For Wholesale Investors only - October 2020

DEEP DECARBONIZATION

Green Hydrogen, Net Zero, and the Future of the EU-ETS

BNP PARIBAS
ASSET MANAGEMENT

The asset manager for a changing world

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Important Note: BNPP AM does not hold EUAs in any of its investment portfolios.

PREFACE

CARBONOMICS: THE THEORY BEHIND CARBON PRICING IN THE EU-ETS

This paper offers a theoretical approach to the foundations of price formation in the EU's Emissions-Trading Scheme (EU-ETS).

It postulates that the pricing paradigm of the European carbon market should in theory be a function of three variables:

(i) market participants' understanding of the purpose for which the EU-ETS has been established (i.e. the policy objective it is intended to achieve);

(ii) market participant's perception of the effectiveness of design of the EU-ETS, and hence of its technical ability to achieve the policy objective;

(iii) market participants' assessment of the political priority attached to achieving this objective, and hence of policymakers' commitment to ensuring that the supply of European carbon allowances (EUAs) is engineered to deliver this outcome.

The paper's key insight is that as a cap-and-trade scheme that allows policymakers to modulate the supply of EUAs with a view to meeting a specific policy objective, the pricing paradigm for the EU-ETS is in theory fundamentally different from that of other commodity markets.

The pricing paradigm for naturally occurring commodity markets such as oil or copper is based on the supply/demand balance in the prompt, with the forward curve reflecting the market's assessment of how this balance will develop over time, and the shape of the curve a function of the cost of carry.

By contrast, in a policy-driven market such as the EU-ETS, the forward curve should in theory reflect the market's assessment of the price at which the supply of allowances will be sufficiently constrained to achieve the desired policy objective, and the point in time at which this will occur, with the forward curve then derived by discounting back from this future point of convergence at the appropriate discount rate.

As such, today's price should in theory reflect today's perception of the future price required to deliver the policy goal adjusted for the time value of money.

In short, in a naturally occurring commodity market the forward curve is derived from the prompt, while in the EU-ETS – in theory at least -- the forward curve should be derived backwards from the most valuable point in the future.

As a contribution to the theoretical discussion over the nature and structure of price formation in the EU-ETS, this paper should not be read as a recommendation to buy, hold, or sell EUAs. Rather, its aim is to show how the deep decarbonization required across the entire EU economy in order for the policy objective of net-zero emissions by 2050 to be achieved could lead to a wide range of potential pricing outcomes if – as we think it will – the emerging technology of green hydrogen comes to be viewed by EU-ETS market participants as the marginal abatement option that will deliver the EU's 2050 net-zero target.

The logic of this paper's argument is straightforward, and rests on three key premises.

First, given that the EU's target for achieving net-zero emissions by 2050 is soon to be enshrined in EU law, there is now a clear endgame in place for the EU-ETS. This endgame consists in ensuring that EUA prices reach the level required to achieve the policy objective of net-zero emissions by 2050.

Second, according to the European Commission's recently launched strategic vision for green hydrogen – i.e. hydrogen produced via electrolyzers powered by wind- and solar-generated electricity – the ultimate objective of net-zero emissions by 2050 cannot be achieved without green hydrogen contributing a significant part of the solution. At some point, therefore, EUAs will have to reach the price level that incentivizes the use of green hydrogen over alternative fossil-fuel energy sources in buildings, transportation, and power generation.

Third, the pre-requisite for making green hydrogen commercially viable as an energy source is to make it commercially viable as an industrial feedstock by 2030.

This is because green hydrogen will be competitive with grey hydrogen as a feedstock well before it will be competitive with fossil-fuel energy carriers such as natural gas or petroleum products as an energy source for space heating or transport or power generation.

Owing to the fact that the production process for grey hydrogen is very carbon intensive, the higher production costs for green hydrogen can be offset by means of a carbon price. However, the greater the production-cost differential between green and grey hydrogen, the higher the carbon price will need to be in order for green hydrogen to displace grey hydrogen.

This means that the cost of producing green hydrogen needs to be reduced significantly between now and 2030 so that carbon pricing at a politically acceptable level can make green hydrogen competitive with grey hydrogen. The European Commission is targeting a production cost for green hydrogen by 2030 of around €2 per kilogramme (kg), compared with cost estimates today of €4.5/kg-€6/k. This compares with a production cost for grey hydrogen today of around €1.5/kg.

It is not our purpose here to analyze in detail the feasibility of reducing the cost of green hydrogen to the range of €1.1/kg-€2.4kg by 2030 envisaged by the Commission, not least as there are a number of specialist studies already available that have looked at this in exhaustive detail both at the global and the EU level. Rather, our objective is to consider the theoretical carbon-pricing implications in the EU from today's standpoint for a range of potential green-hydrogen cost outcomes by 2030 assuming that the cost of green hydrogen can be brought down to a range of €2/kg–€2.5/kg.

That being said, and based on both (i) our review of the literature on the economics of green hydrogen, and (ii) our own analysis of the Commission's investment estimates for scaling up green-hydrogen production, we think it is reasonable to assume that the cost of producing it can indeed be reduced to €2/kg-€2.5/kg by 2030.

From these three premises it follows that the EU-ETS will only be able to play its part in delivering net-zero emissions by 2050 if it first enables green hydrogen to displace grey hydrogen as a feedstock by 2030.

Accordingly, this paper concludes that if the EU's 2050 net-zero target is to be met then the EU-ETS pricing paradigm will need to shift at some point from one based on fuel-switching in the power sector to one based on fuel-switching in industry, whereby the cost of switching from grey hydrogen to green hydrogen becomes the key pricing parameter.

REALCARBONIK: FROM THEORY TO PRACTICE VIA COVID

Whether, how, and when the market shifts at some point from pricing EUAs off the fuel-switching level in the power sector to pricing instead off the fuel-switching level for green hydrogen to replace grey hydrogen will be a function of how seriously market participants view the EU's commitment to its ultimate policy objective of net zero, and hence its commitment to the interim step of making green hydrogen competitive as an industrial feedstock by 2030. In effect, therefore, the speed with which green hydrogen is scaled up is the litmus test for how serious the EU and its member states are about delivering on the soon to be legally binding 2050 net-zero target.

What seems unarguable to us, though, is that if the market becomes convinced of the EU's political will to achieve net zero, then prices will at some point have to move onto a trajectory consistent with making green hydrogen commercially viable as a feedstock by 2030. This is because there is no plausible pathway to net zero without green hydrogen becoming a significant source of energy for transport, heating, and power over 2031-50, and there is no plausible pathway for that to happen without green hydrogen first becoming commercially viable as an industrial feedstock in place of grey hydrogen.

Other things being equal, then, we think that the sooner it becomes clear to the market that the EU and its member states are putting effective measures in place to incentivize green hydrogen, the more smoothly EUA prices will react to reflect the new pricing paradigm. By contrast, the longer the market doubts the seriousness of the EU and its member states to achieving net zero, the greater the risk of a sudden and more violent repricing of EUAs later in time as policymakers are forced to respond with tougher measures in order to reaffirm their commitment to meeting the legally-binding net-zero target.

In this respect, the fact that the Commission is now proposing an increase in the EU's emissions-reduction target to "at least -55%" by 2030 versus 1990 compared with the current target of -40% is already a clear declaration of intent regarding the road ahead to net zero by 2050. As the commissions' President, Ursula von der Leyen, said in her state of the Union speech on 17 September:[1]

> *"We are doing everything in our power to keep the promise that we made to Europeans:* ***make Europe the first climate neutral continent in the world, by 2050****. Today marks a major milestone in this journey. With the new target to cut EU greenhouse gas emissions* ***by at least 55%*** *by 2030, we will lead the way to a cleaner planet and a green recovery. Europe will emerge stronger from the coronavirus pandemic by investing in a resource-efficient circular economy, promoting innovation in clean technology and creating green jobs."* (Emphasis ours)

1. Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1599

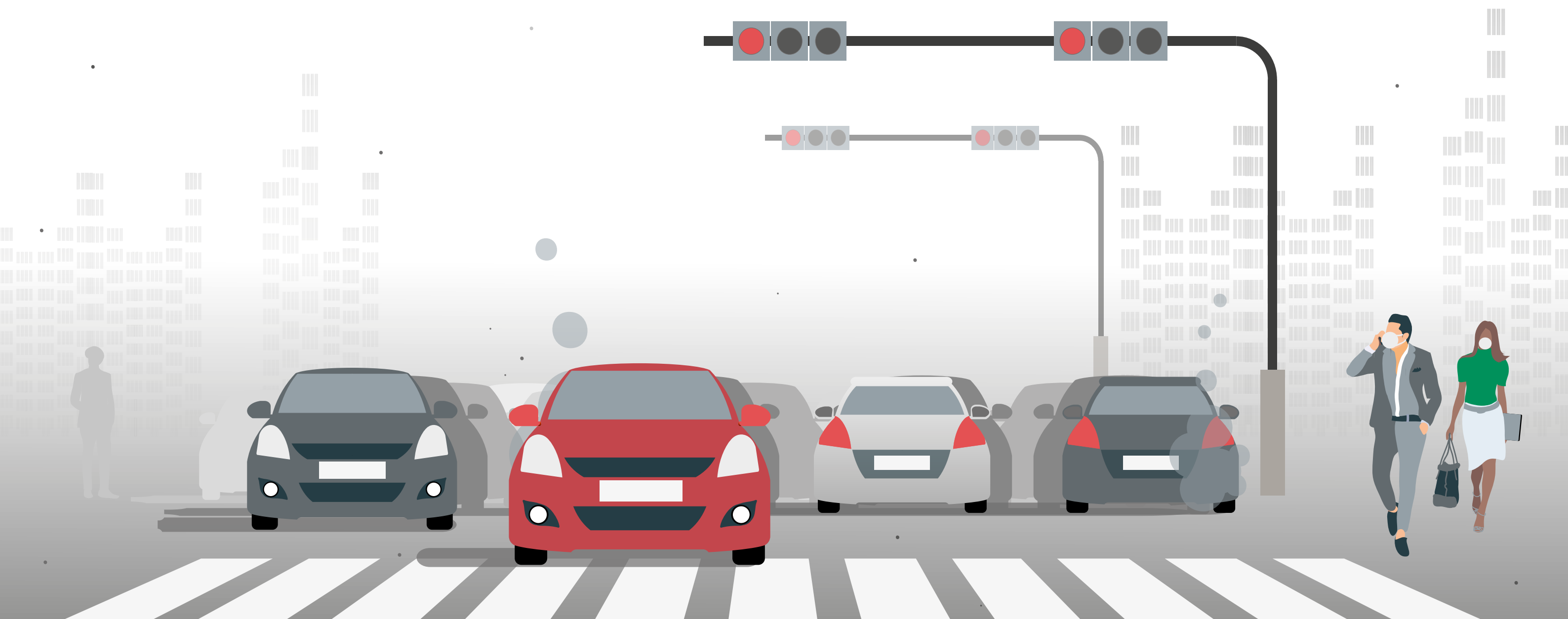
Of course, all of this discussion about net zero by 2050 comes against the backdrop of the COVID pandemic and the severe impact this is having on the EU economy, and hence on the natural compliance demand for EUAs in the near term. Indeed, owing to the structural impact that we expect the COVID pandemic to have on emissions over the next decade, our scenario modelling of the EU-ETS even under a -55% target projects that there is still a market surplus of EUAs in 2030, albeit a significantly smaller one (462Mt) than would be the case if no change were made to the current -40% target (1,150Mt).

However, what matters from a pricing point of view is how a more ambitious 2030 target changes market psychology and hence market participants' behaviour. In our view, there is no plausible pathway to net zero by 2050 without the scaling-up of green hydrogen so that it is commercially viable as an industrial feedstock by 2030, and as an energy source thereafter

As a result, if the market thinks net zero is as serious a policy commitment as its legally binding status portends, both compliance players and financial investors will at some point start to assume that the EU will do what it takes to engineer the conditions for prices to reach this level by 2030.

Finally, and to state what is an obvious point: assuming the market were at some point in the next 18-36 months to conclude that the EU is fully committed to net zero by 2050, with all that entails about engineering the degree of EUA scarcity necessary to drive deep decarbonization across all the sectors covered by the EU-ETS, it is unlikely that the forward curve would move to reflect the smooth and steep contango pattern our theoretical analysis dictates that it should. In practice, as with other markets, the prompt will likely continue to be the main driver of prices across the curve, as that is just how commodity markets work in reality.

In turn, however, that would most likely simply mean a higher prompt price than any of those shown in our theoretical pricing trajectories below, and hence a gentler contango in the forward curve than the one implied by the 6% discount rate we have assumed.



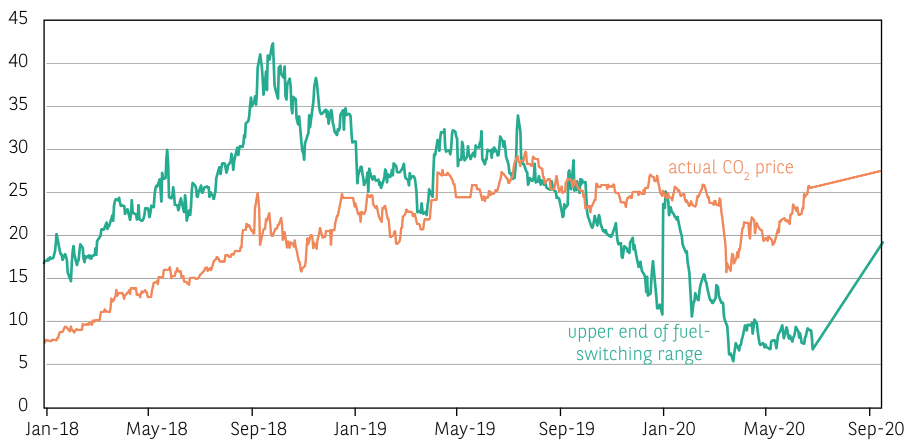
1 EXECUTIVE SUMMARY

1.1 BEYOND THE FUEL-SWITCHING PARADIGM: THE EU-ETS AND THE GOAL OF NET-ZERO EMISSIONS

Given the economic shock to the EU-ETS from COVID, the price of EU carbon allowances (EUAs) has held up remarkably well in recent months. From a low of €14.3/t in the early stages of the lockdowns across the EU the benchmark Dec-20 contract recovered to a near-record all-time high of €30.8/t in June, and has held at pre-COVID levels ever since.

Perhaps more significantly, though, and as can be seen in Figure 1, the Dec-20 EUA contract has also traded at or above the upper end of the coal-to-gas fuel-switching range for most this year. We believe this is the first time in the 15-year history of the EU carbon market that EUAs have traded above the upper end of the fuel-switching range, i.e. the range in which EUA prices incentivise less carbon-intensive gas plants to displace more carbon-intensive coal plants in the merit order of power production.

Figure 1: Dec-20 EUA price versus implied fuel-switching level, Jan-2018-Sep 2020 (€/t)



Source: BNP Paribas Exane

The reason why this is so significant is that for most of their 15-year history, EUAs have traded either somewhere in the middle of the fuel-switching range or – at times of excessive over-supply – well below this range. For prices to trade above the top end of this range therefore opens the door to new interpretations of what the market is signalling.

And one interpretation is that despite the devastating impact of COVID on emissions, market participants are starting to think beyond coal-to-gas fuel switching in the power sector as the marginal-abatement option that ultimately clears the EU-ETS over the long term. And with good reason, we think: given the policy-based nature of the EU-ETS and the ultimate policy objective of achieving net-zero emissions in the EU by 2050, a whole new pricing paradigm could be in the offing.

1.2 CARBONOMICS IN THEORY: IT TAKES CO_2 TO CONTANGO

From a theoretical point of view, the key insight about a cap-and-trade scheme such as the EU-ETS is that it is a regulatory construct designed to achieve a specific policy outcome, namely a given reduction in emissions over a given period of time. The EU-ETS differs from a carbon tax in that it is a market mechanism: the regulator sets the targeted emissions reduction over a given period in advance and market forces then determine the price at which the required reduction occurs. By contrast, with a carbon tax the regulator sets the price on emissions over a given period, and this price then determines the level of emissions over the period.

At the same time, the EU-ETS differs from other commodity markets in that the regulator can modulate supply to engineer the desired policy outcome. In other words, whereas in any other commodity market supply and demand are in a continuous feedback loop between one another as the price fluctuates in response to the market balance, in the EU-ETS the regulator sets the level of supply at the level expected to achieve the targeted emissions reduction by the targeted date. Indeed, that is the whole point.

With EUAs bankable across trading periods the forward curve for EUAs should therefore in theory follow a classic contango pattern whereby today's price reflects the most valuable expected price in the future discounted back in real terms. The most valuable point in the future is where the EUA price hits the level required to fulfill the policy objective.

With the EU in the process of legislating for net-zero emissions by 2050 and also now pursuing an aggressive green-hydrogen strategy as a central pillar of this net-zero target, we think the de facto policy objective of the EU-ETS henceforth is to make green hydrogen – i.e. hydrogen produced via electrolysis using renewable electricity – commercially viable as a feedstock by 2030, and as a fuel by 2040 or sooner.

We call the point at which green hydrogen becomes commercially viable the point of convergence, and we see 2030 as the year in which convergence happens.

1.3 GREEN HYDROGEN IS CENTRAL TO THE EU'S 2050 NET-ZERO EMISSIONS OBJECTIVE

In 2018 the Inter-governmental Panel on Climate Change (IPCC) published a special report looking at the impact of climate change under a scenario of 1.5°C of global warming. The report established that the difference between an average global temperature increase of 1.5°C and 2°C is material and alarming, and that if the world is to stand a reasonable chance of restricting the temperature increase to 1.5°C then emissions need to fall to zero on a net basis by 2050.

In March 2020 the European Commission set out its legislative proposal for achieving net-zero emissions in the EU by 2050, with its formal passage into law expected in Q4 this year or Q1 2021. In July, it then set out an ambitious hydrogen strategy as a central pillar of the framework for achieving the net-zero target, with a goal of deriving up to 15% of final energy consumption in the EU by 2050 (compared with only 2% today).

1.4 FOR NET ZERO TO HAPPEN BY 2050 GREEN HYDROGEN MUST FIRST BE A COMPETITIVE FEEDSTOCK BY 2030

The pre-requisite for achieving the 2050 hydrogen vision is to make green hydrogen commercially viable as an industrial feedstock by 2030. This is because green hydrogen will be competitive with grey hydrogen as a feedstock well before it will be competitive with fossil-fuel energy carriers such as natural gas or petroleum products as an enrgy source for space heating or transport or power generation.

1.5 MAIN DRIVER OF EUAS SET TO BECOME GREEN-HYDROGEN TARGET

The EU today produces about 8.2Mt of hydrogen, most of which is made from the steam-methane reforming (SMR) process using natural gas (this fossil-fuel based hydrogen is known as grey hydrogen). Most of this hydrogen is for use as an industrial feedstock in oil refining, and in the production of ammonia and methanol. The problem with the SMR process, however, is that it is highly carbon intensive, with 9kg of CO_2 produced for every kg of hydrogen. This equates to 0.27 tonnes of CO_2 per megawatt-hour (0.27t/MWh).

As the production of hydrogen under the SMR process is an activity covered by the EU-ETS, replacing today's production with green hydrogen from electrolysis using renewables-based electricity by 2030 would in itself reduce EU-ETS emissions by 80-90Mt per year (equivalent to 6% of total 2019 EU-ETS emissions). This would already be a significant achievement but the real prize for the EU is much greater. This is because making green hydrogen commercially viable as an industrial feedstock by 2030 is the pre-requisite for achieving the EU's overall 2050 hydrogen vision.

The lesson from the history of the EU renewables industry over the last decade is that wind and solar energy became commercially viable owing to a positive feedback loop incentivized initially by subsidies and mandates. These subsidies and mandates attracted capital, which in turn enabled the industry to scale up and the technology to improve. As the costs came down the incentives continued, albeit at a progressively lower rate over time, while the targets for renewables became more ambitious. This then enabled further economies of scale and continuing technology improvements.

The key point is that while the scaling up of renewables was achieved by means of subsidies and mandates rather than by means of the carbon price, wind and solar have reached a point where they are now commercially viable at today's carbon price of €25/t-€30/t. In the same way, the EU's plan for green hydrogen is to scale up production to >300TWh by 2030 by means of subsidies and mandates, and thereby reduce the cost of production to €2/kg (€51/MWh) or less in order to make it competitive with grey hydrogen.

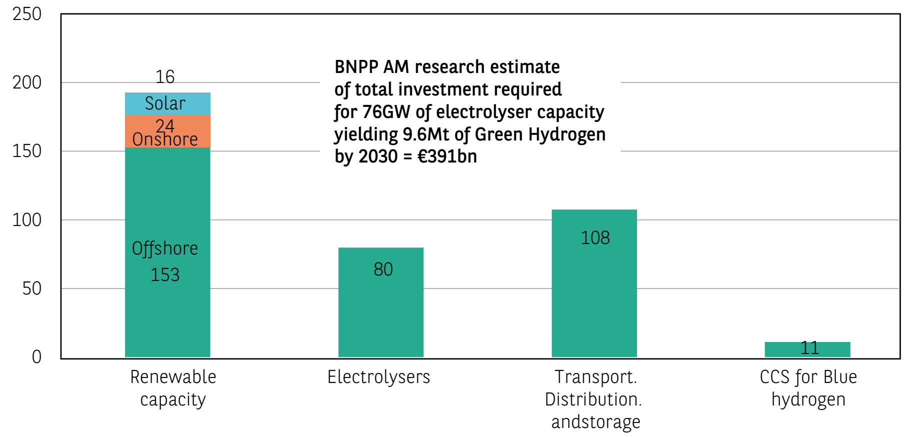
The Commission estimates the total investment required to achieve its 2030 vision at €320-€460bn, with €220-€340bn of this to cover €80GW-120GW of dedicated new wind and solar capacity, and €24bn-€42bn for 40GW of electrolyzer capacity.

Reviewing the literature and doing our own analysis, we find that the Commission's numbers are both too optimistic and too pessimistic.

We think they are too optimistic in that we simply do not see how 40GW of electrolyzers would be enough to produce 10Mt of green hydrogen. We calculate that at least 76GW of electrolyzers and 96GW of dedicated new renewables capacity would be necessary, even assuming that most of the renewable capacity required to power these electrolyzers were connected to the grid rather than attached directly to the electrolyzers themselves (attaching to the grid would allow a much higher utilization rate for the electrolyzers).

At the same time, we think the Commission's cost estimates are too pessimistic, as the capital costs assumed for the required dedicated renewable capacity seem significantly higher than those observable in the market already today for new wind and solar projects, never mind the lower costs that are likely to be achieved within the next five years. Accordingly, we derive a total investment budget of €391bn for the electrolyzer and renewable capacity – and also including storage and distribution infrastructure – required to produce 10Mt by 2030 (Figure 2). This puts us in the middle of the Commission's €340-€460bn range.

Figure 2: BNPP AM's estimated cost for building up the EU's green-hydrogen economy by 2030 (€bn)



Source: BNPP AM Research estimates

1.6 OUR ANALYSIS IMPLIES A THEORETICAL RANGE FOR THE FAIR VALUE OF EUA PRICES IN 2030 OF €34/T-€149/T

Looking at a range of potential production costs for green hydrogen in 2030, as well as a range of potential EU gas prices in 2030, we derive a range of implied theoretical fair values for EUAs for making green hydrogen competitive with grey hydrogen in 2030 (Figure 3).

The range of our assumed costs for producing green hydrogen in 2030 goes from 1.75/kg at the low end, to €2.5/kg at the high end. The range of our assumed gas prices is 10/MWh, €15/MWh, and €20/MWh. We then derive the implied theoretical fair value for each of the 12 permutations these assumptions give rise to in a two-step process. First, we calculate the gap to bridge between the cost of green hydrogen at our four assumed cost levels, and the cost of grey hydrogen at the three different gas prices we have assumed. Second, we then multiply this difference by the carbon intensity of grey hydrogen (0.27t/MWh).

We note that the cost of grey hydrogen is highly sensitive to fuel costs such that a €5/MWh change in the 2030 gas price in either direction moves the implied 2030 EUA price to make green hydrogen competitive with grey hydrogen by plus or minus €23/t.

The range varies from a low of €34/t to a high of €149/t, reflecting the range of potential 2030 values for the cost of producing green hydrogen and the price of gas in the EU. If we look at the potential 2030 costs for green hydrogen, we find that in the middle of our range – i.e. at €2/kg and €2.25/kg – the implied 2030 fair values for carbon would be €79/t and €103/t respectively.

Figure 3: Implied 2030 EUA fair values for green hydrogen to displace grey hydrogen with gas at €10/MWh, €15/MWh, €20/MWh

Matrix shows implied 2030 fair value for EUAs on our four 2030 cost scenarios for green hydrogen

	€1.75	€2	€2.25	€2.5
€10/MWh	€79/t	€103/t	€126/t	€149/t
€15/MWh	€56/t	€79/t	€103/t	€126/t
€20/MWh	€34/t	€57/t	€81/t	€104/t

Source: BNPP AM Research estimates

On the basis of all the assumptions we have made in this study concerning the production costs for green hydrogen and the price of gas in the EU by 2030, we think €79/t-€103/t is a fair indication of the range in which EUAs would need to trade in 2030 in order for green hydrogen to be competitive with grey hydrogen by that date.

Over the following decade 2031-40 the challenge will then be to make green hydrogen competitive as an energy source. We think this is possible at a carbon price of €100/t-€140/t by 2040, again depending on the cost of producing green hydrogen and the EU gas price by then. Assuming that the cost of producing green hydrogen falls to €1.25/kg by 2040, and at a gas price of €15/MWh, this would make hydrogen competitive as a fuel for power generation at €100/t. On the other hand, assuming the same green-hydrogen cost of €1.25/kg but gas prices of €10/MWh in 2040 would make hydrogen competitive with gas for power generation at a carbon price of €137/t.

1.7 WHAT IS THE RIGHT DISCOUNT RATE FOR CARBON?

The discount rate for carbon should in theory be the cost of capital of the compliance buyers and/or investors arbitraging the gap between the prevailing market price today on the one hand, and the implied fair value today of the 2030 price required to make green hydrogen commercially viable as a feedstock by 2030 on the other.

Given the current very low interest-rate environment in the EU, we see the cost of capital for industrial and financial players in the EU-ETS ranging from 4%-10%, and choose 6% for our purposes here.

1.8 OUR ANALYSIS IMPLIES A RANGE FOR THE THEORETICAL FAIR VALUE OF EUAS IN 2020 OF €18/T-€80/T, AND A MID-RANGE FAIR VALUE OF €49/T

Figure 4 shows the implied 2020 fair value for EUAs across all the permutations shown in our various scenarios above discounted back from 2030 at 6%.

Figure 4: Implied 2020 EUA fair values for green hydrogen to displace grey hydrogen

Matrix shows implied 2020 fair value for EUAs discounted back from 2030

	€1.75	€2	€2.25	€2.5
€10/MWh	€43/t	€55/t	€68/t	€80/t
€15/MWh	€30/t	€42/t	€55/t	€68/t
€20/MWh	€18/t	€31/t	€43/t	€56/t

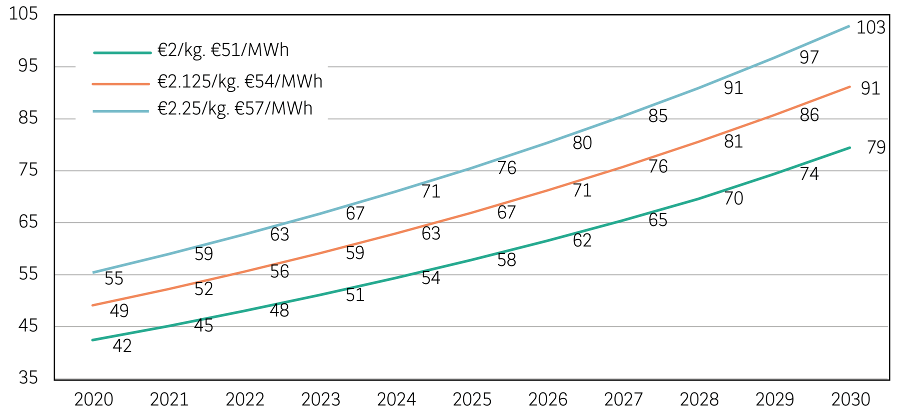
Source: BNPP AM Research estimates

The range varies from a low of €18/t to a high of €80/t. If we then look at the potential 2030 costs for green hydrogen, we find that in the middle of our range – i.e. at €2/kg and €2.25/kg – the implied 2020 fair values for carbon discounted back from 2030 are €42/t and €55/t respectively.

We think €42/t-€55/t is a fair indication of the theoretical fair-value range for EUAs today based on the need for green hydrogen to be competitive as an industrial feedstock in 2030.

Figure 5 takes the middle of our 2030 theoretical fair-value range for EUAs – €2/kg-€2.25/kg – to derive the resulting implied theoretical forward curves. This shows that at our mid-range scenario for 2030 EU gas of €15/MWh, and at a 2030 cost of production for green hydrogen of €2.213/kg, the implied fair value for EUAs would be €91/t. In turn discounting back at 6% would give us a theoretical implied 2020 fair value of €49/t.

Figure 5: Implied shape of EUA forward curve with varying 2030 costs of green hydrogen from €2/kg-€2.25/kg, and with grey hydrogen gas-input costs of €15/MWh



Source: BNP Paribas AM research estimates

1.9 PROMPT STILL DRIVING EUA PRICES FOR NOW BUT THE FUEL-SWITCHING PARADIGM HAS RUN ITS COURSE

We have modelled a scenario for the EU-ETS under which the recently proposed -55% EU-wide target for 2030 is adopted, showing how this might compare with the EU-ETS under the current -40% target. Owing to the structural impact that we expect the COVID pandemic to have on emissions over the next decade, our scenario modelling of the EU-ETS under a -55% target projects that there is still a market surplus of EUAs in 2030, albeit a significantly smaller one (462Mt) than would be the case if no change were made to the current -40% target (1,150Mt).

However, what matters from a pricing point of view is how a more ambitious 2030 target changes market psychology and hence market participants' behaviour. In our view, there is no plausible pathway to net zero by 2050 without the scaling-up of green hydrogen so that it is commercially viable as an industrial feedstock by 2030, and as an energy source thereafter

This means that in the final analysis, convincing the market that deep decarbonization is an urgent priority would be the single greatest catalyst for bringing about a step change in the EUA forward curve consistent with both (i) our theoretical analysis in Section 2, and – depending on the market's view of green-hydrogen costs and EU gas prices by 2030 – (ii) our scenario modelling in Section 3.

This is because if the market thinks deep decarbonization is an urgent priority, both compliance players and financial investors will assume that the Commission will engineer the conditions for prices to reach this level by 2030.

2 CARBONOMICS IN THEORY: THE POINT OF CONVERGENCE IS KEY

This section sets out the theory behind our pricing framework for the EU-ETS.

From a theoretical point of view, the key insight about a cap-and-trade scheme such as the EU-ETS is that it is a regulatory construct designed to achieve a specific policy outcome, namely a given reduction in emissions over a given period of time. The EU-ETS differs from a carbon tax in that it is a market mechanism: the regulator sets the targeted emissions reduction over a given period in advance and market forces then determine the price at which the required reduction occurs. By contrast, with a carbon tax the regulator sets the price on emissions over a given period, and this price then determines the level of emissions over the period.

At the same time, the EU-ETS differs from other commodity markets in that the regulator can modulate supply to engineer the desired policy outcome. In other words, whereas in any other commodity market supply and demand are in a continuous feedback loop between one another as the price fluctuates in response to the market balance, in the EU-ETS the regulator sets the level of supply at the level expected to achieve the targeted emissions reduction by the targeted date. Indeed, that is the whole point.

That said, and until recently, once the cap for a given trading period had been set in the past the Commission had no further ability to regulate supply in response to changing demand over the rest of that trading period. As a result, the price in a given trading period was vulnerable to demand shocks. For example, when emissions fell sharply in 2009 as a result of the global financial crisis and ensuing recession in the EU, the carbon price also fell sharply as the market realized that there was an oversupply of EUAs relative to demand and that this oversupply would last not only until the end of Phase-2 of the EU-ETS but well beyond.

However, since 2019 the Market Stability Reserve (MSR) has been in place and this mechanism enables a significant portion of the over-supply in the market at any given time to be removed on an annual basis at a pre-determined rate. More importantly still, the fact that the functioning of the MSR is subject to periodic reviews, with the first of these due in 2021, means that if the Commission feels a further tightening of the cap within a given trading period is warranted, it can recommend a tightening of supply via the MSR accordingly.[2]

What all of this means is that with EUAs bankable across trading periods linking today's supply with the long-term target, and with the market reassured that any over-supply in the near term can be corrected by the MSR, the forward curve should in theory follow a classic contango pattern whereby today's price reflects the most valuable expected price in the future discounted back in real terms. The most valuable point in the future is where the EUA price hits the level required to fulfill the policy objective.

With the EU in the process of legislating for net-zero emissions by 2050 and also now pursuing an aggressive green-hydrogen strategy as a central pillar of this net-zero target, we think the de facto policy objective of the EU-ETS henceforth is to make green hydrogen commercially viable as a feedstock by 2030, and as a fuel for space heating, power generation, and transport by 2040 or sooner. We call the point at which green hydrogen becomes commercially viable the point of convergence, and with the recently announced Commission proposal to raise the EU's 2030 emissions target to at least -55% and the newly announced green-hydrogen strategy targeting 10Mt of production by the same year, we see 2030 as the year in which convergence happens.

In theory, then, and all other things being equal,[3] all we need to calculate the fair value of EUAs today is: (i) an understanding of the ultimate policy objective behind the EU-ETS; (ii) a view on the date by which

2. We examine the mechanics of the MSR and its central role in bolstering market confidence in Section 4 below.
3. In practice we also need to know the cost of producing grey hydrogen, which is highly dependent on natural-gas prices. We discuss the sensitivity of grey hydrogen to gas prices in detail in Section 3 below, but from a theoretical point of view if the cost of grey hydrogen is assumed to be stable at a given level, then the three variables we discuss here are all we need to derive the theoretical fair value for carbon today.

this policy objective will be achieved (i.e. a view on the point of convergence); and (iii) an appropriate discount rate to convert the future fair value of EUAs at the point of convergence into the implied fair value today.

In practice, of course, the crucial ingredient for the theoretical fair value to be realised in the market price of EUAs is confidence on the part of EU-ETS compliance players and/or investors that (i) the cost of green hydrogen can be brought down to a level that makes it commercially viable with an acceptable carbon price by 2030, and (ii) that the supply of EUAs over Phase 4 will be sufficiently constrained to engineer a price of €91/t by 2030.

Accordingly, Section 3 and Section 4 then explore these practical questions.

2.1 CARBONOMICS IN THEORY: PLAN FOR GREEN HYDROGEN OFFERS NEW PRICING PARADIGM FOR HE EU-ETS

In theory, and all other things being equal, the price trajectory for EUAs can be determined on the basis of three variables: (i) the policy objective of the ETS; (ii) the point in time at which the ETS cap will be sufficiently tight to drive the EUA price to the level required to achieve this policy objective; and (iii) the appropriate discount rate for converting this nominal future EUA price at the point of convergence into the fair value it implies for EUAs today.

VARIABLE 1: THE POLICY OBJECTIVE BEHIND THE ETS: NET-ZERO EMISSIONS BY 2050 WITH GREEN HYDROGEN PLAYING KEY ROLE

In October 2018 the Inter-governmental Panel on Climate Change (IPCC) published a special report (IPCC SR15) looking at the impact of climate change under a scenario of 1.5°C of global warming.[4] The report established that the difference between an average global temperature increase of 1.5°C and 2°C is material and alarming,[5] and that if the world is to stand a chance of restricting the temperature increase to 1.5°C then emissions need to fall to zero on a net basis by 2050, and that the optimal policy framework for achieving net-zero emissions by 2050 would entail high carbon prices (IPCC, SR15: 95):

> *"**Limiting warming to 1.5°C implies reaching net zero CO_2 emissions globally around 2050 and concurrent deep reductions in emissions of non-CO_2 forcers**, particularly methane (high confidence). Such mitigation pathways are characterized by energy-demand reductions, decarbonization of electricity and other fuels, electrification of energy end use, deep reductions in agricultural emissions, and some form of CDR with carbon storage on land or sequestration in geological reservoirs. (...) **Policies reflecting a high price on emissions are necessary in models to achieve cost-effective 1.5°C pathways**."* (Emphasis in original)

4. IPCC Special Report, Global Warming of 1.5°C, available at: https://www.ipcc.ch/sr15/.
5. For a very useful summary of the IPCC's explanation of the most significant differences between 1.5°C and 2°C of global warming on a range of natural and human indicators see the analysis by the World Resources Institute (WRI) available at: https://www.wri.org/blog/2018/10/half-degree-and-world-apart-difference-climate-impacts-between-15-c-and-2-c-warming.

In March 2020 the European Commission set out its legislative proposal for achieving net-zero emissions in the EU by 2050 (EU COM [2020] final 80),[6] citing both the appetite for more radical climate action from its citizenry and the IPCC's SR15 as catalysts for this more ambitious policy commitment (EU COM [2020] final 80: 1):

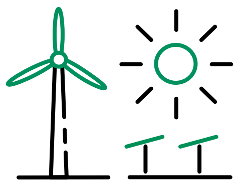
"European citizens see climate change as a serious problem and want to see increased action. (...) The Intergovernmental Panel on Climate Change (IPCC) Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse-gas emission pathways confirms that the impacts of climate change increase rapidly with increasing global mean temperature, and indicates that already at 2°C the world would see dramatic impacts due to climate change. ***It estimates that in order to be on a pathway to limit temperature increase to 1.5°C, net-zero*** CO_2 ***emissions at global level needs to be achieved around 2050 and neutrality for all other greenhouse gases somewhat later in the century. This urgent challenge calls for the EU to step up its action to show global leadership by becoming climate-neutral by 2050, covering all sectors of the economy and compensating, by 2050, not only any remaining*** CO_2 ***but also any other remaining greenhouse gas emissions."*** (Emphasis ours)

6. European Commission (EU COM [2020] final 80), Proposal for a Regulation of the European Parliament and of the Council establishing the framework for achieving climate neutrality and amending Regulation (EU) 2018/1999 (European Climate Law), available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020PC0080&from=EN: Article 2 of the Proposal defines clearly what net-zero emissions means for the purposes of the EU legislation (p. 14): "Union-wide emissions and removals of greenhouse gases regulated in Union law shall be balanced at the latest by 2050, thus reducing emissions to net zero by that date."

In July 2020, the Commission then set out its green-hydrogen strategy (EU COM [2020] 301 final)[7] as a central pillar of the framework for achieving the net-zero target (EU COM [2020] 301 final: 1):

"Hydrogen can be used as a feedstock, a fuel or an energy carrier and storage, and has many possible applications across industry, transport, power and buildings sectors. Most importantly, it does not emit CO_2 and almost no air pollution when used. It thus offers a solution to decarbonise industrial processes and economic sectors where reducing carbon emissions is both urgent and hard to achieve. ***All this makes hydrogen essential to support the EU's commitment to reach carbon neutrality by 2050 and for the global effort to implement the Paris Agreement while working towards zero pollution."*** (Emphasis ours)

Crucially, the Commission's hydrogen blueprint emphasizes that the ultimate objective is to make all the hydrogen produced in the EU green hydrogen, i.e. hydrogen produced from electrolysis using renewable electricity (EU COM [2020] 301 final: 5):



"***The priority for the EU is to develop renewable hydrogen, produced using mainly wind and solar energy. Renewable hydrogen is the most compatible option with the EU's climate neutrality and zero pollution goal in the long term and the most coherent with an integrated energy system.*** *The choice for renewable hydrogen builds on European industrial strength in electrolyzer production, will create new jobs and economic growth within the EU and support a cost-effective integrated energy system. On the way to 2050, renewable hydrogen should progressively be deployed at large scale alongside the roll-out of new renewable power generation, as technology matures and the costs of its production technologies decrease.* ***This process must be initiated now."*** (Emphasis ours)

7. European Commission (EU COM [2020] final 301), A Hydrogen Strategy for a Climate-neutral Europe, available at: https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.

In short, the overriding climate-policy objective of the EU is now to achieve net-zero emissions by 2050, and green hydrogen will play a central role in achieving this objective. Given that the EU-ETS is the cornerstone of the EU's climate policy, this means that EUAs must at some point rise to the level required to make the green-hydrogen vision a reality.

The next question is at what point in time does the EUA price hit the level required to achieve this?

VARIABLE 2: THE POINT OF CONVERGENCE, GREEN HYDROGEN MUST BE A COMPETITIVE FEEDSTOCK BY 2030

Nearly all of the hydrogen produced in the EU today – 325TWh in 2019 according to Hydrogen Europe[8] – is produced from the highly carbon-intensive SMR method[9] for use as industrial feedstock: in 2018 153TWh was used in refining, 129TWh in ammonia production, and 27TWh in methanol production.[10] This indicates that the pre-requisite for achieving the EU's green-hydrogen vision and hence the overarching EU climate-policy target of net-zero emissions by 2050 is to make green hydrogen commercially viable as an industrial feedstock by 2030.

This is because as a feedstock green hydrogen is ready to use once produced, whereas as an energy source it needs to undergo further transformation, for example via a boiler (for space heating), via a fuel cell (for transport), or via a combined-cycle turbine (for power generation). All of these transformation processes entail efficiency losses and thus make it more expensive for green hydrogen to compete as an energy source than as a feedstock, such that these end-use applications will only achieve the necessary scale to be commercially viable over 2030-40 or beyond. This is because green hydrogen will be competitive with grey hydrogen as a feedstock well before it will be competitive with fossil-fuel energy carriers such as natural gas or petroleum products as an energy source for space heating or transport or power generation.

So, when can we expect green hydrogen to be produced at a competitive cost? The European Commission sees the production of green hydrogen as being competitive with that of grey hydrogen by 2030 (EU COM [2020] 301 final: 4-5):

"*Costs for renewable hydrogen are going down quickly. Electrolyzer costs have already been reduced by 60% in the last ten years, and are expected to halve in 2030 compared to today with economies of scale. In regions where renewable electricity is cheap,* ***electrolyzers are expected to be able to compete with fossil-based hydrogen in 2030****. These elements will be key drivers of the progressive development of hydrogen across the EU economy."* (Emphasis ours)

8. Hydrogen Europe, Hydrogen 2030: the Blueprint (p. 5), available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20 2030_The%20Blueprint.pdf
9. Referencing the IEA the Commission (EU COM [2020] 301 final: 4) states that 9kg of CO_2 are released for every kg of fossil-based hydrogen produced, and adds that displacing this production with green hydrogen would in itself reduce EU-ETS emissions by 80-90Mt per year.
10. See the report by Fuel Cells and Hydrogen 2 Joint Undertaking, Hydrogen Roadmap Europe: A Sustainable Pathway for the European Energy Transition (page 40)

We examine the economics of green hydrogen versus grey hydrogen in much greater detail in Section 3 below, but for our immediate purposes here in estimating the most likely date for the point of convergence it is enough to know that the Commission sees green-hydrogen production costs in a range around €2/kg by 2030. As such, it sees green hydrogen already contributing to the EU's 2030 emissions-reduction target (EU COM [2020] 301 final: 2):[11]

> *"In the integrated energy system of the future hydrogen will play a role, alongside renewable electrification and a more efficient and circular use of resources. Large-scale deployment of clean hydrogen at a fast pace is key for the EU to achieve a higher climate ambition,* ***reducing greenhouse-gas emissions by a minimum 50% and towards 55% by 2030****, in a cost-effective way."* (Emphasis ours)

And the main initial role that the Commission sees for green hydrogen in 2030 is as an industrial feedstock in refineries, ammonia production, and methanol production (EU COM [2020] 301 final: 10):

> *"The creation of new lead markets goes hand in hand with the scaling up of the production of hydrogen. Two main lead markets,* ***industrial applications*** *and mobility, can be gradually developed to use the potential of hydrogen for a climate-neutral economy cost-effectively.* ***An immediate application in industry is to reduce and replace the use of carbon-intensive hydrogen in refineries, the production of ammonia, and for new forms of methanol production, or to partially replace fossil fuels in steel making****. In a second phase, hydrogen can form the basis for investing in and constructing zero-carbon steel making processes in the EU, envisioned under the Commission's new industrial strategy."* (Emphasis ours)

Assuming green hydrogen could be produced at a cost of €2.13/kg by 2030, we derive an implied theoretical mid-range fair value for the carbon price required to make green hydrogen competitive with grey hydrogen by that date of €91/t.[12]

11. Of course, the Commission has now formally proposed that the 2030 target be raised to -55% versus 1990.
12. We set out the full analysis behind this number with all assumptions in Section 3 below, but again for our immediate purposes here we are simply looking at how the theoretical fair value of EUAs can be calculated on the basis of our three key variables.

In short, the EU has effectively set 2030 as the point of convergence, i.e. the point at which the most valuable expected price in the future is achieved. This is because ensuring that green hydrogen is commercially competitive as a feedstock by 2030 is a pre-requisite for realizing the EU's 2050 hydrogen vision and hence for achieving its overarching policy aim of net-zero emissions by 2050.

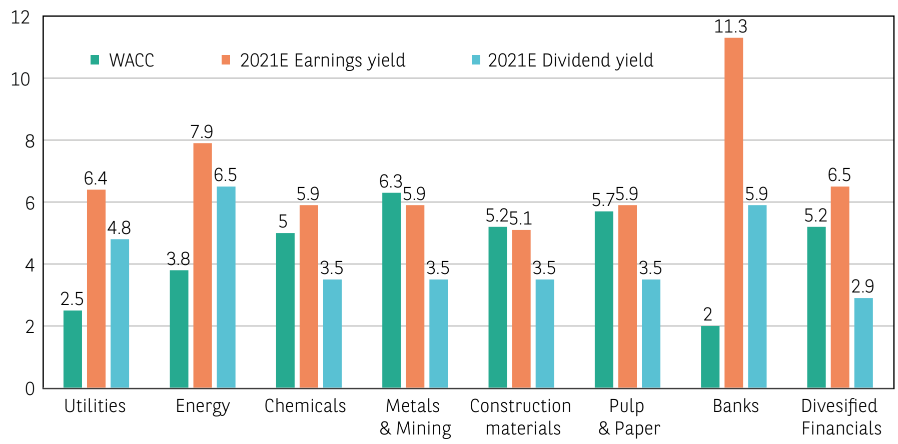
VARIABLE 3: THE APPROPRIATE COST OF CARRY

The appropriate discount rate to use for converting the implied fair value of EUAs at the future point of convergence into today's fair value should in theory be the weighted average cost of capital (WACC) of whoever we think is most likely to arbitrage the gap between the prevailing market price today on the one hand, and the implied fair value today of the 2030 price required to make green hydrogen commercially viable as a feedstock by 2030 on the other.

This will be either the industrial companies with compliance obligations in the EU-ETS or financial players such as banks, institutional investors, and hedge funds. Given the current very low interest-rate environment in the EU, Morgan Stanley estimates the costs of capital for the relevant industrial sectors covered by the EU-ETS in a range from 2.5% tor utilities to 6.3% for metals and mining, and for banks and diversified financials at 2% and 5.2% respectively (Figure 6). For hedge funds we think this would be closer to 10%.

The average WACC across all the sectors shown in Figure 6 is 4.5%, while the average 2021E earnings and 2021E dividend yields across all of these sectors are 6.9% and 4.3% respectively.

Figure 6: **Estimated WACC, and 2021E Earnings and Dividend Yields for EU-ETS industrial sectors and financials (%)**



Source: Morgan Stanley Equity Research; The figures shown are for the MSCI Europe.

Averaging all three of these indicators across all of these sectors would yield a discount rate of 5.2%, but we add a premium to this to reflect the higher required rate of return for hedge funds (hedge funds have played an important speculative role in the EU carbon market over the years). Accordingly, we view 6% as the appropriate discount rate for EUAs.

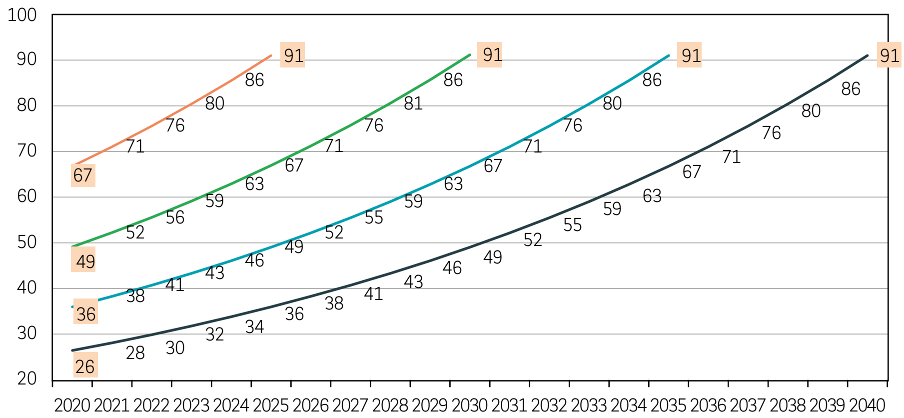
2.2 THE EUA FORWARD CURVE IN THEORY

What our analysis above reveals is that in an efficient market, today's EUA price is a function of the most valuable price in the future, discounted back at the appropriate cost of carry, and our three key variables above are all we need to impute today's EUA price.

The sooner the cap is tight enough at some point in the future to drive the carbon price to the nominal level at which green hydrogen becomes competitive as an industrial feedstock, the higher the implied EUA fair value in 2020 as the nominal future price will be discounted back in real terms over a shorter period of time. Conversely, the longer it takes for the cap to tighten to the point where the nominal carbon price reaches the point of convergence, the lower today's implied EUA price floor as the nominal future price will be discounted back in real terms over a longer period of time.

Using this framework, Figure 7 shows a range of EUA fair-value levels based on our 2030 theoretical mid-range price of €91/t depending on whether convergence were reached in 2025, 2030, 2035, or 2040.

Figure 7: Implied EUA forward curves at various points of convergence for green hydrogen as feedstock discounted at 6%



Source: BNP Paribas AM research estimates

If the cost of green hydrogen could be brought down to €2.13/kg already by 2025, then the €91/t carbon price we estimate would be necessary to displace grey hydrogen would imply a theoretical fair value for EUAs today of €67/t. In our view, however, it is unrealistic to assume that the cost of green hydrogen could be brought down this quickly.

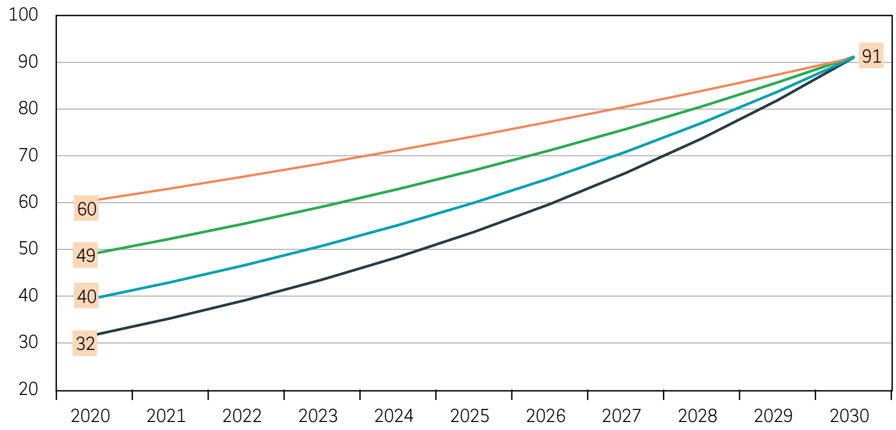
Our mid-range scenario has green hydrogen hitting €2.13/kg by 2030, implying a theoretical fair value today of €49/t, while if it were to take until 2035 for green hydrogen to be producible at €2.13/kg then the implied fair value of EUAs today would be €36/t. Finally, if green hydrogen could not be produced at €2.13/kg until 2040, then the implied fair value of EUAs today would be €26/t.[13]

Figure 8 then shows how different the forward curve would look from our base-case 2030 point of convergence but using a range of values for the discount rate. If we were to discount back at 10%, then the implied theoretical fair value today would be €32/t, at 8% it would be €40/t, at our base-case of 6% we derive €49/t, and at €4% a higher €60/t.[14]

13. his is consistent with the current Dec-20 market price for EUAs, so one way of reading the current market signal from the EU-ETS is that compliance players and investors do not think green hydrogen will be producible at €2.13/kg until 2040.

14. The current Dec-20 market price of €25/t is consistent with a discount rate of 11.5% from our 2030 point of convergence.

Figure 8: Implied EUA forward curves from 2030 convergence for green hydrogen discounted at 10%, 8%, 6%, and 4%.



Source: BNP Paribas AM research estimates

What happens after the point of convergence is reached?

That depends on whether the point of convergence has to be maintained in real or nominal terms beyond the point at which it is reached.

In theory, once the point of convergence is reached – i.e. once green hydrogen is competitive as an industrial feedstock – the challenge thereafter is to ensure that the cap remains tight enough to stabilize the EUA price at this level in real terms such that it becomes competitive as a fuel source by 2040 at the latest.

Otherwise, neither the 2050 hydrogen vision nor the 2050 net-zero target will be met. Once hydrogen is commercially viable as an energy source, though, the carbon price need only be maintained in nominal terms thereafter as the policy goal will have been met.

In practice, what happens after 2030 will also depend on (i) the evolution of gas prices over 2031-40 (natural gas will be the main competition for hydrogen as an energy source in space heating and power generation), and (ii) the evolution of green-hydrogen prices over 2031-40.

This means that It would also be possible for carbon prices to fall beyond the point of convergence if either (i) the cost of natural gas in the EU were to increase to uncompetitive levels beyond 2030, or (ii) the cost of producing green hydrogen were to fall further, or (iii) there were some combination of both of these developments.

We consider this point in more detail in Section 3.3 below.

2.3 CONCLUSION: IT TAKES CO_2 TO CONTANGO

Our theoretical framework for valuing carbon dictates that the forward curve should always be in contango, slanting upwards to the point of convergence at the appropriate cost of carry, and then once the policy objective has been achieved either rising in line with inflation or declining in line with the falling cost of producing green hydrogen.

From all of this it follows that the EUA price trajectory to the point of convergence is the long-run marginal-cost curve for the ETS, or the long-run abatement-supply curve. As such, the longer the EUA price is below the level implied today by the convergence trajectory, the greater the amount of more expensive abatement options that will have to be used in the future.

As we have seen, the theoretical framework for pricing EUAs from the point of convergence can give rise to a range of fair-value price levels for 2020 EUAs depending on the assumptions we make about the three key variables.

As a result, the challenge is to make the most plausible range of assumptions possible regarding these variables on the basis of the imperfect knowledge at our disposal today.

We have already shown above that we think the first key variable – understanding the ultimate policy objective behind the EU-ETS – is very clear: it is for the EU-ETS to be the main driver of the EU's achieving net-zero emissions by 2050. In turn, this entails driving the realization of the EU's vision for a green-hydrogen economy.

Accordingly, Section 3 now turns to the second key variable, namely the point of convergence, and the practicalities of making green hydrogen competitive as an industrial feedstock by 2030.

3 WHAT PRICE GREEN HYDROGEN IN 2030?

The EU today produces 8.2Mt of hydrogen, most of which is made from the SMR-process using natural gas and is therefore grey hydrogen. Most of this hydrogen is for use as an industrial feedstock in oil refining, and in the production of ammonia and methanol. The problem with the SMR process, however, is that it is highly carbon intensive, with 9kg of CO_2 produced for every kg of hydrogen.

As the production of hydrogen under the SMR process is an activity covered by the EU-ETS, replacing today's production with green hydrogen from electrolysis using renewables-based electricity by 2030 would in itself reduce EU-ETS emissions by 80-90Mt per year (equivalent to 6% of total 2019 EU-ETS emissions). This would already be a significant achievement but the real prize for the EU is much greater. This is because making green hydrogen commercially viable as an industrial feedstock by 2030 is the pre-requisite for achieving the EU's overall 2050 hydrogen vision.

The EU's plan for green hydrogen is to scale up production to >300TWh by 2030 by means of subsidies and mandates, and thereby reduce the cost of production to €2/kg (€51/MWh) or less in order to make it competitive with the grey hydrogen produced under the SMR process. The Commission estimates the total investment required to achieve its 2030 vision at €320-€460bn, with €220-€340bn of this to cover €80GW-120GW of dedicated new wind and solar capacity, and €24bn-€42bn for 40GW of electrolyzer capacity.

Reviewing the literature and doing our own analysis, we find that the Commission's numbers are both too optimistic and too pessimistic. They are too optimistic in that we simply do not see how 40GW of electrolyzers would be enough to produce 10Mt of green hydrogen. We calculate that at least 76GW of electrolyzers and 96GW of dedicated new reneables capacity would be necessary, even assuming that most of the renewable capacity required to power these electrolyzers were connected to the grid rather than attached directly to the electrolyzers themselves (thereby allowing a much higher utilization rate for the electrolyzers).

At the same time, we think the Commisison's cost estimates are too pessimistic, as the capital costs assumed for the required dedicated renewable capacity seem significantly higher than those observable in the market already today for new wind and solar projects, never mind the lower costs that are likely to be achieved within the next five years. Accordingly, we derive a total investment budget of €391bn for the electrolyzer and renewable capacity – and also including storage and distribution infrastructure – required to produce 10Mt by 2030. This puts us in the middle of the Commission's €340-€460bn range.

We note, however, that the cost of grey hydrogen is highly sensitive to fuel costs such that a €5/MWh change in the 2030 gas price in either direction moves the required 2030 EUA price to make green hydrogen competitive with grey hydrogen by plus or minus €23/t. Discounting back at 6%, a €5/MWh in the 2030 gas price in either direction translates into an impact on the implied 2020 EUA fair value of plus or minus €13/t.

After reviewing a selection of specialist third-party estimates, we derive a range of potential outcomes for the cost of producing green hydrogen by 2030, with the middle of our range being €2.13/k (€54/MWh). Similarly, we look at a range of potential outcomes for the price of natural gas in the EU by 2030, with the middle of this range being €15/MWh, and the implied cost of producing grey hydrogen at this gas price being €1.15/kg (€29/MWh).

With grey hydrogen's emissions intensity of 0.27t/MWh, this would imply an EUA price of €91/t in 2030 in order for green hydrogen to be competitive with grey hydrogen as an industrial feedstock. We derive this implied price by first calculating the gap to bridge between the cost of green hydrogen (€54/MWh) and the cost of grey hydrogen (€29/MWh) and multiplying this difference by the carbon intensity of grey hydrogen: **€24.6/0.27/t = €91/t.**

Over the following decade 2031-40 the challenge will then be to make green hydrogen competitive as an energy source. We think this is possible at a carbon price of €100/t-€140/t by 2040, depending on the cost of producing green hydrogen and the EU gas price.

Assuming that the cost of producing green hydrogen were to fall to €1.25/kg by 2040, and at a gas price of €15/MWh, this would make hydrogen competitive as a fuel for power generation at €100/t.

On the other hand, assuming the same green-hydrogen cost of €1.25/kg but gas prices of €10/MWh in 2040 would make hydrogen competitive with gas for power generation at a carbon price of €137/t.

3.1 THE COST OF PRODUCING GREY HYDROGEN IN THE EU TODAY

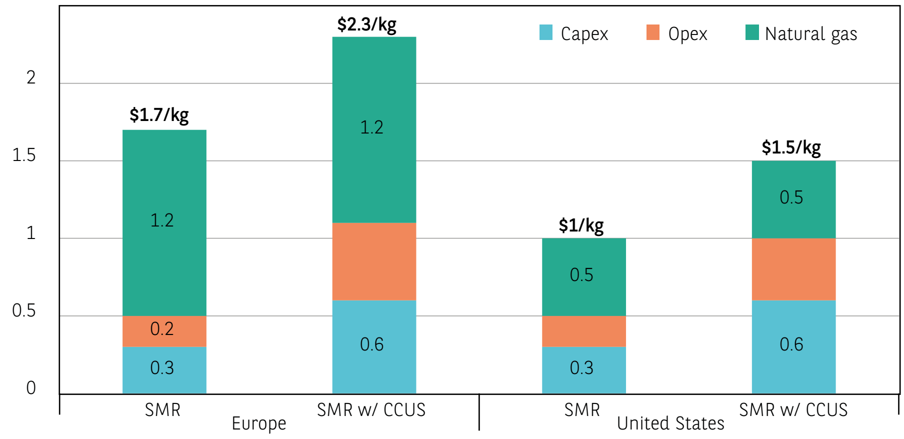
The economics of grey hydrogen are very sensitive to two key variables: (i) natural-gas prices, and (ii) carbon prices.

3.1.1. How sensitive is grey hydrogen to gas prices?

Figure 9 shows the costs for producing hydrogen from the SMR process in Europe and the US at 2018 prices both with and without carbon-capture, utilization, and storage (CCUS) technology, as estimated by the IEA in its landmark report The Future of Hydrogen.[15]

As can be seen the cost of producing grey hydrogen varies a lot depending on (i) gas prices, and (ii) whether CCUS is fitted to capture emissions or not.

Figure 9: Cost of producing SMR-based (grey) and SMR w/CCUS (blue) hydrogen in the EU and the US, 2018 ($/kg)*



Source: IEA. *The costs here are shown in US $ per kg assuming a European gas price of $7.3/mmbtu (equivalent to €21/MWh at 2018 €/$ exchange rate).

With natural-gas gas prices structurally lower in the US than in Europe, it is significantly cheaper to produce grey hydrogen in the US than in Europe.

15. Available at: https://webstore.iea.org/download/direct/2803. The Future of Hydrogen was published in 2019 and is probably the most comprehensive study currently available of the costs of the different technologies for producing hydrogen and of the future applications of hydrogen in a decarbonized global energy system. Indeed, the European Commission's A Hydrogen Strategy for a Climate-neutral Europe document relies on this IEA study when comparing the costs of green hydrogen with those of grey hydrogen and blue hydrogen.

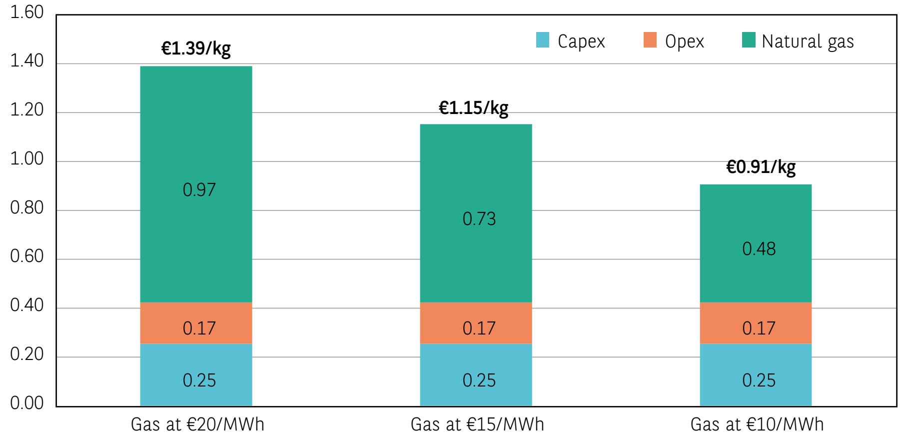
Without CCUS, the cost in the US in 2018 as estimated by the IEA was only $1kg compared with $1.7/kg in the EU, while including CCUS it was $1.5/kg in the US versus $2.3/kg in the EU.

To underline just how sensitive the economics of producing grey hydrogen are to the gas price, Figure 10 then shows the implied cost of producing grey hydrogen in the EU at different gas-input prices.

This time we break the costs down in Euros. The capex and opex assumptions are the same as those shown in figure converted from $ into € at the current exchange rate of €1 = $1.18,[16] but we show the cost of producing grey hydrogen with gas prices of €20/MWh, €15/MWh, and €10/MWh respectively.

As can be seen, the overall cost per kg of hydrogen produced is very sensitive to gas prices: every €5/MWh change in the gas price moves the cost of producing hydrogen by €0.24/kg.

Figure 10: Production cost of SMR-based (grey) hydrogen in the EU at different gas prices, excluding carbon (€/kg)



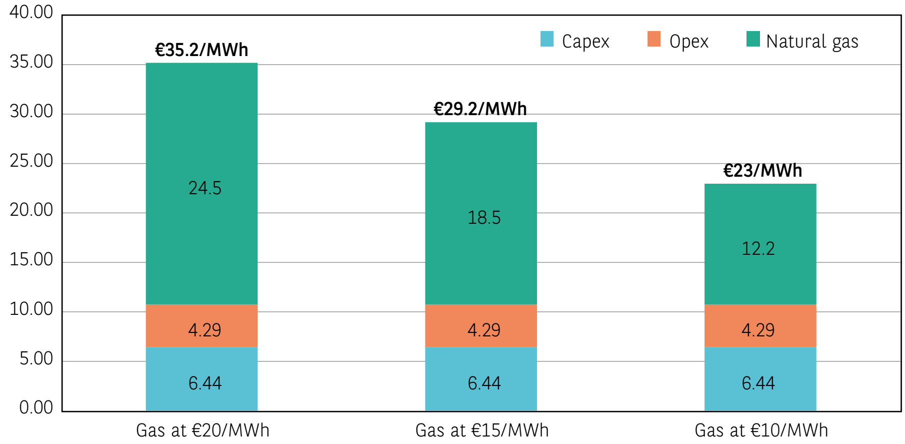
Source: BNPP AM Research estimates (based on IEA analysis in The Future of Hydrogen).

It is easier to show this sensitivity by pricing in MWh rather than kilogrammes. One kg of hydrogen is equivalent to 39.4kWh of energy,[17] so to derive the cost of producing grey hydrogen in MWh we divide the cost in kg by 39.4 to get the cost in kWh and then multiply by 1,000. This gives us a production cost of €35/MWh, €29/MWh, and €23/MWh at gas-input prices of €20/MWh, €15/MWh, and €10/MWh respectively (Figure 11). Every €5/MWh change in the gas price moves the cost of producing hydrogen by €6/MWh.

16. Today's €/$ exchange rate of €1 = $1.18 is the same as the average rate for 2018, used by the IEA in its 2018 cost analysis (Figure 9 above). This means our Euro-denominated cost and sensitivity analysis in Figures 10 and 11 are consistent with the IEA's numbers in Figure 9.

17. This at the higher heating value (HHV) of hydrogen rather than at the lower heating value (LHV) of 33.3kWh/kg. We distinguish between these two values depending on whether we are assuming the hydrogen is being used as a feedstock or as a fuel source. As a feedstock, we use the HHV as the hydrogen will be used for its chemical rather than its energy properties and will therefore not be combusted. By contrast, when it is being used as a fuel to be combusted -- for example, in power generation – it is the LHV that we take as some of the energy will be lost as water vapour in the combustion process.

Figure 11: Production cost of SMR-based (grey) hydrogen in the EU at different gas prices, excluding carbon (€/MWh)



Source: BNPP AM Research estimates (based on IEA analysis in The Future of Hydrogen)

In short, producing grey hydrogen is more expensive in the EU than in the US owing to the sensitivity to gas prices and the fact that gas prices are structurally much higher in the EU than in the US. But what about carbon prices? The production of grey hydrogen in the EU is covered by the EU-ETS, so how do the economics change when we introduce carbon pricing into the equation?

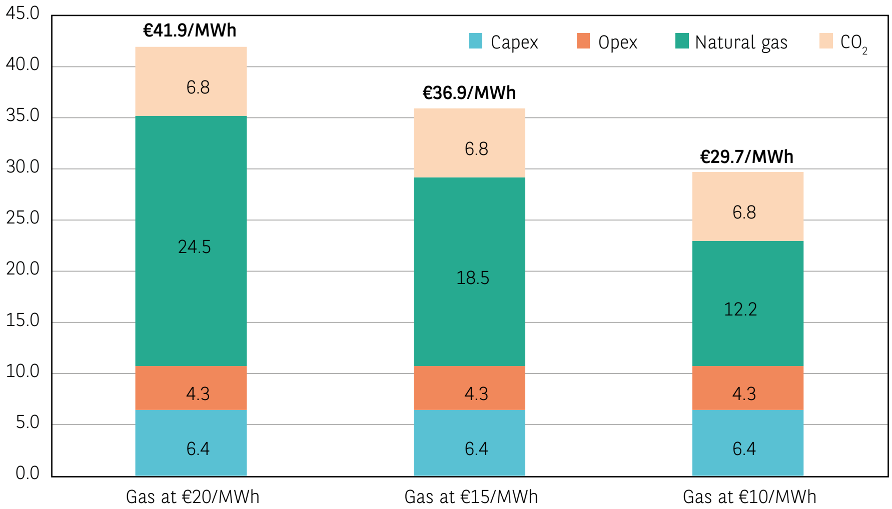
3.1.2. How sensitive is grey hydrogen to carbon prices?

In its Communication of 8 July, A Hydrogen Strategy for a Climate-neutral Europe, the Commission made the point that the production of grey hydrogen is currently covered by the EU-ETS but that as it is one of the activities deemed to be at risk of carbon leakage the installations that make grey hydrogen receive free allocations of EUAs up to 100% of the relevant industry benchmark (EU COM [2020] 301 final: 13):

"Almost all existing fossil-based hydrogen production is covered by the ETS, but the sectors concerned are deemed to be at a significant risk of carbon leakage and therefore receive free allocation at 100% of benchmark levels. As foreseen in the ETS Directive, the benchmark used for free allocation will be updated for phase 4. ***In the forthcoming revision of the ETS, the Commission may consider how the production of renewable and low-carbon hydrogen could be further incentivised, while taking due account of the risk for sectors exposed to carbon leakage****. Should differences in climate ambition levels around the world persist, the Commission will propose a Carbon Border Adjustment Mechanism in 2021 to reduce the risk of carbon leakage, in full compatibility with WTO rules, and will also look at the implications for hydrogen."* (Emphasis ours)

As is clear from the sentence we have highlighted in the above excerpt, the Commission is thinking about how to ensure that the cost of carbon be reflected in the selling price of grey hydrogen so that other, low-carbon (blue hydrogen) or zero-carbon (green hydrogen) production techniques can compete. This will ultimately require that the installations making grey hydrogen pay for their EUAs rather than receiving them for free, and this is why the Commission is now thinking seriously about the possibility of a Carbon Border-Adjustment Mechanism (CBAM).[18]

Figure 12 Production cost of SMR--based (grey) hydrogen in the EU at different gas prices, with carbon at €25/t (€/MWh)



Source: BNPP AM Research estimates (based on IEA analysis in The Future of Hydrogen).

So, what would be the impact of reflecting the current EUA market price in the cost of making grey hydrogen? Making grey hydrogen is highly carbon intensive, with 9kg of CO_2 emitted for every kg of hydrogen produced.[19] This equates to 0.27 tonnes of CO_2 for every MWh of grey hydrogen. Figure 12 shows that at the current EUA price of €25/t this would add €7/MWh to the cost shown in Figure 11 above, such that the total cost would be €42/MWh, €37/MWh, and €30/MWh at gas-input prices of €20/MWh, €15/MWh, and €10/MWh respectively.

So, what carbon price would be needed to make first blue hydrogen and then green hydrogen competitive with grey hydrogen?

3.2 THE EU VISION TO 2030

The EU's hydrogen strategy to 2050 foresees three phases, with a staged ramp-up in the production of both low-carbon and green hydrogen in Phase-1 (2020-24), an emphasis on green hydrogen as a feedstock in Phase-2 (2025-30), and then emphasis on deploying hydrogen at large scale as a fuel for power generation and transport over the third phase (2031-50). Each of these phases has ambitious targets, starting with Phase-1 (EU COM [2020] 301 final: 5):

> *"In the first phase, from 2020 up to 2024, the strategic objective is to install at least 6 GW of renewable-hydrogen electrolyzers in the EU and the production of up to 1 million tonnes of renewable hydrogen, to decarbonise existing hydrogen production, e.g. in the chemical sector and facilitating take up of hydrogen consumption in new end-use applications such as other industrial processes and possibly in heavy-duty transport."*

18. We would note, however, that even if a CBAM is not ultimately introduced by the EU, and even if grey-hydrogen producers therefore continued to receive a significant portion of their allowances for free all the way to 2030, the principle of opportunity cost would still dictate that the rational thing to do if and when the carbon price were to hit the level at which green hydrogen becomes more competitive than grey hydrogen would be to stop producing grey hydrogen and instead to sell the free allowances on the market.
19. See Section 2.1 above, Footnote 9.

Phase-2 is then all about scaling up the production of green hydrogen (EU COM [2020] 301 final: 6):

> *"In a second phase, from 2025 to 2030, hydrogen needs to become an intrinsic part of an integrated energy system with a strategic objective to install at least 40 GW of renewable-hydrogen electrolyzers by 2030 and the production of up to 10 million tonnes of renewable hydrogen in the EU."*

And Phase-3 is then all about commercializing green hydrogen at scale as an energy source in sectors where electricity cannot provide a zero-carbon solution (EU COM [2020] 301 final: 7):

> *"In a third phase, from 2030 onwards and towards 2050, renewable-hydrogen technologies should reach maturity and be deployed at large scale to reach all hard-to-decarbonise sectors where other alternatives might not be feasible or have higher costs."*

At the same them, the Commission notes that in the first phase it will be necessary for blue hydrogen to act as an interim solution as a low-carbon variation on grey hydrogen (EU COM [2020] 301 final: 6):

> *"In the short and medium term, however, other forms of low-carbon hydrogen are needed, primarily to rapidly reduce emissions from existing hydrogen production and support the parallel and future uptake of renewable hydrogen."*

In short, the EU is looking to make green hydrogen commercially viable as a feedstock by 2030 and as an energy source for much broader application over 2031-50, but in the very near term it acknowledges that blue hydrogen is a valid option for reducing the carbon intensity of hydrogen production. So what are the current economics of blue hydrogen, and how does the Commission expect its relative competitiveness to develop over 2021-30 versus both grey hydrogen and green hydrogen?

3.2.1. At what carbon price would blue hydrogen be competitive with grey hydrogen?
In A Hydrogen Strategy for a Climate-neutral Europe, the Commission makes the point that neither blue hydrogen nor green hydrogen are competitive with grey hydrogen today (EU COM [2020] 301 final: 13):

> *"Today, neither renewable hydrogen nor low-carbon hydrogen, notably fossil-based hydrogen with carbon capture, are cost-competitive against fossil-based hydrogen. Estimated costs today for fossil-based hydrogen are around €/1.5kg for the EU, highly dependent on natural gas prices, and disregarding the cost of CO_2. Estimated costs today for fossil-based hydrogen with carbon capture and storage are around €2/kg, and renewable hydrogen €2.5-5.5/kg."*[20]

As the Commission has relied on the same IEA study we have referenced above, these numbers for grey and blue hydrogen in the EU are consistent with those in Figure 9 above, giving an implied cost of production in MWh terms – excluding carbon – of €37/MWh and €49/MWh for grey and blue hydrogen respectively.

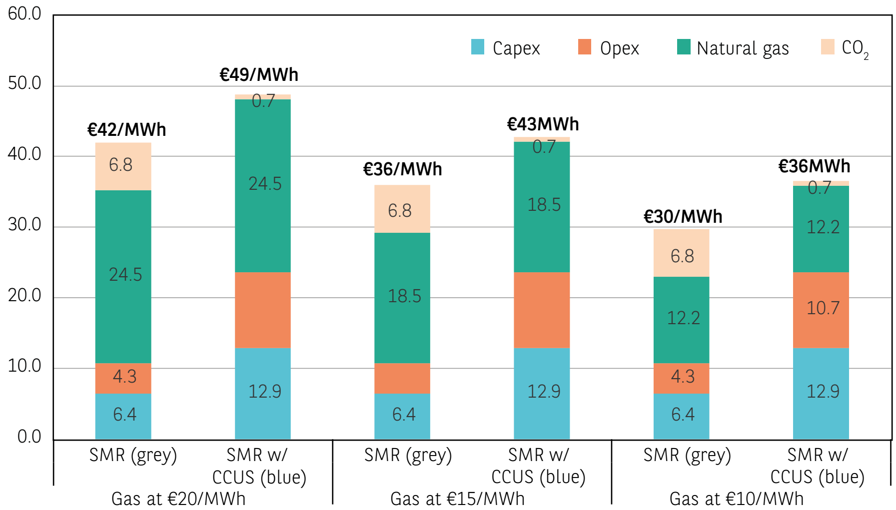
But how would this picture change with the cost of carbon included?

20. Note that even assuming the middle of the €2.5/kg-€5.5/kg range given here for green hydrogen would imply a production cost of €100/MWh: (€4/kg/39.4)*1000 = 100/MWh. In turn, this would necessitate a carbon price of €233/t for green hydrogen to be competitive with blue hydrogen today: (€100/MWh-€37/MWh)/0.27t = €233/t.

    And even if such a carbon price today were politically acceptable (and it would not be), the scale of green-hydrogen production kit available today is nowhere near big enough to make the use of carbon pricing as a tool to scale it up either a practical or indeed a practicable policy option. As explained in Section 3.2.2. below, this means that while carbon pricing will be the right tool once green hydrogen is available at scale (2030 on our assumptions), subsidies and mandates are the more appropriate measure to achieve the scaling-up itself between now and 2030.

Figure 13 shows the cost of producing grey and blue hydrogen on the same assumptions as in Figure 9 above but for our chosen range of gas prices, and with CO_2 priced at the current market level for Dec-20 EUAs of €25/t. We also assume here that the blue hydrogen is produced with the CCUS equipment capturing 90% of the carbon emissions, the upper end of the CCUS efficiency scale. On these assumptions it can be seen that grey hydrogen is cheaper by €7/MWh in each case, whether the gas-input price is €20/MWh, €15/MWh, or €10/MWh.

Figure 13: Production cost of grey versus blue hydrogen in the EU at different gas prices with carbon at €25/t (€/MWh)



Source: BNPP AM Research estimates (based on IEA analysis in The Future of Hydrogen)

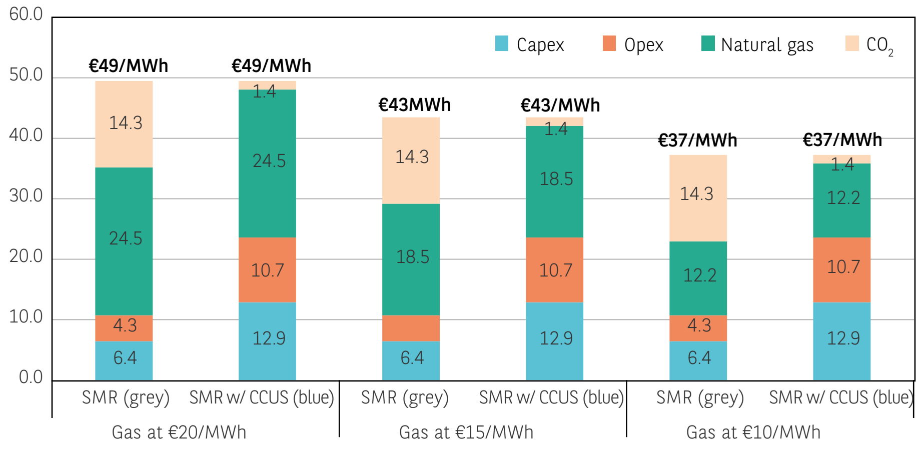
As shown in Figure 14, the carbon price required to equalize the total cost of producing grey and blue hydrogen would be €53/t.[21] At this price, the cost of carbon for the grey-hydrogen producer is €14.3/MWh (i.e. €53/t*0.27/t), while the cost of carbon to the blue-hydrogen producer is only €1.4/t as the blue-hydrogen producer is capturing 90% of the emissions. Accordingly, the grey and blue producers have the same total cost base whatever the gas-input price.

With the required carbon price to make blue hydrogen competitive with grey hydrogen today ranging between 2x and 3x the current market price for EUAs, the Commission states that support schemes will be required, with one possible instrument being carbon contracts for difference (CCfDs), as explained in A Hydrogen Strategy for a Cimate-neutral Europe (EU COM [2020] 301 final: 13):

> *"With the need to scale-up renewable and low-carbon hydrogen before they are cost-competitive, support schemes are likely to be required for some time, subject to compliance with competition rules. A possible policy instrument would be to create tendering systems for carbon contracts for difference ('CCfD'). Such a long-term contract with a public counterpart would remunerate the investor by paying the difference between the CO_2 strike price and the actual CO_2 price in the ETS in an explicit way, bridging the cost gap compared to conventional hydrogen production."*

21. If we assumed the lower end of the range for CCUS-efficiency range (56%), then we calculate that a carbon price of €83/t would be necessary to make blue hydrogen competitive with grey hydrogen today. Our carbon-pricing analysis for making grey hydrogen competitive with blue hydrogen in the EU today is thus consistent with that of the Commission, who give a range of €55/t-€90/t compared with our €53/t-€83/t (see page 4 of A Hydrogen Strategy for a Climate-neutral Europe).

Figure 14: Implied cost of grey versus blue hydrogen in the EU at different gas price with carbon at €53/t (€/MWh)



Source: BNPP AM Research estimates (based on IEA analysis in The Future of Hydrogen)

However, there are four things to say about the potential of CCfDs to accelerate the deployment of alternatives to grey hydrogen.

First, given the economics of green hydrogen today, then in the near term CCfDs would almost certainly be more attractive for boosting blue rather than green hydrogen. As already mentioned,[22] even at the mid-range estimate of the cost of producing green hydrogen today of €4/kg, we estimate that a carbon price of €233/t would be necessary to make hydrogen produced from electrolysis using renewable electricity competitive with SMR-based hydrogen. The Oxford Institute for Energy Studies (OIES) makes the same point in its analysis of the Commission's vision, EU Hydrogen Strategy: A Case for Urgent Action Towards Implementation (p.4):[23]

> *"Given the significantly lower cost of blue-hydrogen production today, it is to be expected that any auction for CCfDs would be won by blue-hydrogen projects initially, with green hydrogen having to rely on more direct support schemes until costs have reduced sufficiently."*

Second, CCfDs can only be a short-term solution in any case, as blue hydrogen itself is intended only to be an interim technology while green-hydrogen capacity is being scaled up. The Commission makes this point very clearly (EU COM [2020] 301 final: 13):

22. See Footnote 20 above

23. Available at: https://www.oxfordenergy.org/wpcms/wp-content/uploads/2020/07/EU-Hydrogen-Strategy.pdf. It is not our aim here to explain the other potential measures proposed or required to make blue hydrogen competitive as an interim technology, but the OIES study offers a good summary of this.

"Boosting demand and supply of hydrogen is likely to require various forms of support, differentiated ***in line with the vision of this strategy to prioritise the deployment of renewable hydrogen.*** *While in a transition phase, appropriate support will be needed for low-carbon hydrogen,* ***this should not lead to stranded assets.*** *The revision of the State aid framework, including the State-aid guidelines for energy and environmental protection, foreseen in 2021, will be an opportunity to create a comprehensive enabling framework to advance the European Green Deal and in particular decarbonisation, including with respect to hydrogen while limiting potential distortions of competition and adverse effects in other Member States."* (Emphasis ours)

Third, the whole point about the EU-ETS is that it is a pan-European market with exactly the same price for every tonne of CO_2 emitted under the scheme across the EU. As a result, to the extent that CCfDs could lead to varying carbon-price reference points between EU member states if implemented at a national level, the EU will likely want to be selective in how widely they are used.

Fourth, governments prefer taking in revenues from auctioning EUAs to paying out public funds to compensate for EUA prices not being high enough. This means that if a CCfD reference price were significantly higher than the EUA price it would actually create an incentive for EU member states to close the gap via the tightening of the EU-ETS cap, thereby allowing them to benefit from auctioning EUAs at higher prices.

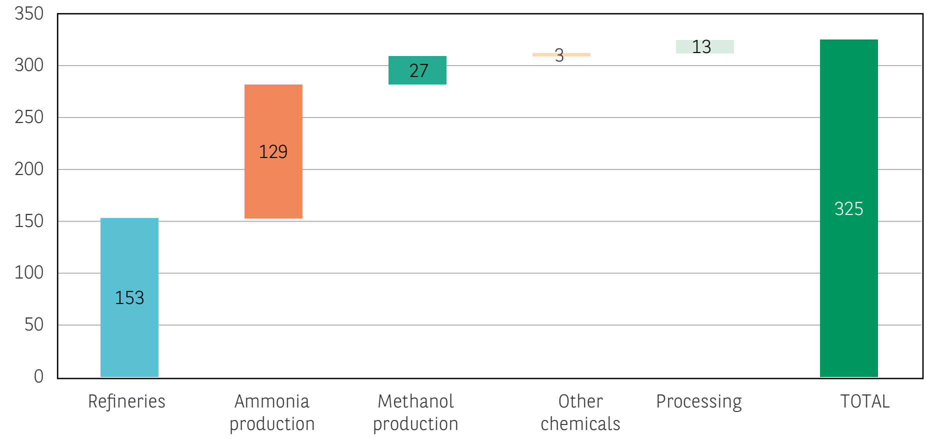
All of this being said, a CCfD under which bidders were compensated for the difference between the market price for EUAs and the carbon price necessary to make blue hydrogen competitive – €53/t-€83/t on our numbers, €55/t-€90/t according to the Commission – could have a strong signaling value regarding where EUA prices themselves would ultimately have to go by 2030.

All of these considerations indicate that CCfDs would likely only be an interim policy measure, as ultimately the realization of the Commission's net-zero vision depends on scaling up green hydrogen to make it competitive first as an industrial feedstock by 2030, and then as an energy source at scale over the following two decades. The key to realizing the first part of this vision is (i) using subsidies and mandates to attract the necessary capital for the scaling up over the next decade, and then (ii) tightening the EU-ETS cap such that the EUA price will be sufficiently high in 2030 to ensure that the green hydrogen being produced by then will be able to displace grey hydrogen as an industrial feedstock

3.3 WHAT PRICE GREEN HYDROGEN IN 2030?

The EU currently produces 8.2Mt (325TWh) of hydrogen,[24] nearly all of which is produced under the SMR process and used as industrial feedstock. Figure 15 shows the breakdown of how this grey hydrogen is used,[25] with refineries and ammonia production accounting for most of the demand, while methanol production, other chemicals, and other industrial-processing uses account for the remainder.

Figure 15: Current use for hydrogen as an industrial feedstock in the EU (TWh)



Source: Fuel Cells and Hydrogen 2 Joint undertaking.

As already explained above, the cost of green hydrogen today is much higher than that of either grey or blue hydrogen. However, the costs have been falling rapidly and there is clear potential to bring the costs down significantly further by 2030. In its document A Hydrogen Strategy for a Climate-neutral Europe, the Commission cites the IEA, IRENA, and BNEF as sources for its statement that green hydrogen will be competitive with fossil-based hydrogen by 2030 (EU COM [2020] 301 final: 4-5).

"Costs for renewable hydrogen are going down quickly. Electrolyzer costs have already been reduced by 60% in the last ten years, and are expected to halve in 2030 compared to today with economies of scale. In regions where renewable electricity is cheap, electrolyzers are expected to be able to compete with fossil-based hydrogen in 2030. Assuming current electricity and gas prices, low-carbon fossil-based hydrogen is projected to cost in 2030 between €2-2.5/kg in the EU, and renewable hydrogen is projected to cost between €1.1-2.4/kg (IEA, IRENA, BNEF)."

The Commission's vision of green-hydrogen costs in a range of €1.1/kg-€2.4kg by 2030 are way below the range of €2.5/kg-€5.5/kg that it gives for today, and achieving it will depend above all on scaling up the production of both electrolyzers and renewable energy so as to leverage economies of scale and technology improvements.

This is why the Commission has set an ambitious volume target of 10Mt of green hydrogen to be produced in the EU by 2030, requiring 40GW of electrolyzer capacity and up to 120GW of dedicated new renewable-energy capacity (mostly in the form of offshore wind). Only if capacity and production can be scaled to these kinds of levels will it be possible to bring the costs down to the range of €1.1/kg-€2.4kg that the Commission aspires to.

24. See Hydrogen Europe, *Hydrogen 2030: the Blueprint* (p. 5), available at: https://hydrogeneurope.eu/sites/default/files/Hydrogen%20 2030_The%20Blueprint.pdf. As explained above, when looking at the use of hydrogen as an industrial feedstock we take the HHV, with 1kg equivalent to 39.4kWh

25. The data here is from the report by Fuel Cells and Hydrogen 2 Joint Undertaking, *Hydrogen Roadmap Europe: A Sustainable Pathway for the European Energy Transition* (page 40) available at: https://www.fch.europa.eu/sites/default/files/Hydrogen%20 Roadmap%20Europe_Report.pdf

As explained from the outset of this report, it is not our purpose here to analyze in detail the feasibility of reducing the cost of green hydrogen to the range of €1.1/kg-€2.4kg by 2030 envisaged by the Commission, not least as there are a number of specialist studies already available that have looked at this in exhaustive detail both at the global and the EU level.[26] Rather, our objective is to consider the carbon-pricing implications in the EU from today's standpoint for a range of potential green-hydrogen cost outcomes by 2030 – it will then be for participants in the EU carbon market to determine whether the EU's plans are credible, and hence whether today's price should indeed reflect the implied 2030 carbon price required to make green hydrogen competitive as an industrial feedstock.

That being said, and before we look in more detail at these carbon-pricing implications for different 2030 green-hydrogen cost outcomes, it is useful to summarize both the policy measures outlined by the Commission to achieve its targeted 2030 costs, capacity, and production volumes, and the views of the studies we have just referenced regarding what would be required to bring green-hydrogen production costs down to these levels.

3.3.1 Green hydrogen in 2030: achieving scale is key to reducing costs

Producing the kind of volumes by 2030 that the Commission aspires to will require substantial investment from the private sector, which in turn will require support in the form of subsidies and mandates. The Commission itself estimates that the execution of its vision all the way out to 2050 will require €180-€470bn of investment in production capacity (electrolyzers and renewable-energy capacity) and infrastructure (storage facilities and transportation links). Between now and 2030, most of the investment required is for the electrolyzers themselves (€24-€42bn), and for the new renewable-energy capacity that will be needed to power the electrolyzers (€220-€340bn).[27]

> The Commission underlines how challenging the 2030 vision will be to achieve, emphasizing that it will require close collaboration between the public and private sectors across all Member States (EU COM [2020] 301 final: 2):
>
> *"Deploying hydrogen in Europe faces important challenges that neither the private sector nor Member States can address alone. Driving hydrogen development past the tipping point needs critical mass in investment, an enabling regulatory framework, new lead markets, sustained research and innovation into breakthrough technologies and for bringing new solutions to the market, a large-scale infrastructure network that only the EU and the single market can offer, and cooperation with our third-country partners.* ***All actors, public and private, at European national and regional level, must work together, across the entire value chain, to build a dynamic hydrogen ecosystem in Europe."*** (Emphasis ours)

Accordingly, the Commission emphasizes the launch and role of the European Clean Hydrogen Alliance as a key player in helping to galvanize investment in the EU's green-hydrogen economy (EU COM [2020] 301 final: 8):

26. We would note in particular the study by the Hydrogen Council, Path to Hydrogen Competitiveness: A Cost Perspective, January 2020 (https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf); BNEF's Europe's $500bn Plan Will Scale Up Green Hydrogen, 13 July 2020 (https://www.bnef.com/insights/23661/view, subscribers only), BNEF's Hydrogen Economy Outlook, 30 March 2020 (https://www.bnef.com/core/insights/22567 subscribers only); BNEF's Hydrogen: The Economics of Production from Renewables, 21 August 2019 (https://www.bnef.com/core/insights/21213, subscribers only); Hydrogen Europe's Hydrogen 2030: The Blueprint, May 2020 (https://hydrogeneurope.eu/sites/default/files/Hydrogen%20 2030_The%20Blueprint.pdf); and the IEA's The Future of Hydrogen, June 2019 (https://webstore.iea.org/download/direct/2803).

27. See A Hydrogen Strategy for a Climate-neutral Europe (EU COM [2020] 301 final: page 7).

"The Alliance will play a crucial role in facilitating and implementing the actions of this Strategy and supporting investments to scale up production and demand for renewable and low-carbon hydrogen. It is strongly anchored in the hydrogen industrial value chain from production via transmission to mobility, industry, energy, and heating applications, and supports the related skills and labour market adjustments where needed. It will bring together the industry, national, regional and local public authorities and the civil society. (...) ***The key deliverable of the Alliance will be to identify and build up a clear pipeline of viable investment projects****. This will facilitate coordinated investments and policies along the hydrogen value chain, and cooperation across private and public stakeholders across the EU, providing public support where appropriate* ***and crowding in private investment. (...) At this point, already 1.5-2.3 GW of new renewable hydrogen production projects are under construction or announced, and an additional 22 GW of electrolyzer projects7are envisaged and would require further elaboration and confirmation."***
(Emphasis ours)

The Commission sees its own role as that of a facilitator, with the private sector providing the bulk of the investment, and member states most of the subsidies and public-sector loans that will be required to crowd-in the private-sector investment. This will encompass, amongst others, the following measures (EU COM [2020] 301 final: 22-23):

"Boosting demand for green hydrogen and scaling up production:

- *Exploring additional support measures, including demand-side policies in end-use sectors, for renewable hydrogen building on the existing provisions of Renewable Energy Directive (by June 2021).*
- *Working to introduce a common low-carbon threshold/standard for the promotion of hydrogen production installations based on their full life-cycle GHG performance (by June 2021).*
- *Working to introduce a comprehensive terminology and European-wide criteria for the certification of renewable and low-carbon hydrogen (by June 2021).*
- *Developing a pilot scheme – preferably at EU level – for a Carbon Contracts for Difference programme, in particular to support the production of low-carbon and circular steel, and basic chemicals.*

Designing and enabling and supportive framework: support schemes, market rules and infrastructure

- *Start the planning of hydrogen infrastructure, including in the Trans-European Networks for Energy and Transport and the Ten-Year Network Development Plans (TYNDPs) (2021) taking into account also the planning of a network of fuelling stations.*
- *Accelerate the deployment of different refuelling infrastructure in the revision of the Alternative Fuels Infrastructure Directive and the revision of the Regulation on the TransEuropean Transport Network (2021).*
- *Design enabling market rules to the deployment of hydrogen, including removing barriers for efficient hydrogen infrastructure development (e.g. via repurposing) and ensure access to liquid markets for hydrogen producers and customers and the integrity of the internal gas market, through the upcoming legislative reviews (e.g. review of the gas legislation for competitive decarbonised gas markets (2021)."*

The Commission says that it will also promote R&D in green-hydrogen, as well as cooperation with bordering countries such as Ukraine and Morocco. Indeed, according to Hydrogen Europe (HE) if the EU is to stand a realistic chance of producing 10Mt of green hydrogen by 2030 then the already ambitious target of building 40GW of electrolyzers by that time within the EU will have to be complemented by a further 40GW of electrolyzer capacity in neighbouring countries such as these.[28]

This is because with the amount of new dedicated renewable-electricity capacity envisaged by the Commission for the purposes of meeting the 2030 10Mt target – 80GW-120GW – HE argues it is simply not possible to produce this volume given the load factors of wind and solar on the one hand, and the efficiency rate of electrolyzers on the other.[29] HE assumes that of the 40GW electrolyzer capacity envisaged by the Commission, 6GW could be used in captive-market conditions (i.e. with the electrolyzers located at or close to industrial facilities, and with the green hydrogen then used as feedstock), and 34GW for the developing hydrogen market (i.e. with the electrolyzers located at or close to the source of renewables generation and then stored and transported for use as a fuel in energy applications).

HE then assumes a big difference between the assumed load factors for the electrolyzers depending on whether they are being employed by the captive market for feedstock or the market for using hydrogen as an energy source.

For the 6GW of electrolyzer capacity for the captive industrial market, HE assumes that the electrolyzers run at 8,000 hours per year (a 90% load factor), and 6.4GW and 5.4GW of dedicated new offshore- and onshore-wind capacity run at 57% and 34% respectively. This enables the production of 1Mt of green hydrogen.

The electrolyzers run at 90% capacity because HE assumes that they are connected to the grid. It is thus assumed that despite the intermittency of the dedicated 11.8GW of wind capacity matched with the electrolyzer capacity, the electrolyzers can take renewable power from the grid whenever needed via a guarantee-of-origin and traceability scheme.

Figure 16 shows how this works: 11.8GW of wind capacity produces a total of 48TWh, which at an assumed efficiency rate of 70% gives a net production of 33.6TWh, or 0.96Mt of green hydrogen.[30]

28. Our review of HE's analysis here is based on their report *Hydrogen 2030: The Blueprint*, referenced above.
29. Industrial electrolyzers have an efficiency rate of 70% (see Kaveh Mazloomi et al, 'Electrical Efficiency of Electrolytic Hydrogen Production', in *International Journal of Electrochemical Science*, 7, [2012], available at http://www.electrochemsci.org/papers/vol7/7043314.pdf).
30. HE is here assuming a conversion rate of 35.4kWh/kg, which is mid-way between the HHV (39.4) and LHV (33.3) of hydrogen.

Figure 16: Potential production of green hydrogen from 6GW of electrolyzers for captive hydrogen-for-feedstock market

Net output assumes 70% efficiency rate for electrolyzers

	Electrolyzers	Offshore Wind	Onshore wind	Total Wind
Capacity (GW)	6.0	6.4	5.4	11.8
Assumed LF (hours)	8,000	5,000	3,000	n/a
Gross throughput (GWh)	48,000	32,000	16,000	48,000
Net output (GWh)	34,000	22,667	11,333	34,000
Net green hydrogen (Mt)	0,96	0.64	0.32	0.96

Source: Hydrogen Europe, BNPP AM Research estimates

For the 34GW pf electrolyzer capacity for the hydrogen-for-energy market, HE assumes that the electrolyzers run for only 5,000 hours per year (a 57% load factor), and that 8.5GW, 14.5GW, and 47.5GW of dedicated new offshore- and onshore-wind and solar capacity run at 57%, 34%, and 20% respectively, thereby enabling the production of 3.4Mt of green hydrogen. In this instance, the electrolyzers run for only 5,000 hours per year because their capacity is constrained by the load factor of the renewable-energy resources to which they are connected, or close to which they are located (Figure 17).

Figure 17: Potential production of green hydrogen from 34GW of electrolyzers for hydrogen-for-energy market

Net output assumes 70% efficiency rate for electrolyzers

	Electrolyzers	Offshore Wind	Onshore wind	Solar
Capacity (GW)	34.0	8.5	14.2	47.5
Assumed LF (hours)	5,000	5,000	3,000	1,800
Gross throughput (GWh)	170,000	42,500	42,500	85,000
Net output (GWh)	120,000	30,104	30,104	60,208
Net green hydrogen (Mt)	3.4	0.85	0.85	1.70

Source: Hydrogen Europe, BNPP AM Research estimates

BNEF makes exactly the same point as HE, saying that 40GW of electrolyzer capacity is simply not enough to produce 10Mt of green hydrogen: "The 10Mt figure [for green hydrogen by 2030] does not appear to be aligned with the target of 40GW of electrolyzers, which would only yield 3Mt per year."[31] BNEF's assumption here is that all of the electrolyzers would be producing at or close to the renewable-energy resource and would therefore be constrained by the load factors of wind and solar. BNEF also assumes a lower average load factor for wind and solar than HE of only 43%, such that 132GW of electrolyzer capacity would be required to produce 10Mt. Assuming grid connection, BNEF states that the electrolyzers' load factors could be increased to 71%, requiring 80GW of electrolyzer capacity (although still twice the 40GW that the Commission states could theoretically produce 10Mt).

We agree that the Commission's target of 10Mt from 40GW is too optimistic as it assumes close to 100% load factor for the electrolyzers, and is a gross amount rather than the net amount after the 30% efficiency loss. Our view of the maximum amount of green hydrogen that could reasonably be produced with 6GW of captive market and 34GW of capacity for the hydrogen-for-energy market is 5.8Mt, as follows:

- **1Mt** from the 6GW of captive-feedstock capacity, as per the HE analysis in Figure 16 above

31. See the BNEF report referenced above, *Europe's $500bn Plan Will Scale Up Green Hydrogen* (p.3-4).

- **4.8Mt** from 34GW of electrolyzer capacity for the hydrogen-to-energy market. This is higher than HE's 3.4Mt shown in Figure 17 as we assume (i) an extra 14GW of offshore-wind capacity compared with HE's modelling,[32] and (ii) that the electrolyzers can run at a higher average load factor of 80% (versus 57% under HE's modelling) as we assume that all of the offshore-wind is grid-connected with full traceability via Certificates of Origin.

Our stylized modelling is shown in Figure 18.

Figure 18: Potential production of green hydrogen from 34GW of electrolyzers for hydrogen-for-energy market

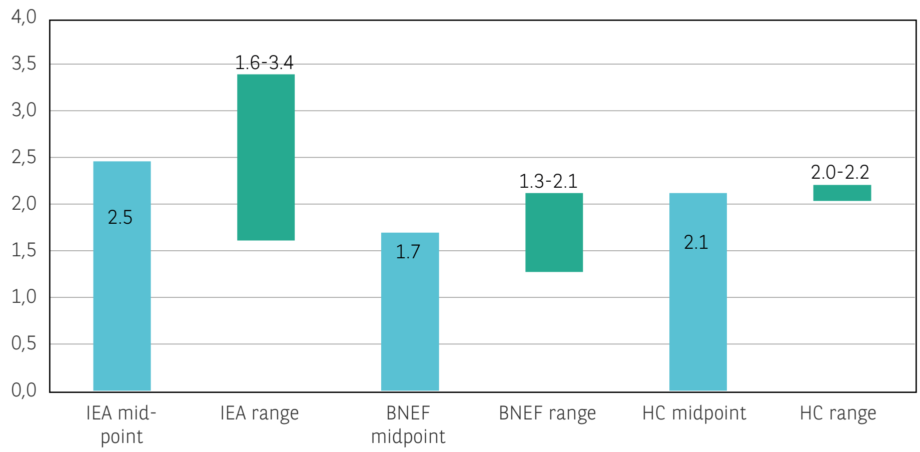
Net output assumes 70% efficiency rate for electrolyzers

	Electrolyzers	Offshore Wind	Onshore wind	Total Wind
Capacity (GW)	34	22.2	14.2	47.5
Assumed LF (hours)	8,000	5,000	3,000	n/a
Gross throughput (GWh)	238,272	110,679	42,293	85,301
Net output (GWh)	168,776	78,397	29,858	60,421
Net green hydrogen (Mt)	4.8	2.21	0.85	1.71

Source: BNPP AM Research estimates

However, and notwithstanding the precise amount of green hydrogen that could be produced with 40GW of electrolyzer capacity, the more important question is whether it is possible to bring the cost of producing green hydrogen down to €2/kg by 2030. Figure 19 shows the cost estimates for green hydrogen by 2030 of the IEA, BNEF, and the Hydrogen Council.[33] Averaging the base-case estimate of all three gives an expected cost of €2.1/kg, with a range of €1.3/kg-€3.4/kg.[34]

Figure 19: Selected estimates for the range of production costs for green hydrogen in 2030 (€/kg)



Source: IEA, BNEF, Hydrogen Council, BNPP AM Research estimates

32. As explained above, the Commission's range for the amount of dedicated new renewables capacity required to meet the 2030 target of 10Mt of green hydrogen is 80-120GW. HE's assumed total is 82GW (12GW for the captive feedstock market, and 70GW for the hydrogen-to energy market) is at the lower end of this range, while our assumed total 96GW (12GW for the captive market, 84GW for the energy market) puts us in the middle of the range. Given the constraints on the electrolyzers' running hours – even with full grid connection for the offshore-wind component we do think it is reasonable to assume a load factor of more than 80% – this is the maximum amount of renewable capacity we think could realistically be accommodated by the electrolyzers even under a stylised analysis such as this. To produce 10Mt of green hydrogen we estimate it would be necessary to build 76GW of electrolyzer capacity (6GW for the captive market, 70GW for the energy market), and 116GW of dedicated new renewables capacity (of which 70GW of grid-connected offshore wind). We set out our estimates for the cost implications of this below.
33. In each case here we have converted the $/kg estimates for the cost of green-hydrogen production in 2030 to €/kg at the current €/$ exchange rate of 1.18.
34. This compares with the range of €1.1-2.4/kg that the Commission gives in A Hydrogen Strategy for a Climate-neutral Europe, as already quoted above.

The cost is expected to fall dramatically from today's levels – estimated by the Hydrogen Council to be as much as $6/kg in northern Europe – owing to the falling cost of electrolyzers per kW of capacity as economies of scale kick in, and to the continuing decline in the cost of renewable energy, particularly offshore wind:[35]

> *"The cost of renewable hydrogen produced from offshore wind in Europe starts at about USD 6 per kg in 2020. This rate is expected to decline by about 60 per cent by 2030 to approximately USD 2.50 per kg, driven by scale in electrolyzer manufacturing, larger systems, and lower-cost renewables."*

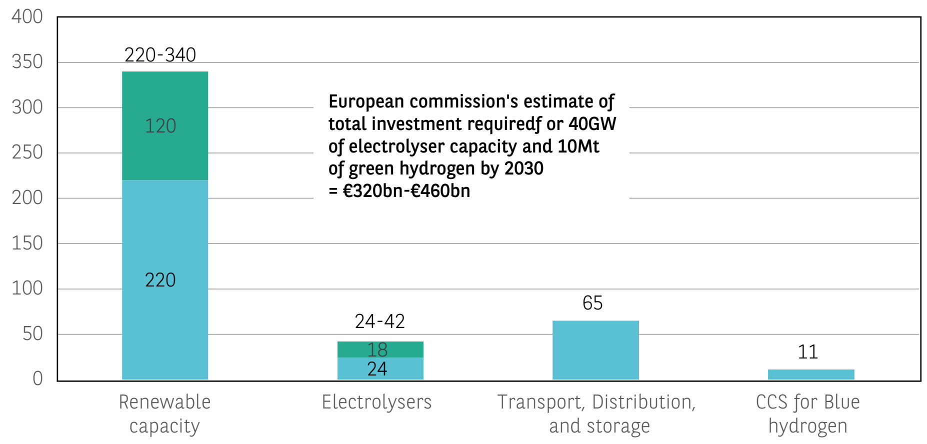
Indeed, BNEF states that if the EU really can scale to 40GW of electrolyzer capacity by 2030 this would be enough to bring costs down to the lower end of its range:[36]

> *"A 40GW target for EU-based production is hugely ambitious. If realized, building 40GW of electrolyzer capacity by 2030 would put the sector on the path to scale. BloombergNEF's 'Hydrogen Economy Outlook' estimates 27GW of cumulative installations would be needed to reduce the capex of alkaline electrolyzers in Europe from $1,200/kW in 2019 to$115/kW by 2030 (Figure 2). A 40GW-by-2030 scenario should bring costs closer to $100/kW. This could see renewable hydrogen production becoming 60% cheaper within the next decade, reaching $1.6/kg in Germany or $1.5/kg in Spain by 2030.That would put it firmly below the predicted 2030 cost of gas-based hydrogen with carbon capture and storage (CCS), forecast at $2.5/kg for Germany"*

In short, it seems that industry specialists believe that if the EU can achieve the scale in electrolyzer capacity that it is targeting by 2030, then the cost of green-hydrogen production could indeed fall to €2/kg by then, or perhaps even lower. This means that the key to achieving this cost reduction will be getting the required capital to flow in order to get the scaling-up that will drive economies of scale.

Figure 20 shows the total amount of investment the Commission estimates will be necessary to deliver its 2030 vision of 40GW of electrolyzers and 10Mt of green hydrogen production based on the numbers in *A Hydrogen Strategy for a Climate-neutral Europe*.[37] The range the Commission gives for this is €320bn-€460bn.

Figure 20: European Commission estimated cost of building up the EU's green-hydrogen economy by 2030 (€bn)



Source: European Commission

35. See the Hydrogen Council's report referenced above, *Path to Hydrogen Competitiveness: A Cost Perspective* (p. 21).
36. See the BNEF report referenced above, *Europe's $500bn Plan Will Scale Up Green Hydrogen* (p. 2).
37. As explained above, the Commission's 10Mt volume target looks unachievable with only 40GW of electrolyzer capacity but we are here concerned with the cost of building and servicing the 40GW of electrolyzer capacity as reaching this 40 GW target is the key to getting the cost of green hydrogen down.

Although €340bn-€460bn sounds like a lot of money, some contextualization is in order.

First, perhaps the most striking feature of this graph is that the cost of the electrolyzers themselves is only 7%-9% of the overall total investment required. This means that even though electrolyzers of the size envisaged by the Commisison (100MW-1GW) have not yet been developed, the cost should not in itself be a serious obstacle if the right incentives are made available.

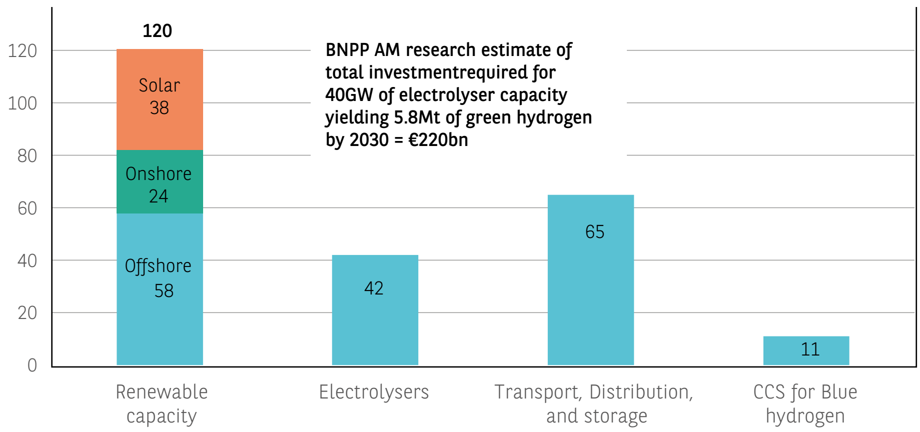
Second, even the upper end of the Commission's range is a small number when set against the EU's GDP. In 2019, EU GDP (excluding the UK) was €13.9trn,[38] so even the higher end of the Commission's range for financing green-hydrogen investments is only 3.3% of EU GDP (€460bn/€13,900bn). Amortizing this capital investment over the ten years to 2030 it would be only 0.3% of EU GDP.

Third, by far the biggest chunk of the investment is for the dedicated wind and solar capacity (70%-75% of the total). These are proven technologies at scale with costs that are still falling and that in most cases now do not require subsidies any more.

Indeed, they are very attractive technologies for precisely these reasons, and also because wind and solar projects deliver low-risk, predictable returns over a long period. It is for all these reasons that the major European oil companies are setting increasingly ambitious targets for their investments in renewables.[39]

Fourth, we think the Commission is likely overestimating the investments required in both renewables and electrolyzers, at least as far as scaling up to build, supply, and service 40GW of electrolyzer capacity is concerned. For the required dedicated renewables capacity, we assume costs of €2bn/GW for offshore wind, €1.2bn/GW for onshore wind, and €800m/GW for solar.[40] Taking the upper end of the Commission's estimates for the required investment in electrolyzers and its numbers for the other variables, we derive a total investment requirement of €220bn (Figure 21).

Figure 21: BNPP AM's estimated cost of building up and servicing 40GW of electrolyzers for the EU's green-hydrogen economy by 2030 (€bn)



Source: BNPP AM Research estimates

As for the cost of the electrolyzers, BNEF thinks that the Commission's estimates are too pessimistic:[41]

> *"The Commission's €180-470bn investment range also includes €24-€42bn to deliver 40GW of electrolyzers by 2030. This could be an over-estimate, and seems to assume a fairly conservative electrolyzer cost around $500/kW over the next decade. We think electrolyzer*

38. See Eurostat: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20200508-1
39. For example, BP is now targeting 50GW of renewables capacity by 2030, and a tenfold increase in its capex on renewables from $500m in 2019 to $5bn by 2030: https://www.greentechmedia.com/articles/read/bp-to-invest-5b-a-year-on-low-carbon-and-cut-fossil-fuel-output-by-40-percent-by-2030
40. Our estimates are based on analysis from the utilities equity-research teams at BNP Exane and Credit Suisse. For more details on our estimates, see our report *Wells, Wires, and Wheels* from August 2019 (since when costs can in fact reasonably be expected to have fallen further, available at: https://investors-corner.bnpparibas-am.com/investing/petrol-eroci-petroleum-age/
41. See the BNEF report referenced above, *Europe's $500bn Plan Will Scale Up Green Hydrogen* (p.5).

costs can sink quickly to $600/kW by 2022 in Europe, and then continue to fall rapidly toward $100/kW by 2030, if the cost structure of Chinese electrolyzer manufacturers can be emulated. At our projected prices, €41bn would be enough to build 132GW of electrolyzers and deliver the full 10MMT hydrogen production target."

It is interesting that BNEF estimates that the upper end of the Commission's estimate for the cost of 40GW of electrolyzers would actually be enough to meet the necessary capacity for producing 10Mt, not least as this is on the most conservative BNEF assumption whereby the renewables capacity for green-hydrogen is connected directly to the electrolyzers themselves, which are then constrained by the limited running hours of wind and solar.[42]

Our own estimates regarding how much electrolyzer and dedicated renewables capacity would have to be built to meet the 2030 production target of 10Mt are 76GW of electrolyzer capacity (6GW for the captive market, 70GW for the energy market), and 116GW of dedicated new renewables capacity (of which 70GW of grid-connected offshore wind), as shown in Figure 22. Adding the 8.6Mt of green hydrogen we estimate possible on these assumptions to the 1Mt of captive-market production shown in Figure 16 above gets us to 9.6Mt.

Figure 22: Potential production of green hydrogen from 70GW of electrolyzers for hydrogen-for-energy market

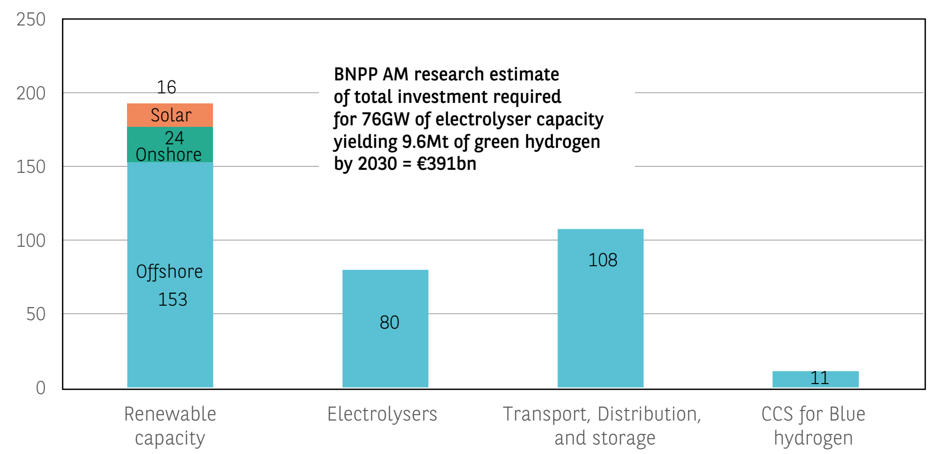
Net output assumes 70% efficiency rate for electrolyzers

	Electrolyzers	Offshore Wind	Onshore wind	Total Wind
Capacity (GW)	70	70	14.2	20
Assumed LF (hours)	8,000	5,000	3,000	n/a
Gross throughput (GWh)	427,707	349,524	42,293	35,916
Net output (GWh)	302,978	247,580	29,958	25,441
Net green hydrogen (Mt)	8.6	7.0	0.85	0.72

Source: BNPP AM Research estimates

Our estimate of the investment costs implied to achieve this 10Mt of production is shown in Figure 23. Adding in the costs for the extra offshore-wind and electrolyzer capacity at the same per GW level as shown in Figure 23, and scaling up the transport, distribution, and storage expenditure in proportion to the extra production volume, we derive a total investment budget of €391bn.

Figure 23: BNPP AM's estimated cost of building up the EU's green-hydrogen production to 10Mt by 2030 (€bn)



Source: BNPP AM Research estimates

42. Note, however, that BNEF's estimate that 132GW of electrolyzer capacity would be required to meet the 10Mt production target is on their conservative assumption that all of the renewables capacity would be connected directly to the electrolyzers. On their more optimistic scenario that the renewables capacity is connected to the grid, they see a need for only 80GW of electrolyzer capacity.

This puts us in the middle of the Commission's range of €340-€460bn.

Finally, the EU and its member states have already shown that they can scale up new and immature technologies and bring the cost down significantly over the period of a decade with wind and solar. Significant subsidies and mandates were needed to scale up wind and solar in the early years,[43] but these technologies are now directly competitive with traditional forms of power generation on a new-build basis at a carbon price of €25/t, and on a short-run marginal-cost basis they have a cost of zero.

In short, large as the investments required to meet the Commission's vison for green hydrogen by 2030 sound, when placed into context we find that the financing in itself should not be a major obstacle.

The bigger constraint, in our view, will be the logistical challenge of building out the large amount of infrastructure that will be necessary to develop and service a green-hydrogen economy. Again, however, this has been achieved with renewables.

3.4 AT WHAT CARBON PRICE WOULD GREEN HYDROGEN BE COMPETITIVE WITH GREY HYDROGEN BY 2030?

Our review of the Commission's vision for green hydrogen to 2030 and of some of the key pieces in the literature analyzing the prospects for the economics of green hydrogen leads us to the conclusion that it is reasonable to assume a range of €1.75/kg-€2.5/kg for the cost of production in the EU by 2030.

However, even assuming that the cost of producing green hydrogen can be brought down to this range by 2030, we then need to consider what carbon price would be necessary by that time to make it competitive with the grey hydrogen produced from natural gas under the SMR-process.[44]

With the economics of grey hydrogen so sensitive to natural-gas prices, in comparing grey hydrogen with green hydrogen in 2030 for use as an industrial feedstock we need to take into account not only a range of potential production costs for green hydrogen but also a range of potential natural-gas prices in the EU.

Figure 24 shows the potential range for the cost of grey hydrogen in 2030 in both €/kg and €/MWh terms for our range of gas-input prices assuming the same capex and opex assumptions as in Figure 9 above.

Figure 24: **Range for 2030 cost assumptions for grey hydrogen as feedstock**

2030 EU gas price	€10/MWh	€15/MWh	€20/MWh
€/kg	€0.91	€1.15	€1.39
€/MWh	€23	€29.2	€35.2

Source: BNPP AM Research estimates

Figure 25 shows the potential range for the cost of green hydrogen in 2030 in both €/kg and €/MWh terms for our range of gas-input prices assuming the same capex and opex assumptions as in Figure 9 above.

Figure 25: **Range for 2030 cost assumptions for green hydrogen as feedstock**

	2030 Green-hydrogen cost scenarios			
€/kg	€1.75	€2	€2.25	€2.5
€/MWh	€44	€51	€57	€63

Source: BNPP AM Research estimates

43. Based on BNP Exane data we estimate that over 2010-20 Germany has subsidised wind and solar to the tune of €100bn, and the EU as a whole by €200bn-€250bn. This is equivalent to roughly half of the total €320bn-€460bn investment in green hydrogen that the Commission estimates will be needed over 2021-30. The point is, the EU has successful experience of using subsidies to scale up immature technologies.
44. We do not look at the economics of blue hydrogen in 2030 here as it is clear from the extracts cited in Section 3.2.1 above that the Commission sees blue hydrogen as an interim solution only, with the essential objective being to make green hydrogen commercially competitive with grey hydrogen by 2030.

To calculate the implied carbon price that would be required to make green hydrogen competitive with grey hydrogen on all possible permutations of these cost assumptions, it is then simply a question of working out the gap to bridge and then using the carbon intensity of grey hydrogen – 0.27t/MWh – to derive the value.

We do this by dividing the gap to bridge by 0.27/t.
Figure 26 shows the worked examples for mid-range scenario for 2030 gas-prices, with grey hydrogen here facing a gas-input cost of €15/MWh compared with our four 2030 cost scenarios for green hydrogen.

Figure 26: Implied 2030 carbon prices for green hydrogen to be competitive with grey hydrogen with gas at €15/MWh

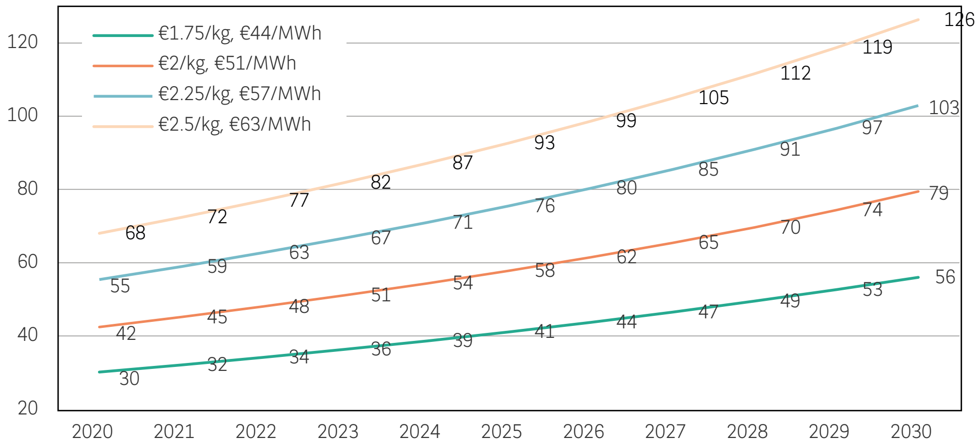
All values in MWh except carbon (€/t)

Grey hydrogen with gas at €15/MWh	€29.2	€29.2	€29.2	€29.2
Green hydrogen cost scenarios	€44.3	€50.6	€57	€63
Gap to bridge	€15.1	€15.4	€27.8	€34.1
Equation for carbon	€15.1/0.27t	€15.4/0.27/t	€27.8/0.27t	€34.1/0.27t
Implied carbon price	€56/t	€79/t	€103/t	€126/t

Source: BNPP AM Research estimates

Figure 27 then shows all the resulting implied EUA forward curves discounted back to 2020 from 2030 at our assumed rate of 6%.

Figure 27: Implied shape of EUA forward curve with varying 2030 costs of green hydrogen from €1.75/kg-€2.5/kg, and with grey hydrogen gas-input costs of €15/MWh



Source: BNP Paribas AM research estimates

As can be seen, the range of implied 2030 carbon prices on these assumptions is €56/t-€126/t, which discounted back at 6% gives us an implied fair-value range for 2020 EUAs of €30/t-€68/t.

Figure 28 then shows the worked examples for our high-case scenario for 2030 gas-prices, with grey hydrogen here facing a gas-input cost of €20/MWh compared with our four 2030 cost scenarios for green hydrogen.

Figure 28: Implied 2030 carbon prices for green hydrogen to be competitive with grey hydrogen with gas at €20MWh

All values in MWh except carbon (€/t)

Grey hydrogen with gas at €15/MWh	€35.2	€35.2	€35.2	€35.2
Green hydrogen cost scenarios	€44.3	€50.6	€57	€63.3
Gap to bridge	€9.1	€21.5	€21.8	€28.1
Equation for carbon	€9.1/0.27t	€21.5/0.27t	€21.8/0.27t	€34.1/0.27t
Implied carbon price	€34/t	€57/t	€81/t	€104/t

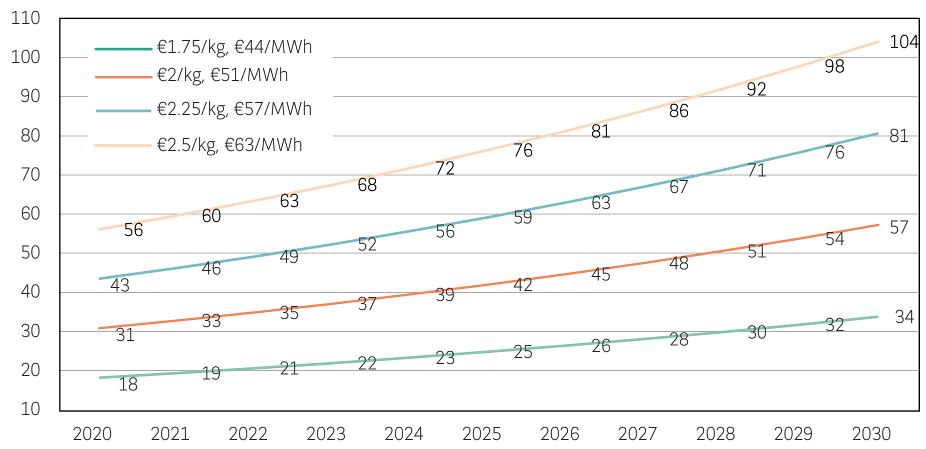
Source: BNPP AM Research estimates

Figure 29 then shows all the resulting implied EUA forward curves discounted back to 2020 from 2030 at our discount rate of 6%.

Given the higher assumed 2030 gas price here of €20/t, the implied 2030 carbon prices are lower than under our base-case scenario, ranging from €34/t-€104/t.

Discounting back at 6% gives us an implied fair-value range for 2020 EUAs of €18/t-€56/t.

Figure 29: Implied shape of EUA forward curve with varying 2030 costs of green hydrogen from €1.75/kg-€2.5/kg, and with grey hydrogen gas-input costs of €20/MWh



Source: BNP Paribas AM research estimates

Finally, Figure 30 shows the worked examples for our low-case scenario for 2030 gas-prices, with grey hydrogen here facing a gas-input cost of only €10/MWh compared with our four 2030 cost scenarios for green hydrogen.

Figure 30: Implied 2030 carbon prices for green hydrogen to be competitive with grey hydrogen with gas at €10/MWh

All values in MWh except carbon (€/t)

Grey hydrogen with gas at €15/MWh	€23	€23	€23	€23
Green hydrogen cost scenarios	€44.3	€50.6	€57	€63.3
Gap to bridge	€21.3	€27.7	€34	€40.3
Equation for carbon	€21.3/0.27t	€27.7/0.27t	€34/0.27t	€40.3/0.27t
Implied carbon price	€79/t	€103/t	€126/t	€149/t

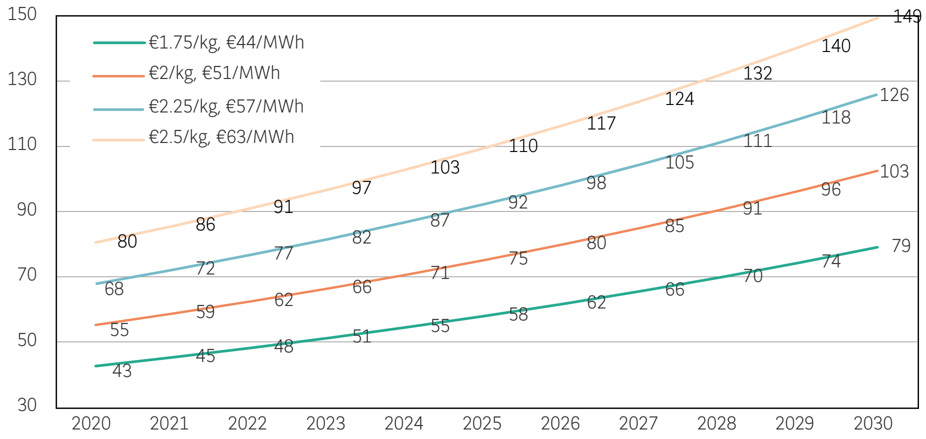
Source: BNPP AM Research estimates

Figure 31 then shows all the resulting implied EUA forward curves discounted back to 2020 from 2030 at our discount rate of 6%.

Given the lower assumed 2030 gas price here of €10/t, the implied 2030 carbon prices are higher than under our base-case scenario, ranging from €79/t-€149/t.

Discounting back at 6% gives us an implied fair-value range for 2020 EUAs of €43/t-€80/t.

Figure 31: Implied shape of EUA forward curve with varying 2030 costs of green hydrogen from €1.75/kg-€2.5/kg, and with grey hydrogen gas-input costs of €10/MWh



Source: BNP Paribas AM research estimates

3.4.1 Conclusion on the implied 2030 fair value for EUAs for green hydrogen to be competitive as a feedstock

Figure 32 summarizes the implied 2030 fair value for EUAs across all the permutations shown in our various scenarios above.

The range varies from a low €34/t to a high of €149/t, reflecting the range of potential 2030 values for the cost of producing green hydrogen and the price of gas in the EU.

Our mid-range scenario for 2030 EU gas price is €15/MWh, which represents an extrapolation of the current forward curve in 2025. If we then look at the potential 2030 costs for green hydrogen, we find that in the middle of our range – i.e. at €2/kg and €2.25/kg – the implied 2030 fair values for carbon are €79/t and €103/t respectively.

On the basis of all the assumptions we have made for the purposes of this analysis, and on the basis of the information available to us today, we think €79/t-€103/t is a fair indication of the range in which EUAs would need to trade in 2030 in order for green hydrogen to be competitive with grey hydrogen

Figure 32: Implied 2030 EUA fair values for green hydrogen to displace grey hydrogen w/ gas at 10/MWh, 15/MWh, 20/MWh

Matrix shows implied 2030 fair value for EUAs on our four 2030 cost scenarios for green hydrogen

	€1.75	€2	€2.25	€2.5
€10/MWh	€79/t	€103/t	€126/t	€149/t
€15/MWh	€56/t	€79/t	€103/t	€126/t
€20/MWh	€34/t	€57/t	€81/t	€104/t

Source: BNPP AM Research estimates

Figure 33 then shows the implied 2020 fair value for EUAs across all the permutations shown in our various scenarios above discounted back at 6%.

The range varies from a low €18/t to a high of €80/t. If we then look at the potential 2030 costs for green hydrogen, we find that in the middle of our range – i.e. at €2/t and €2.25/t – the implied 2020 fair values for carbon discounted back from 2030 are €42/t and €55/t respectively.

We think €42/t-€55/t is a fair indication of the theoretical fair-value range for EUAs today based on the need for green hydrogen to be competitive as an industrial feedstock in 2030.

Figure 33: Implied 2020 EUA fair values for green hydrogen to displace grey hydrogen

Matrix shows implied 2020 fair value for EUAs discounted back from 2030

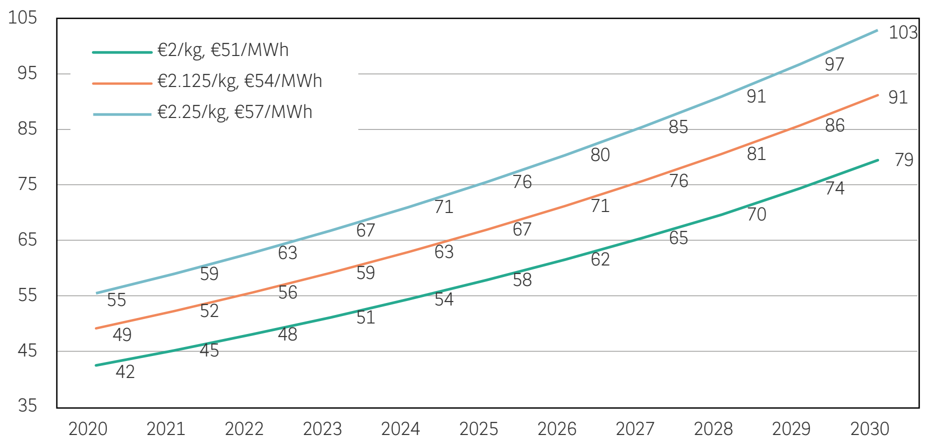
	€1.75	€2	€2.25	€2.5
€10/MWh	€43/t	€55/t	€68/t	€80/t
€15/MWh	€30/t	€42/t	€55/t	€68/t
€20/MWh	€18/t	€31/t	€43/t	€56/t

Source: BNPP AM Research estimates

Finally, Figure 34 takes the middle of our 2030 theoretical fair-value range for EUAs – €2/kg-€2.25/kg – to derive the resulting implied forward curves. This shows that at our base-case scenario for 2030 EU gas of €15/MWh, and at a 2030 cost of production for green hydrogen of €2.213/kg or €54/MWh, the implied fair value for EUAs would be $91/t.

In turn discounting back at 6% would give us a theoretical implied 2020 fair value of €49/t.

Figure 34: Implied shape of EUA forward curve with varying 2030 costs of green hydrogen from €2/kg-€2.25/kg, and with grey hydrogen gas-input costs of €15/MWh



Source: BNP Paribas AM research estimates

In short, on the basis of the information available to us today regarding (i) the EU policy for net-zero emissions by 2050, (ii) the crucial role that green hydrogen will have to play as a feedstock already in 2030 if this vision is to be achieved, (iii) the cost reductions in the production of green hydrogen that can reasonably be expected by 2030, and (iv) our assumption on EU gas prices in 2030, we conclude that the implied theoretical fair value for EUAs in 2030 would be €91/t. Discounting back at 6%, we derive an implied theoretical fair value for 2020 of €49/t.

There remains the question, though, of how the price of carbon would need to develop beyond 2030 in order for hydrogen to achieve its decarbonization potential as an energy source, and thereby enable the EU to meet its 2050 net-zero goal.

3.5 BEYOND 2030: MAKING GREEN HYDROGEN COMPETITIVE AS AN ENERGY SOURCE

As explained above, for the EU's 2050 net-zero emissions target to become reality, green hydrogen will have to become viable as an energy source across numerous applications, most notably transport, space heating, and power generation over the period 2031-50.

Accordingly, to conclude our analysis here we briefly consider one of these applications – power generation – to examine what carbon price would be necessary in 2040 to make hydrogen competitive with natural gas as a fuel source for power generation.

Again, we consider a range of potential production costs for green hydrogen, but as we could reasonably expect the cost to fall quite sharply over 2030-2040, our range is lower than the one we used for 2030: €1/kg (€30/MWh), €1.25/kg (€37/MWh), and €1.5/kg (€45/MWh).

For gas prices, we consider only two scenarios – €15/MWh, and €10/MWh – as we assume that the ongoing decarbonization of the EU energy system will have reduced demand for gas such that prices of €20/MWh are unlikely.

Finally, we assume a 55% efficiency rate for the power plant for both gas and hydrogen, giving us a carbon intensity for gas-fired generation of 0.35t/MWh.

Figure 35 shows the worked examples for natural gas at €15/MWh in 2040 compared with our three 2040 cost scenarios for green hydrogen, and assuming a power-plant thermal efficiency of 55% for both gas and hydrogen.[45]

Figure 35: Implied 2040 carbon prices for green hydrogen to be competitive with natural gas at €15/MWh

All values in MWh except carbon (€/t). Assumed thermal efficiency of all power plants is 55%

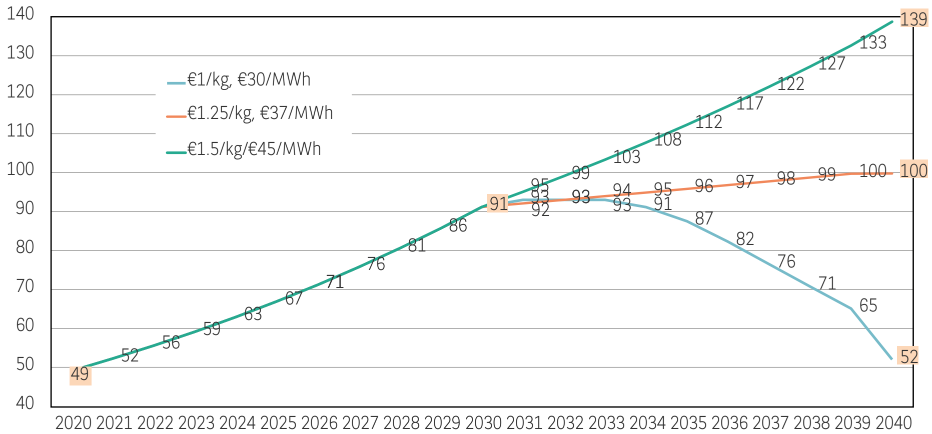
Cost of natural gas	€15	€15	€15
Cost of gas generation	€33.3	€33.3	€33.3
Green hydrogen cost	€30	€37	€45
Cost of green-hydrogen generation	€54.6	€68.2	€81.9
Gap to bridge	€21.3	€34.9	€48.6
Equation for carbon	€21.3/0.35t	€34.9/0.35t	€48.6/0.35t
Implied carbon price	€52/t	€100/t	€139/t

Source: BNPP AM Research estimates

As can be seen, the range of implied 2040 carbon prices on these assumptions is €52/t-€139/t. Figure 36 shows these values diagrammatically beyond our base-case 2030 theoretical fair value of €91/t.

45. Note that here we take the LHV for both natural gas and hydrogen. This means that whereas we assumed 1kg of green hydrogen yields 39.4kWh of energy value in our analysis of its use as an industrial feedstock, we here assume an energy value of only 33.3kWh per kg as some of the gross potential energy value is lost in the combustion process. For natural gas, the LHV is equivalent to 91% of the HHV, for hydrogen 85%.

Figure 36: Implied theoretical EUA forward curves 2020-40 based on varying costs of green hydrogen in 2040, and with 2040 EU gas price of €15/MWh



Source: BNP Paribas AM research estimates

As can be seen, beyond our point of convergence in 2030 and the theoretical implied fair value at that point of €91/t, the curve takes three radically different courses depending on the assumed cost of producing green hydrogen in 2040.

On the low-cost trajectory (€1/kg in 2040), the implied theoretical fair value for carbon is significantly lower in 2040 than it is in 2030 owing to the fact that the cost of producing green hydrogen falls so sharply by that point. Such a trajectory would imply that the EU was well on track to achieving its ultimate policy goal of net-zero emissions by 2050 and that the EU-ETS had effectively already achieved its part of the policy objective.

On our-mid-cost trajectory (€1.25/kg in 2040), the implied theoretical fair value for carbon is not much higher in 2040 than it is in 2030, such that the EU-ETS cap would not need to be tightened much further between 2030 and 2040 in order to remain on track to achieving the ultimate policy goal by 2050.

On our high-cost trajectory (€1.5/kg in 2040), the implied theoretical fair value for carbon is much higher in 2040 than it is in 2030, such that the EU-ETS cap would need to be kept tight between 2030 and 2040 in order for the EU to remain on track to achieving the ultimate policy goal by 2050.

On this schedule 2030 is still the most valuable point in the future from today's standpoint,[46] but to all intents and purposes the point of convergence is not 2030 as a single year but rather the entire period 2030-40.

Figure 37 then shows the worked examples for natural gas at €10/MWh in 2040 compared with our three 2040 cost scenarios for green hydrogen.

46. It is the most valuable point in the future from today's standpoint in the sense that it is the point from which we discount back at 6%. The effective discount rate from 2040 to 2030 on this schedule is 4.1%, and from 2040-2020 the implied discount rate on this schedule would be 5.1%.

Figure 37: Implied 2040 carbon prices for green hydrogen to be competitive with natural gas at €10/MWh

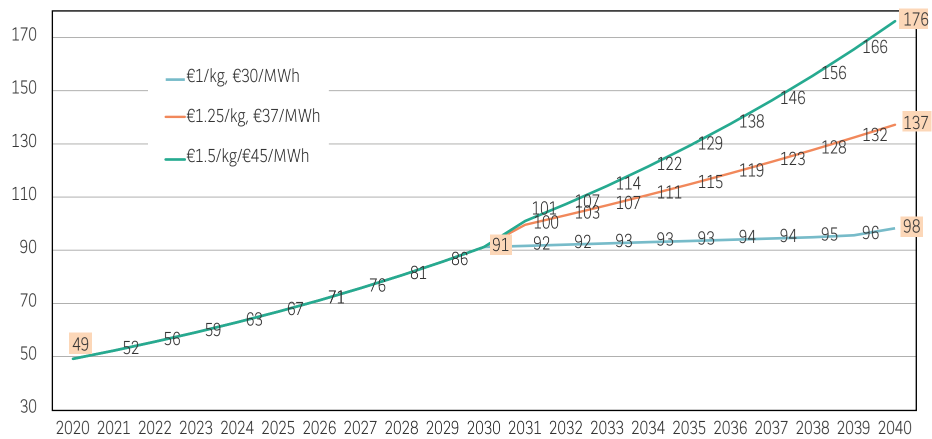
All values in MWh except carbon (€/t). Assumed thermal efficiency of all power plants is 55%

Cost of natural gas	€10	€10	€10
Cost of gas generation	€22.2	€22.2	€22.2
Green hydrogen cost	€30	€37	€45
Cost of green hydrogen generation	€54.6	€68.2	€81.9
Gap to bridge	€34.4	€48.0	€61.7
Equation for carbon	€34.4/0.35t	€48/0.35/t	€61.7/0.35t
Implied carbon price	€98/t	€137/t	€176/t

Source: BNPP AM Research estimates

Figure 38 then shows these values diagrammatically, again beyond our base-case 2030 theoretical fair value of €91/t. This time, with gas prices at €10/MWh, the implied carbon price is higher on each of our three green-hydrogen cost scenarios.

Figure 38: Implied theoretical EUA forward curves 2020-40 based on varying costs of green hydrogen in 2040, and with 2040 EU gas price of €10/MWh



Source: BNP Paribas AM research estimates

On the low-cost trajectory (€1/kg in 2040), the implied theoretical fair value for carbon in 2040 is €98/t. Such a trajectory would imply that the EU-ETS cap would not need to be tightened much further between 2030 and 2040 in order to remain on track to achieving the ultimate policy goal by 2050.

On our-mid-cost trajectory (€1.25/kg in 2040), the implied theoretical fair value for carbon in 2040 is €137/t, such that the EU-ETS cap would need to be kept tight between 2030 and 2040 in order to remain on track to achieving the ultimate policy goal by 2050.

On our high-cost trajectory (€1.5/kg in 2040), the implied theoretical fair value for carbon is the same in real terms in 2040 as it is in 2030,[47] such that the EU-ETS cap would need to be kept very tight between 2030 and 2040 in order for the EU to remain on track to achieving the ultimate policy goal by 2050. On this schedule, the point of convergence is not 2030 as a single year but rather the entire period 2030-40.

47. In other words, the discount rate back to 2040 from 2040 is 6%, the same as from 2030 to 2020.

3.5.1 Conclusion: beyond 2030 it's the shape of the curve that counts

The implied 2040 carbon price required to make green hydrogen competitive as an energy source will vary across the different applications (transport, heating, power generation), and our brief analysis of the economics of green hydrogen for power generation in 2040 is interesting more for what it tells us about the range of potential shapes in the forward curve beyond 2030 than for the theoretical 2040 fair values that we have derived themselves.

3.6 CONCLUSION: WE SEE THE THEORETICAL FAIR VALUE FOR 2030 EUAS AT €91/T, IMPLYING 2020 THEORETICAL FAIR VALUE OF €49/T

At the mid-point of our assumed range for the cost of producing green and level of EU gas prices in 2030, the implied theoretical fair value for EUAs would be €91/t by 2030, implying in turn a 2020 theoretical fair value of €49/t when discounted back at 6%.

To put it another way: based on the information available to us today, the middle curve of the three shown in Figure 34 above is our best estimate of the long-run marginal abatement curve for carbon in the EU.

In theory, the more efficient the market, the more quickly the EUA price will move to the level of the long-term supply curve, and the more likely it will be that the carbon price will not have to deviate materially from this trajectory thereafter. By contrast, the less efficient the market, the longer it will take for the EUA price to reach the level implied by the long-term supply curve, and the greater the likelihood of the price rising above the long-term supply curve thereafter.

In practice, however, we think that the implied fair-value our analysis points to will only be recognized once compliance players and/or investors are convinced that the EU is serious about achieving net-zero emissions by 2050.

We believe the key pre-requisites for triggering this conviction are (i) the raising of the EU's 2030 emissions target to -55% (already proposed, with the modalities for achieving this likely to be legislated for by the middle of next year), and (ii) the passing of the formal legislation requiring net-zero emissions by 2050 (we expect that to happen either by the end of this year or in Q1 2021).

However, while these catalysts are necessary we do not think that on their own they will be sufficient: beyond legislation for these overarching targets it will still be necessary to convince participants in the EU carbon market that the specific strategic vision for green hydrogen is credible.

In the meantime, though, we think it is already clear that we are reaching the end of the fuel-switching paradigm for the EU-ETS

4 THE END OF THE EU-ETS FUEL-SWITCHING PARADIGM

Given the economic shock to the EU-ETS from COVID, the EUA price has held up remarkably well in recent months. From a low of €14.3/t in the early stages of the lockdowns across the EU the benchmark Dec-20 contract recovered to a near-record all-time high of €30.3/t in June, and has held at pre-COVID levels ever since.

More significantly, though, the benchmark contract this year has for the first time ever traded above the upper-end of the so-called fuel-switching level, i.e. the level at which the least efficient gas-fired power plants displace the most efficient coal plants.

For this to happen in the middle of a pandemic-induced economic crisis that will hit the short-term demand for EUAs harder than it has ever been hit before tells us, we think, two things: (i) the market has confidence in the Market Stability Reserve's ability to cushion the economic hit to demand by withholding a higher level of future supply; (ii) the market is starting to think beyond fuel switching as the marginal abatement option that ultimately clears the EU-ETS.

Indeed, in our view the main reason that EUA prices have remained so robust in the face of COVID is that the market started pricing in an increase in the EU's level of ambition regarding the 2030 emissions-reduction target earlier this year after the Commission formally began the legislative process for a net-zero EU by 2050 in early March. The proposed increase in the 2030 EU-wide emissions-reduction target to at least -55% is consistent with this, and will tighten the EU-ETS cap considerably.

At the same time, the scope of the EU-ETS will potentially be broadened over the first half of this decade to include buildings and transport, both of which have significant emissions footprints and need to start decarbonizing at a much faster rate than they have to date. The modalities of how buildings and transport might be included are not yet clear, and nor is it yet certain that they will be included, so we do not attempt to model their inclusion here. However, what is already clear is that the EU sees green hydrogen as a key part of the decarbonization strategy for both of these sectors.

As a result, we have modelled a scenario for the EU-ETS under which the recently proposed -55% target for 2030 is adopted, showing how this might compare with the effective EU-ETS cap under the current -40% target. Owing to the structural impact that we expect the COVID pandemic to have on emissions over the next decade, our scenario modelling of the EU-ETS under a -55% EU-wide target projects that there is still a market surplus of EUAs in 2030, albeit a significantly smaller one (462Mt) than would be the case if no change were made to the current -40% target (1,150Mt).

In the final analysis, convincing the market that deep decarbonization is an urgent priority would be the single greatest catalyst for bringing about a step change in the EUA forward curve consistent with both (i) our theoretical analysis in Section 2, and – depending on the market's view of green-hydrogen costs and EU gas prices by 2030 – (ii) our scenario modelling in Section 3.

This is because if the market thinks this is an urgent priority, both compliance players and financial investors will start to see much greater long-term value in EUAs than is currently recognized by the market today because they will assume that the Commission will engineer the conditions for prices to reach this level by 2030.

So what would it take for that to happen?

In our view, it would require the translation of the policy measures outlined in the Commission's A Hydrogen Strategy for a Climate-neutral Europe document into concrete and credible policy measures. This is because, as we explained in Section 3 above, there is no plausible pathway to net zero by 2050 without the scaling-up of green hydrogen so that it is commercially viable as an industrial feedstock by 2030, and as an energy source for transport, heating, and power generation thereafter

4.1 DESPITE THE DEPRESSIVE IMPACT OF COVID ON EU-ETS EMISSIONS, EUA PRICES REMAIN BUOYANT

The hit to EU-ETS emissions from the ongoing impact of COVID has been very severe, especially for the aviation sector, and in our view the pandemic will lead to a structural step down in emissions all the way to 2030. However, EUA prices have rebounded from their March lows to near a near all-time record high, suggesting that a paradigm shift may be in the offing.

4.1.1 The COVID impact: a structural hit to emissions beyond the immediate impact

The impact of COVID on the EU economy has been devastating, with Q2 GDP down by 12% year-on-year.[48] With the pandemic continuing to prevent the normalization of economic activity for the foreseeable future, we expect EU-ETS emissions for fixed installations this year to drop by some 240Mt, to 1,290Mt.

In absolute terms this would equal the previous record decline of 2009 after the global financial crisis, but in relative terms this would be the biggest ever annual decrease (a 15% drop compared with 11% in 2009). After including the aviation sector, the impact is even greater, as we expect emissions from intra-EU flights this year to fall by 50% compared with 2019, to 34Mt.[49] This means that for total EU-ETS emissions, we expect an annual decline of some 270Mt, or 17%.

More significantly, we think 2020 will now represent a new and permanently lower base for the future level of emissions in the EU-ETS. Some of the activity lost this year will take time to come back while some can be expected to be lost for good as firms accelerate the closure of certain plants in response to the depressed economic environment.

The aviation sector is perhaps the best example of an industry that will continue to suffer long after the immediate impact of the pandemic has passed. Previously, aviation emissions were the fastest growing source of demand for EUAs but given the devastating impact of the virus on aviation and the obvious constraints on business and leisure flights that will continue to weigh on the sector until a vaccine is found, we do not expect a return to 2019 emissions levels from intra-EU flights until 2025.

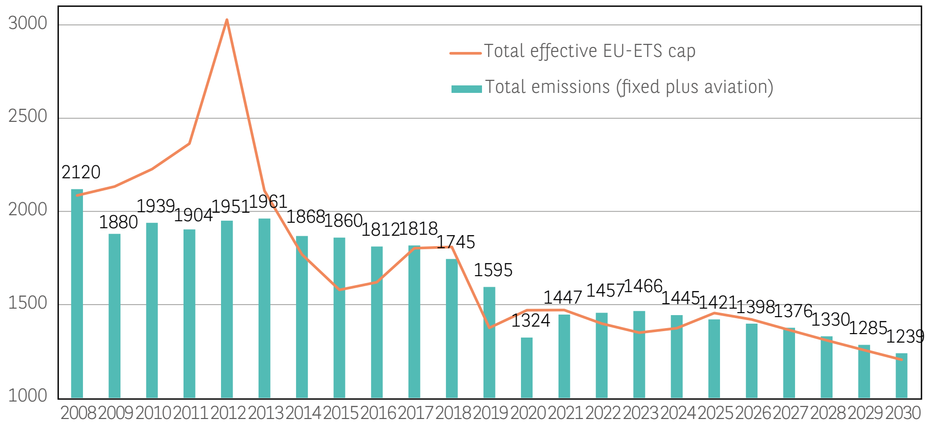
Figure 39 shows our projections for EU-ETS emissions out to 2030 – the total for fixed installations and aviation combined – set against the total effective cap[50] on emissions over the whole period 2008-30, and based on the current 2030 EU target of reducing emissions by 40% versus 1990 levels, and the current regulations pertaining to the operation of the MSR.[51] We expect a rebound in emissions in 2021 to 1,447Mt as the EU economy rebounds from the severe shock suffered this year, and with the last of the German nuclear plants going offline at the end of 2022 we see emissions in the power sector receiving a temporary boost over 2022-2024.

48. See the Eurostat press release of 31 July: https://ec.europa.eu/eurostat/documents/2995521/11156775/2-31072020-BP-EN.pdf/cbe7522c-ebfa-ef08-be60-b1c9d1bd385b
49. At the peak of the lockdowns across the EU, intra EU flights were down 80%, and they are currently still running 55% below 2019 levels in early September (see Eurocontrol data at: https://www.eurocontrol.int/covid19
50. We define the effective EU-ETS cap as the total number of EUAs and European Aviation Allowances (EUAAs) that are actually made available to the market, together with the carbon credits from the Kyoto project mechanisms – the clean Development Mechanism (CDM) and the Joint Implementation (JI) scheme – that were allowed into the EU-ETS as valid compliance instruments over 2008-20 (CDM credits are known as Certified Emissions Reductions, or CERs, and JI credits as Emissions Reduction units, or ERUs). As such, the total effective cap over 2008-30 equals the combined amount of EUAs, EUAAs, CERs, ERUs available to the market and eligible for compliance purposes.
51. Under the current rules, the MSR will remove 24% of the total number allowances in circulation (TNAC) – i.e. the cumulative surplus that has built up over time from the difference between the emissions of fixed installations since 2008 and the total number of credits (EUAs/CERs/ERUs) that they have they have had access to since then – on a trailing basis over the five years 2019-23 by withholding them from the number of EUAs to be auctioned in each of those years. Thereafter, the MSR reduces the TNAC at a lower rate of 12% per year for as long as the TNAC remains above 833Mt. For more on the MSR regulations see the Commission's explainer: https://ec.europa.eu/clima/policies/ets/reform_en.

We expect German nuclear plants to produce about 55TWh of zero-emissions electricity in 2020, and if all of this were to be replaced by coal and gas then we could expect an increase in emissions in the German power sector on an annualized basis by 2023 of 35Mt. In reality, we think up to half of this lost nuclear output will be replaced by renewables such that the actual increase in emissions from the closure of the last German nuclear-power stations 2022-24 will be in the order of 20Mt. Thereafter we assume all of it will be covered by renewables and that this temporary bump in German power emissions is therefore eradicated from 2025.

Otherwise, our emissions projections to 2030 assume that nearly all of the fuel switching that can be achieved via gas displacing coal in the power-generation industry occurs (as is already happening at current EUA prices in the €25/t-€30/t range),[52] and with many EU member states having already announced phase-out plans for coal in any case we expect to see an accelerated structural decline in the power sector's emissions from 2025 onwards.

Figure 39: BNPP AM base-case EU-ETS emissions versus total EU-ETS cap under current 40% target, 2008-2030 (Mt)



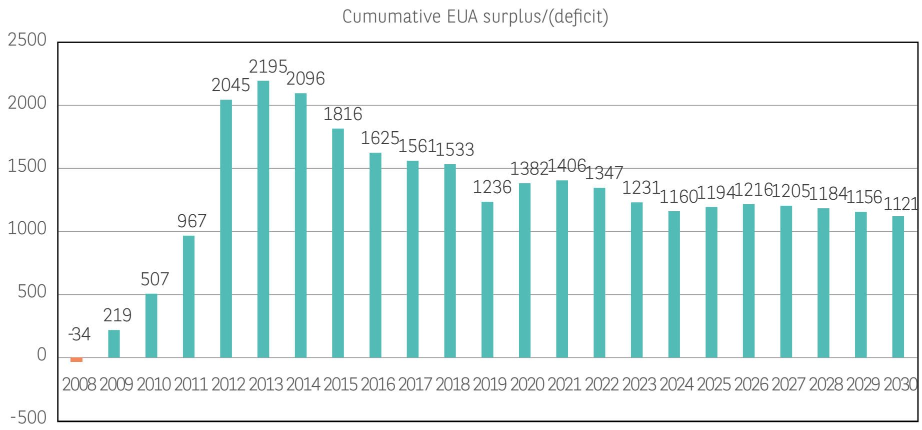
Source: BNP Paribas AM research estimates

On these assumptions, our projected total EU-ETS emissions fall back to 1,239Mt by 2030. This breaks down as 1,129Mt from fixed installations, and 99Mt from aviation.

Figure 40 then sets out our projections for the development of the accumulated EUA surplus out to 2030. We define this surplus as the sum of (i) the TNAC – total number of allowances (EUAs) in circulation – plus (ii) the cumulative balance of EUAAs in the aviation sector.

52. There is therefore an obvious but necessary circularity in our reasoning here, which we resolve in Section 4.2 below. The circularity arises from the fact that our modelling of emissions out to 2030 versus the current cap is artificial given that the European Commission has now proposed a more ambitious 2030 target. As a result, while our modelling of emissions here assumes that EUA prices will remain in the current trading range of €25/t-€30/t all the way out to 2030, the only reason prices are at this level in the first place is that the market was already anticipating a tighter 2030 cap than the one we have at the moment under the current legislation. As such, our modelling of emissions versus the cap under the current but soon-to-be-superseded legislation is relevant more as context for the modelling we set out below in Section 4.2 under the more ambitious cap that we now expect folllowing the Commission's recently proposed more ambitious 2030 EU-wide target.

Figure 40: BNPP AM base-case projection for total EU-ETS surplus (including aviation) under current 2030 EU -40% target (Mt)



Source: BNP Paribas AM research estimates

As can be seen, under the current 2030 EU target of a -40% reduction in emissions versus 1990, and even after taking into account the operation of the MSR as currently mandated, our emissions projections versus the cap over 2021-30 result in a stubbornly high overall surplus of EUAs in the market over 2021-30, as shown in Figure 40.

On our emissions-to-cap projections shown in Figure 39 above, we estimate that the overall surplus under the existing -40% EU-wide target and the current MSR rules[53] would rise from the 1,236Mt in 2019 to a second peak of 1,406Mt in 2021 before falling back again to a still very substantial 1,121Mt by 2030.

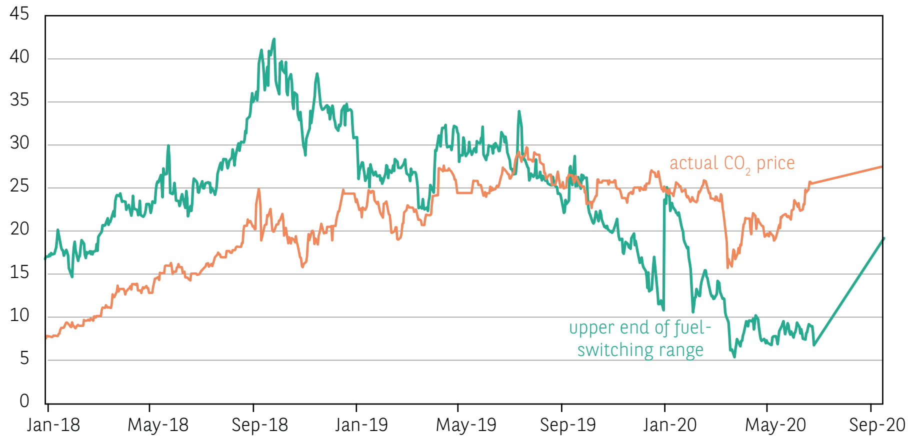
4.1.2 Given the huge over-supply, why are EUAs trading above the fuel-switching range and near all-time record highs?

Figure 41 shows the EUA price since January of this year relative to the implied fuel-switching range between coal- and gas-fired power generation.

With the exception of the sharp but short-lived drop to €14.3/t in the early stages of the lockdown across large parts of the EU in March, the Dec-20 price has consistently traded above €20/t and for most of the last four months it has traded in a range of €25/t-€30/t. Indeed, its high this year of €30.8/t is very close to the all-time high for the front-year EUA contract of €31/t recorded in April 2006.

53. We would note that given (i) the automatic way in which the MSR functions in response to the TNAC, and (ii) the increase in the TNAC caused by the COVID-induced slump in emissions, the effective EU-ETS cap over 2021-30 – i.e. the number of EUAs actually made available to the market – will now be significantly lower than would have been the case in the absence of the pandemic. Indeed, depending on what is assumed about the non-EU-ETS sectors of the economy, the decline in the effective EU-ETS cap we are now projecting even under the current 40% EU-wide emissions target would in fact already be consistent with an EU-wide emissions target of 50%-55% by 2030.

Figure 41: Dec-20 EUA price versus implied fuel-switching level, Jan-2018-Sep 2020 (€/t)



Source: BNP Paribas Exane

Perhaps more significantly, though, and as can be seen in Figure 41, the Dec-20 EUA contract has also traded at or above the upper end of the coal-to-gas fuel-switching range for most this year. We believe this is the first time in the 15-year history of the EU carbon market that EUAs have traded above the upper end of the fuel-switching range.

This might suggest that despite the devastating impact of COVID on emissions, market participants are starting to think beyond coal-to-gas fuel switching as the marginal-abatement option that ultimately clears the EU-ETS over the long term.

4.2 THE MARKET ALREADY SEEMS TO BE PRICING IN A REVISED 2030 EU EMISSIONS-REDUCTION TARGET OF -55%

In our view, the main reason that EUA prices have remained so robust in the face of the COVID-induced hit to demand is that the market is already thinking beyond the current EU legislation and starting to price in the recently proposed increase in the EU's level of ambition regarding the 2030 emissions-reduction target.

We believe the Commission has proposed the higher end of the -50% to -55% range for two main reasons:

1) The sharp drop in emissions caused by the pandemic and the likelihood that this will lead to structurally lower emissions over the next decade means that a higher level of ambition – and hence a tighter EU-ETS cap to 2030 – will not be as painful for EU industry as it might have been before COVID appeared.

2) Given the EU's ambitious targets for kick-starting and scaling up a green-hydrogen economy, higher carbon prices will be necessary, and the level of ambition proposed for EU climate policy to 2030 will therefore be read by industry and financial markets as a key gauge of how serious the Commission and the EU are about the net-zero target to 2050.

In short, the proposed new target of -55% is a declaration of intent regarding the road ahead to net zero by 2050, whereas a -50% target would have signalled a cautious approach that would not, in our view, have been enough to increase the sense of urgency within industry and financial markets on the need for increased action on and investments in deep decarbonization.

Our scenario modelling for the EU-ETS under a -55% target for 2030 makes the following key assumptions:

- We assume the same scope for the EU-ETS to 2030 as is currently the case. We know the EU is considering the possibility of including other sectors between now and 2030 – most notably buildings and transport (including the maritime sector) – but as there is no visibility on the timing or modalities of such a move we do not think it is possible to model their inclusion at this point.

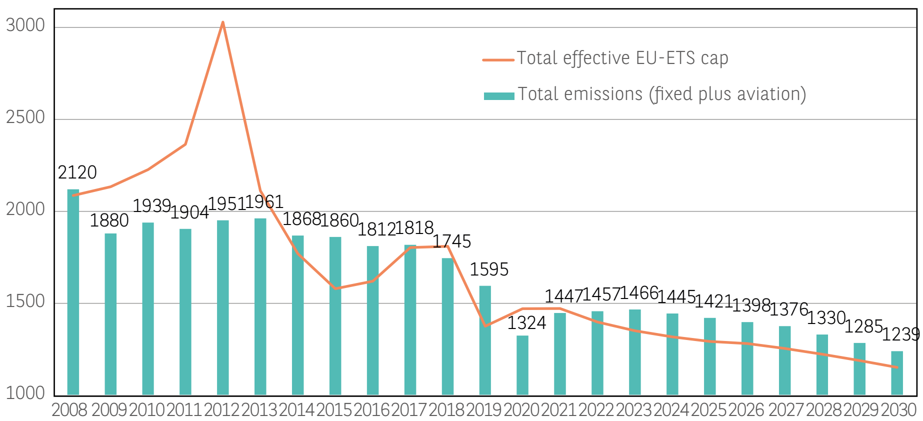
- We assume the same relative burden between the EU-ETS and non-EU-ETS sectors of the economy for the emissions reductions required under a 55% target as is currently the case under the 40% target. Modelling this on a straight-line basis from 2021 would result in an implied reduction target for the EU-ETS of 60% versus 2005 levels, compared with 43% under the current EU-wide target of 40%. It would also imply a linear-reduction factor (LRF) of 4.1% from 2021, implying a 2030 EU-ETS cap of 943Mt (compared with 2.2% and 1,333Mt respectively under the current -40% EU-wide target).

- However, there is clearly not enough time for the EU to put in place all the measures that would be necessary to begin reducing the cap at this rate from 2021. As a result, we model the reduction in the EU-ETS cap via a different method, assuming simply that the MSR continues to reduce the TNAC by 24% per year beyond 2023 all the way out to 2030.[54]

Figure 42 shows our projected base-case emissions over 2020-2030 as already shown above in Figure 39, but this time mapped against the cap we have derived on the basis of our assumptions regarding the EU-ETS cap under a -55% EU-wide target for, 2030.[55]

Comparing Figure 42 with Figure 39, on our scenario modelling of a -55% EU-wide target, EU-ETS emissions are consistently higher than the effective cap from 2022 onwards such that emissions exceed the cap by 935Mt cumulatively over 2021-30. By contrast, under our modelling of the current -40% target, emissions exceed the cap by only 260Mt over 2021-30.

Figure 42: BNPP AM scenario modelling of EU-ETS emissions v total EU-ETS cap under potential -55% target, 2008-2030 (Mt)



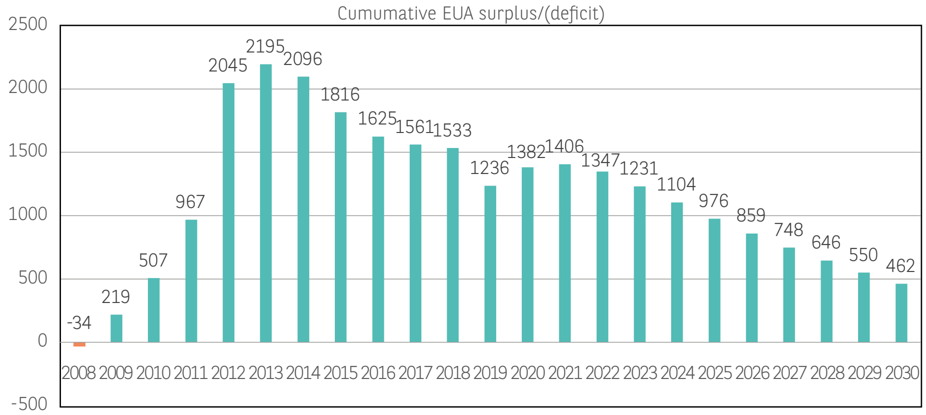
Source: BNP Paribas AM research estimates

54. To be clear, we are not arguing that this is how the more ambitious EU-ETS cap that will be formally required under an upward revision of the EU's 2030 target to -55% will actually be implemented, simply that it is convenient for our modelling purposes here. That being said, there is a scheduled review of the MSR in 2021, and this does in fact offer scope for the Commission to recommend such a change and/or to recommend changes to the TNAC thresholds for withholding EUAs from auctions for inclusion in the MSR (833Mt) and re-introducing EUAs to the market via auctions (400Mt).

55. In fact, our modelling here is consistent with a 57% reduction in EU-wide emissions, this being the result by 2030 of the emissions forecasts we have modelled and of the automatic operation of the MSR on the EU-ETS cap on our assumption of an injection rate of 24% all the way out to 2030. In turn, this is consistent with a 4.6% LRF from 2021, and an EU-ETS cap by 2030 of 800Mt. This is less surprising than it might sound as in fact there is ample precedent for having a cap that is tighter on a de facto basis than it is de jure. For example, the backloading of 900m EUAs over 2014-16 ended up tightening the Phase-3 cap on a de facto basis even though the de jure Phase-3 cap remained unchanged. Similarly, the introduction of the MSR from 2019 tightened both the Phase-3 cap and the Phase-4 cap on a de facto basis, even though the Phase-3 and Phase-4 caps remained unchanged de jure at the time of the MSR's introduction. Subsequent to the MSR's introduction, of course, the EU has now set out its legislative plans for a net-zero 2050 target, and this will entail a change to the de jure Phase-4 cap consistent with a -55% target, but the key point is that there are precedents for tightening the EU-ETS cap within trading periods on a de facto basis without changing it de *jure*.

Nonetheless, even under our scenario modelling of a -55% target there is still a surplus of EUAs by 2030, albeit a significantly smaller one of 462Mt (Figure 43) than the 1,121Mt we derived under the current -40% target (Figure 40 above).

Figure 43: BNPP AM scenario modelling of EU-ETS surplus (including aviation) under potential -55% 2030 target (Mt)



Source: BNP Paribas AM research estimates

However, what matters from a pricing point of view in the face of any projected surplus of EUAs are two things:

1) expectations regarding further tightening of the cap beyond 2030, and potentially before 2030 as well;[56]

2) who is holding this balance of surplus EUAs (compliance players or financial investors), and hence how likely they are to be traded on the market.

On the first point, our conclusion regarding the price action in EUAs over the course of 2020 in general, and since the rebound from the low of €14.3/t in late March in particular, is that the market seems already to be pricing in a scenario similar to the one we have modelled in Figure 42 and Figure 43. In other words, we think the market is already effectively assuming that the Commission's proposal for a more ambitious -55% 2030 EU-wide target will result in a significant reduction in the surplus of EUAs in the market out to 2030 compared with the surplus that would accumulate under the current -40% EU-wide target.

On the second point, it is very difficult to know how the surplus of EUAs in the market breaks down between compliance players and financial investors, but to the extent that a more ambitious 2030 target will tighten the number of EUAs available to compliance players over Phase-4, then other things being equal it seems reasonable to assume that these players – especially industrials – will be more reluctant to sell any surplus holdings they might have in the future. In turn, this makes EUAs a more interesting asset class for financial investors.

56. See the explanation of this point in Footnote 55 above.

4.3 CONCLUSION: FOR GREEN HYDROGEN TO EMERGE AS THE NEW MARGINAL-ABATEMENT OPTION, MORE POLICY SIGNALS NEEDED

If the market really is already pricing in a -55% target, then for a structural change to occur whereby EUA prices move onto a trajectory consistent with making green hydrogen competitive by 2030 we think the market will have to become convinced that the EU is serious about its 2050 net-zero target. This would require further signals from the Commission and/or EU member states that the push towards deep decarbonization beyond the power sector now needs to ramp up in earnest.

For example, this could include the following two signals that we know are already under consideration, by the Commission:

- **The expansion of the EU-ETS to include other sectors such as buildings and transport:** Broadening the scope of the EU-ETS to include sectors that have not faced the same kind of pressure to reduce their emissions before now as the sectors covered by the EU-ETS would bring a bigger share of the overall EU emissions cake into play, and would therefore open up the possibility of deeper relative cuts for those sectors than for the sectors already covered.

  In this respect, Germany has already provided a template by setting out a carbon-pricing trajectory for its emissions from buildings and transport. The trajectory starts at a flat rate of €25/t, rising at €5/t per year to €55/t in 2025, with allowances in 2026 to be auctioned in a corridor of €55/t-€65/t, and thereafter the market determining the price.[57]

- **The proposal of a Carbon-Border-Adjustment Mechanism:** this would show that the EU was serious about subjecting all sectors covered by the EU-ETS to the full EUA price signal. Depending on how it was designed, it could also bring foreign producers of steel, cement, and other carbon-intensive products that export into the EU into the scope of the EU-ETS by requiring them to purchase EUAs as well (albeit from a proportionately larger EUA pool commensurate with the EU's policy target).

  Again, the effect here would be to open up the possibility of deeper relative cuts for foreign exporters into the EU who have not before now faced the same pressure as their EU counterparts to reduce emissions.

Above all, though, it would require the translation of the policy measures outlined in the Commission's A Hydrogen Strategy for a Climate-neutral Europe document into concrete and credible policy measures. This is because, as we explained in Section 3 above, there is no plausible pathway to net zero by 2050 without the scaling up of green hydrogen so that it is commercially viable as an industrial feedstock by 2030, and as an energy source for transport, heating, and power generation over 2030-40.

An obvious place to start would be to get auctions for CCfD contracts up and running in order to provide a market-determined price signal for low-carbon hydrogen, albeit outside the EU-ETS. For the reasons explained in Section 3, this would likely be for blue hydrogen initially, but it would provide a psychological marker for the carbon price required for green hydrogen later in the decade.

At the same time, public-policy incentives for industrial companies to invest in the plant and processes required for scaling up green hydrogen would demonstrate that deep decarbonization for the EU was a priority.

And in the final analysis, convincing the market that deep decarbonization is an urgent priority would be the single greatest catalyst for bringing about a step change in the EUA forward curve consistent with both (i) our theoretical analysis in Section 2, and – depending on the market's view of green-hydrogen costs and EU gas prices by 2030 – (ii) our scenario modelling in Section 3.

57. It is interesting to note that these prices for domestic German emissions from buildings and transport for 2025 and 2026 are broadly aligned with the trajectory we estimate to be consistent with making green hydrogen competitive with grey hydrogen by 2030: our central trajectory as shown in Figure 34 in Section 3 above has the implied fair value of EUAs in 2025 at €67/t and in 2027 at €71/t. For more details on the German plan for buildings and transport see the reports on Clean Energy Wire, 'Germany's carbon-pricing system for transport and buildings', 16 December 2019 (https://www.cleanenergywire.org/factsheets/germanys-planned-carbon-pricing-system-transport-and-buildings), and 'German lawmakers agree to raise planned CO_2 price for buildings, transport', 17 December 2019 (https://www.cleanenergywire.org/news/german-lawmakers-agree-raise-planned-co2-price-buildings-transport).

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