before 2030,[xliv] according to Bloomberg New Energy Finance (BNEF) (Figure 4). Renewable hydrogen will become more cost effective because it will benefit from falling electrolyser and renewable energy costs.

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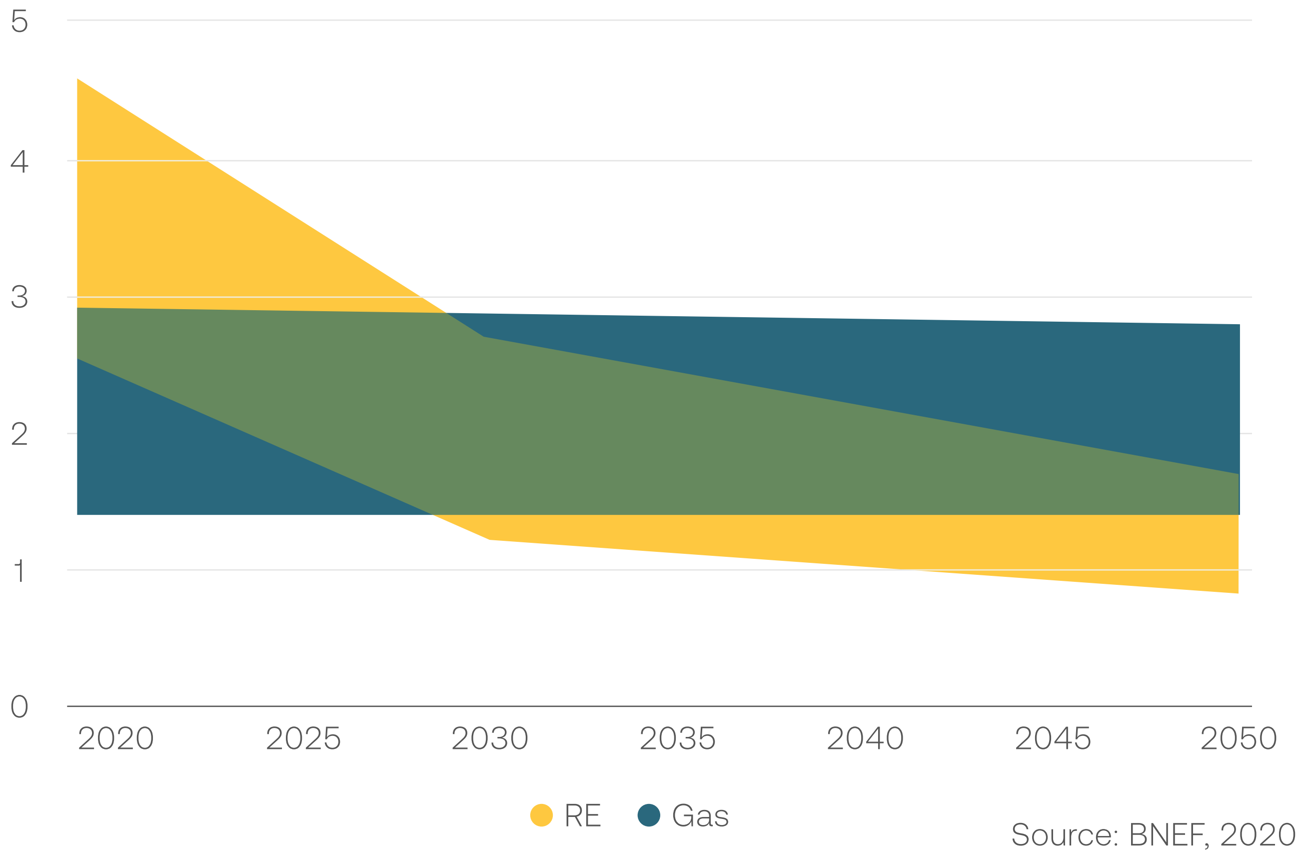
[3] The levelized cost of energy (LCOE), also referred to as the levelized cost of electricity or the levelized energy cost (LEC), is a measurement used to assess and compare alternative methods of energy production. The LCOE of an energy-generating asset can be thought of as the average total cost of building and operating the asset per unit of total electricity generated over an assumed lifetime.

Figure 4: BNEF expects renewable hydrogen to be cheaper than hydrogen produced using gas before 2030



Source: BNEF, 2020

Renewable hydrogen is the only zero emissions option for decarbonisation and will become cheaper than its fossil fuel counterparts.

This means:

1. Renewable hydrogen offers the best climate and commercial opportunities over the medium-to-long term.
2. Renewable hydrogen should be prioritised over investments in blue hydrogen, because:
    - Investments in fossil-based alternatives, such as blue hydrogen, will be about 200 times higher in emissions; including often-ignored upstream methane.
    - These emissions will be locked in for the lifetime of the asset (about 25 years), creating higher climate risk and higher risk of stranded assets.
    - Blue hydrogen investments will be less economical due to higher costs compared to renewable hydrogen over the longer-term.
3. Companies have about eight years (2022 to pre-2030) to bridge incentive gaps for renewable hydrogen and win policy support to do so.

Part II: Chemical sector deep-dive

Part II: Chemical sector deep-dive

Hydrogen in chemical production

Hydrogen is used by chemical companies to produce different chemicals. The following sections analyse how hydrogen is used in different chemical production processes.

All hydrogen and production processes need to switch to renewable hydrogen by 2050 to be aligned with 1.5C pathways for the chemicals sector. The switch to renewable hydrogen is also the most cost-effective pathway to carbon-neutrality for chemical companies.

This goal applies to all companies producing chemicals. Figure 5 breaks down key European companies by the chemical products in their portfolio, as a starting point for investor engagement.

Figure 5: List of European chemical companies by chemicals produced

Company Name	Country	Ammonia	Methanol	Light olefins	BTX	Plastics/ polymers	Fertiliser
BASF SE	Germany		X	X	X	X	
Covestro AG	Germany			X	X	X	
Croda International plc	UK					X	X
EMS Chemie Holdings AG	Switzerland			X	X	X	
Evonik Industries AG	Germany			X	X	X	
Koninklijke DSM N.V.	Netherlands					X	
L'Air Liquide S.A.	France	X	X	X	X		
Lanxess AG	Germany	X		X	X	X	
LyondellBasell	Netherlands		X	X	X	X	
Givaudan SA	Switzerland						
Solvay SA	Belgium	X	X	X	X	X	X
Yara International ASA	Norway	X					X
Symrise AG	Germany		X	X	X		

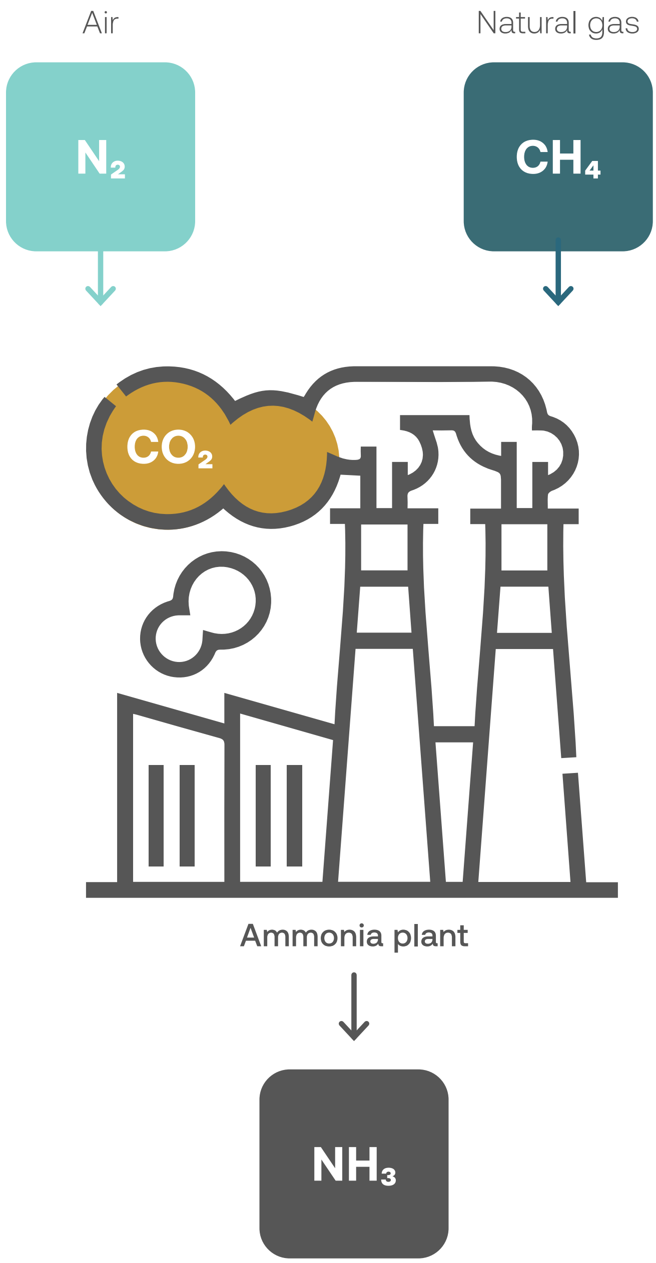
Ammonia

The role of hydrogen in ammonia production[xlv]

Ammonia requires nitrogen and hydrogen as inputs in its production process. These need to become net zero in emissions.

Today, the hydrogen component comes from natural gas, which is split into hydrogen and carbon during steam reforming. Ammonia production therefore uses grey hydrogen as an input. Carbon emissions are a waste product from the process.

Figure 6: The ammonia production process today



Source: fertilisers europe, 2020

This carbon is either emitted into the atmosphere or re-used for other purposes, such as further conversions from ammonia to urea fertilisers. Carbon that is repurposed in this way is also released into the atmosphere at the end of its life. For example, when urea fertiliser is applied to the field.

Pathways compatible with the Paris Climate Agreement require a fast decline in emissions to reach net zero by 2050. This means ammonia needs to eliminate all its emissions from production.

Since carbon is not needed for ammonia production, carbon emissions can be completely avoided if producers choose to. For that to happen, chemical companies need to replace fossil-fuel feedstock with an emission-free alternative that can provide the required hydrogen component.

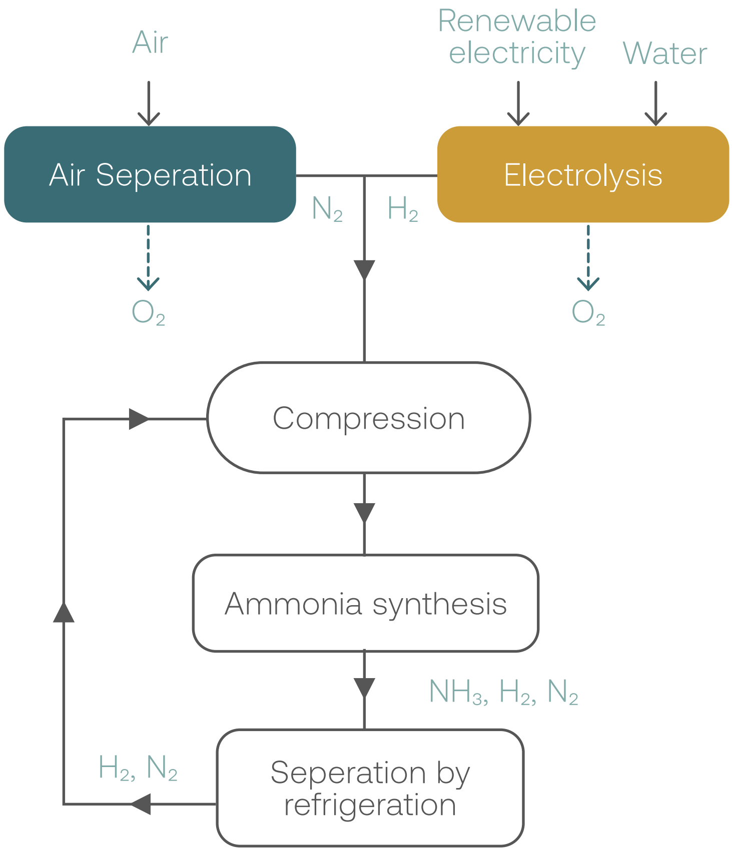
We can replace fossil fuels with net zero alternatives[xlvi]

With some adjustments to the process, ammonia production can be made emissions-free (Figure 7).

Replacing fossil fuels with renewable hydrogen completely decarbonises feedstock requirements and omits the carbon emission waste stream during production.

When coupled with electrified processes that run off 100 percent renewable energy, ammonia production would be aligned with net zero pathways by 2050.

Figure 7: Net zero ammonia production



Source: DECHEMA, 2017

Emissions comparison: Renewable hydrogen comes out on top

1 About half of the emissions from ammonia production come from grey hydrogen today[xlvii] and will only reach zero with renewable hydrogen

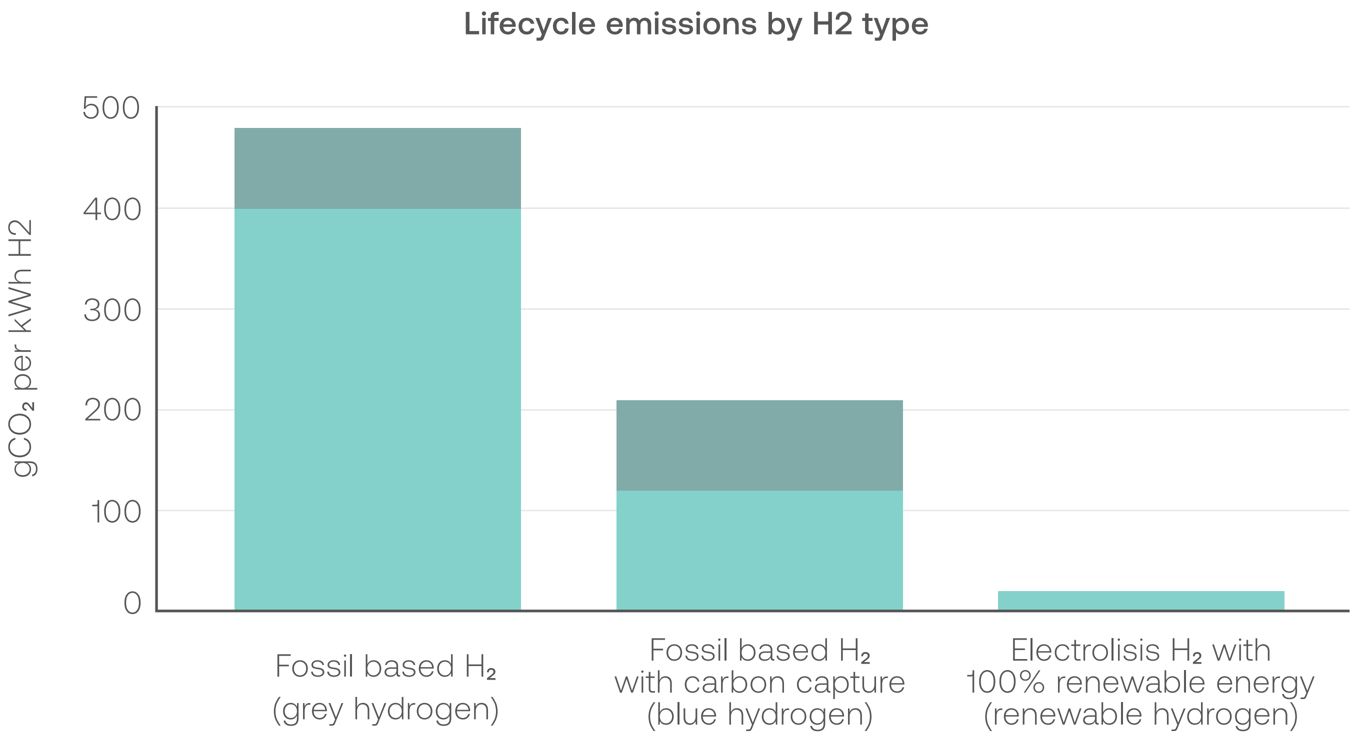
There are two ways to reduce these emissions:

- Using renewable hydrogen to replace fossil feedstock.
- Installing carbon capture equipment to capture the “waste” carbon during the hydrogen reforming process.

The latter is equivalent to using blue hydrogen.

As mentioned earlier, blue hydrogen’s emissions are 200 times higher than those of renewable hydrogen and are not compatible with zero emissions pathways. Simultaneously, renewable hydrogen is the only near zero emissions feedstock.

Figure 8: Hydrogen emissions comparison by type



Source: Agora Energiewende, 2021

2 Other production-related emissions come from process energy needs, which are at risk of being locked-in through blue hydrogen investments

Fossil fuel usage for the chemical production process (e.g., heat and compression) make up the other half of production-related emissions – the first half stemming from feedstock. They can be avoided through full electrification of processes and using 100 percent renewable energy.

Choosing blue hydrogen/carbon capture pathways for ammonia production will likely mean locking in fossil use for processes, too, as the hydrogen production process is integrated into the whole production chain. Incentives to make changes to the entire production process would be low if fossil fuels are already in use for hydrogen production.

This will create higher emissions compared to full electrification of the process using 100 percent renewable energy – a process that is compatible with using renewable hydrogen.

Renewable hydrogen is the only net-zero aligned option. Carbon capture/blue hydrogen emits more carbon and risks locking in emissions from fossil fuels in ammonia production.

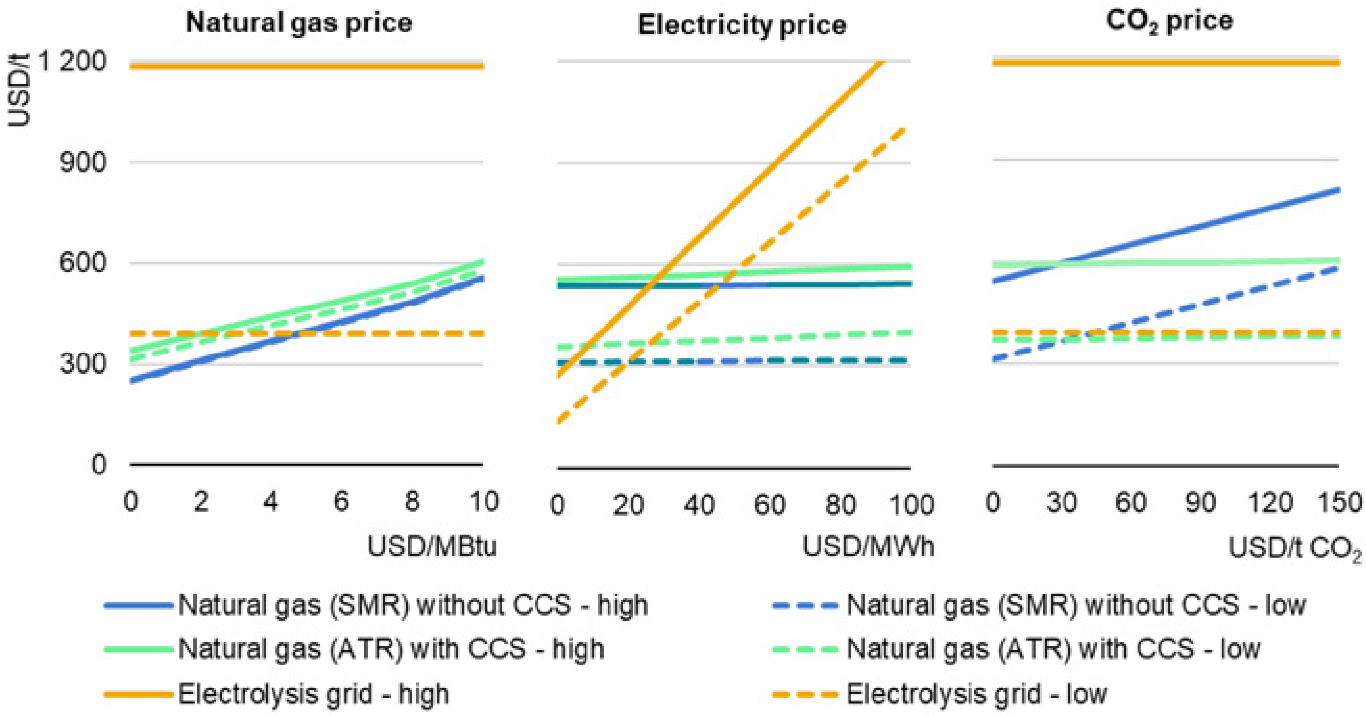
Cost comparison: Renewable hydrogen conditions make it cost-competitive

The cost of renewable hydrogen will be lower than the carbon capture/blue hydrogen route for ammonia production.

According to research by the IEA on ammonia production[xlviii] (Figure 9), once electrolyser costs fall by 60 percent, renewable hydrogen will be cheaper when electricity prices are at or below $40 per megawatt hour. Research by chemical engineers at DECHEMA also supports the premise that zero emissions chemical production with renewable hydrogen is economically viable at this price.[xlix]

If the price of natural gas increases above $10 Mbtu, even higher electricity costs would not undermine the competitiveness of renewable hydrogen.

Figure 9: Levelised cost of ammonia production varying according to gas, electricity, and CO2 prices



Source: IEA, 2021

The cost of electrolysers has already fallen 60 percent over the last decade and is expected to halve again by 2030[l]. This is well within the IEA's assumptions.

Recent government targets such as those set by Germany will fast-track key local grids in Europe to be 100 percent renewable by 2035.[li] Due to the significantly lower costs of renewables,[lii] procurement prices for chemical producers will decrease.

Renewable hydrogen will start to undercut the cost of fossil-based alternatives in around 2030. This will make renewable hydrogen the most economically attractive and lowest emission pathway for ammonia production.

Methanol & High-value chemicals (HVC)

The role of hydrogen in methanol and HVC production[liii]

Methanol requires hydrogen and carbon as inputs for its production process. These need to reach net zero in emissions.

The current production process uses fossil fuels such as natural gas for steam reforming, which splits feedstocks into hydrogen and carbon. The process is analogous to grey hydrogen production.

The hydrogen and carbon are then used in further production steps to create methanol.

Emissions created during this process include:

- "Waste carbon": Not all carbon released at the grey hydrogen production stage is needed for further production steps. Some of the carbon is released into the atmosphere.
- Scope 3: The carbon used to make methanol will also be contained in methanol-derived end products. Methanol is mainly used to make other chemicals, such as formaldehyde (accounting for ~40 percent of total usage), which forms the basis of a variety of plastics, paints, and textiles.[liv] At the end of its life, the carbon within methanol/the end-product is released back into the atmosphere. For example, when a piece of methanol-based plastic is burned upon disposal.

Paris-agreement compatible pathways require a fast decline in emissions and net zero by 2050. This means methanol production needs to eliminate its direct (during production) and indirect (end-of-life) emissions.

It is vital that companies switch to an alternative to grey hydrogen, with a low-carbon hydrogen and circular carbon replacement.

High-value chemicals[lv]

The term “high-value chemicals” refers to BTX chemicals (benzene, toluene, xylene). These are also known as “aromatics”, and ethylene and propylene are also known as “olefins”. They are currently produced using naphtha – a fossil fuel.

To continue production on a 1.5C-aligned pathway, plants will require green methanol to be used as an input instead of naphtha. Green methanol refers to emission-neutral methanol that has been created with renewable hydrogen and electrified production processes that use 100 percent renewable energy.

More information on green methanol can be found here: “Slow Reactions: Chemical companies must transform in a low-carbon world”.

Consequently, this section on methanol production is relevant to high-value chemicals by extension.

We can replace fossil fuels with net zero alternatives[lvi]

Renewable hydrogen can replace the natural gas feedstock and steam reforming process involved in creating methanol – just as it can with ammonia.

However, by replacing natural gas with renewable hydrogen, carbon is still needed to form methanol. With natural gas this would be synthesised during steam reforming.

Hence, CO2 needs to be added to the process. For this to be carbon neutral, the CO2 used must have been captured elsewhere, and needs to be neutral on a lifecycle basis. This way, methanol production can become a net user rather than producer of CO2 in a carbon neutral future.
When coupled with electrified processes that run off 100 percent renewable energy, methanol production would be aligned with net zero pathways by 2050.

Emissions comparison: Renewable hydrogen comes out on top

1 Renewable hydrogen eliminates emissions from methanol production that come from fossil fuel usage for hydrogen and process energy needs

There are two ways to tackle emissions during production:

1. Using renewable hydrogen to replace fossil feedstock.
2. Install carbon capture equipment to capture the carbon during the hydrogen reforming process that is not turned into methanol.

The latter option is equivalent to using blue hydrogen. This is not the optimal choice for methanol producers because:

A As with ammonia production, blue hydrogen's emissions are 200 times higher than those of renewable hydrogen and are not compatible with zero emissions pathways. Simultaneously, renewable hydrogen is the only near zero emissions feedstock.

B Opting for blue hydrogen increases the risk of locking-in fossil fuels for the whole production process, such as for heat and steam. This causes more overall emissions compared to renewable hydrogen pathways.

Consequently, renewable hydrogen is aligned with 1.5C pathways, whereas blue hydrogen is not, because it causes additional emissions.

2 Methanol also has significant Scope 3 emissions, which blue hydrogen doesn't resolve

Using new carbon sources such as fossil fuels as an input into methanol production embeds additional carbon into the chemical. This carbon will be released at the end of life for methanol-derived products. This limits the scope for grey and blue hydrogen.

When blue hydrogen is used to produce methanol, only the excess carbon that is not needed for the methanol chemical structure is captured. In the case of grey hydrogen, no carbon is captured at all.

Grey and blue hydrogen use natural gas and both the hydrogen and carbon components from that natural gas will be embedded in the methanol end-product. This is additional carbon that will be released into the atmosphere when, for example, a piece of methanol-based plastic is burned at the end of its life. In other words, the emissions coming from the natural gas feedstock will eventually be released just the same as burning natural gas in the first place.

Hence, blue hydrogen does not eliminate Scope 3 emissions but causes them. These emissions make up around 50 percent of methanol's overall emissions.

To eliminate downstream Scope 3 emissions, the carbon input for methanol production must be circular. In practice, that means carbon must be captured elsewhere first. When combined with renewable hydrogen, both the hydrogen and captured carbon components do not cause any additional emissions and are compatible with net zero pathways.

Renewable hydrogen is the only net zero aligned option for methanol and HVC production. Carbon capture/blue hydrogen emits more carbon, risks locking in emissions from fossil fuels along the whole production process, and does not tackle Scope 3 emissions.

Cost comparison: Renewable hydrogen is cost-competitive

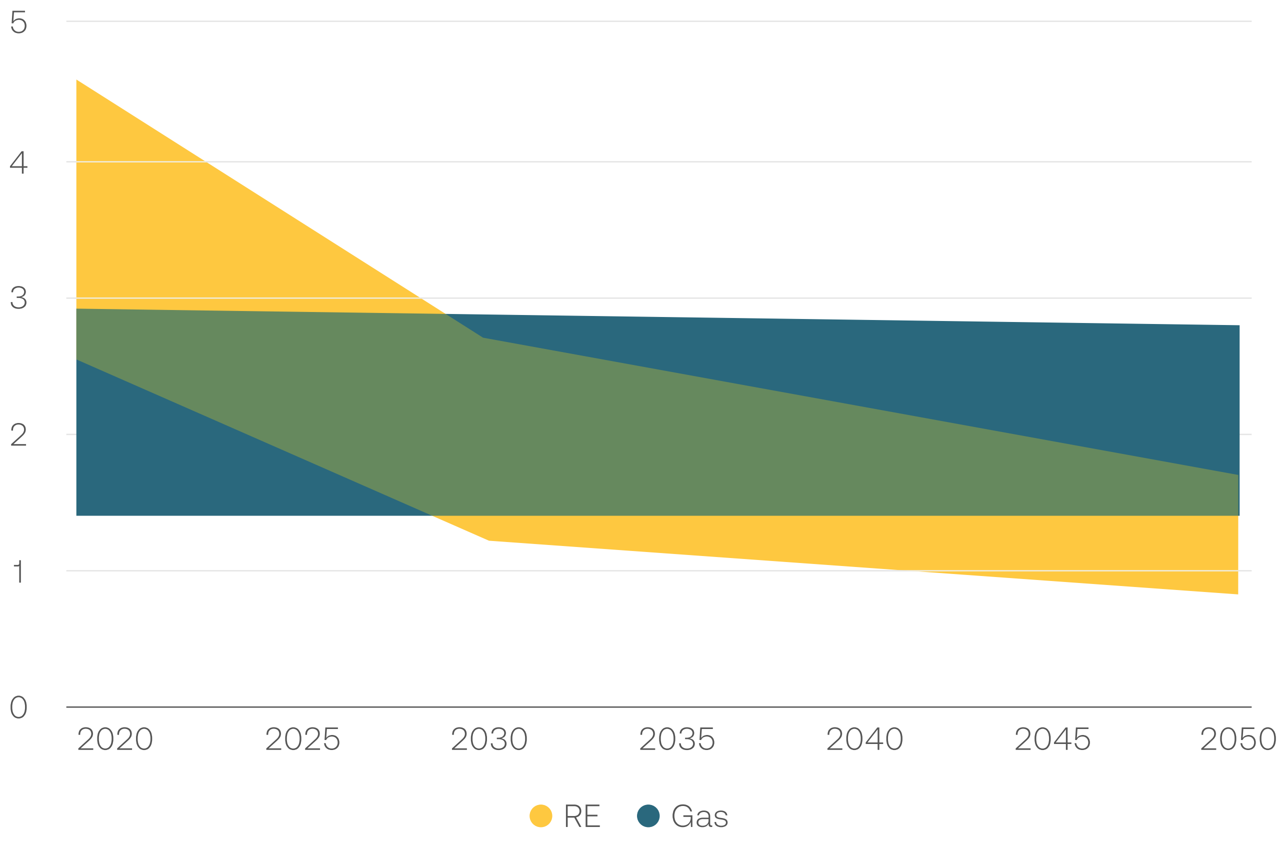
No similar assessment to ammonia by the IEA exists yet for methanol.

However, research by DECHEMA shows that methanol production using renewable hydrogen should become economically viable at energy prices of €0.04 per kilowatt hour in Europe.[lvii] This is the same as for ammonia under the IEA's scenario.

Since the production process for hydrogen does not differ much whether the end product is methanol or ammonia, we can likely infer a similar analysis for methanol as for ammonia by the IEA. Renewable hydrogen will be cheaper than blue hydrogen for methanol production in the medium-to-long-term. These expected costs are also underlined by the general cost trajectory of blue and renewable hydrogen globally.

This is also underlined by the general cost trajectory of blue and renewable hydrogen globally (Figure 10).

Figure 10: BNEF expects renewable hydrogen to be cheaper than hydrogen from gas before 2030



Source: BNEF, 2020

Renewable hydrogen will start to undercut the cost of fossil-based alternatives around 2030. This will make renewable hydrogen the most economically attractive, as well as the lowest emission pathway for methanol production.

Comparison with the IEA scenario

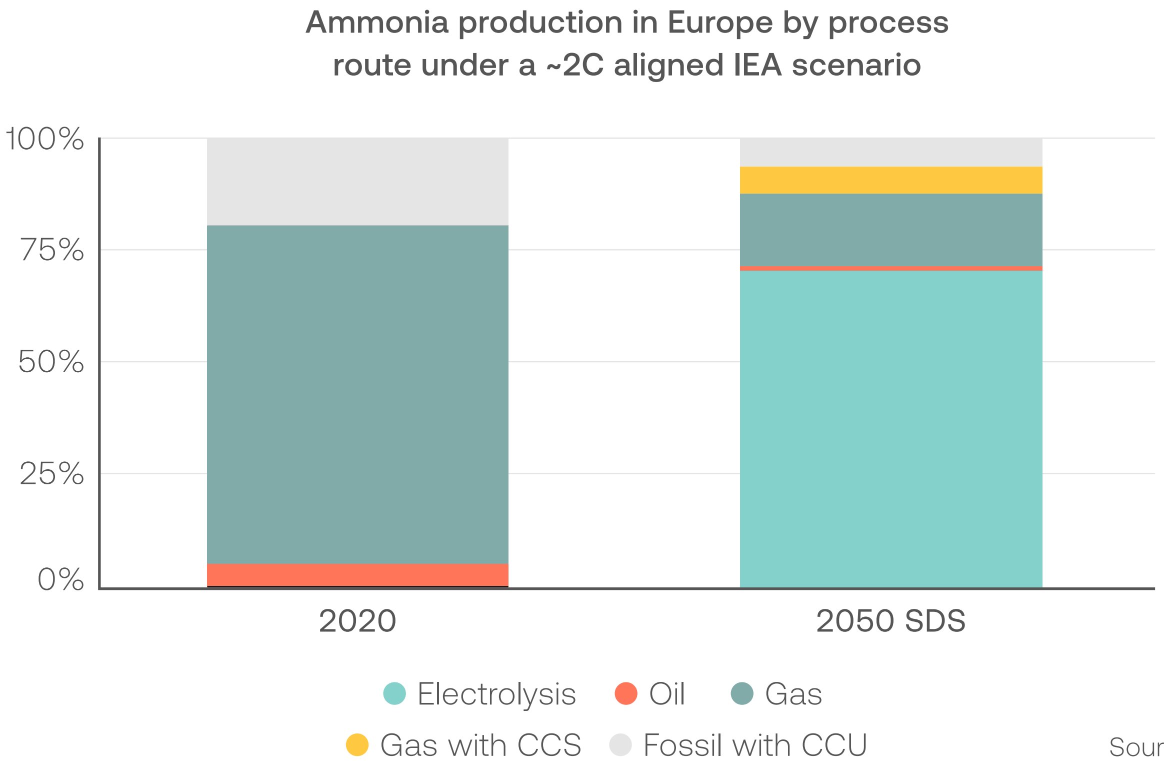
The IEA's own report acknowledges that, with greater investment in already proven renewable energy technologies, it wouldn't be necessary to expand fossil fuel-based CCS.

It also highlights that depending on the region, renewable hydrogen will be a preferred option:

> "CCUS-equipped conventional routes and pyrolysis technologies are most competitive in regions with access to low-cost natural gas, while electrolysis is the favoured option in regions where the deployment of CCUS is impeded by a lack of infrastructure or public acceptance."

In fact, for ammonia production in Europe, the IEA expects 70 percent of production to be based on renewable hydrogen by 2050 (Figure 11), compared to below 25 percent in other regions, such as the Middle East.[lviii] This is under the IEA's less ambitious Sustainable Development Scenario. This means it is aligned with 2C but not yet 1.5C pathways.[lix] We would expect a revision upwards to nearly 100 percent renewable hydrogen under a 1.5C aligned assessment.

Figure 11: Ammonia production by route in Europe in 2050 according to the IEA



Source: IEA, 2021

As such, our assessment is not at odds with the IEA's. It does extend and supplement it under 1.5C considerations.

The European chemical industry is now approaching a critical decision point on which route to choose – renewable hydrogen or CCS. As such, the window to avoid locking in higher emissions and higher risk assets is quickly closing.

This finding was echoed by the outgoing chairman of the UK Hydrogen and Fuel Cell Association, Chris Jackson. Resigning from his role, Jackson said:

> "I would be betraying future generations by remaining silent on that fact that blue hydrogen is at best an expensive distraction, and at worst a lock-in for continued fossil fuel use."

We know blue hydrogen/carbon capture pathways will lead to higher emissions and costs than renewable hydrogen pathways.

That is why we encourage investors in European chemical companies to confidently engage and push for renewable options in the industry's transition choices.

Key decision points for chemical producers

The lifecycle of hydrogen investments is about 25 years and the lifetime of chemical production plants is around 50 years.[lx]

Emissions from chemical production need to decline by 50 percent by 2030 and reach net zero by 2050, according to IPCC 1.5C pathways.

This means that:

By 2025:

- All new plants built by 2025 need to be based on renewable hydrogen.
- All retrofits from 2025 onwards need to be based on renewable hydrogen.

Up until 2050:

- All existing plants using fossil-based hydrogen need to be retrofitted for renewable hydrogen usage by 2050 at the latest.
- Companies need to show how non-retrofitted plants up until 2050 will still be aligned with intermediate emission reduction targets, such as a 50 percent reduction by 2030 across the company.

High-value chemicals

For high-value-chemicals, renewable hydrogen pathways refer to processes that use methanol derived from renewable hydrogen as an input instead of naphtha – a fossil fuel. This also requires a switch from current production processes to methanol-to-olefin or methanol-to-aromatics production. For more details, please see our last report.

As highlighted in ShareAction's last report, companies need to decarbonise their energy consumption alongside their feedstock. This means that:

From today:

- All new plants need to be entirely electrified and run off 100 percent renewable energy. This is because plant lifetimes span to approximately 50 years and need to be zero emissions in production by 2050 – in 25 years.

Up until 2050:

- All existing plants need to be entirely electrified and run off 100 percent renewable energy by 2050.

Myth buster: Could blue hydrogen be used as an intermediate solution?

The average lifespan of hydrogen investments is about 25 years.

Blue hydrogen does not fully eliminate all emissions. It is therefore not a zero emissions solution to feedstock in the chemical industry. This means there is limited scope for carbon capture/blue hydrogen investments in the chemical industry under 1.5C pathways by 2050.

Consequently, chemical companies face a very short time window on making decisions around feedstock solutions to reach net zero by 2050.

This means there is nearly no window left for carbon capture investments today; as new plants and retrofits with carbon capture technology/blue hydrogen feedstock after 2025 would emit additional emissions post-2050.

Further, as renewable hydrogen costs fall and gas prices rise, carbon capture/blue hydrogen investments face a high risk of becoming stranded assets before the end of their lifetime.

As all avoidable emissions must reach zero by 2050, carbon capture/blue hydrogen for chemical production in 2025 and beyond would not be aligned with 1.5C pathways. Consequently, all new plants and retrofits from 2025 and after need to be based on renewable hydrogen pathways.

This realistically means that chemical companies have no scope for carbon capture/ blue hydrogen investments but need to focus on renewable hydrogen pathways.

Part III: Investor engagement guide

Part III: Investor engagement guide

Chemical company-specific engagement questions

As an investor with holdings in the chemical sector, here are some questions to ask and objectives to track to assess a company's transition plans and hold them to account.

1. Will [company name] commit to emissions-free (for ammonia producers)/emissions-neutral (for methanol/high-value chemicals producers) feedstock by 2050 across all operations?

2. How does [company name] plan to transition to emissions-free/emissions-neutral feedstock by 2050?

Tracking outcome:

The company has a credible strategy for emissions-neutral feedstock by 2050.

This means that:

- i By 2025:
    - All new plants built by 2025 need to be based on renewable hydrogen.
    - All retrofits from 2025 onwards need to be based on renewable hydrogen.
- ii Up until 2050:
    - All existing plants using fossil-based hydrogen need to be retrofitted for renewable hydrogen usage by 2050 the latest.
    - Companies can show how non-retrofitted plants up until 2050 align with intermediate emission reduction targets, such as a 50 percent reduction by 2030 across the company.
- iii For methanol and high-value chemicals only:
    - All carbon comes from circular sources on a lifecycle basis (no additional carbon is emitted during production or as Scope 3).

3. How does [company name] plan to transition to emissions-free production processes by 2050?

Tracking outcome:

The company has a credible strategy for emissions-free production processes by 2050.

This includes:

i From today:
  - All new plants need to be entirely electrified and run off 100 percent renewable energy. This is because plant lifetimes span to about 50 years and need to be zero emissions in production by 2050 – in 25 years.

ii Up until 2050:
  - All existing plants need to be entirely electrified and run off 100 percent renewable energy by 2050.

Note on high-value chemicals: For high-value-chemicals, renewable hydrogen pathways refer to processes that use methanol derived from renewable hydrogen instead of naphtha – a fossil fuel. This also requires a switch from current production processes to methanol-to-olefin or methanol-to-aromatics production. For more details, please see our last report.

General hydrogen engagement questions

1 Does [company name]'s transition strategy include the use of hydrogen?

Tracking outcome:

The company only includes the use of hydrogen in its transition strategy if it is part of the "priority" sectors.

These include chemicals, steel, long-haul aviation, maritime shipping, and to some extent storage for the power sector.

Companies outside these specific sectors should not be using hydrogen as part of their transition strategy.

2 Where hydrogen is needed for [company name]’s transition plan, which type of hydrogen will be used?

Tracking outcome:

Credible transition plans by companies have a specific commitment to only renewable hydrogen.

Plans for blue hydrogen are unlikely to be 1.5C aligned and should not be included in credible transition plans. Where these are included, a company may prove how non-renewable hydrogen investments are aligned with 1.5C pathways. Such proof must include sound modelling choices including all lifecycle emissions and realistic capture rates. In the absence of such full disclosure around the alignment of blue hydrogen investments and facilities, investors should view them as unaligned.

Annex

Annex

What policy support do chemical producers need?

Investments in renewable hydrogen are currently seen as unattractive because the cost of using it exceeds fossil-based alternatives. However, the recent rise in gas prices has shown that this can change quickly. Renewable hydrogen already undercuts the cost of grey hydrogen as of March 2022.[lxi] This heralds a general trend: Even without a significant increase in gas prices, modelling shows that renewable hydrogen prices will start to undercut those of grey and blue hydrogen before 2030.[lxii] This is because renewable hydrogen will benefit from falling electrolyser and renewable energy costs.

Policy support is needed to bridge that gap for now and make renewable hydrogen a more attractive choice while it is becoming more commercially viable. This is particularly important for chemical producers who face critical decision points regarding their transition investments before the end of the decade.

Policy support can help with the provision of cheaper renewable hydrogen in the market through supply-side interventions. It can also help chemical producers directly to bridge the gap in their procurement costs between renewable and blue hydrogen through demand-side interventions.

Here’s how supply-side and demand-side interventions could help encourage greater use of renewable hydrogen.

Supply-side interventions: Making renewable hydrogen cost-competitive[lxiii]

Electrolyser costs

The cost of electrolysers could be subsidised through direct financial support, exemptions from taxes and levies, and the creation of hydrogen supply contracts. This would cause the overall cost to the buyer to fall rapidly and help bridge the cost gap between blue and renewable hydrogen.

We are already seeing some of this support in practice. The EU supports low-carbon technologies such as electrolysers through revenues from the emissions trading system (ETS). Further, Germany recently revised its levies to partially exempt companies that produce renewable hydrogen.

Renewable energy prices

The chemical industry requires renewable electricity prices of around €0.04 per kilowatt hour, as established by the IEA and DECHEMA.

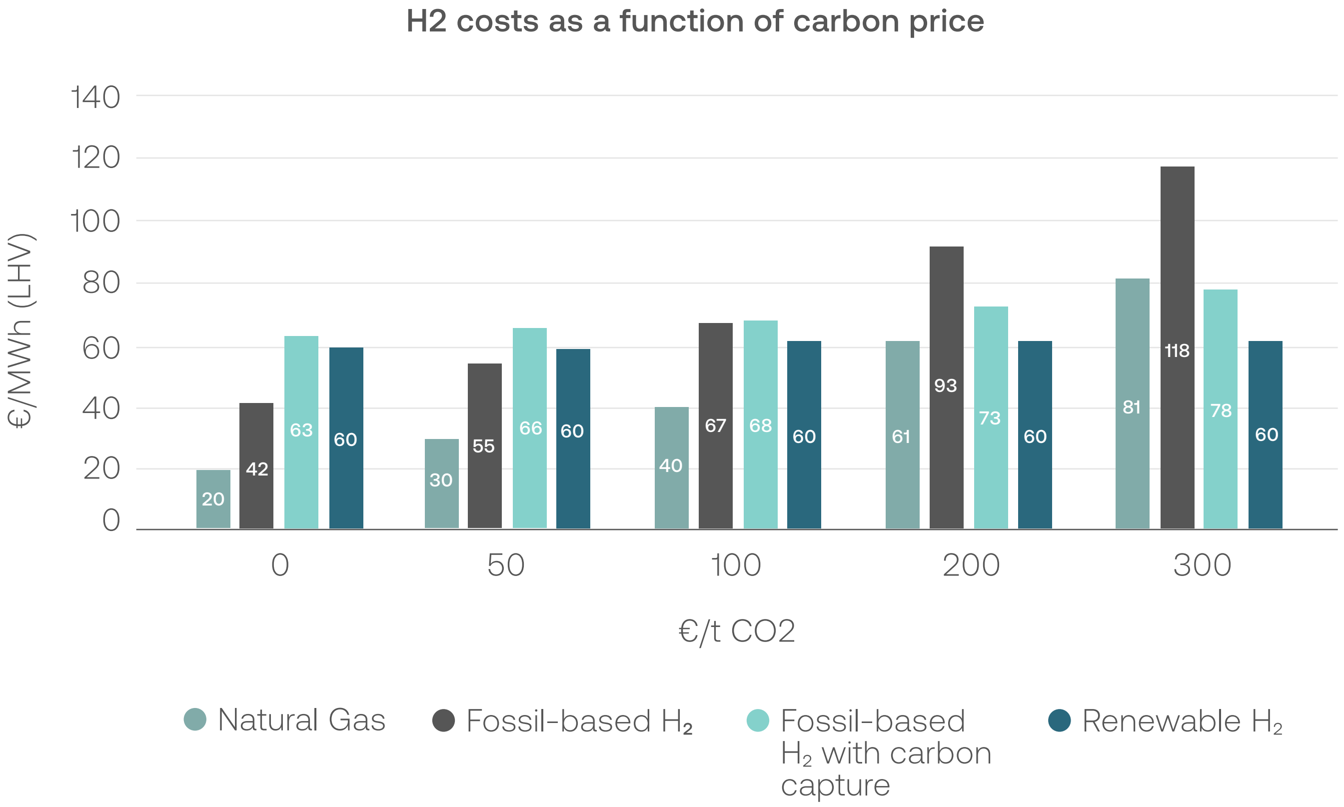
Policy support is needed to scale up renewable energy supply and meet cost requirements. Recent government targets, such as those set by Germany, will fast-track all local grids in Europe to be 100 percent renewable by 2035.[lxiv] Due to the significantly lower costs of renewables,[lxv] this will help chemical companies meet required procurement prices.

Carbon pricing

Analysis by Agora Energiewende shows that renewable hydrogen is already cost-competitive today if carbon prices reach €100 per tonne of CO2 (Figure 12).

The EU Emissions Trading System (ETS) already reached a peak price of €98 per tonne of CO2 in February 2022.[lxvi] As the EU ETS system is adjusting the supply of carbon credits in the market to better reflect the block's carbon budget,[lxvii] we are likely to see higher prices closer to €100 that make renewable hydrogen cost competitive.

Figure 12: Carbon price sensitivity of hydrogen costs



Source: Agora Energiewende, 2021

Demand-side interventions: Supporting the chemical industry

Renewable hydrogen investment support

Sector-specific policy support will be needed to encourage renewable hydrogen investments over fossil-based alternatives before 2030.

Carbon Contracts for Difference (CCfD) are an instrument, which, in simplified terms, cover the difference in costs between fossil-based and renewable technologies to support low-carbon solutions.

As long as carbon prices are lower than needed to create a level-playing field between renewable and blue hydrogen, fossil-based hydrogen production would be cheaper. In a CCfD setting, the government would therefore guarantee a fixed carbon price over a certain time period and would pay the difference between that fixed and the actual price[lxviii]. This would effectively bridge the gap in costs between renewable and blue hydrogen for chemical producers.

Myth-busting renewable hydrogen claims

Renewable hydrogen's implications for water consumption

Analysis by the IEA shows that water consumption for renewable hydrogen is in fact lower than for fossil-derived hydrogen. Water stress is lower with a switch to renewable hydrogen.

As per the IEA:

> "In addition to energy, hydrogen production requires water. Water electrolysis has the smallest water footprint, using about 9 kg of water per kg of hydrogen. Production from natural gas with CCUS pushes water use to 13-18 kg H2O/kg H2, while coal gasification jumps to 40-85 kg H2O/kg H2, depending on water consumption for coal mining.
>
> In the Net zero Emissions Scenario, global water demand for hydrogen production reaches 5 800 mcm, corresponding to 12% of the energy sector's current water consumption. While total water demand for hydrogen production is rather low, individual large-scale hydrogen production plants can be significant consumers of fresh water at the local level, especially in water stressed regions.
>
> Using seawater could become an alternative in coastal areas. While reverse osmosis for desalination requires 3-4 kWh of electricity per m3 of water, costing around USD 0.70-2.50 per m3, this has only a minor impact on the total cost of water electrolysis, increasing total hydrogen production costs by just USD 0.01-0.02/kg H2. As the direct use of seawater in electrolysis currently corrodes equipment and produces chlorine, various research projects are investigating ways to make it easier to use seawater in electrolysis in the future."[lxix]

Considerations of renewable energy availability[lxx]

Using green hydrogen and electricity to run chemical production processes requires large quantities of cheap renewable energy for the chemical sector to decarbonise.

Companies may question the feasibility of this, proposing blue hydrogen, biomass, and carbon capture as a solution instead.

However, the world has the technical and economic potential to meet energy demand in 2050 a hundred times over with renewable energy.[lxxi] In fact, renewable energy sources are several times more abundant than any tapped and untapped fossil fuel reserves, according to recent research by the Carbon Tracker Initiative (CTI).

A numerical example by CTI highlights this fact:

> “Global energy consumption in 2019 was 65 Petawatt hours (PWh). However, with current technology the world has the potential to capture more than 5,800 PWh annually from solar PV alone – as much power in a single year as could be generated by burning all known fossil fuel reserves. In addition, onshore and offshore wind could capture nearly 900 PWh a year.”

Renewables are already more economical than fossil fuels in the case of around 60 percent of solar and 15 percent of wind power generation. By 2030, all solar energy will be economical compared to fossil fuels, and at current growth rates renewables will have pushed oil and gas out of our energy systems by 2035.

Other common myths circulating about the feasibility of 100 percent renewable energy are related to land use, storage, and intermittency.

In fact, renewables would only take up about 0.3 percent of available landmass – even less than fossil fuel infrastructure currently does. Land constraints are not a limitation. We might even be able to free up land through the shift to clean energy.

There are many solutions to questions around storage and intermittency. Most importantly, the numbers from CTI to establish the world’s renewable potential already use the levels of energy generation in the lowest month of the year. This means estimates of renewable energy potential are already incredibly prudent. Even with that degree of prudence, renewable energy is abundant.

In a nutshell, we have the potential for renewable energy generation far beyond what fossil fuels could ever supply, and we will ever need. It will be better for our planet and our pockets.

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ShareAction is a NGO working globally to define the highest standards for responsible investment and drive change until these standards are adopted worldwide. We mobilise investors to take action to improve labour standards, tackle climate change and address pressing global health issues. Over 15 years, ShareAction has used its powerful toolkit of research, corporate campaigns, policy advocacy and public mobilisation to drive responsibility into the heart of mainstream investment. Our vision is a world where the financial system serves our planet and its people.

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