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Mark Lewis, Chief Sustainability Strategist, joined BNP Paribas Asset Management in January 2019. Previous roles include Managing Director and Head of Research at the Carbon Tracker Initiative; Managing Director and Head of European Utilities Research at Barclays; Chief Energy Economist at Kepler Cheuvreux; and Managing Director and Global Head of Energy Research at Deutsche Bank. He is a member of the Financial Stability Board's Task Force on Climate-related Financial Disclosures.

Deep Decarbonisation

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

Mark Lewis

Beyond the fuel-switch 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.

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.

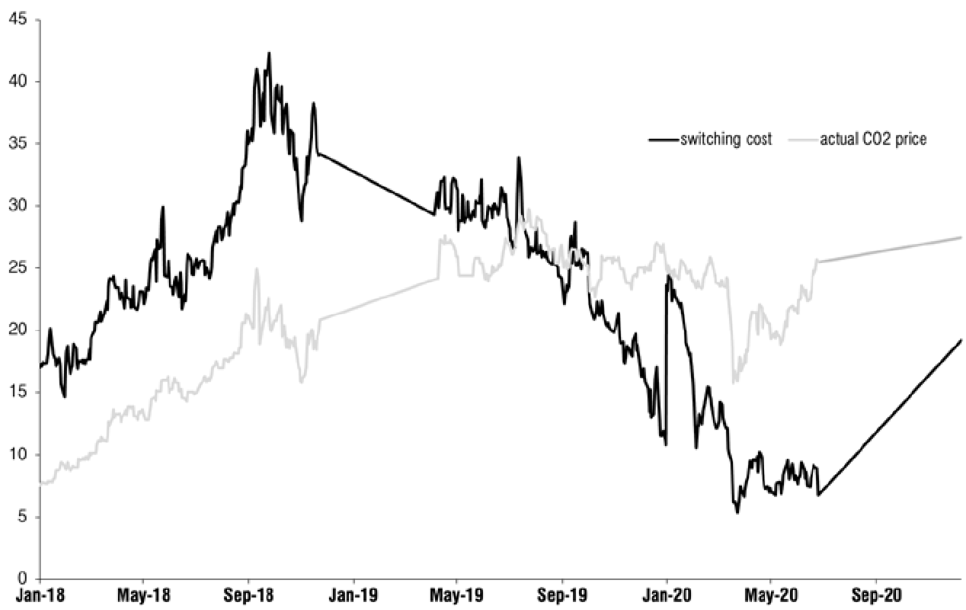
And one interpretation is that despite the devastating impact of COVID-19 on emissions, market participants are starting to think beyond coal-to-gas fuel switching in the power sector as the marginal-abatement option that ultimately clears the EU-ETS over the long term. And with good reason, we think: 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.

Carbonomics in theory: It take CO_2 to cotango

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

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



Source: BNP Paribas Exane

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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 fulfil 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.

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).

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 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.

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 hy-

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drogen 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 CO2 produced for every kg of hydrogen. This equates to 0.27 tonnes of CO2 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.

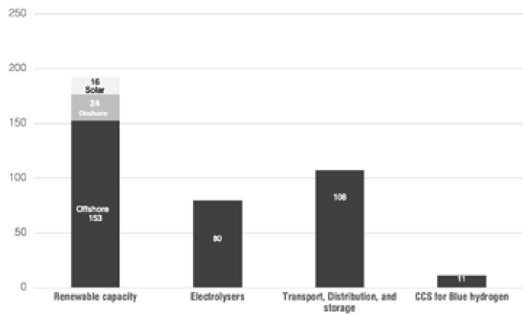
The Commission estimates the total investment required to achieve its 2030 vision at €320-€460bn, with €220-€340bn of this to cover €80GW-120GW of dedicated new wind and solar capacity, and €24bn-€42bn for 40GW of electrolyzer capacity.

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 – while 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 of building up the EU's green-hydrogen economy by 2030 (€bn)



Source: BNPP AM Research estimates

Our analysis implies theoretical range for 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/kg	€2/kg	€2.25/kg	€2.5/kg
€10/MWh	€79/t	€103/t	€126/t	€149/t
€15/MWh base case	€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.

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.

Our analysis implies a range for the 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/kg	€2/kg	€2.25/kg	€2.5/kg
€10/MWh €	€43/t	€55/t	€68/t	€80/t
€15/MWh base case	€30/t	€42/t	€55/t	€68/t
€20/MWh	€18/t	€31/t	€43/t	€56/t

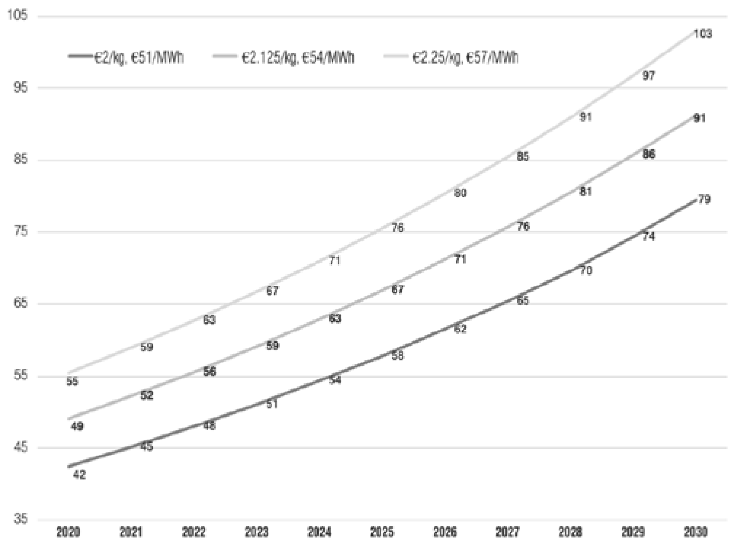
Source: BNPP AM Research estimates

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: BNPP AM Research estimates

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 decarbonisation 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 decarbonisation 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. **FS**

Important Note:

BNPP AM does not hold any EUAs in any of its investment portfolio