C-MACC

Chemical Market Analysis & Consulting Company

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Subjects Covered

- *Recycling*
- *Renewables*
- *Carbon Capture*
- *Emissions*
- *New Energy*
- *The Hydrogen Economy*
- *ESG Investing*

Products Mentioned

- *Hydrogen*
- *Steel*
- *Cement*
- *Chemicals*
- *Ethylene*
- *Polyethylene*
- *Ethylene Glycol (MEG)*
- *Wind Power*
- *Solar Power*
- *Industrial Gas*

Companies Mentioned

- *Tesla*
- *ExxonMobil*
- *Chevron*
- *Phillips 66*
- *CP Chemical*
- *Total*
- *BP*
- *Shell*
- *Ineos*
- *Equinor*
- *United Airlines*
- *Occidental*

C-MACC Weekly "CRETER" (Climate etc.)

Hydrogen – The Promise, The Problem and Path to the Dream

- **The "learning curve" expectations for those pushing the quick adoption of Green Hydrogen are likely far too hopeful; not because the technology to produce green hydrogen cannot improve, but because the expectations around the affordability and quantum of low-cost electricity is likely to fall well short of potential demand.**
- **The science and the low carbon promise of green hydrogen is compelling, but a long blue hydrogen runway is likely the least economically painful way to achieve lower CO2 in the near-term, while building a hydrogen infrastructure that can work for the long-term. Blue hydrogen investment will not occur without some return assurances**
- **Otherwise, this week, the "I want to be green" headlines continue – with the Canada CO2 tax hike the most striking – see below.**

First this week, we dive into hydrogen (something you should never do while smoking a cigarette or carrying an open flame). The appeal of green hydrogen as a clean burning fuel has been a constant and its is partly shown in the Google Trend chart below with prior peaks in interest early in Google's tracking history, which is unusual for most "trend" searches – Exhibit 1

Exhibit 1: Global Google Trend search for Green Hydrogen shows the current peak but a not uninterested past

Clearly there has been a significant step up in interest since late 2019, but while some of this interest as been sparked by the general wave of climate related activity, we believe that it was only in 2019 that the idea of cheap, or possibly free, renewable power became more mainstream. Today, the variable cost (pre-capital recovery) of green hydrogen is estimated to be around $3 per pound versus less than $1 per pound for conventional hydrogen production from natural gas. The cost of power, at current industrial rates makes up almost all the difference. Water does not want to split into hydrogen and oxygen as readily as, for example, salt wants to split into chlorine and caustic soda, and the power required to make the split is high. This has been the stumbling block for the "hydrogen" dream for decades and why electric vehicles have been more successful that hydrogen fuel cells – you cannot make the hydrogen cheaply enough – or can you?

As we add more wind and solar power, we are hitting points during the day in some places (Texas would be good example) where there is more power being generated than required – incremental power is occasionally free in Texas should you have the ability to exploit it. As renewable power capacity is added, this is becoming a more

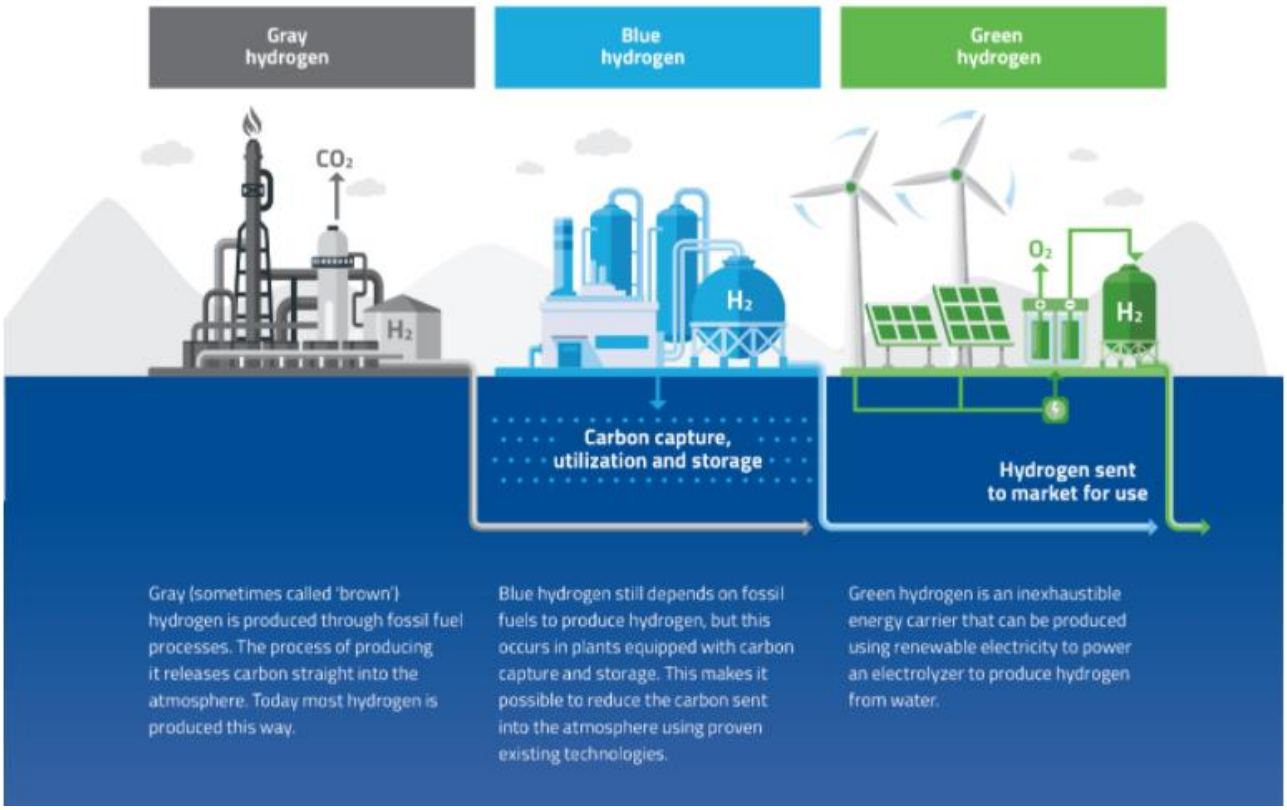
common occurrence and the question becomes what the best way is to store the surplus energy. Tesla would likely tell you it is a battery, but most chemical engineers and many power generators would say hydrogen. If power is free, green hydrogen is competitive with traditional (brown or grey) hydrogen. But there is not much demand for an intermittent supply of hydrogen and consequently the only options are to build a lot of storage (to create a buffer supply) or to use the hydrogen intermittently to generate clean power when demand is higher (this would be the integrated power generation model).

Solving transport and hard to avoid heating requirements (steel, cement, chemicals) with hydrogen will require substantial volumes of hydrogen – more than could be displaced as refinery demands shrink and more than can be produced by occasional surplus power. Some prominent chemical companies are looking at technology to use electric based heat in cracking processes which currently use natural gas. While this might be an alternative to replacing the natural gas fuel with hydrogen, it requires more renewable power to get the green solution that the companies are looking for. Which even way you do the math, the necessary investment in renewable power such that green hydrogen can make a meaningful dent in its potential market is huge and the current wind and solar models need another step up in technology/efficiency if the promise of green hydrogen is to become a widespread reality.

Is Blue Hydrogen The Steppingstone?

Exhibit 2 is a great illustration of the different hydrogen production and labeling variants for those who are not clear about the differences – it is part of a more comprehensive description from **Worley** and can be found on their website at the link here.

Exhibit 2: A good illustration of the different categories of hydrogen today – The Pembina Institute has another linked here. Almost all the current hydrogen produced globally is grey. There is some nominal but hard to segregate blue hydrogen (Air Products provides some CO2 into the Denbury pipeline system in the US but it is not clear that any hydrogen is segregated on that basis). Green hydrogen volumes are very low, but, as we discuss, there are plenty of plans.

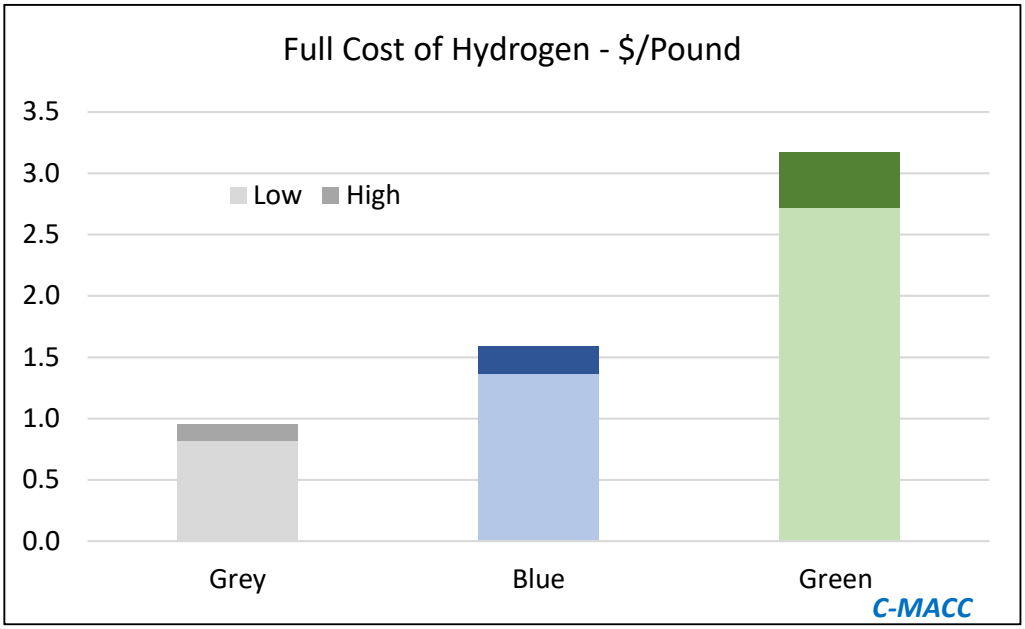


Some blue hydrogen positives:

- **A natural gas-based hydrogen facility where all the CO2 is captured, or used, has a fraction of the carbon footprint of any other large scale current combustion fuel alternative**.
- We have plenty of natural gas.
- We know how to sequester the carbon – and where to build the hydrogen to minimize logistic challenges from both the hydrogen demand and ease of sequestration perspectives.
- A purpose-built blue hydrogen facility would have a lower carbon capture and compression costs than the cost of adding that to an existing hydrogen plant.

But who would commit billions of dollars of capital to projects that might not have or might lose government/regulatory support because "green is better" even if it is unattainable for decades without hugely expensive subsidies? Blue hydrogen is almost certainly the practical and economic solution for the near and medium term. We have seen various studies on costs of hydrogen and the chart in Exhibit 3 puts bands around the current thinking on highs and lows. We have seen studies that only talk about variable production costs but given that we need NEW investment in hydrogen capacity we have included capital costs.

Exhibit 3: C-MACC estimates of hydrogen costs - an aggregate of multiple sources. The Green hydrogen cost assumes current industrial power prices and power accounts for a little less than half of the full cost and more than half of the cost pre capital recovery



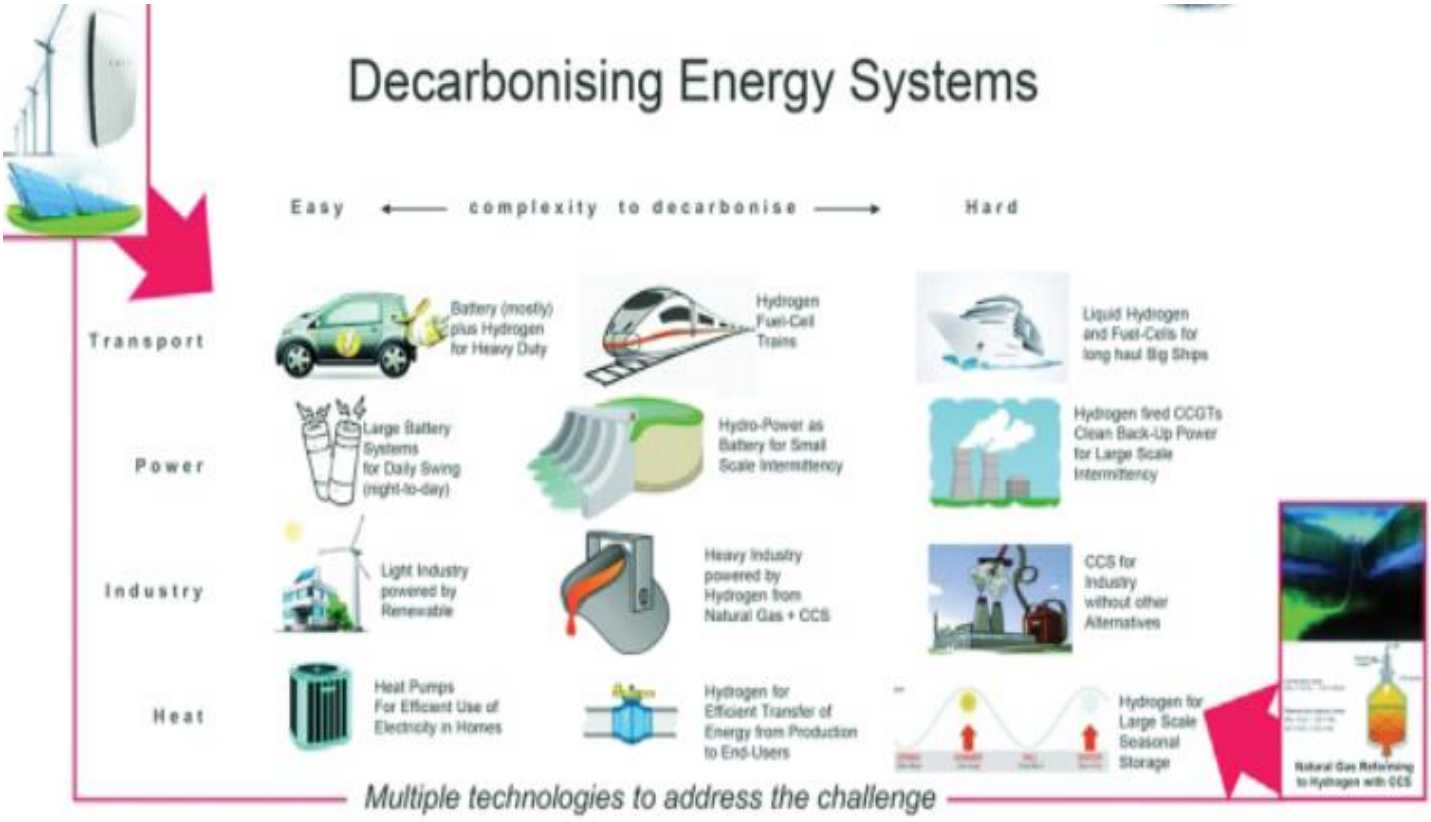
With free power the green bar would drop to a point where it is more competitive than blue hydrogen but sill higher than grey hydrogen.

- In the blue hydrogen bar, the higher end of the cost assumption is the cost of refitting existing hydrogen facilities to capture carbon. We have assumed that a greenfield or brownfield investment where, carbon capture is part of the initial design, could be less costly, especially if built at scale.
- In the green bar, the learning curve that those excited about the technology are looking for is not just about cheaper power, as there is an expectation that the cost of building and operating electrolysis technology could also come down. Again, there would be benefits of scale, but there would need to be enough power available to provide the scale opportunity.
    - We struggle to see how green hydrogen will work well unless the producer is also either the owner of, or directly linked to the power generator – as with the proposed Neom venture in Saudi Arabia. These projects are more likely to work if the return on investment is being captured across the entire process – generation to hydrogen delivery.

- The blue hydrogen alternative also probably needs an integrated feedstock, as natural gas price volatility could be a deterrent to investment. This year alone, NYMEX natural gas prices have ranged from a low of around $1.50 per MMBTU to $3.20 per MMTBU.
    - Success with blue hydrogen may require partnership with a natural gas producer as well as some sort of regulatory guarantee that a "green" mandate will not put the investment on the rocks before an adequate return is generated.

In Exhibit 4, we show a chart from one of our Dailies, taken from the Qatar Tribune. Here the call is for the use of Blue Hydrogen as an important bridge. We see corporate reports and consulting studies every day that talk about different paths to a clean energy future – this one is more focused on blue hydrogen than most and looks more practical than the "what-if" green hydrogen "nirvana" projections.

Exhibit 4: We highlight a chart from a Qatar Tribune article titled "Natural gas-sourced blue hydrogen to usher in era of decarbonization" that displays the role of blue-hydrogen in decarbonizing various energy systems.



Source: Qatar Tribune, GECF, C-MACC Analysis, December 2020

In conclusion, we believe that the economic best path forward to hydrogen goes through blue hydrogen for decades before we can have attractively price green hydrogen in large enough volumes to make a difference.

For this to work, potential blue hydrogen producers need be confident that they will have a market for long enough to justify the investment and will not be rolled-over by a "green" wave which is as impractical as it is expensive – at least for the next 20 years. The story behind the headline below summarizes the risk:

- **After George Floyd, carbon capture tech tiptoes into racial justice**

If we think about hydrogen as a transport fuel – blue hydrogen is a way of capturing the CO2 before it comes out of an exhaust pipe.

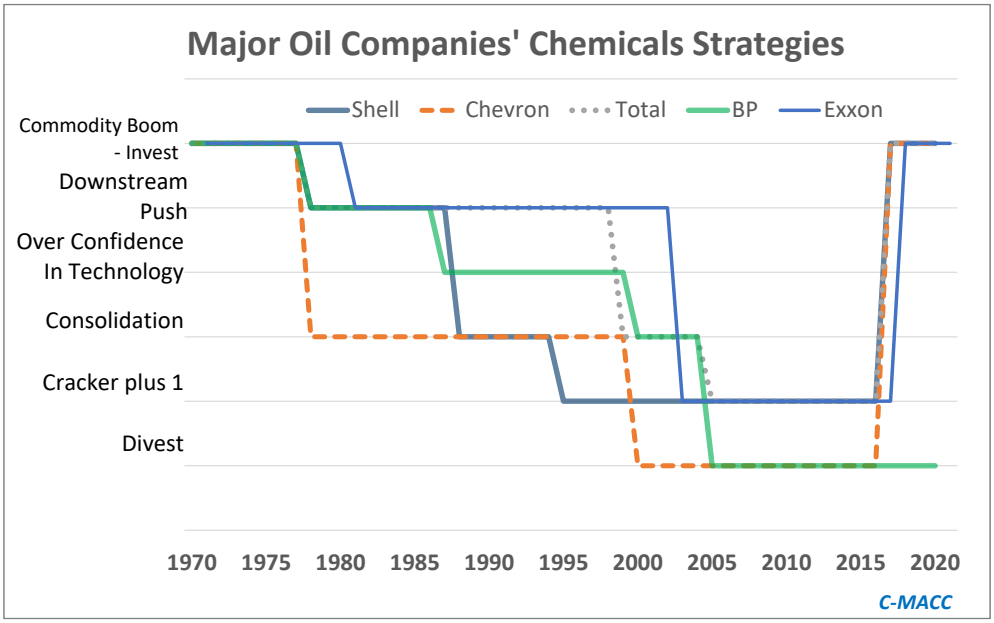
Second topic of the week – Energy Transition By The Energy Majors

This week ExxonMobil has come under the headlight again, first because of activist pressure to adopt a more climate friendly strategy and then because an announced response to that call which has generally underwhelmed those that have commented so far. ExxonMobil stated ambitions are significantly less aggressive than peers, with the possible exception of Chevron, which has talked a better game, but may not necessarily be playing a better one.

ExxonMobil is calling for "market based" solutions to address emissions and climate change. What ExxonMobil wants is a level playing field where costs are imposed on the industry, ideally in ExxonMobil's case though a carbon tax. ExxonMobil generally takes the view that, given a set of clear rules or empirical inputs (like the price of oil or gas) which apply to all, then the company can outperform. This has certainly been its history until recently.

We use chemicals as an example, and Exhibit 5 is as rough guide to the way in which the majors have evolved in chemicals since the early 70s. In this case the rules/data were clear – they all knew the price of oil and gas in the various regions in which they were focused, and all evolved to the conclusion that they should really only be in basic chemicals (essentially to consume captive hydrocarbons), or they should not be in at all. In the US we have seen that change with the shale gas wave.

Exhibit 5: The oil majors' chemical strategies have evolved at different paces over the last 50 years, but they have all essentially arrived at one of two places – they either adopt an integrated approach to consume captive feedstock and stop at the easiest to sell chemical (mainly polymers and ethylene glycol) or they have divested completely



Source: Corporate Reports, Media Coverage and C-MACC Analysis

Some notes on Exhibit 5:

- BP's divestment point in the diagram marks the original sale to Ineos – the company kept its PTA chain until recently and still has one ethylene plant in Germany integrated into a refinery.
- Chevron divested, but to its 50/50 venture with Phillips 66.
- Exxon played the integrated investment card much longer than others (with the exception of the recent US wave, in which Shell, CP Chem and Total are participating), with the initiatives in Singapore and Saudi Arabia.
- Only BP was not sucked into the US shale investment wave and our view is that BP would have been involved also had it not been for the Macondo incident.

Energy Transition and Climate Change present a set of problems for the energy majors that are not like the chemical decisions, as they are filled with uncertainty and subjective valuation – which they don't like. The infographic recently published by S&P and linked below makes a good attempt at ranking the majors with respect to their adoption of cleaner energy strategies. While it shows ExxonMobil clearly in last place, everyone above ExxonMobil on the list is currently relying on assumptions, in addition to oil and gas demand and prices, over which they have little control. Total, BP, Shell, Equinor and others are betting that power generation (renewable) is the path forward, while some of the US refiners are betting on bio-based fuels, trusting that credit systems like the LCFS program on the West Coast will remain in place and that values will be high enough to support their transitional investment.

- **Infographic: Power Plays: Energy majors' transition strategies**

Similar to the Hydrogen issues discussed above, the lack of uniform regulatory approach leads to an uneven playing field and the risk that you are only guessing where the playing field is today, and with a real risk that the location changes halfway through the game. When ExxonMobil talks about "market based" solutions, what they really mean is tangible and equally applied values/penalties for the issues that need to change – a carbon tax would be a good example. If a $100 per ton carbon tax was applied in the US to all industrial emitters of CO2, ExxonMobil and others could build that cost into their economic models, as the incentive to avoid the cost would be measurable.

One of the leadership roles that needs to be played in moving the Paris Agreement forward (maybe soon by the US), is to agree on an emissions carrot and stick mechanism that incentivizes emitters to make real change to eliminate greenhouse gas emissions rather than re-focus investment in countries with less onerous rules.

ExxonMobil has an exemplary track record of performing efficiently, and profitably, operating between well-defined tram lines – as have other major oil companies. If the right tram lines are now created that push companies to meaningfully change emissions, they will change. However, the risk is that the longer governments take to reach an accord, the more invested specific energy companies will be in pursuing their own paths, and the harder it will be to get a consensus view that works for all.

Recycling/ Renewables

Looking at this week's headlines, we first reiterate one of the challenges that we discussed last week, which is that when you introduce renewable based plastics into the packaging mix you add another level of complexity to the already challenging recycling problem, especially if a renewable based plastic container is hard to distinguish from a polyolefin-based container.

With the ExxonMobil announcement below we see another example of what we think will be a trend – the major polymer producers buying into either successful recycling operations or those in development that have a good business model. The major polymer producers cannot allow third parties to dominate the recycled polymer markets unless they are willing to cede market share and lose traction with customers.

- **DSM launches new range of plant-based Decovery resins**
- **Neste RE enables a future where all plastic products can be made of renewable and recycled materials**
- **ECHA to send proposed restriction on microplastics to EU Commission**
- **Independent analysis reveals reusable packaging up to 85% more climate-friendly than single-use**
- **Ineos Styrolution, Indaver granted EU funding for project to produce ABS from recycled feedstock**
- **LyondellBasell and SUEZ increase plastics recycling capacity**
- **The plastics cycle and contaminated recyclate**

- **Commodities 2021: Middle East renewables on rebound after project delays**
- **Axens licenses ethanol-to-ethylene technology to Sumitomo for circular project in Japan**
- **Beiersdorf to use certified renewable polypropylene from SABIC's TRUCIRCLE™ portfolio**
- **ExxonMobil takes 25% stake in Cyclyx recycling consortium**
- **Bioplastics struggle to build scale and grow into a more significant alternative to petrochemicals**
- **Going Circular: Seizing the opportunity in plastic recycling**
- **Multilayer packaging with polyamide can be recycled**
- **Plastic waste: what is new is old**
- **State of play for collected and sorted plastic waste in Europe**
- **Enerkem announces waste-to-methanol, biofuels plant in Quebec**
- **Axens selected by Sumitomo Chemical for a waste-to-polyolefins project**
- **Sealed Air launches food-grade film made using recycled plastic**
- **Report advocates for improving chemical recycling life cycle assessments (LCAs)**

Carbon Capture and Emissions

The three headlines of most interest this week are the Canada Carbon Tax Hike (from today), United Airlines venture with Oxy and the LNG concerns. We also note the official Norwegian approval of the Norther Lights Project.

The carbon tax hike in Canada to C$170 (by 2030) per ton of CO2 – rising from C$50 in 2022 by C$15 a year to 2030, should encourage significant investment in carbon avoidance and carbon capture. The current best estimate in the US is that CCS from dilute CO2 streams would cost around $120 per ton or less today. The Canada incentive/stick should drive substantial investment.

United is trying to invest its way to carbon neutrality, essentially partnering with Occidental in (a first) direct air capture project, where Oxy will use the CO2 in enhanced oil recovery in the Permian. Direct air capture is a very expensive way to get CO2, but if United can get the offset and Oxy can get the enhanced crude recovery it may make economic sense for both. It will make more sense if there is a way that United could monetize the carbon offset through more than just the 45Q tax and might suggest that United sees more onerous carbon penalties on the horizon and have taken what is first mover advantage to partner with someone who has use for CO2. It still all seems very expensive to us.

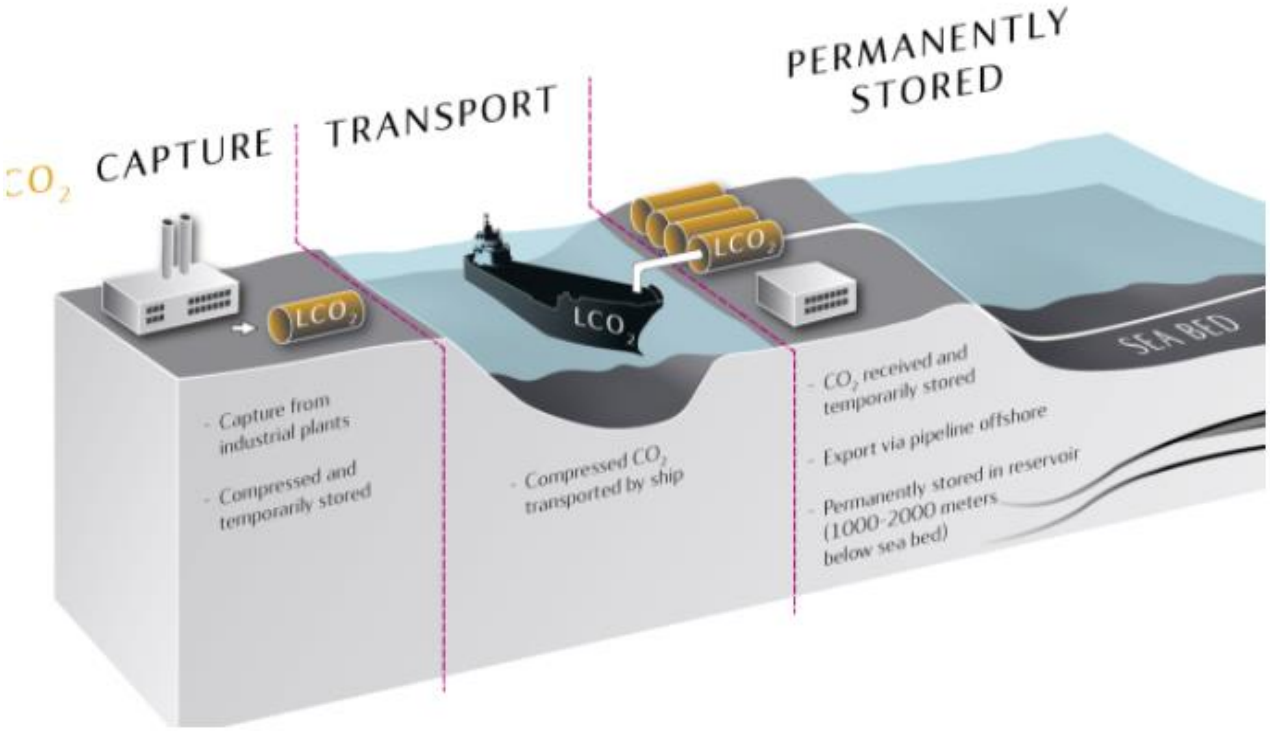
The LNG news is interesting only because it supports an idea that we believe will become mainstream very quickly. We do not think that you will see greenfield investment in any large industrial complex in the US or Europe going forward that does not address the carbon footprint of the project. It is unlikely that you would get project-based finance today without a carbon plan, and it is also likely that corporations will come under stakeholder pressure from here is they try to build something, without borrowing, that does not have a carbon plan. LNG has two streams of CO2 – a smaller pure stream that is purged from the gas before the main compression stage, and a much larger dilute stream associated with generating the power to run the compression turbines.

- **Biden under pressure to quickly regulate methane**
- **Carbon capture milestone reached at Dakota Gas**
- **Fuel and plastics could be created from new carbon capture method**
- **EIA expects U.S. energy-related carbon dioxide emissions to fall 11% in 2020**

- New North America LNG projects hindered by dearth of contracting, climate concerns
- United Airlines invests in carbon-capture project to be 100% green by 2050
- Braskem Enters Research Partnership for Sustainable Plastic Production Using CO2 Capture and Utilization Tech
- After George Floyd, carbon capture tech tiptoes into racial justice
- China looks to carbon capture and hydrogen to push aviation, shipping, power plants, industry towards 2060 target
- Carbon capture heralded as a critical tool in climate fight, but at what cost?
- ExxonMobil sets new emission reduction plans; anticipates meeting 2020 goals
- UK to launch emissions-trading system in January
- Time for India's net zero target
- BP acquires majority stake in US carbon offset firm Finite Carbon. Also, see LINKS 1 & 2.
- Canada to hike carbon tax to C$170/tonne in bid to reach Paris target
- Carbon Border Adjustment Mechanism – possible implementations and EUA market implications
- The three pathways to 2050 for German emissions reduction
- World's largest copper miner to cut carbon emissions 70% by 2030
- Xi Jinping's pledge to cut China's carbon emissions raises questions over whether Beijing is moving quickly enough | South China Morning Post (scmp.com)

We have talked about the Northern Lights project in previous work. Yesterday the Norwegian Government gave the project the green light. Participants in the project include Total, Shell and Equinor and the government guarantees, and subsidies are substantial. The diagram in Exhibit 6 outlines the components of the project

Exhibit 1: Total CEO: North Sea Could Switch from Oil Reservoir to CO2 storage is an item gaining incremental attention, and we flag an Equinor video presentation commenting to the development of the North Sea to store CO2 – see LINK. Also, see a rough flow chart below to conceptualize the initiative.



Source: Equinor per LINK

Renewable Fuels, Power, Hydrogen

As discussed above, the complicating factor with current green hydrogen initiatives is that they are not scalable because of the both the costs and availability of renewable power. Using all the renewable power available to make hydrogen does not make a lot of sense as the EV fleet rises, also ideally looking for renewable power to create a carbon free transport alternative. Conversion from internal combustion engines to EVs could on its own have an inflationary impact on power costs before a step change in power demand from hydrogen. If green hydrogen investments get ahead of available power sources, the green hydrogen bar in Exhibit 3 could rise, especially if the green hydrogen producers have firm customer obligations.

The momentum here is significant and we would invest in the renewable power companies – wind and solar – simply because of the step up in demand that must come with the green hydrogen initiatives. We would also own the industrial gas companies as we have indicated previously.

- Enel, Maire Tecnimont to build green hydrogen plant in US
- EU postpones aviation and sustainable fuels strategy
- EU Commission proposes legislation for sustainable batteries
- EU wants 30mn zero-emission vehicles by 2030
- First commercial-scale green ammonia plant planned
- Green Hydrogen: a Fuel Bursting With Climate-Saving Potential
- Japan aims to boost government use of renewable power
- Japan's MoI, Tohoku ink deal for wind-powered coal ship
- Toyota shows off new Mirai fuel cell car in fresh push for hydrogen technology
- What's the Role of Hydrogen in the Clean Energy Transition?
- Linde, Snam to collaborate on clean hydrogen projects in Europe
- Japan firms test Al, alloys to generate hydrogen in EVs
- Electric truck industry advances as EU cuts tolls
- Borealis commissions waste-to-energy facility to supply polyolefin plant in Beringen, Belgium
- Chart Industries **made two announcements this morning: a)** Chart Industries to Acquire Sustainable Energy Solutions**; and b)** Chart Industries Acquires 15% Ownership of HTEC Hydrogen Technology & Energy Corporation and Signs Strategic Commercial Hydrogen MOU**. See presentation in** LINK
- LG Chem to operate Chinese cathode material plant with renewable energy
- Phillips 66 slashes 2021 capital spending; focus on renewable fuels projects
- Department of Energy Puts $33 Million More into Green Hydrogen
- Establishing a regional hydrogen economy
- EU energy ministers agree hydrogen, offshore wind conclusions
- Fortescue partners Japanese firms on green hydrogen
- Provisions for cleaner energy pushed for US spending bill
- What is needed to kick-start hydrogen infrastructure in the UK?
- Why green hydrogen is the renewable energy source to watch in 2021
- South Korea's EV sales, exports up in November
- LG Chem launches battery firm LG Energy Solution
- EC proposes excluding gas projects from PCI funding, focus on hydrogen
- EU to shift funding away from gas, into low-carbon energy

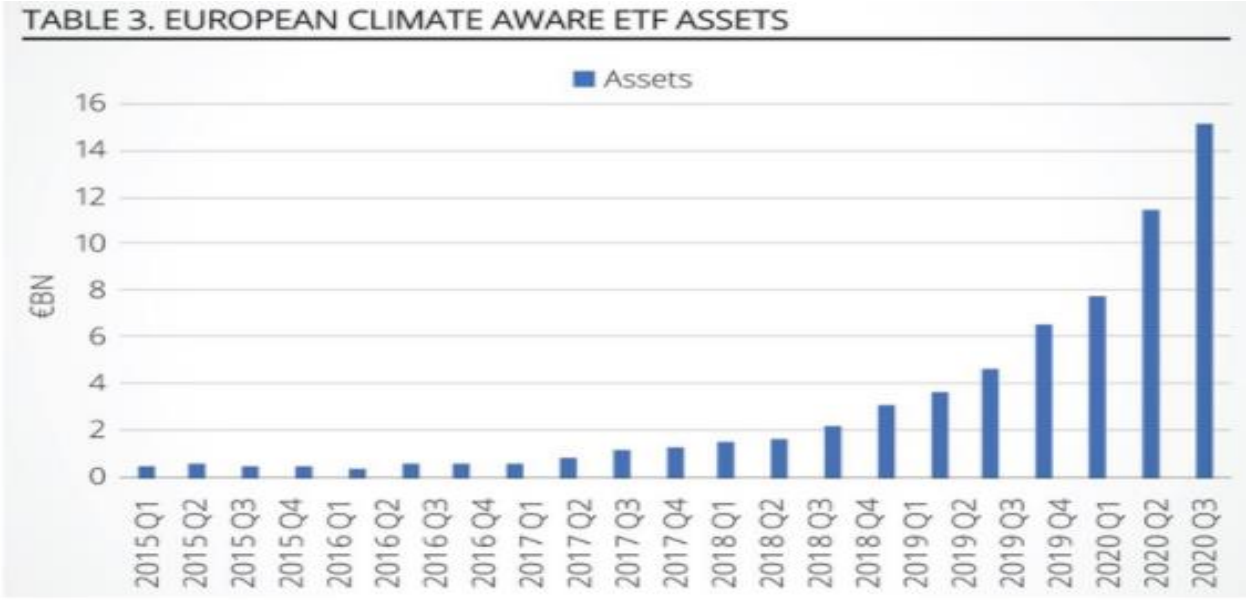
- Clean Energy Funding Finds Its Way Into Congressional Spending Bill
- Green Hydrogen, The Fuel Of The Future, Set For 50-Fold Expansion
- Hydrogen drone flight completed in Scandinavia
- Hydrogen plane startup ZeroAvia gets backing from Amazon, Shell
- Maybe "The Hydrogen Economy" Will Become "The Ammonia Economy"
- US solar installations booming, could overtake onshore wind longer term
- Banks show the carbon footprint of the ships they finance

ESG Investing

We include two charts below that show the sheer volume of money that is moving into ESG labeled funds and how much of this is being taken by ETFs. The risk with the ETFs is that they are based on a set of metrics or ratings that have not yet fully evolved – something we wrote about last week. Two similarly labeled ETFs but based on metrics by different providers may hold many different equities. It is interesting to see the headline focusing on the "E" part of ESG. Our understanding is that the smart active managers realize the breadth of definition variability in both the "E" and "S" measures and are more focused on more tangible Governance ranking and measures today.

- ESG investments reflect the search for value
- Who is making the ESG investment choices?
- 4 in 5 companies to change ESG measures in exec pay plans, survey finds
- How the "E" in ESG Is Paying Off for Companies, Investors
- Redefining 'Normal': The Top 5 ESG Trends For 2021
- Investors Turn to SPACs for Clean-Energy Bets **– we note the surge in ESG investing below in Ex. #4, and highlight the rise in SPACs in 2020 in LINK. Also, see this May 2020 article in LINK.**
- The Industrialization of ESG Investment
- Retail and ESG will shape market landscape in 2021
- ESG Investing: A Sizzling Sector That Will Get Even Hotter Under President Biden
- Investors failing to 'walk the talk' on ESG products
- The power of ESG investing
- ESG bonds offer rare bright spot next year in Europe
- What counts as climate finance? Define urgently
- ESG Investments Are Making Inroads Across All Age Groups
- BlackRock to step up sustainability action in 2021
- Is the playing field tilting further in favor of ESG investing in DC plans?
- Investors Pile Into ETFs Devoted to Socially Responsible ESG

Exhibit 7: This chart comes from an article titled "The year of ESG" and displays a positive trend in European climate ETF investing not only from 5yrs ago but on a YoY basis.



Source: Morningstar

Exhibit 8: Inflows into environmental, social, and governance (ESG) funds have soared during the past five years, and the number of ESG dedicated ETFs has skyrocketed with it. The chart below highlights both trends and was taken from an article yesterday titled: MSCI: Is ESG investing a price bubble? Probably not.

Source: MSCI, C-MACC, December 2020

Others Relevant News

- **BASF launches circular-economy program. For more information, see the BASF site in LINK. And, we note an article titled "Interview: At BASF, our target is not only to produce more, but also to produce better**
- **Australia to fall short of 2030 GHG reduction target**
- **Big Oil laggard Exxon faces a new climate threat from Wall Street**
- **Chevron CEO says company is embracing, investing in a lower carbon energy system**
- **China's long march to zero carbon**
- **US EPA sets new rules for clean air decisions**

- **Brazil pledges carbon neutrality, seeks compensation**
- **BMW steps up sustainability standards en-route to e-mobility growth**
- **European Commission sees maritime, aviation sector hardest to decarbonize amid fresh targets**
- **EC proposes fresh battery rules to boost industry sustainability**
- **EU planning sustainable fuel target to cut airline emissions**
- **Only one in five transport companies aligned with Paris climate deal: TPI**
- **China details targets for non-fossil energy transition**

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All data for this publication sourced from Corporate Reports, Bloomberg, Government Publications.