THE HYDROGEN ECONOMY

WEEKLY REPORT #32
February 6, 2024

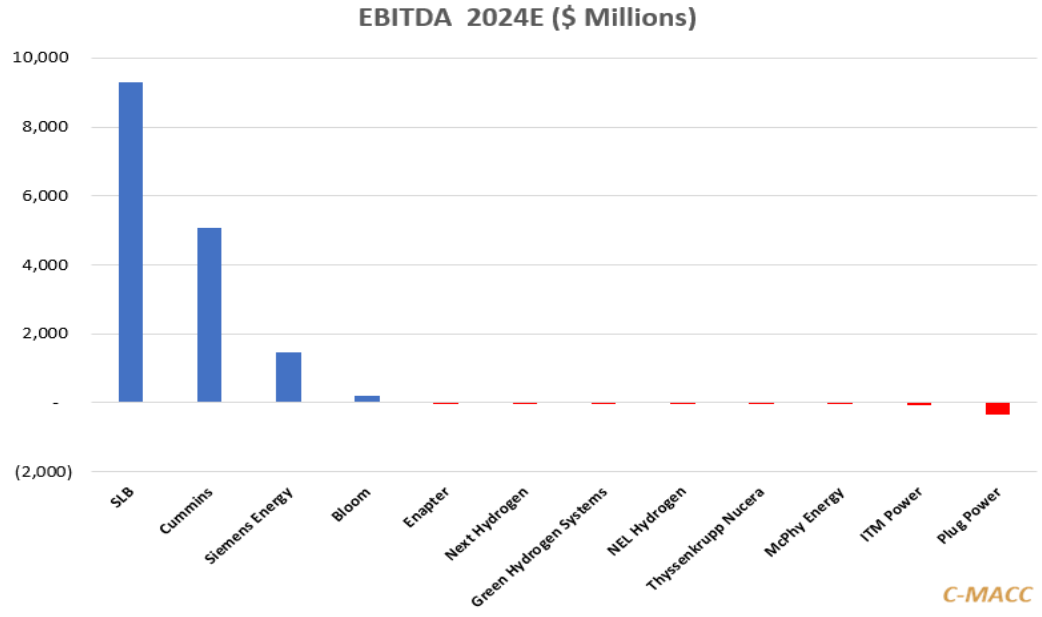
Industrial Hydrogen, Neither Intermittent & Cheap Nor High-Cost High Capacity Power Works

- *Weekly Theme: Clean Power Availability Will Limit Industrial Hydrogen Activity*
  - *News Update*
  - *Projects Update*
  - *Ammonia/Methanol Update*
  - *Power Update*
- *Next Week: Transport: Is Hydrogen Going To Take-Off?*

Key Points

- **In our recent work, we have focused on power, which appears to be a significant constraint to industrial decarbonizing investments – a lack of availability will scale back hydrogen investments (although not the noise).**
- **The choice appears to be between intermittency at very low operating rates (projects advocated at 20% capacity factor) or power that is too expensive to make even the best subsidies worthwhile.**
- **The more obvious conclusion is that projects will stall as no one is willing to pay up to cover the high costs – equipment providers who have invested early and who are cash flow negative have a high failure risk.**
- **None of this applies to China or international projects supported by China and using cheap Chinese equipment – this will give China significant economies of manufacturing scale well ahead of any companies in the West.**
- **We look at power more broadly, from our most recent Sustainability report, and we also look at some ammonia initiatives, more blue than green. For all the reasons discussed above – new project announcements are slow.**

Exhibit 1: Who do you trust to be there for you with equipment in 2026/27?



Source: Capital IQ and C-MACC Analysis

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Next week, we will host a webcast on the challenges of finding renewable power at the price and supply consistency you need if you are an industrial consumer – link here for more information. One of the side benefits of pursuing a unique project to expand run of river power, is that we get to talk to a lot of people, some for whom the water-based power may be very suitable today and others where there is just a high level of interest – and possibly for greenfield investment. As we look at a possible timeline for what we are trying to achieve, it would be 2028/29 before we had manufacturing scale – if a pilot project proves the potential. This is a best-case scenario. Our discussions with possible offtake partners and others looking for pathways to decarbonization suggest that this timing may be a best case for all potential options, even those looking at existing wind and solar projects, not just because of the time taken to build the power projects but the time and complication of adding the necessary infrastructure (including storage) to run something 24/7 from power that is intermittent.

Exhibit 2: The Numbers Behind Exhibit 1

Company	Technology	EBITDA 2024E ($ Millions)
SLB	Solid Oxide (planned)	9,298
Cummins	PEM	5,058
Siemens Energy	PEM Electrolyser	1,470
Bloom	Solid Oxide	190
Enapter	Anion Exchange Membrane	(6)
Next Hydrogen	Alkali	(8)
Green Hydrogen Systems	Alkali	(29)
NEL Hydrogen	PEM and Alkali	(36)
Thyssenkrupp Nucera	Alkali	(43)
McPhy Energy	Alkali	(45)
ITM Power	PEM Electrolyser	(61)
Plug Power	PEM	(338)
Sunfire	Alkaline and solid oxide (SOEC)	-
Electric Hydrogen	PEM	-

Source: Capital IQ and C-MACC Analysis

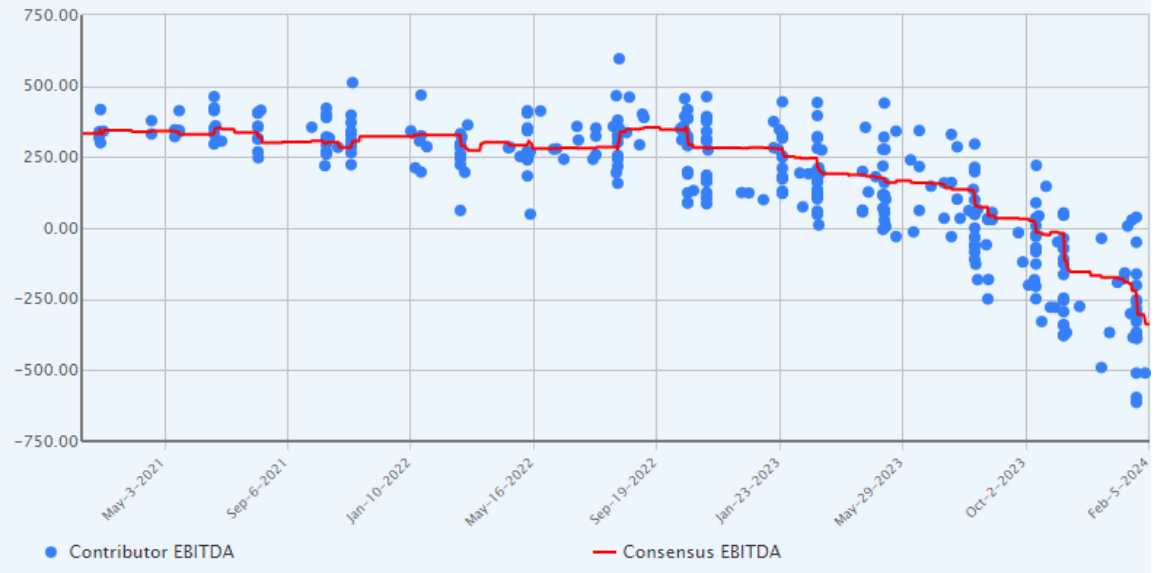
So, what does this mean for hydrogen ambitions (the focus here is the US and Europe). In our view it means that near term opportunities for green hydrogen are small, unless heavily subsidized, and focused on pockets of curtailed power – i.e., wind and solar based power that is not needed because of supply/demand mismatches. This could be only a few hours a day when the power source does not have a higher value on the grid. The matching requirements of the 45V IRA credit mean that you could not profitably run the electrolyzers on grey power when the wind and solar was not available. The most important conclusion is that estimates of demand for electrolyzers and other hydrogen equipment and infrastructure investments in the US and Europe are too optimistic, and that the level of demand that many have built manufacturing capacity to support will not be there for several years. Projects may make it past the planning stage, and with them there will be nominal orders for equipment, but the orders will not be filled for some time. This will leave equipment makers with significant nominal books of business – which look good – but no cash flow. This is the reason why we are so negative on the electrolyzer producers that are already cash flow negative, as we see the cash burn lasting longer than the companies and the analysts expect. It is unclear whether the project owners have worked this out yet as the vulnerable equipment makers continue to get orders – and funding – see the headline below and the mixed messages in the following two headlines.

- Green Hydrogen Pioneer Plug Power to Build 6 Plants With Big US Loan
- 'No light at the end of the tunnel' for hydrogen electrolyser maker Nel amid 'enormous' market oversupply
- 'Righting the ship' | Hydrogen electrolyser maker ITM quadruples revenues as strategic overhaul bears fruit

Despite the DOE loan, analysts are wrong to get excited about this Plug news, as DOE loans are very prescriptive and can only be used to pursue exactly what they are allocated for. This funding may not help Plug's cash position, and we struggle to understand where the company will find the 1.3GW of inexpensive 100% capacity-factor clean power to make the investments profitable. We have always maintained that the "hydrogen hub" was the wrong focus, by this administration and the DOE; power is the real constraint here and the focus should be on power hubs – if we get these

right the hydrogen will follow. We would be paying much more attention to those in the electrolyzer business that have stronger balance sheets and cash flows, as suggested in the first two exhibits, as the industry may have to weather several years of slower than anticipated growth.

Exhibit 3: Consensus 2024 EBITA Estimates for Plug Power. This is not a good trend.

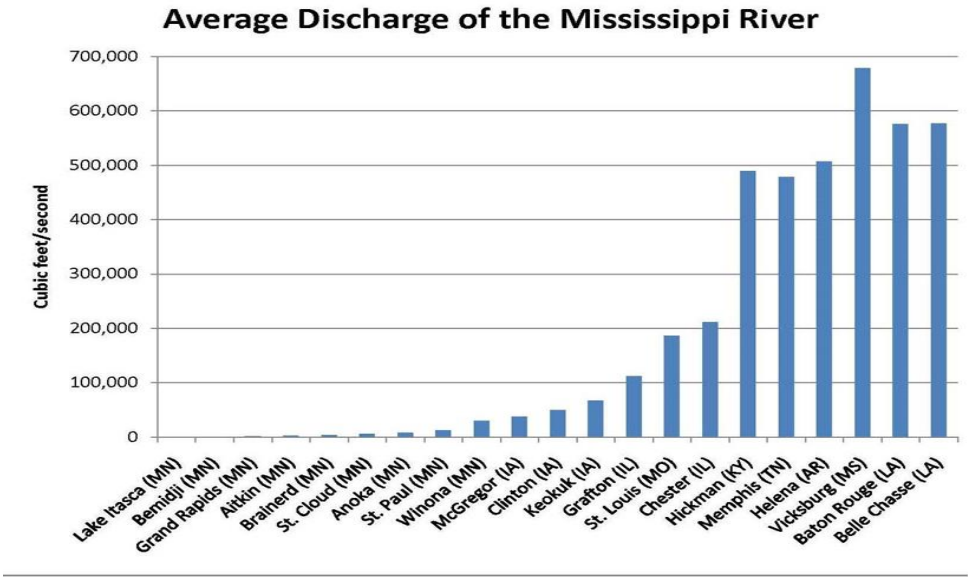


Source: Capital IQ

But waterpower, even at its most successful, is not a full solution. In the chart below we show the average volume of water moving down the Mississippi at different points. This does not show the speed, but it does show how much momentum you might have with the speed. Like all renewable power options things are not simple.

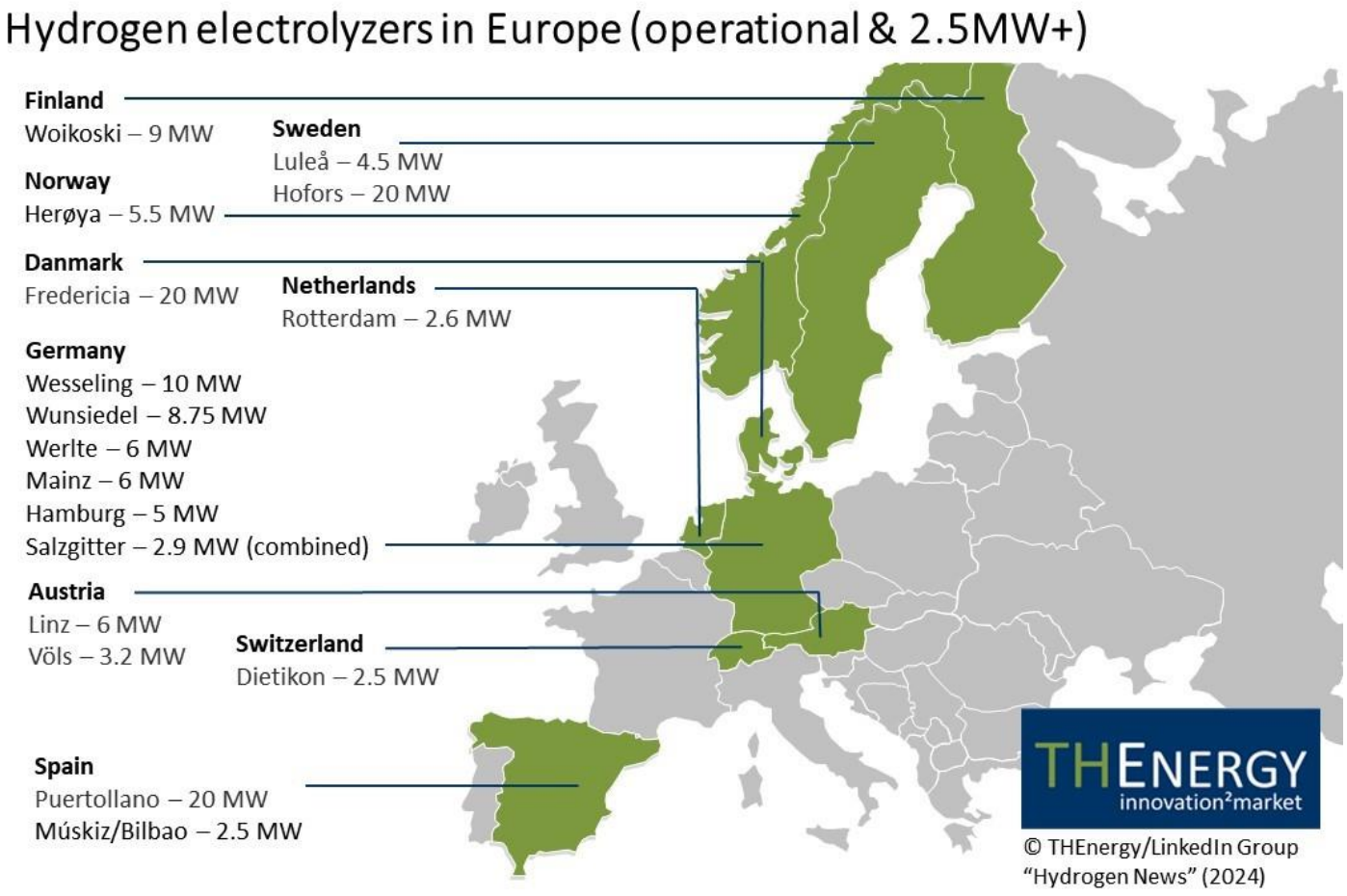
- River speed is not uniform so like retail – location is everything!
- Where there is demand today there is not enough space on the river to meet all that demand
- Where there is ample space and ideal conditions to generate power there is no demand – for example, we have a preliminary FERC permit for a stretch of the river that could generate enough power to cover the entire domestic needs of the state of Mississippi!
- There are opportunities outside the Mississippi and outside the US, but frequent droughts in some areas make the projects challenging as the power would then become intermittent.
- Best case run of river power demand could make up 0.7% of global power needs by 2040.

Exhibit 4: The flow rate of the Mississippi at different stages.



Hydrogen In Europe – Too Small to Matter: The European picture below is almost irrelevant in the grand scheme of things as, in total, we are looking at less than 125 MW of capacity, which at 100% capacity factor would be around 18,000 tons a year of hydrogen – note that a world scale ammonia plant would need closer to 250,000 tons of hydrogen a year, and you are not going to drive a lot of transport with such a small hydrogen production level – see the number of transport headlines below – this has now become a focus. If these electrolyzers are using curtailed power then the hydrogen cost could be attractive, but at the same time, if this is the case the capacity factor would be low and production in total could be less than 5,000 tons per annum. If they are not using curtailed power, then hydrogen would be expensive. There are more than likely plenty of potential hydrogen users in Europe willing to pay up for small volumes, but you cannot think of these as more than limited PR opportunities versus meaningful contributors to emission reduction.

Exhibit 5: **The Hydrogen Stream: Europe prioritizes PEM electrolysis**



Source: PV-Magazine, January 2024

But the ambition is huge – possibly too huge and possibly misdirected. Take the headline below for example, making hydrogen from renewable power, which may still be in short supply in the time frame suggested, and then using that hydrogen to make electric power – and subsidizing everything with taxpayer money. There must be a better way than this – there is – nuclear power, but the Europeans seem determined to make life difficult. We have discussed at length what we see is a growing risk in Europe, which is that the more extreme and restricted path that Europe is choosing in meeting climate goals is too expensive, and almost certainly more expensive than many of the member states can afford or will find the political will to subsidize to the degree needed. In the case mentioned below, all avenues should be explored to use the renewable power as power. Because of the capacity factor limitations on wind and solar you would need to build 8-10x of the power capacity from burning the hydrogen to get the hydrogen feed – so to get 1 GW of power from burning hydrogen you would need to dedicate 8-10GW of wind and solar capacity – plus the cost of the electrolyzers and cleaning up the hydrogen.

- **'Germany agrees €16bn plan to subsidise first 10GW of hydrogen-ready power plants'**

News Update

Incentives/Policy

- Government funding to support AFC Energy's ammonia cracker technology development
- Babcock & Wilcox and Black Hills Energy Win Wyoming Grant for BrightLoop™ Low-Carbon Hydrogen
- Italy to spend €550m to help industrial giants switch from fossil fuels to green hydrogen
- Japan to allocate clean hydrogen subsidies from $20bn pot to producers by the end of 2024: report

Technology

- Levidian's "ultra-green" hydrogen production technology

Opinion

- 2023: the year the European renewables bubble burst
- Baker Hughes advances the hydrogen economy with new milestones
- Spain to become major green hydrogen exporter to Europe, with domestic production double that of local demand by 2030
- Clean hydrogen is driving the next Gulf Coast energy boom

Projects – Not included below.

- China commits €2bn for Serbian renewable energy and hydrogen project
- IMI electrolyser becomes operational at university's aviation research centre
- Morocco partners with Nareva, GE Vernova in green hydrogen project
- Redding Rancheria to develop Californian green hydrogen plant
- Ingka Group, OX2 plan wind and hydrogen project off the coast of Sweden
- Baker Hughes signs MoU with 10.8GW green hydrogen project developer
- B&W and Black Hills to develop Wyoming hydrogen plant
- Lhyfe breaks ground on 10MW green hydrogen plant in German seaport city

Transport

- Hyzon delivers four hydrogen trucks to PFG amid fresh listing concerns
- Honda launches new hydrogen strategy off the back of first fuel cell production
- Japanese firms to build ammonia-fuelled ammonia carrier
- Logistical woes and high pump prices stall California H2 market development
- Nilsson Energy begins construction of Swedish hydrogen refuelling station
- Yamaha unveils hydrogen-powered golf buggy concept
- Air Liquide, TotalEnergies launch JV for European heavy duty hydrogen mobility
- Air Liquide and TotalEnergies launch hydrogen refuelling JVFe
- Aviation H2 draws closer to ammonia jet turbine conversion
- Stellantis set to scale-up hydrogen fuel cell vehicle production
- Airbus, Nordic partners plan to explore hydrogen infrastructure for airports
- 'We have sold more than 700 hydrogen-powered buses since 2019'
- World's third-largest automaker to introduce eight new hydrogen-powered van models in Europe
- Startup airline looks to ZeroAvia's hydrogen-electric engines to power flights

Other

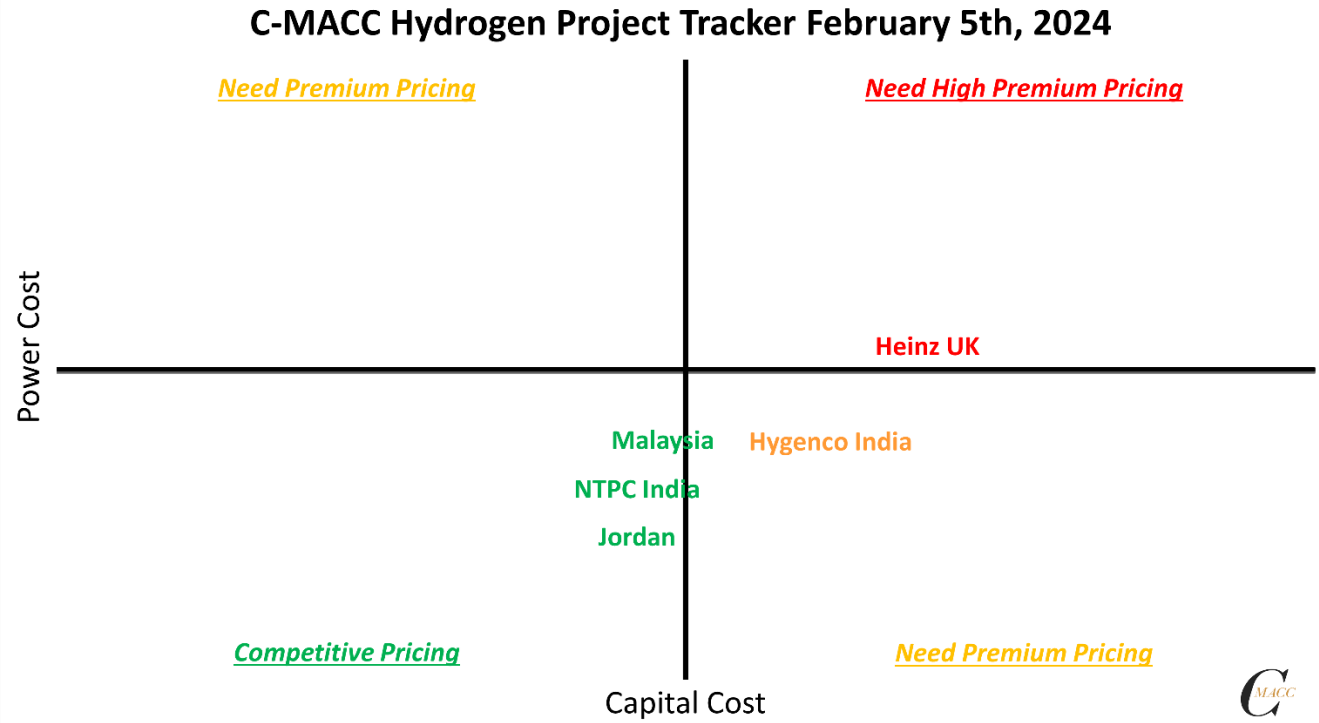
- Lhyfe hails success of offshore hydrogen pilot
- Europe's first offshore hydrogen pilot saw electrolyser performance 'as high as on land'

- BASF, China's Envision Energy work to advance process for producing e-methanol from green hydrogen, CO2
- Cleveland-Cliffs completes hydrogen injection trial at Indiana blast furnace
- Celanese receives Linde hydrogen and captured CO2 for methanol production
- Infinium and Amogy partner to drive green ammonia and e-fuels innovations
- Japanese consortium eyes ammonia supply chain in Soma
- Ador Group enters the hydrogen ecosystem with Yonder H2
- Green hydrogen injection at Moroccan power plant to be studied
- Walmart, Amazon, Home Depot set to receive Plug-produced liquid green hydrogen

Detailed Projects Update

Each week we will take projects that have hit our radar in the last 7 days and show the success factors that would be needed to make each successful. This week we look at a couple of ideas in India that could make sense, one in Jordan that also could work if the demand for the ammonia was local, and a high cost idea from Heinz to limit the gas in its beans!

Exhibit 6: The Project Tracker Grid



Source: Corporate Reports and Announcements and C-MACC Estimates and Analysis

Jordan's Energy Minister Inks MoU For Green Hydrogen Project Feasibility Studies

- The Minister of Energy and Mineral Resources signed a MoU with Mass Group Holding Company to conduct feasibility studies for green hydrogen projects in Jordan.
- Aims for an annual production of 180,000 tonnes of green ammonia and outlines cooperation for a preliminary feasibility study on a new green hydrogen project.

There is plenty of opportunity for low-cost solar power in Jordan, as there is across the Middle East, but the primary issue is what to do with the hydrogen. In this case the idea is to make ammonia, but the plant would be very sub-scale. We were involved with a sub-scale ammonia and urea project several years ago in an established and efficient global market, but the plan made sense because the scale effectively matched the demand of an on-site customer. The inefficiencies in scale were easily countered by the low cost of shipping. If the ammonia in this case has local demand and could push out imports, the project may make some sense. Looking for low cost equipment for power and for hydrogen in China might also help.

Maharashtra Govt Inks MoUs with Seven Companies for Green Hydrogen Production

- The Maharashtra government signed MoUs with seven renewable energy giants worth an estimated INR 2.76 Lakh Crore towards green hydrogen production.
- These projects are anticipated to generate 64,000 direct and indirect job opportunities in the state.
- The proposed projects will have a combined green hydrogen generation capacity of 910 KTPA (Kilo Tonnes per annum) and produce around 4732 KTPA of green ammonia.
- The projects are poised to reduce nearly 511 Crore Kg carbon emissions.
- The companies that signed the MoUs with the Maharashtra government include: NTPC Green Energy, Avaada Green Hydrogen, ReNew E-Fuels, Inox Air Products, L&T Green Tech, JSW Green Hydrogen, and Welspun Godavari GH2.

We will cover each of these projects as we get more data – this week the NTPC project

NTPC plans renewables-heavy hydrogen project in Maharashtra

- NTPC Green Energy Limited aims to develop up to 5 GW of renewables, either with or without a battery storage component, plus pumped hydro storage totaling 2 GW.
- In turn, the annual production capacity of the green hydrogen plant will be up to one million tonnes.
- Its proposal represents a potential investment of about INR 800 billion (USD 9.65bn/EUR 8.87bn).

The basic math is wrong in this announcement, if the power is right, even with the pumped storage, you would get less than a third of the hydrogen production suggested. The project does say renewables-heavy, so it is possible that the balance of the hydrogen is coming from grey power. The scale will bring the capital costs down, and in the chart we show the better capital costs against the sleeve of production that would be based on renewable power – giving the project the benefit of the doubt.

Hygenco to invest $2.5 bn over 3 years to set up Green Hydrogen projects in India

- Hygenco Green Energies is planning to invest $2.5 billion over three years to set up Green Hydrogen projects at a scale of 50-200 MW.
- The projects would be in over seven states where customers belong to refineries, steel, fertilizers, and other industries with hard-to-abate emissions in manufacturing processes.

This is a collection of relatively small electrolyzer projects, which will all need to find power. And possibly getting to bidding wars with the industries they are trying to serve with hydrogen – not as efficient as the project above because of scale

Semarak RE And PowerChina Join Forces For Malaysia's First Large-Scale Green Hydrogen Project

- Semarak Renewable Energy and China Hydropower have entered into a RM1.88 billion agreement to develop Malaysia's inaugural large-scale green hydrogen production project utilizing floating solar photovoltaic power generation.
- The project's main objectives encompass the design, procurement, and construction of floating photovoltaics, hydrogen production units, and hydrogen storage units.

This will be another low capacity-factor project, but based on lower cost equipment from China, which should help the economics. We do not see this as the most cost-effective way to make hydrogen, but it may be the best option locally and given the challenges of moving hydrogen, if there is local demand, this project may make some sense.

Heinz Beanz Goes Green With New £40m Hydrogen Plant

- Kraft Heinz has partnered with energy infrastructure developer Carlton Powers to create a renewable green hydrogen plant.
- The project has the potential to meet 50% of the Heinz Beans manufacturer's annual natural gas demand.

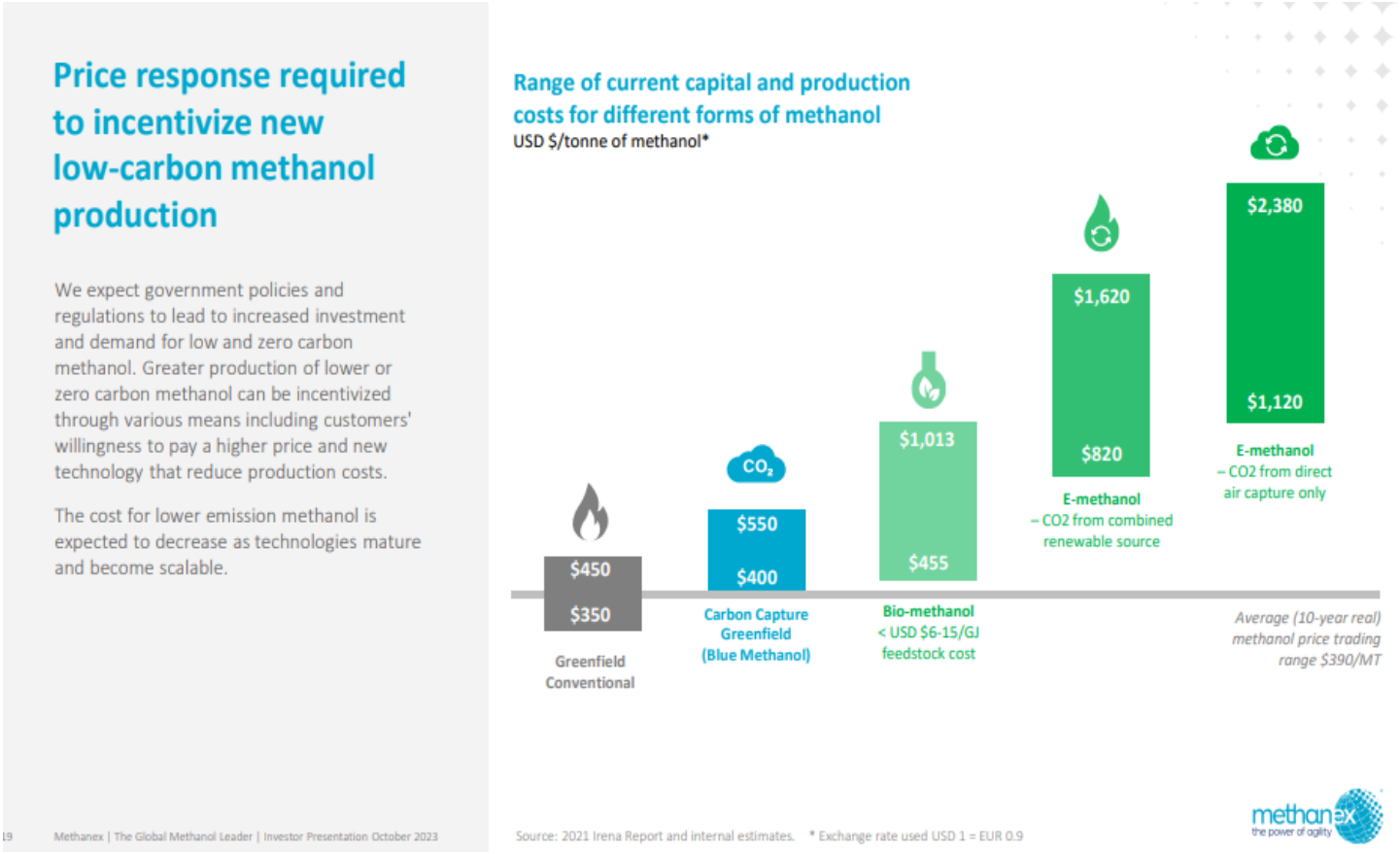
This project likely looked a lot more interesting to Heinz when natural gas prices in the US were $15 per MMBTU, and it will be interesting to see what happens to this project if UK natural gas prices keep falling. This project is unlikely to have

low capital costs or low power costs. Any use of curtailed power will simply limit operating rates and lead to even greater capital inefficiency – we add this one to the pile of smaller vanity projects in Europe, although Heinz may be able to sell beans with less gas at a premium!

Ammonia/Methanol Update

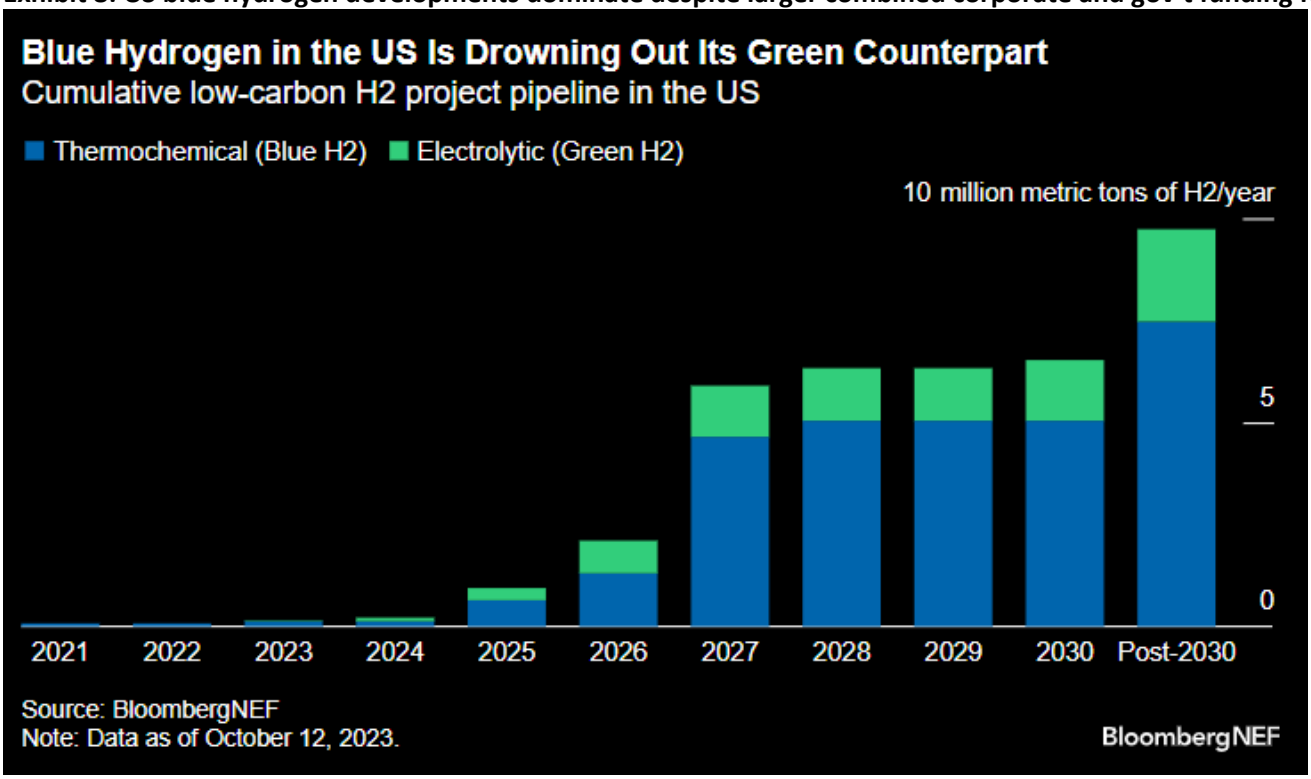
Methanol, Ammonia, and renewable fuels – separating the challenges of sustainable feedstocks from low carbon: We have done a lot of work on alternative fuels, as recently as this week - Grey Ammonia and Methanol Have Futures, But Not Long Ones and last week - Fly Me to The Moon – But Not for Some Time with Renewable Fuel, and one of themes that runs through the work is the challenges of managing carbon. This applies equally to those looking at renewable fuels as it does to those looking at blue ammonia and methanol. To get the low carbon label that the fuels consumers are looking for it is not just about feedstock choice and/or CCS, it is also about how you power all the processes in that mix. Grey power for CCS, especially CO2 compression, meaningfully hurts your "blue" carbon footprint and grey power for direct air capture all but guarantees that you cannot get the lucrative 45Q credit. In our sustainability report this week, we will look again at power and set up a new C-MACC webcast next week, focusing on power. We have some strong views on the power challenges facing energy transition, views that have not changed over the last 3 years and are increasingly reinforced by data and anecdotes from the market. Our waterpower initiative has given us the opportunity to discuss power and its challenges with many industry participants, and we maintain a view that still sits quite distant from consensus. It gives us confidence that we should keep chasing the waterpower idea and drives our views of the likely challenges green hydrogen faces. As we have highlighted before, and again above, all the blue hydrogen capacity suggested in the chart below will face clean power availability challenges.

Exhibit 7: Methanex highlights the cost benefits of blue methanol production in a low-carbon economy relative to green, which will require much higher prices to cover its higher costs to maintain margins. Also, see the next exhibit.



Source: Methanex – 4Q23 Earnings Presentation, February 2024

Exhibit 8: US blue hydrogen developments dominate despite larger combined corporate and gov't funding for green.



Source: BloombergNEF, February 2024

Power Update

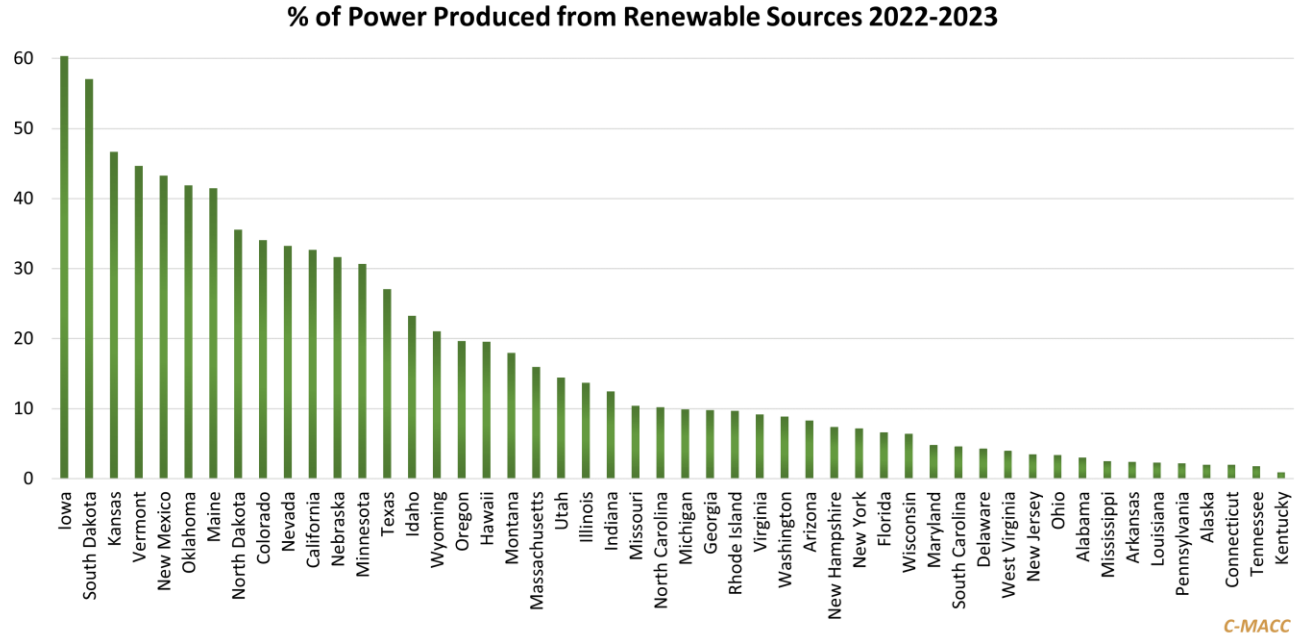
Clean Power Needs, Availability and Timing – Not So Straight Forward – May Influence Location Decisions

When the US announced its hydrogen hub ideas and as Europe started rolling out its hydrogen infrastructure plans, we raised a couple of red flags around putting the cart before the horse – hard to have a hydrogen plan without a power plan and suggested that the assumption that the power would just be there was wrong. We believe that we need to raise those red flags a little higher today, as many of those chasing sustainable feedstocks and contemplating carbon capture are realizing how important low-carbon power is to the story and how challenging getting low-carbon and low-cost power is becoming. Driving through the lower portion of the Texas panhandle last week we were struck by the sheer scale of the wind power generation that has been put in place already, while at the same time noting that it was a long way from any large volume power demand. Many capital-intensive industries have recognized the benefits of brownfield versus greenfield development, especially where industries are well established, as they are in most industrial countries. However, if the power is not where the demand is, demand moves towards supply. This is an evolving issue in the US, and there is a significant current contrast between regulated and unregulated power states. In Texas, for example, you can move the wind power in the North to industrial consumers in the South, but in regulated states such as Louisiana and Mississippi, you cannot. In one of our recent meetings with a company that has assets in both regulated and unregulated states we raised the question of whether the ability to access clean power could drive new investment from regulated states to unregulated states and the answer was a clear yes.

In Exhibit 9, we show the renewable generating capacity as a percentage of use by state for the US; in Exhibit 10, we show the same by country for Europe. There are some very wide differences in both charts but the US wins on the very low levels in some states, the European variability is around a very high average. In the US, not a lot of this power is close to industrial power use, and this is our focus because this is where our clients are grouped. Even in Texas, which boasts by far the largest renewable power capacity – around 140GW (California is second with half of that total) – the power is not that close to the large centers of demand. When we started coverage of energy transition in earnest, roughly three years ago (164 weeks ago to be precise), there was too much optimism around both the likely availability of renewable power and its potential usefulness to industrial consumers. Over the same period, we have followed many of our clients on journeys to move from the early day theories to the practical, and we have yet to find a client who sees the landscape less challenging now than they did then. The more straightforward question of where to find power has been complicated by

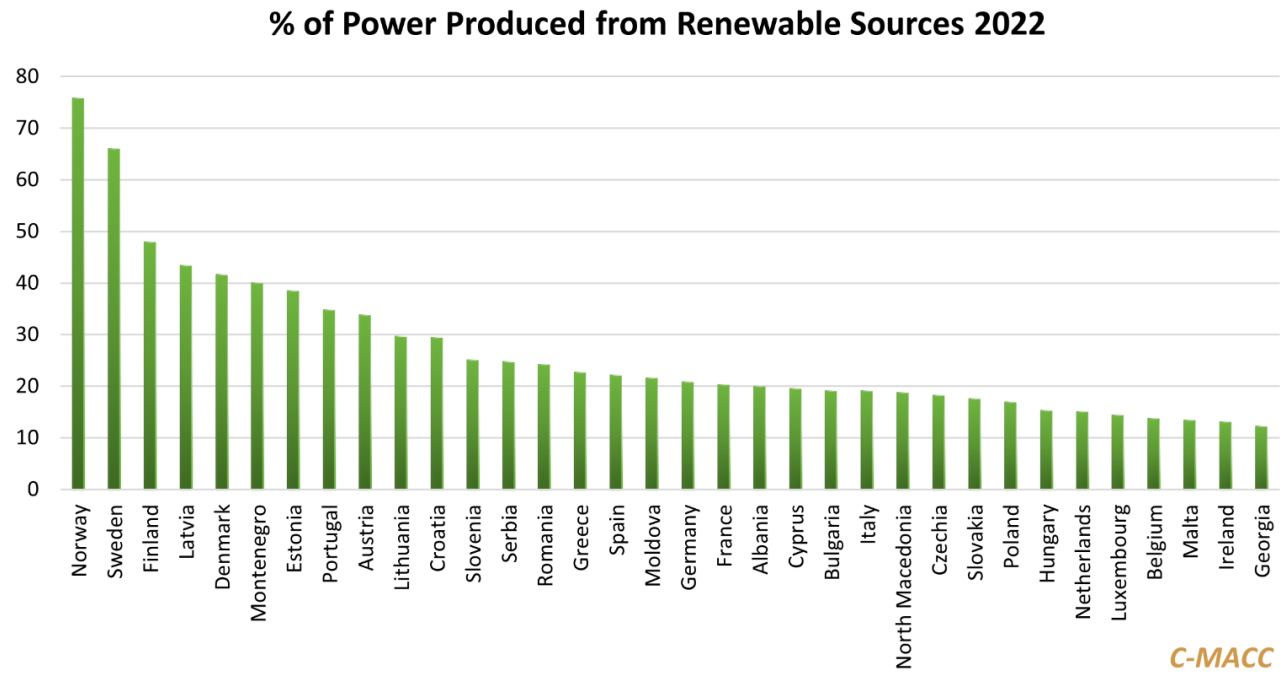
incentive schemes, all of which look encouraging locally, but come with strings attached and, in some cases, change relative competitiveness between regions and countries. Other complicating factors are regulatory delays and permitting challenges and then we also have the addition of timing.

Exhibit 9: The US States with the highest portion of renewable energy do not have high concentrations of industry.



Source: Motley Fool/EIA, C-MACC Analysis, February 2024

Exhibit 10: The European average is higher than the US, but the benefits of geography figure in both charts



Source: Eurostat, C-MACC Analysis, February 2024

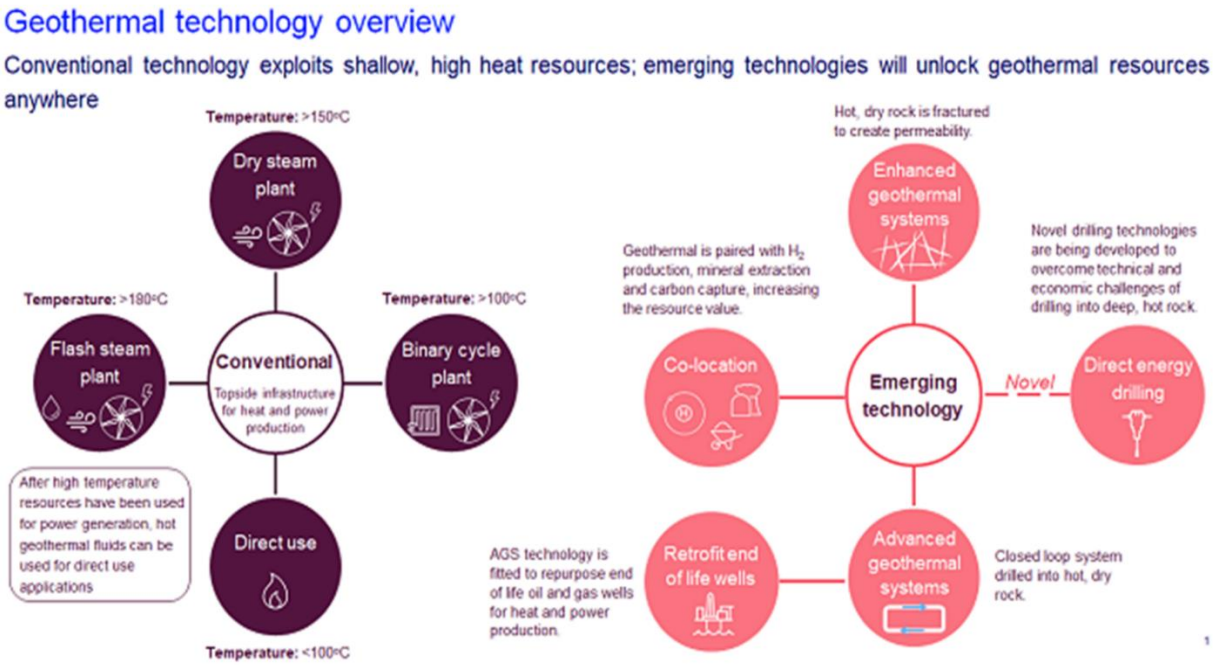
Timing is not only a challenge with power, but it is also impacting many aspects of energy transition. Companies and industries have different deadlines, some self-imposed, some imposed by industry groups and some by governments. Many of those deadlines and targets involve transitioning to something more expensive than what you are doing today. It could be your cheapest source of high capacity-factor renewable power versus grid power today, it could be buying recycled materials versus virgin, or it could be implementing CCS. Rational business management means that you will likely

not pay more for something until you must. This is proving to be a major challenge for companies that have built capacity well ahead these deadlines as while they have longer term interest from a potentially huge client base, the demand may not be there today, leaving the supplier holding unused capacity and, in many cases, dwindling cash. This is most evident today in the electrolyzer space, although physical limitations around power supply are as large a constraint as willingness to pay. There are plenty of locations with curtailed power today where you could build electrolyzer that would run for a couple of hours a day and there are other locations where you could pay up for the renewable power, but few, if any, would be willing to pay the full cost of making the hydrogen. Those who need clean power, but do not need it yet will have to tread a carful path, especially where they are relying on others to supply the power. They may have to take some higher cost power early enough to ensure that the supplier is there when they really need it.

We should be supporting investment in the renewable power companies with the discussion above, but the solar industry has shown its ability in the past to compete away every cent of cost savings and the wind industry seems to struggle to handle growth. The equipment and component makers are likely in the best seats, although we have seen lithium overbuilt in the last 24 months and some other materials may also be weak. The installers are probably in good shape, but these tend to be regional and mostly private companies. The industrial companies themselves are likely not interesting investments on this basis as none of what they are looking at is cheap – they may be interesting investments for other reasons.

Is next-generation geothermal energy positioning to make an impact on the global energy landscape? We highlight the exhibit below from an article discussing the potential of next-generation geothermal energy as a solution for decarbonizing the energy sector. Geological conditions limit conventional geothermal energy. New technologies like enhanced geothermal systems (EGS) and advanced geothermal systems (AGS) aim to make geothermal energy accessible in a broader range of locations. Oil and gas companies are investing in these technologies, attracted by diversification opportunities and their expertise in subsurface and drilling. While cost challenges exist, scaling up and technological advancements could make geothermal competitive with nuclear and hydrogen, potentially leading to significant global investments in the sector. Big Oil's interest in geothermal is mainly driven by its pursuit of net-zero goals and the need for sustainable disciplines as the oil and gas industry transitions, and it is also fostered by subsurface expertise in this area.

Exhibit 11: [Low-carbon tech: is geothermal close to a breakthrough | Wood Mackenzie]



Source: [Wood Mackenzie,] January 2024

Appendix

Exhibit 12: Hydrogen Cost Summary – 05.02.24

Cash Costs - $/KG								
	Feb-24	Jan-24	Dec-23	2H 2023	1H 2023	2023	2022	2021
Green Hydrogen								
US Average	5.73	5.77	5.38	4.94	5.52	5.23	5.22	4.32
US Low	3.87	3.89	3.64	3.36	3.74	3.55	3.54	2.96
Europe Avg	5.53	5.38	6.25	7.15	6.78	6.96	15.29	10.46
Europe Low	3.74	3.65	4.21	4.79	4.55	4.67	13.06	6.95
UK Avg	5.50	5.34	6.07	7.12	10.52	8.82	15.74	11.72
UK Low	3.72	3.62	4.09	4.77	6.99	5.88	13.44	7.77
China Avg	5.22	5.22	5.22	5.52	5.82	5.67	9.42	7.62
China Low	1.62	1.62	1.62	2.82	3.42	3.12	7.62	7.02
Blue Hydrogen								
US Average	0.73	0.80	0.83	0.72	0.87	0.80	1.09	0.90
US Low	0.56	0.62	0.66	0.57	0.70	0.64	0.93	0.77
Europe Avg	2.02	1.98	2.21	2.22	2.80	2.51	4.22	3.06
Europe Low	1.58	1.54	1.74	1.72	2.32	2.02	3.74	2.45
UK Avg	2.13	2.12	2.33	2.33	2.55	2.44	2.52	2.07
UK Low	1.68	1.68	1.87	1.84	1.94	1.89	2.02	1.42
China Avg	2.19	2.01	2.00	2.06	1.98	2.02	2.10	1.69
China Low	1.77	1.58	1.57	1.72	1.67	1.70	1.84	1.55
Grey Hydrogen								
US Average	0.87	0.94	0.97	0.86	1.01	0.93	1.03	0.85
US Low	0.89	0.90	0.87	0.85	0.88	0.86	0.86	0.81
Europe Avg	1.87	1.83	2.08	2.28	2.88	2.58	4.29	2.89
Europe Low	1.70	1.66	1.89	2.06	2.67	2.37	4.08	2.55
UK Avg	1.76	1.71	1.95	2.11	2.49	2.30	2.61	1.91
UK Low	1.59	1.54	1.76	1.89	2.15	2.02	2.39	1.53
China Avg	1.80	1.76	1.75	1.81	1.74	1.78	1.85	1.44
China Low	1.46	1.42	1.41	1.55	1.51	1.53	1.68	1.38

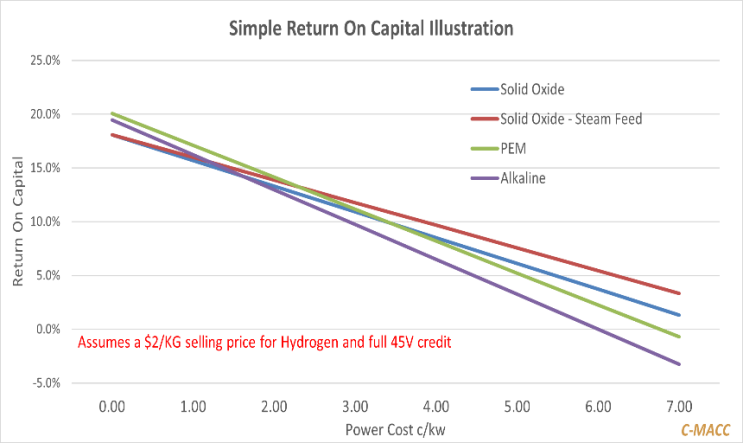
Source: Bloomberg, Capital IQ, and multiple other sources – C-MACC Analysis

Exhibit 13: Input Assumptions – 05.02.24

Inputs									
	Feb-24	Jan-24	Dec-23	2H 2023	1H 2023	2023	2022	2021	Direction
Power ($/MWH)									
US Average	88.5	89.1	82.6	75.4	85.0	80.2	80.0	65.0	Flat→
US Low	57.5	57.9	53.7	49.0	55.3	52.1	52.0	42.3	Flat→
Europe Avg	85.1	82.7	97.2	112.2	105.9	109.1	247.8	167.4	Down↓
Europe Low	55.3	53.8	63.2	72.9	68.9	70.9	210.6	108.8	Down↓
UK Avg	84.7	82.0	94.1	111.6	168.4	140.0	255.4	188.4	Down↓
UK Low	55.1	53.3	61.2	72.6	109.5	91.0	217.1	122.4	Down↓
China Avg	80.0	80.0	80.0	85.0	90.0	87.5	150.0	120.0	Down↓
China Low	20.0	20.0	20.0	40.0	50.0	45.0	120.0	110.0	Down↓
Natural Gas ($/MMBTU)									
US Henry Hub	2.1	2.7	3.3	2.7	3.6	3.1	4.1	3.1	Flat→
Europe	9.0	8.7	10.2	10.5	16.6	13.5	22.4	14.3	Down↓
UK	8.9	8.7	10.3	10.1	10.0	10.0	5.7	3.7	Down↓
China	11.0	10.0	9.9	10.2	9.3	9.8	7.1	4.8	Down↓
Carbon ($/MMBTU)									
US	85.0	85.0	85.0	85.0	85.0	85.0	50.0	50.0	Flat→
Europe	67.6	67.1	70.0	89.0	90.4	89.7	89.3	65.6	Flat-Down→↓
UK	45.5	40.7	44.3	60.0	76.0	68.0	92.0	65.6	Down↓
China	10.3	25.0	25.0	25.0	25.0	25.0	25.0	25.0	Up↑

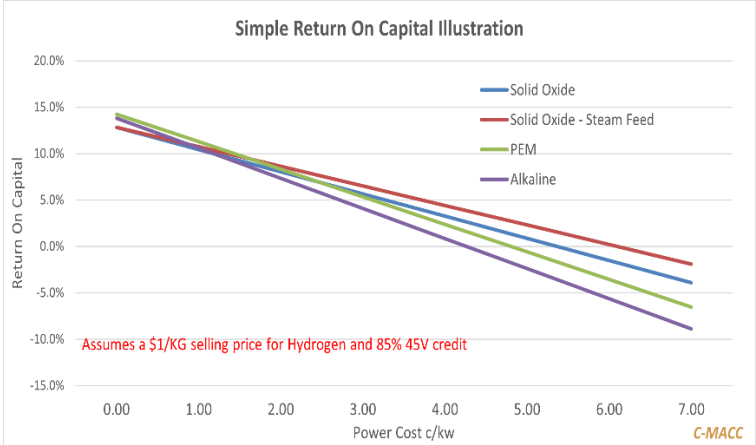
Source: Bloomberg, Capital IQ, and multiple other sources – C-MACC Analysis

Exhibit 14: Green Hydrogen Base Model



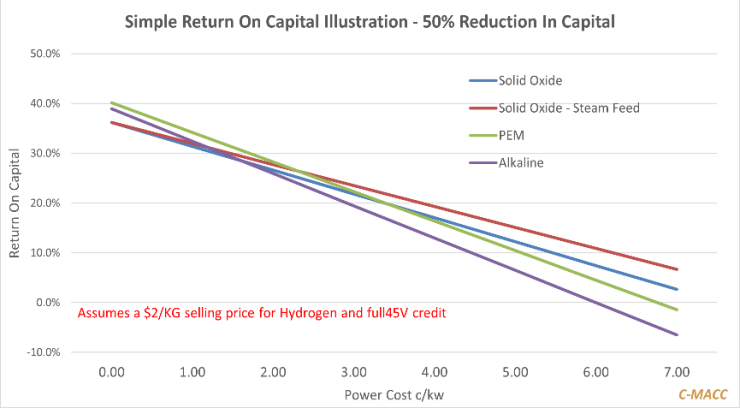
Source: Corporate reports, client discussions, C-MACC

Exhibit 15: Lower H2 Price and Credit Share



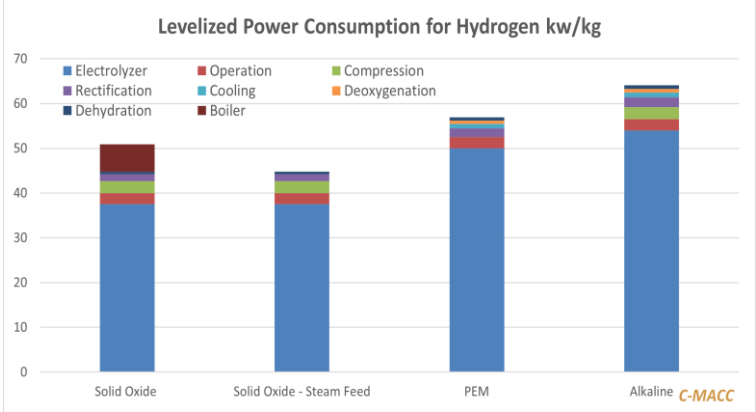
Source: Corporate reports, client discussions, C-MACC

Exhibit 16: With Capital Costs Halved



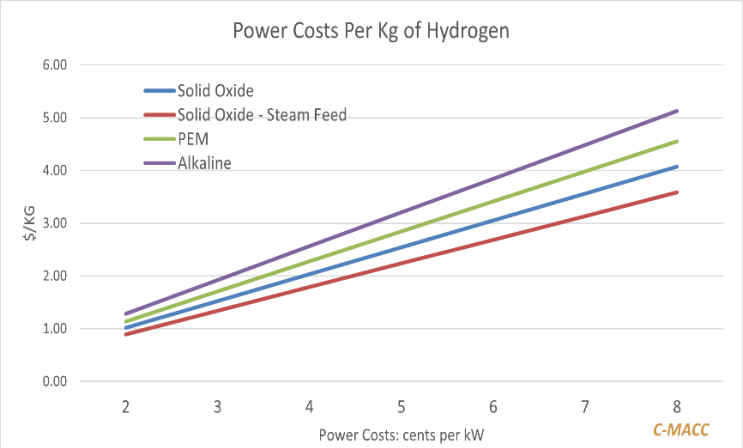
Source: Corporate reports, client discussions, C-MACC

Exhibit 17: Power Consumption per KG of Hydrogen



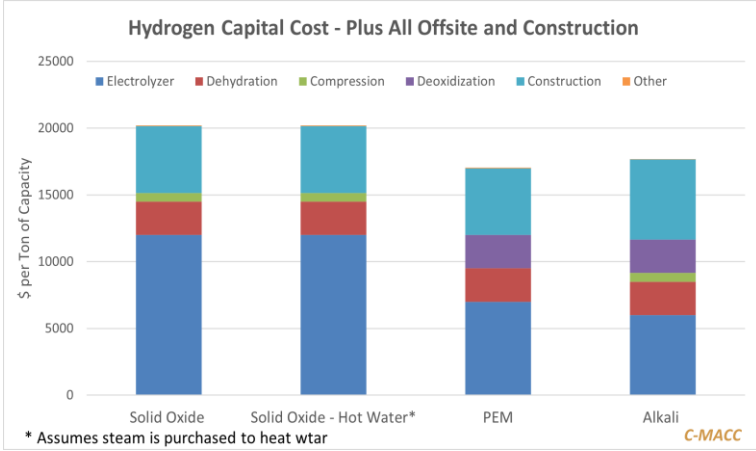
Source: Corporate reports, client discussions, C-MACC

Exhibit 18: This is before the 45V credit



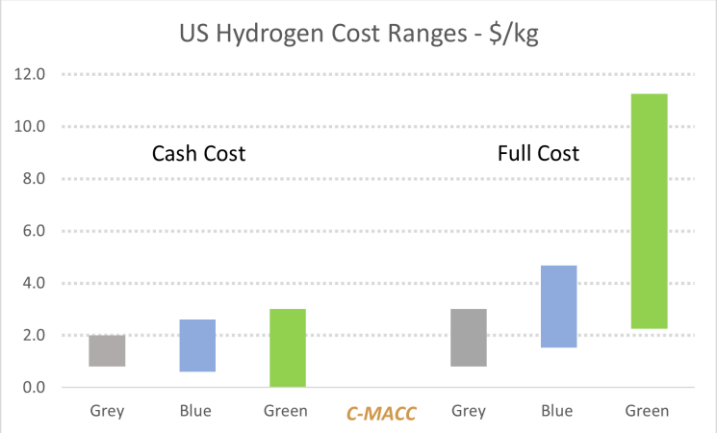
Source: Corporate reports, client discussions, C-MACC

Exhibit 19: Electrolyzer Capital Costs – US



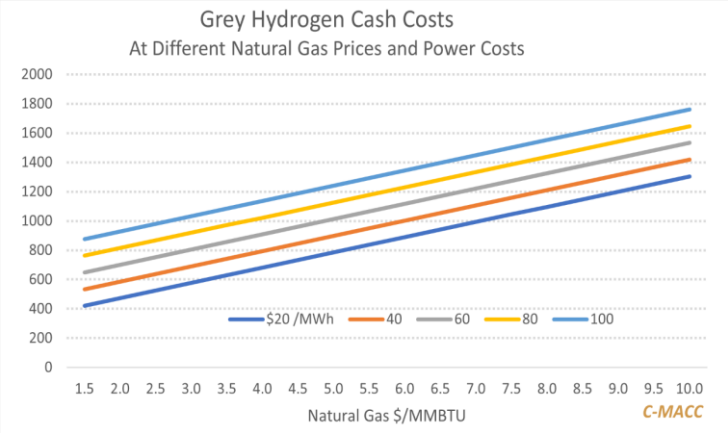
Source: Corporate reports, client discussions, C-MACC

Exhibit 20: US Cost Ranges



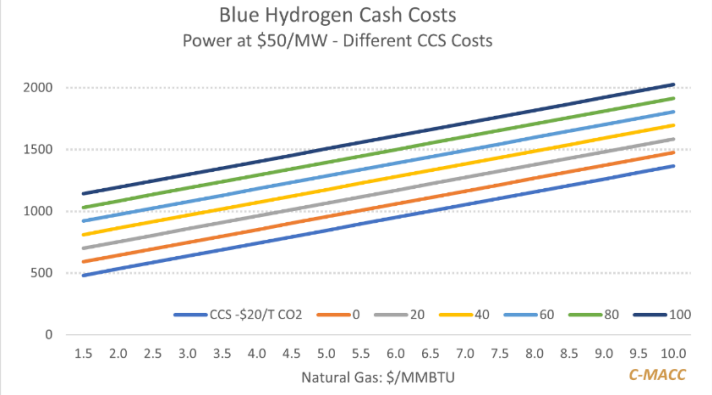
Source: Corporate reports, client discussions, C-MACC

Exhibit 21: Grey Hydrogen Cash Costs



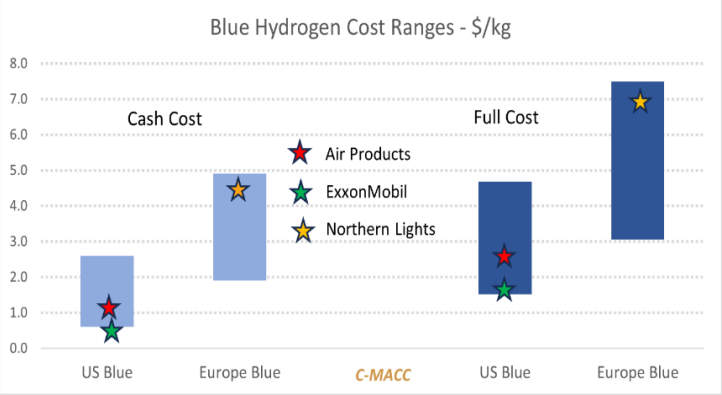
Source: Corporate reports, client discussions, C-MACC

Exhibit 22: Blue Hydrogen Model – Fixed Power



Source: Corporate reports, client discussions, C-MACC

Exhibit 23: Europe US Blue Comparisons



Source: Corporate reports, client discussions, C-MACC

CONSULTING SERVICES

Work done in the last ten years, including at prior companies

Consulting | Advisory

GENERAL STRATEGY

- Advised an Industrial Gas company on changing market dynamics and competitive positioning.
- Worked extensively with two new energy/materials start-up companies on strategy, communication, project costs, etc.
- Competitive analysis for large corporates in the US and Europe. Broad scope and narrow scope.
  - Repeat business from both subsequently.
- Interpreted the competitive nature of the IRA and its impact on trans-Atlantic competition for base chemicals.
- Retained work with an independent in the US CCS business
  - Business plan development - Potential customer vetting
- Advised on the competitive nature of chemical recycling, mechanical recycling, waste to syngas, and incineration.
- Advising the largest run-of-river hydro project in the US
  - All aspects of business development.

M&A

Full financial and market-based analysis:

- Advised a possible buyer of Dow's Chlorine Products business with specific emphasis on the value of the epoxy resins business.
- Advised the same buyer in an unsuccessful attempt to acquire a large business from another major chemical company.
  - The seller ultimately chose an IPO.

Market-based analysis:

- Advised the successful bidder on Dow's rail assets in the US and Canada
- Advised on strategy around divestment of large US assets for non-US client.
- Due diligence for a SPAC on several potential targets in clean energy.

LEGAL CLIENT

- Expert Witness
- Market Briefs for Litigation

NEW PROJECT APPRAISAL

- Wrote and presented the business plan, through FID, for one of the newer ethylene investments in the US.
  - Countless projects in Southeast Asia like this in the early 1990s.
- Multiple Hydrogen Engagements
- US Renewable Fuels Projects

OTHER

- Map of the renewable/ recyclable/ biodegradable polymer markets and their likely evolution.

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