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Green Hydrogen: Plans Potential and Future Outlook

Energy: Financing Green Hydrogen Projects

Tim Buckley (tbuckley@ieefa.org)
Director Energy Finance Studies,
South Asia/Australia

9th March 2021



**Institute for Energy Economics
and Financial Analysis**
IEEFA.org

IEEFA is a global, public interest think-tank focused on the energy-finance-climate nexus.

<https://ieefa.org>

- IEEFA has ~35 energy finance analysts across India, HK, Vietnam, Indonesia, Philippines, Australia, England, Puerto Rico and the US.
- We have no paid consultancies nor government funding. We are funded solely by philanthropy (funders have zero input into our work strategy).
- Before IEEFA I worked in finance for ~20 years. I was at Citigroup for 17 years, a MD, Head of Equity Research.

Yong-Liang Por, Financial Analyst, IEEFA Contributor
August 2020



Great Expectations

Asia, Australia and Europe Leading Emerging Green Hydrogen Economy, but Project Delays Likely

Executive Summary

In July 2020, the European Union unveiled its new Hydrogen Strategy, a visionary plan to accelerate the adoption of green hydrogen to meet the EU's net-zero emissions goal by 2050. Combined with smaller-scale plans in South Korea and Japan, IEEFA believes this could form the beginnings of a global green hydrogen economy.

Green hydrogen, produced exclusively with renewable energy, has been acclaimed for decades, but ever lower solar electricity costs mean this time really is different.

We expect the EU's initiative to find strong support as the proposed investment of €430bn by 2030 places it in pole position to develop a world-class green energy manufacturing industry and provides a vital bridge for energy transition by repurposing existing 'natural' gas pipelines and fossil-fuel dependent ports.

Tim Buckley, Director Energy Finance Studies
May 2020



Who Would Still Fund a New Coal Power Plant in India?

Stranded Asset Risks Continue to Rise as Solar Deflation Continues

Executive Summary

Renewable energy delivered more than two thirds or 9.39 gigawatts (GW) of India's new generating capacity additions in the fiscal year 2019/20.

In contrast, new thermal power plants delivered 4.3GW during 2019/20, net another 2.5GW removed due to end-of-life plant closures. While up from the decade low of just 3.5GW installed in 2018/19, this still marks a near 80% reduction in the rate of thermal power installs delivered in the four years to 2015/16, which at that time was 20GW annually.

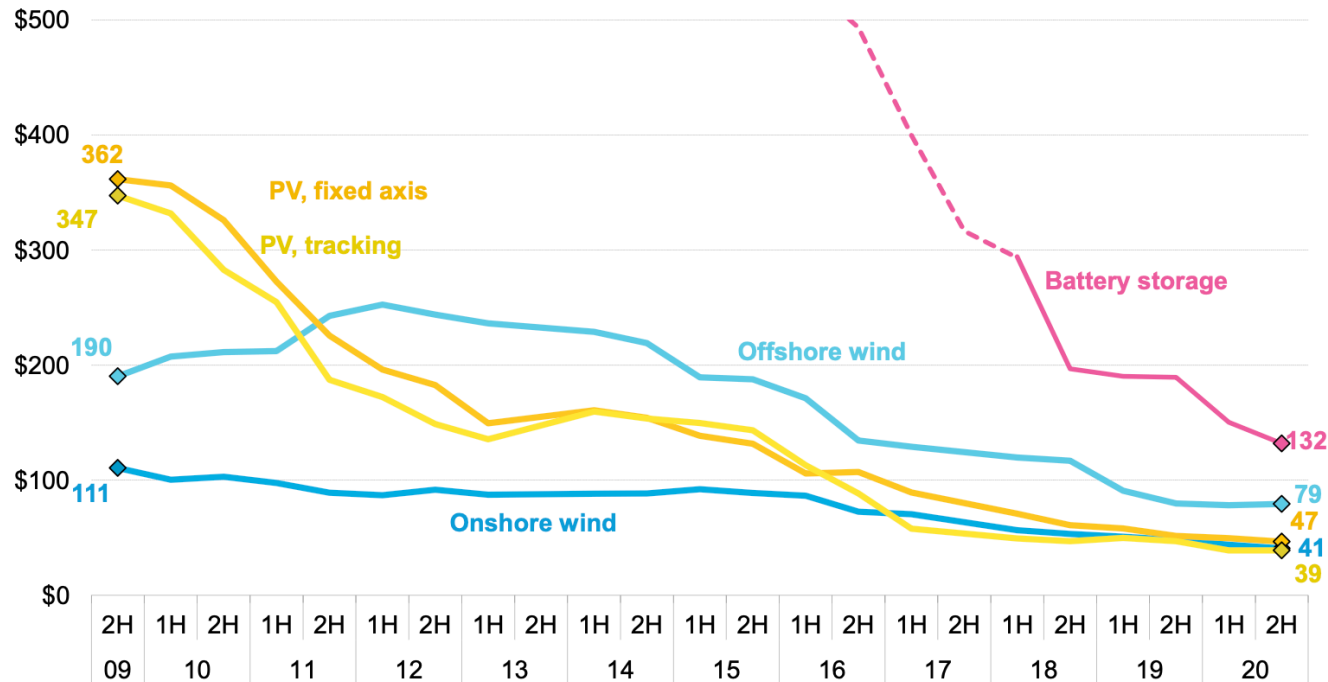
The Government of India's National Electricity Plan of 2018 (NEP2018) called for an additional 70GW or more of new coal-fired power plants by 2026/27, and the closure of another 39GW.¹



This Time Is Different for Green Hydrogen: Ongoing Massive Renewables & Batteries Deflation

Global levelized cost of energy benchmarks

LCOE (\$/MWh, 2019 real)



April 2020 saw a 1.5GW solar tender awarded in Abu Dhabi at US\$13.50/MWh (down 15% since January 2020).

August 2020 saw a 700MW solar tender awarded in Portugal at US\$13.15/MWh (down 24% yoy).

November 2020 saw a 1,070MW solar tender awarded in India at just Rs2.00/kWh (an LCOE <US\$20/MWh) down 15% in six months.

Source: BloombergNEF

China: Peak Emissions by 2030, Net Zero by 2060



Net zero by 2060: China's bold new carbon emissions goal

Chinese and US leaders attack each other's environmental records, as Trump blames China for 'rampant pollution'.



China is the world's biggest carbon emitter but also leads the world in the deployment of clean-energy technologies [File: Thomas Peter/Reuters]

23 Sep 2020



In a jaw-dropping announcement, Chinese President Xi Jinping said his government plans to boost China's Paris climate accord target and called for a green revolution, just minutes after US President Donald Trump blasted Beijing for "rampant pollution".

Addressing the United Nations General Assembly, Xi reiterated China's goal of achieving a peak in carbon dioxide emissions before 2030.

China capacity details (GW)

	2020	2060 base case	2060 Carbon neutral
Coal	1,098	-710	-890
Gas turbine	106	+210	+40
CCS	0	+85	+260
Alternative fuel (H ₂ , NH ₃)	0	+150	+670
Nuclear	49	+280	+620
Hydro	349	+70	+250
Wind	234	+1,300	+2,020
Solar	195	+1,650	+4,530
Storage	38	+970	+3,100

Source: Wood MacKenzie November 2020

"Third, the speed of new energy development will exceed imagination. Fourth, a large number of coal power projects that have been approved but not yet started may be cancelled."

Source: [Weixin](#), 29 January 2021



Japan & Korea: Net Zero by 2050



Japan to reduce greenhouse-gas emissions to net zero by 2050

Suga to make pledge in first general policy speech as industry faces pressure



Prime Minister Yoshihide Suga will soon pledge to reduce Japan's greenhouse-gas emissions to net zero by 2050, as the European Union has already done. (Source photo by Uichiro Kasai)

Nikkei staff writers
October 21, 2020 18:51 JST

TOKYO -- The Japanese government will soon pledge to reduce greenhouse-gas emissions to net zero by 2050, Nikkei has learned.

The new target, set to be unveiled in a speech to lawmakers next week by Prime Minister Yoshihide Suga, means Japan will finally catch up to the European Union, which set the same goal last year. Companies in industries like electric power, automobiles, and steel will be expected to take strict measures to meet the international promise.

Japan public financier to stop approving loans for coal projects

Walter Sim Japan Correspondent In Tokyo

PUBLISHED APR 26, 2020, 5:00 AM SGT



A top Japanese public financier of foreign development projects has said it will stop accepting loan applications for coal power plants, as global pressure ramps up on the world's third largest economy to do more to fight climate change.

The Japan Bank for International Cooperation (JBIC) has been called names like "coal peddler" and "coal store" by environmentalists taking aim at the ongoing Vung Ang 2 coal power plant in Vietnam.

JERA Planning to Shift Coal Power Fleet to 100% Ammonia

Japanese firm JERA, a joint venture between TEPCO and Chubu Electric, on Oct. 13 issued a roadmap to achieve zero carbon emissions by 2050. The move is notable for the company whose business includes a sizable global liquefied natural gas (LNG) portfolio of five upstream projects, 20 fleet carriers, an LNG tank capacity that is equivalent to 30% of Japan's tank capacity, and 11 LNG terminals in Japan. It also owns 27 thermal power stations in Japan, which have a total capacity of 70 GW, and another 30 power projects, including renewables, in more than 10 countries, which amount to about 9 GW.

Under its roadmap, JERA plans to shutter its entire 2.2 GW supercritical coal power generation fleet in Japan by 2030, and then gradually increase the ratio of mixed combustion of fossil fuels to ammonia and hydrogen at ultrasupercritical plants.

Japan's METI has committed to close 100 of 144 subcritical & SC coal plants in Japan by 2030.



1. JERA's 4.1-GW Hekinan Thermal Power Station is one of the world's biggest coal plants. The plant houses five units. Units 1, 2, and 3 are 700-MW units that opened between 1991 and 1993, and Units 4 and 5, 1 GW each, opened in 2001 and 2002. Courtesy: JERA

Co-Firing Planned at a 4.1-GW Coal Plant



THE WHITE HOUSE



BRIEFING ROOM

Executive Order on Tackling the Climate Crisis at Home and Abroad

JANUARY 27, 2021 • [PRESIDENTIAL ACTIONS](#)

The United States and the world face a profound climate crisis. We have a narrow moment to pursue action at home and abroad in order to avoid the most catastrophic impacts of that crisis and to seize the opportunity that tackling climate change presents. Domestic action must go hand in hand with United States international leadership, aimed at significantly enhancing global action. Together, we must listen to science and meet the moment.

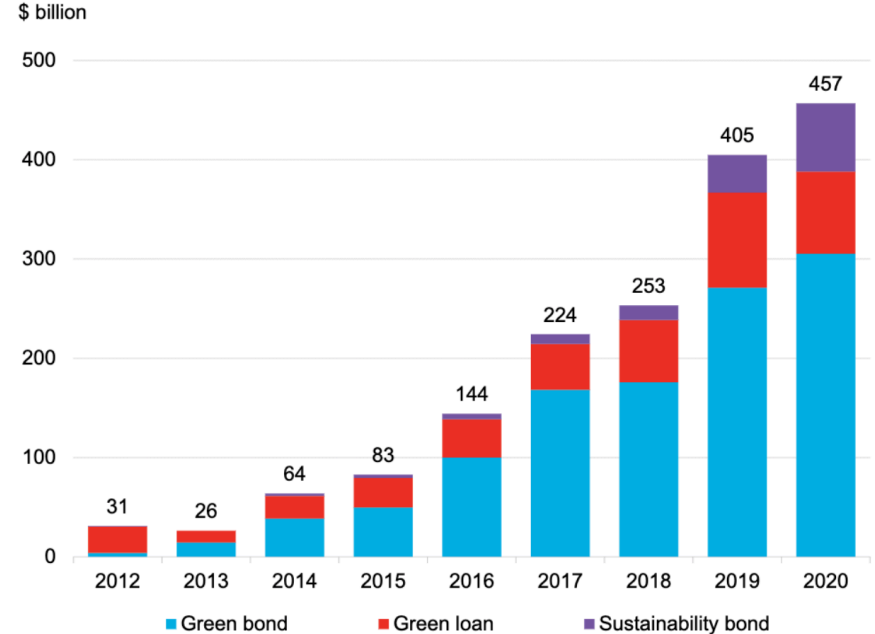
By the authority vested in me as President by the Constitution and the laws of the United States of America, it is hereby ordered as follows:

PART I — PUTTING THE CLIMATE CRISIS AT THE CENTER OF UNITED STATES FOREIGN POLICY AND NATIONAL SECURITY

Section 101. Policy. United States international engagement to address climate change — which has become a climate crisis — is more necessary and urgent than ever. The scientific

1. A social price on carbon (US\$50/t) for all govt. policies
2. Cessation of all fossil fuel subsidies
3. An end to all US Government ECA finance subsidies internationally.
4. The US might join an EU/China/Japan Carbon Border Adjustment Mechanism (CBAM)

Global Capital Is Shifting, Rapidly



Source: Bloomberg NEF

A Tectonic Shift Accelerates

In January of last year, I wrote that climate risk is investment risk. I said then that as markets started to price climate risk into the value of securities, it would spark a fundamental reallocation of capital. Then the pandemic took hold – and in March, the conventional wisdom was the crisis would divert attention from climate. **But just the opposite took place, and the reallocation of capital accelerated even faster than I anticipated.**

From January through November 2020, investors in mutual funds and ETFs invested \$288 billion globally in sustainable assets, a 96% increase over the whole of 2019.¹ I believe that this is the beginning of a **long but rapidly accelerating transition** – one that will unfold over many years and reshape asset prices of every type. **We know that climate risk is investment risk. But we also believe the climate transition presents a historic investment opportunity.**

Energy Firms Need to Transition



Ten-year performance: Exxon (Red, -31%), Peabody Coal (Black, -85%) vs S&P500 US (Purple, +184%) vs NextEra Energy (Green, +419%) – Fossil Fuel Firms are proving a Wealth Hazard!



Source: Yahoo Finance (8 March 2021)

Energy Firms Need to Transition



Ten-year performance: Adani Power (Red, -30%), Coal India Ltd (Black, -56%) vs BSE (Purple, +161%) vs Adani Green (Green, +523%) – Fossil Fuel Firms are proving a Wealth Hazard!



Source: Yahoo Finance (8 March 2021)

Neither Fossil Gas nor 'Blue' Hydrogen are a viable low emissions technology, despite the PR spin



Press Release and Bruce Robertson | March 5, 2020

IEEFA: Volkswagen lied about emissions from their vehicles, and the gas industry is also lying about their emissions



5 March 2020 (IEEFA Australia): The gas industry is misleading government, investors, customers and the broader population about the amount of carbon dioxide and methane emissions being released during production, supply and distribution of both conventional or 'natural' gas and its product for export – liquefied natural gas (LNG), finds a [new report](#) out today by the Institute for Energy Economics and Financial Analysis (IEEFA).

Fines and settlement payouts for vehicle manufacturer Volkswagen are likely to reach up to \$2 billion this year following being caught out with cheating on reporting of actual emissions released from its diesel fleet in 2015.

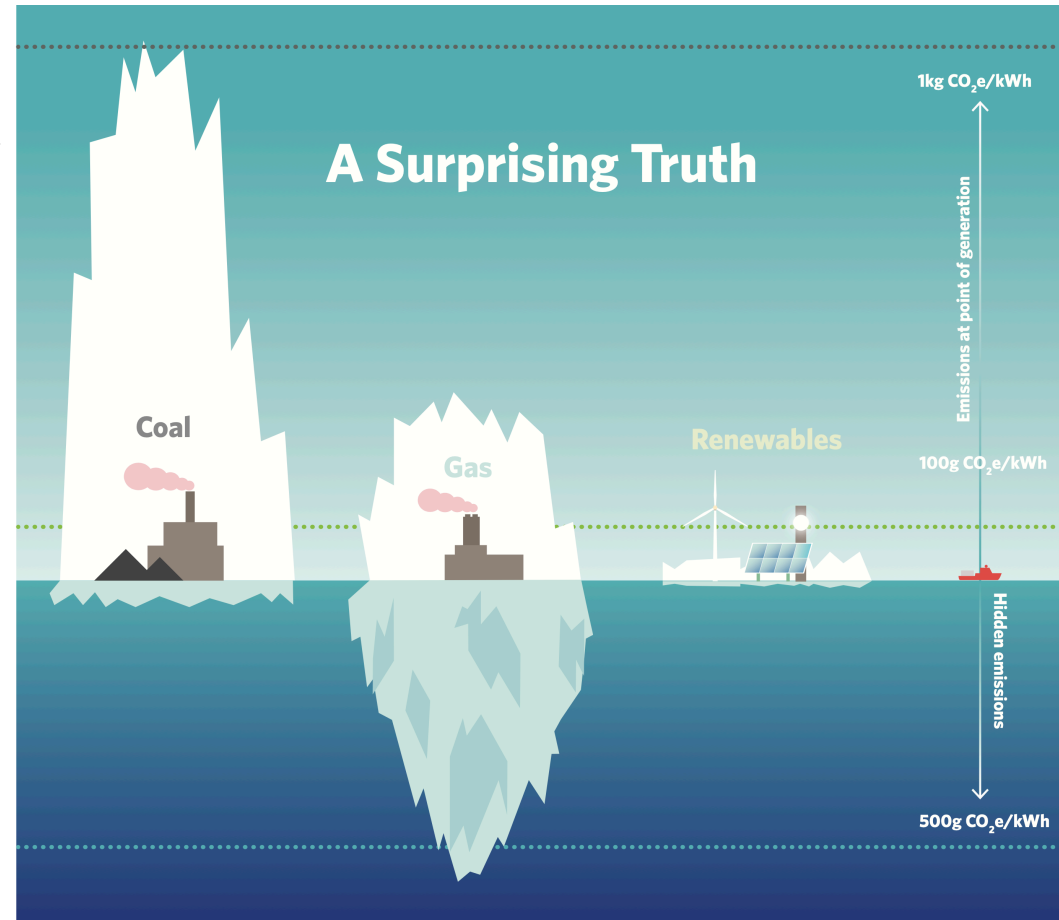
Bruce Robertson, gas/LNG energy analyst with IEEFA notes like Volkswagen, the gas industry is also walking a thin tightrope due to the under-reporting of actual emissions released from both gas and LNG across the supply chain.

"The industry claims burning fossil fuels such as 'natural' gas is cleaner than burning coal, a commodity on its way out as the world transitions to cleaner more sustainable energy sources," says Robertson.

"This is simply not the case.

The gas industry is also walking a thin tightrope due to the under-reporting of actual emissions

Source: <https://ieefa.org/ieefa-volkswagen-lied-about-emissions-from-their-vehicles-and-the-gas-industry-is-also-lying-about-their-emissions/>

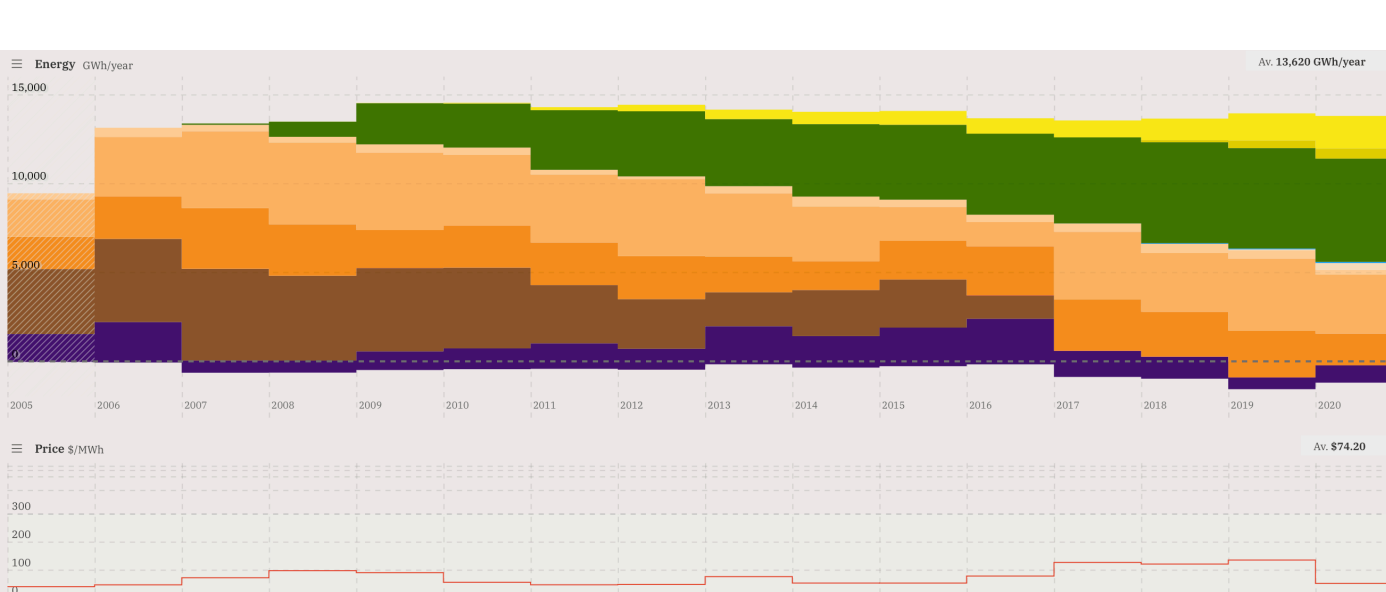


Climate Bonds Initiative. February 2021. www.climatebonds.net. Thanks to: Bruce Robertson, Energy Finance Analyst, Gas/LNG, IEEFA

Renewables have Transformed South Australia: 2005-2020



- Variable renewable energy (VRE) is 59.4% of CY2020 generation in South Australia.
- Average prices are A\$51/MWh in CY2020 vs an average of A\$125/MWh in 2017-2019
- 1QCY2021 saw VRE @ 66% and the pricing a record low wholesale A\$28/MWh (US\$22/MWh)



	Energy GWh	Contribution to demand	Av. Value \$/MWh
Sources	15,016		\$51.07
Solar (Rooftop)	1,834	13.2%	\$25.65
Solar (Utility)	571	4.1%	\$32.67
Wind	5,815	42.0%	\$31.20
Battery (Discharging)	62	0.4%	\$59.43
Gas (Reciprocating)	390	2.8%	\$80.18
Gas (OCGT)	254	1.8%	\$130.77
Gas (CCGT)	3,335	24.1%	\$54.39
Gas (Steam)	1,779	12.8%	\$68.21
Distillate	6.7	0.05%	\$718.36
Coal (Brown)	-	0.0%	-
Imports	969	7.0%	-\$62.33
Loads	-1,227		
Exports	-1,169	-8.4%	\$17.07
Battery (Charging)	-58	-0.4%	\$18.23
Net	13,789		
Renewables	8,220	59.4%	



Storage



WoodMac: Biggest US Battery Build-Out Ever in Q3

The US beat its previous battery installation record by 240%, a sure sign of things to come.

JULIAN SPECTOR DECEMBER 02, 2020 GreenTechMedia

The U.S. energy storage industry smashed its quarterly installation record with an influx of major projects in the third quarter. The industry had just broken records in the second quarter, but it beat that period's performance by 240%, installing 476 MW, according to the Energy Storage Monitor from Wood Mackenzie and the Energy Storage Association.

More significantly, this quarterly record does not look like an outlier. Annual deployments are expected to more than double in 2020 overall and nearly triple in 2021, according to Wood Mackenzie's analysis. The U.S. market is expected to reach 7.5 GW in 2025, which amounts to sixfold growth from 2020.

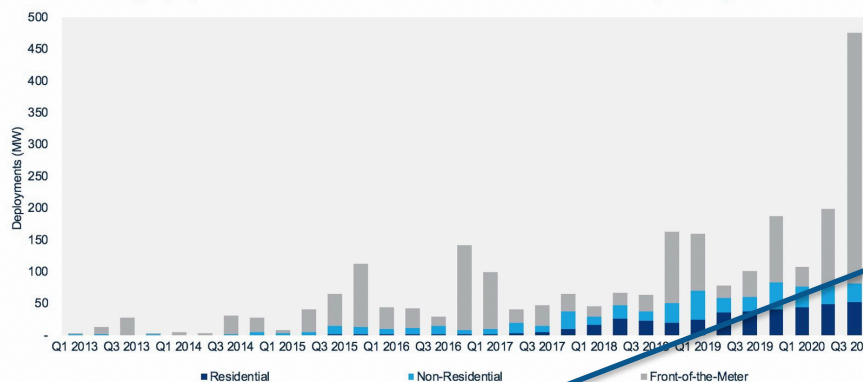
"It's the hockey stick that we've long expected, and it's finally being realized," said Daniel Finn-Foley, energy storage director at Wood Mackenzie. "It's still remarkable to see that y-axis get adjusted so quickly."

Wood Mackenzie P&R/ESA | U.S. energy storage monitor Q4 2020

woodmac.com

U.S. Q3 2020 deployments reached a staggering 476 MW

Record-shattering deployments in California redefined the market's scale - and required big edits to our Y-axis



The pipeline of storage projects seeking interconnection skyrocketed by 64% last quarter, he noted, surpassing 130 GW. Not all of those potential projects will get built, but the pipeline surged across the country, indicating an unprecedented geographic spread in storage development interest.

Dec/Jan 2021 saw NSW announce a 500MW by Neoen & 700MW by AGL battery investments.
<https://reneweconomy.com.au/neoen-plans-massive-500mw-big-battery-west-of-sydney/>

Feb'2021 saw CEP.Energy announce a 1,200MW battery for NSW (8x Tesla Hornsdale Battery SA).
<https://www.afr.com/companies/energy/hunter-set-for-world-s-biggest-battery-20210204-p56zji>

Feb'2021: The IEA forecasts India to have 140-200GW of batteries by 2040.

Explosive headline growth in Hydrogen

Australian miner unveils big solar ambitions

Fortescue Metals has revealed ambitious plans to build one of the biggest renewable energy portfolios in the world, with more than 235 GW of capacity, or five times the current capacity of Australia's National Energy Market.

NOVEMBER 13, 2020 **DAVID CARROLL**

Sinopec to Build 1,000 Hydrogen Refueling Stations in Next Five Years

By FuelCellsWorks | February 22, 2021 | < 1 min read (91 words)

Saudi Arabia's bold plan to rule the \$700bn hydrogen market

Bloomberg March 07, 2021

POSCO to Establish Hydrogen Production Capacity of 5 Million Tons

2020/12/18



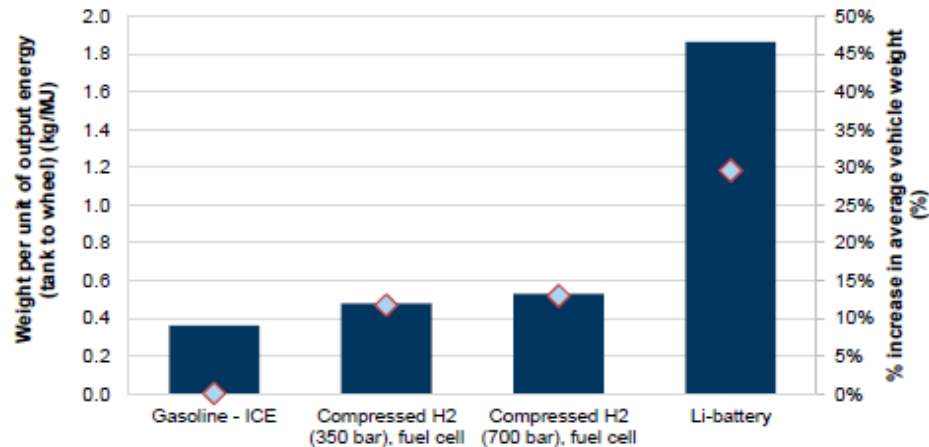
Mukesh Ambani, Ratan Tata, Anand Mahindra Can Join Forces For India's 1st Hydrogen Mission

By FuelCellsWorks | February 7, 2021 | 4 min read (666 words)

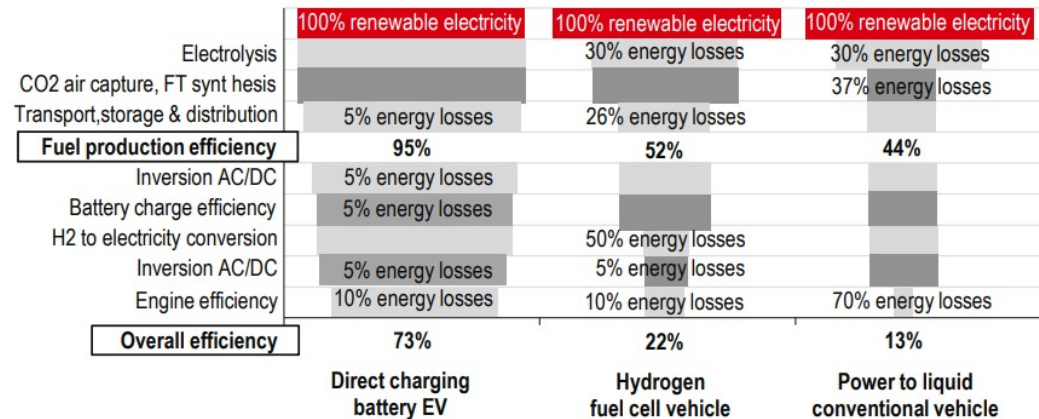


Hydrogen – key characteristics: Weight vs Efficiency

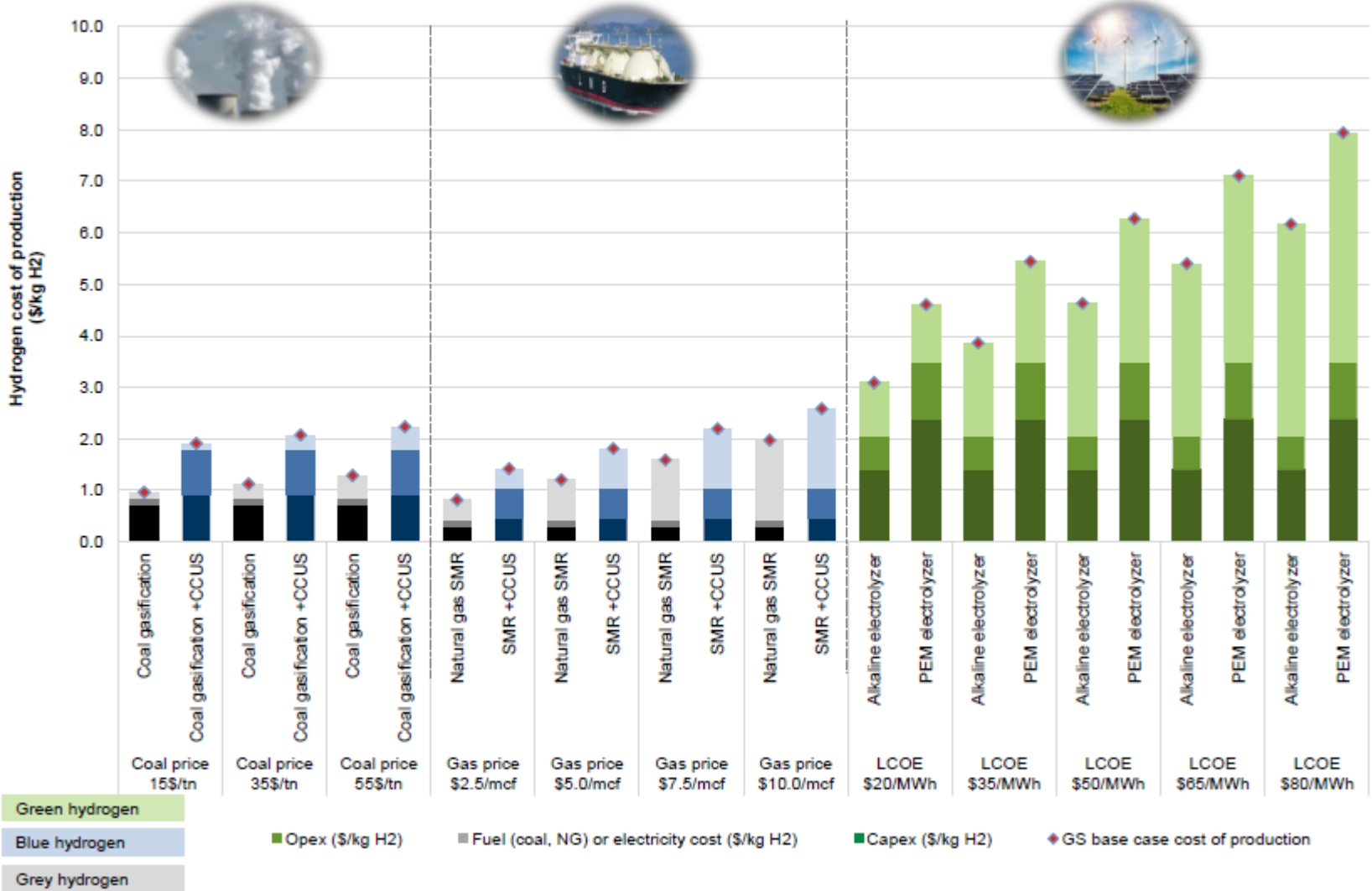
Weight per unit of output energy (tank-to-wheel) and % increase in average vehicle weight



Energy efficiency of different technologies in a passenger car



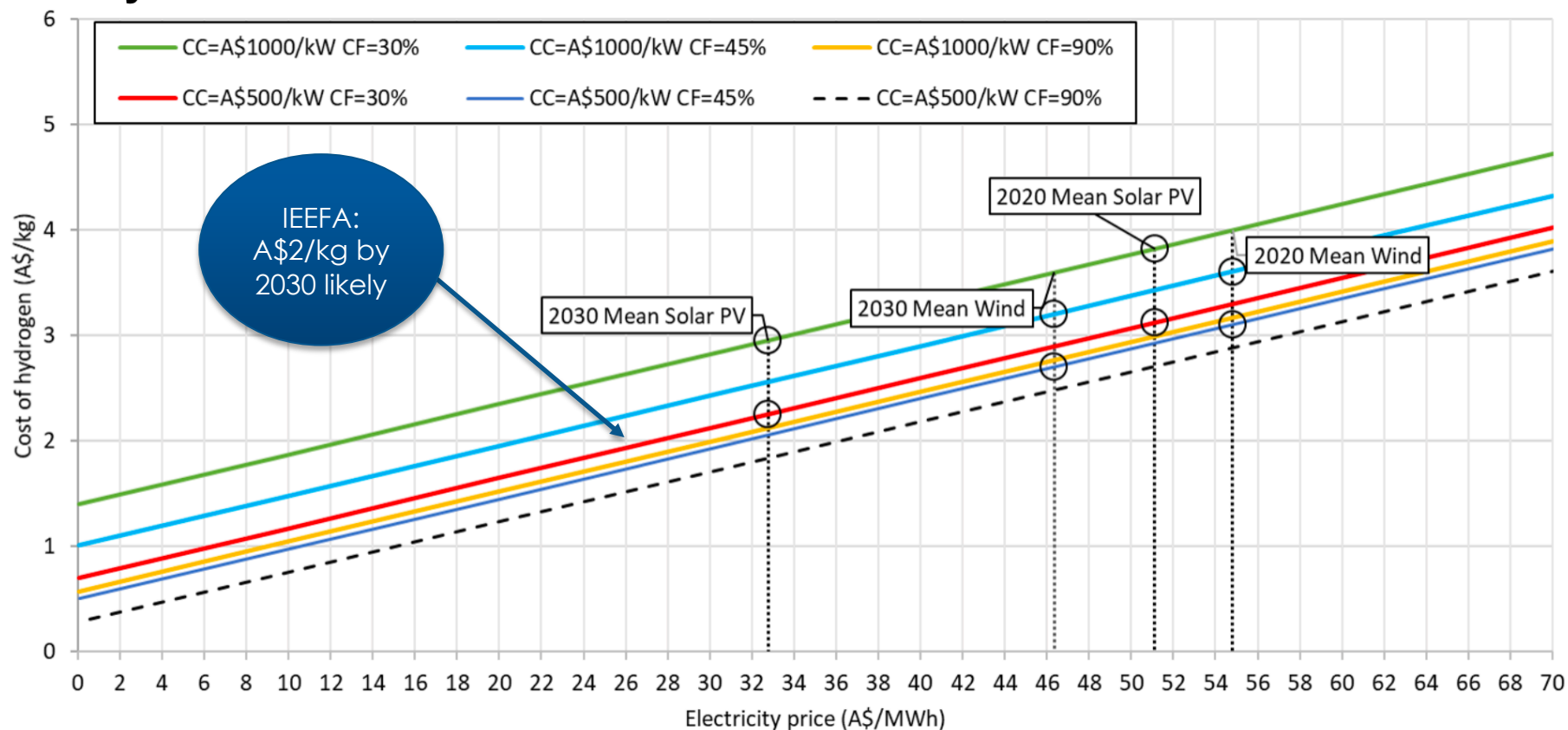
Grey, blue and green hydrogen (2020)





Australia targets “H₂ below A\$2/kg” (US\$1.50/kg)

Figure 2 – Production cost of hydrogen at different electricity costs and electrolyser costs



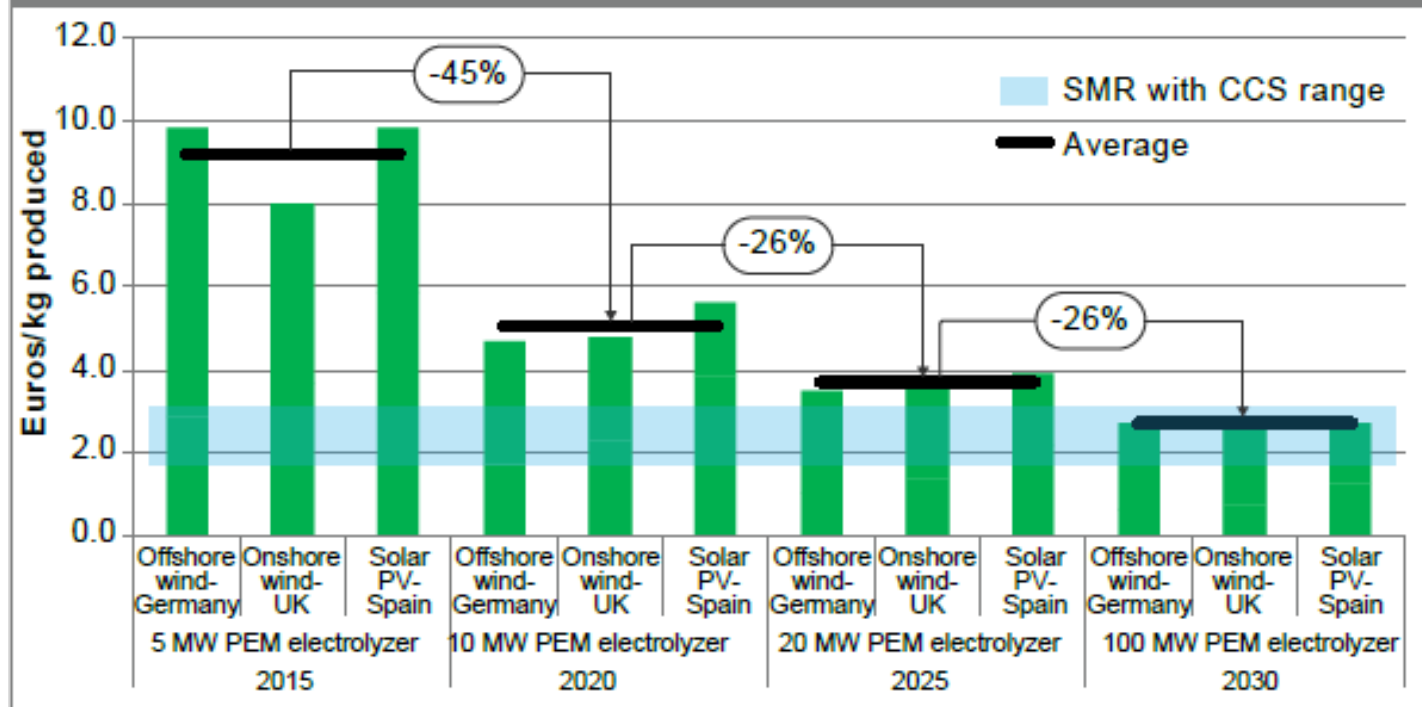


EU Pathway To €2/kg

[Jan'2021: Air Liquide](#) in Canada commissioned the world's first 20MW capacity PEM unit, doubling in just one year vs the [Feb'2020 Fukushima Japan 10MW](#) world's largest.

Jan'2021: Vattenfall/MHI/Shell announced a 100MW PEM unit in Hamburg for commissioning in 2025.

Figure 1: Evolution of the production cost of renewable electricity based hydrogen



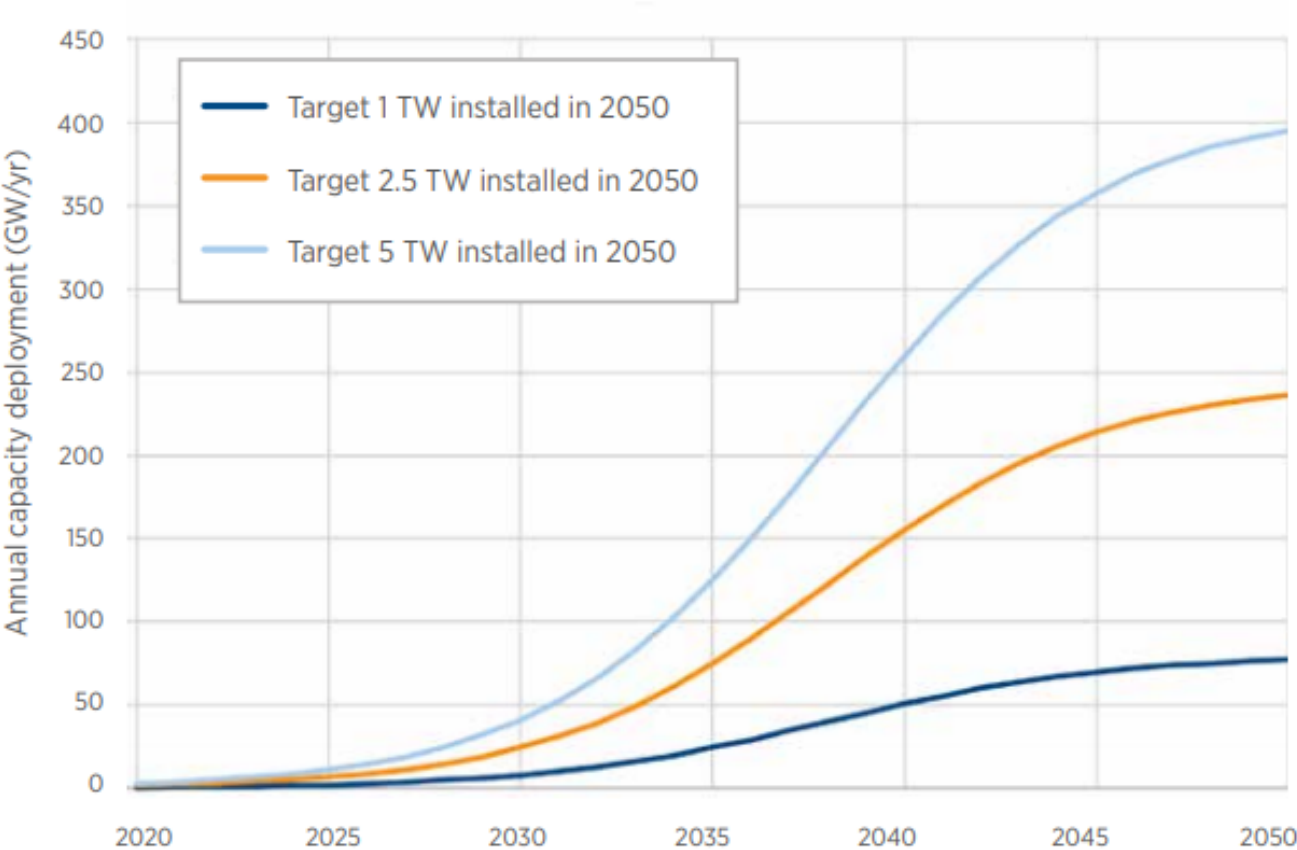
Source: IHS Markit.

© 2020 IHS Markit



Electrolyser capacity requirements

Figure 32. Estimated necessary electrolyser manufacturing capacity (GW/year) to meet different installed capacity targets by 2050.



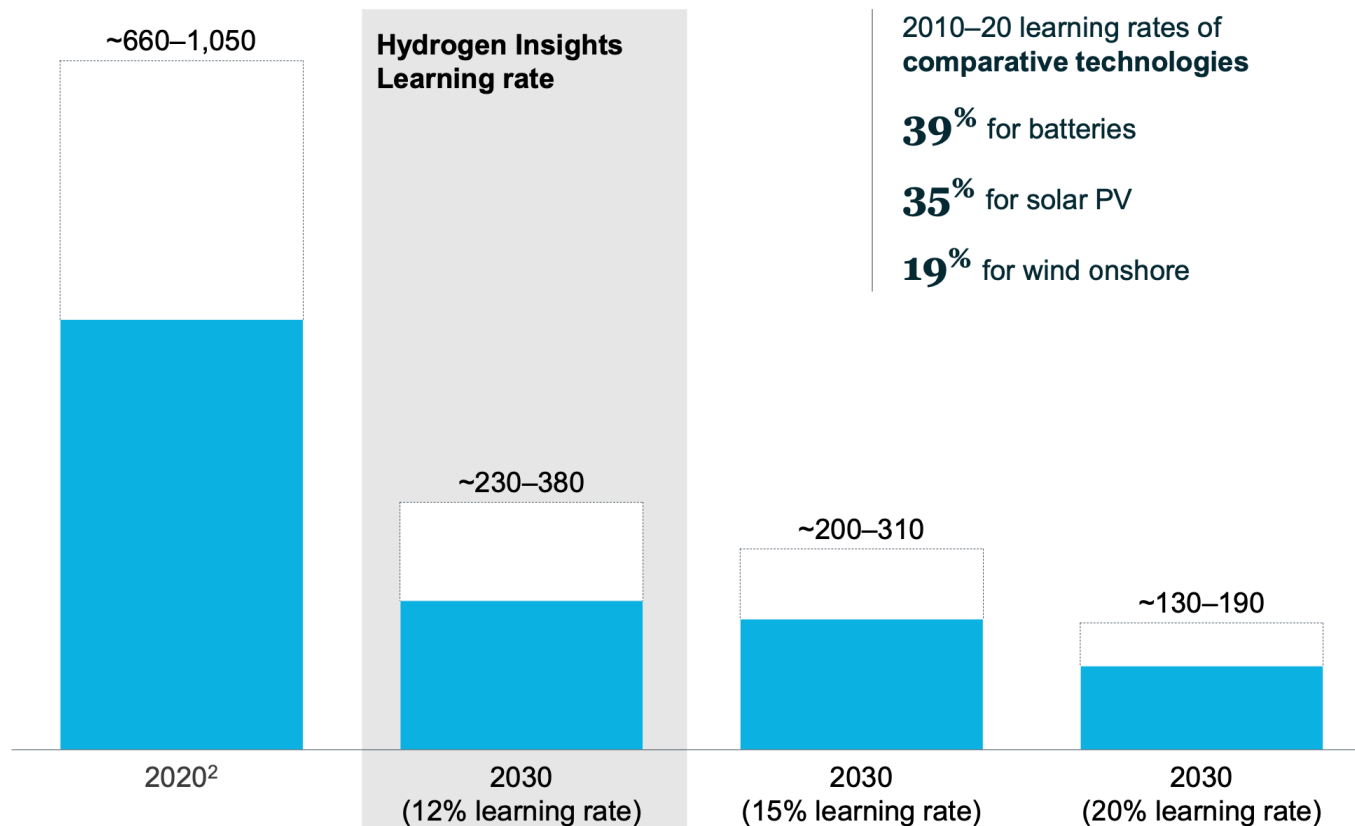
Source: IRENA

Electrolyser capacity costs

Exhibit 9: Electrolyzer capex learning rate scenarios

Electrolyzer system capex¹ for different learning rates

USD/kW



1. Only includes stack and balance of plant. No installation and assembly, building, indirect cost or transportation site
2. Range based on different electrolyzer size classes of 2–20 MW

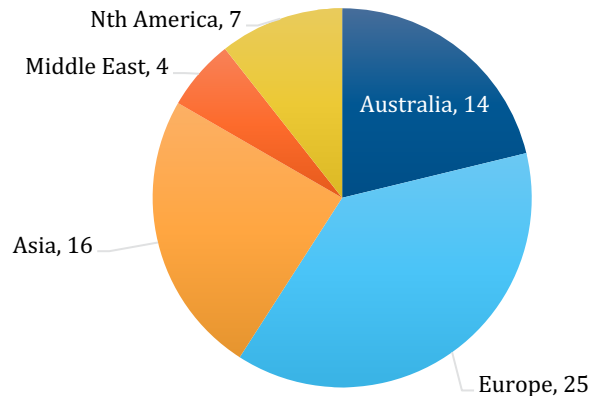


Supply Outlook Takes Shape

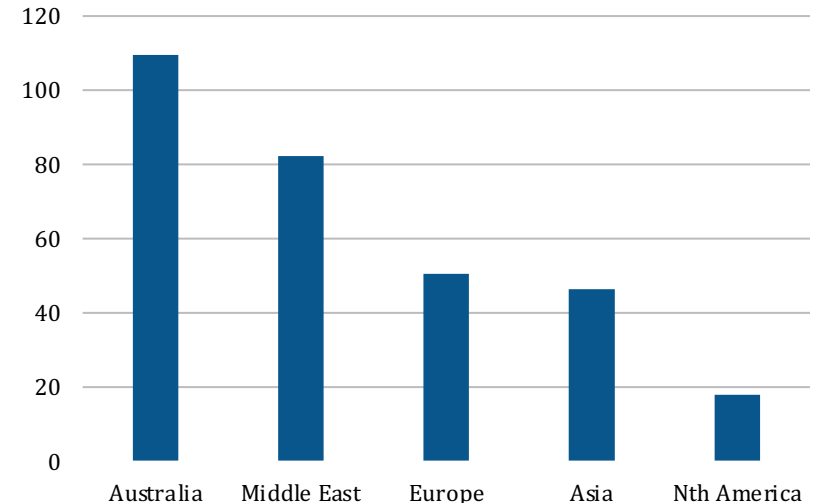
Over 60 viable large-scale hydrogen projects in Aug'20. McKinsey reports this has risen to 228 by Feb'21.

- IEEFA evaluated 60 major project proposals across Asia, Europe and Australia in Aug'20.
- These projects require capex of US\$84bn, electrolyser capacity of 13GW & hydrogen capacity of 4Mtpa. Of these 60 projects, only 20 had started construction & remainder are at a preliminary stage.
- By Feb'2021 McKinsey & Co reports >US\$300bn for 228 projects reviewed (17 with GW scale ambitions, with 38 moving to FID or beyond), and flagged the expected 2030 green hydrogen VRE cost dropping 15% vs that estimated just 12 months ago.

Large scale hydrogen projects by region (No)



(k tpa) Average hydrogen production capacity by plant



Source: Companies, IEEFA estimates

https://ieefa.org/wp-content/uploads/2020/08/Asia_Australia_Europe-Lead-Green-Hydrogen-Economy_August-2020.pdf



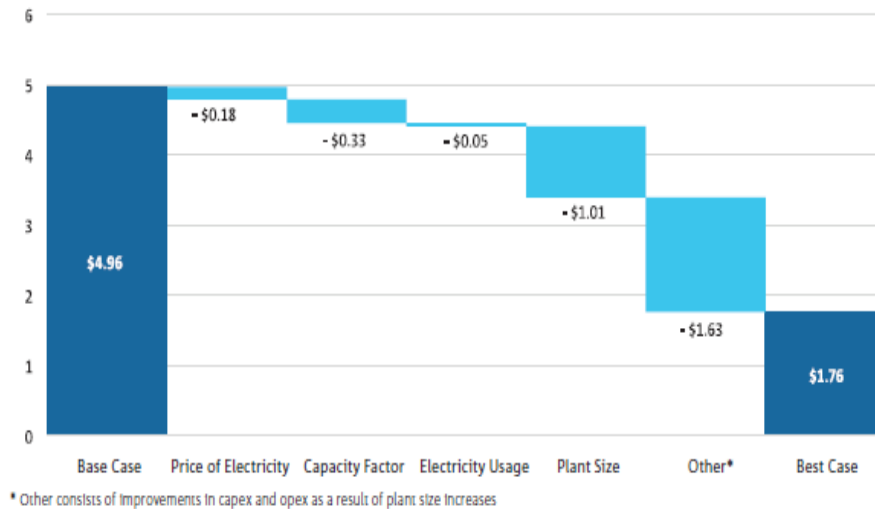
Institute for Energy Economics
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Green Hydrogen Production Challenges

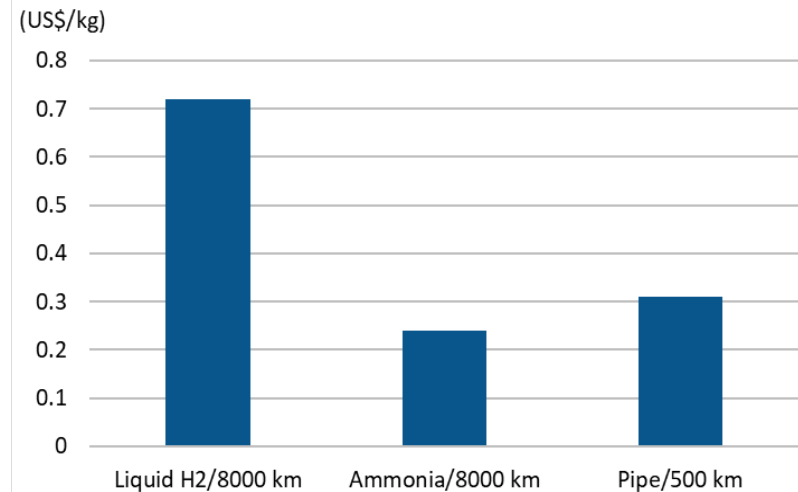
Seaborne transportation is expensive

- Hydrogen, as the lightest molecule, is expensive to transport.
- CSIRO estimates liquefaction costs of A\$1.80/kg.
- Long-distance tanker transport cost of A\$0.70/kg.

Hydrogen liquefaction cost reduction



Hydrogen transportation costs



Green Hydrogen Financing

- EU has proposed investment of €430bn by 2030 to develop a world-class green hydrogen economy. For India to compete, significant investment is required, consistent with the excellent [TERI / ETC report](#) of Dec'2020.
- Finance Minister Nirmala Sitharman announced [National Hydrogen Mission](#) for India in the 2021 budget. This ties in strongly with the [Make in India](#) and the [450GW renewables by 2030](#) ambitions. This will enhance energy security by reducing reliance on imported fossil fuels, including imported fossil ammonia.
- An Indian Coalition is required for collaboration and RD&D in the Indian context. The initial pilot projects will be loss-leaders to facilitate learning by doing, to establish the supply chains, evaluate safety risks et al.
- Private sector project finance wont be the first step.
- Leveraging the corporate balance sheets of SOEs (NTPC) and industrial conglomerates (Tata, Reliance, Adani) to equity finance joint ventures and provide a structure for PPAs and product offtake.
- EU Multi-lateral Development Banks are primed and ready to finance green hydrogen, but have done zero commercial deals, to-date.

Early Global Project Developments

- [Iberdrola-Fertiberia JV in Spain](#): building a €150m / 20MW electrolyser at an existing ammonia fertilizer plant for commissioning end 2021 supplied by NEL Hydrogen Norway and powered by 100MW solar + a 20MWh lithium-ion battery. The initiative has been expanded to a €1.8bn / 800MW multistage development by 2027.
- [Nextera Energy US](#): building a US\$65m / 20MW electrolyser powered by solar in Florida co-located with its existing 1.75GW gas power plant. Blending means a ready application, no transport.
- [Fortescue Metals Group Australia](#): a proposed 235GW VRE ambition, plus a proposed 250MW green hydrogen plant in Tasmania. But stage 1 is a proposal for 100% imported diesel replacement in equipment/rail.
- [JERA Japan](#): already trialing blending grey ammonia in its 4.1 GW Hekinan coal-fired power plant (ramping to 100% ammonia by 2040s?)
- [NorthH2 Netherlands](#): a consortium of Shell, Groningen Seaports Gasunie, RWE and Equinor aims at 1GW by 2027 (4GW by 2030 = 0.4Mtpa of green hydrogen) leveraging high capacity factors of offshore wind in the North Sea. Injection into the gas pipeline network, and sale to local industry.
- [Statkraft/Cesla Norway](#): 40-50MW electrolyser for the Mo scrap steel recycling plant.
- [NEL Hydrogen](#) is the world's largest PEM/Alkaline electrolyser equipment manufacturer. Its global capacity was 90MW pa in 2020, aiming for 540MW by 3Q2021 (5x the global 2020 electrolyser market). Moving from 2MW to 20MW units, with the aim of 100MW units.

India's Starting Opportunities

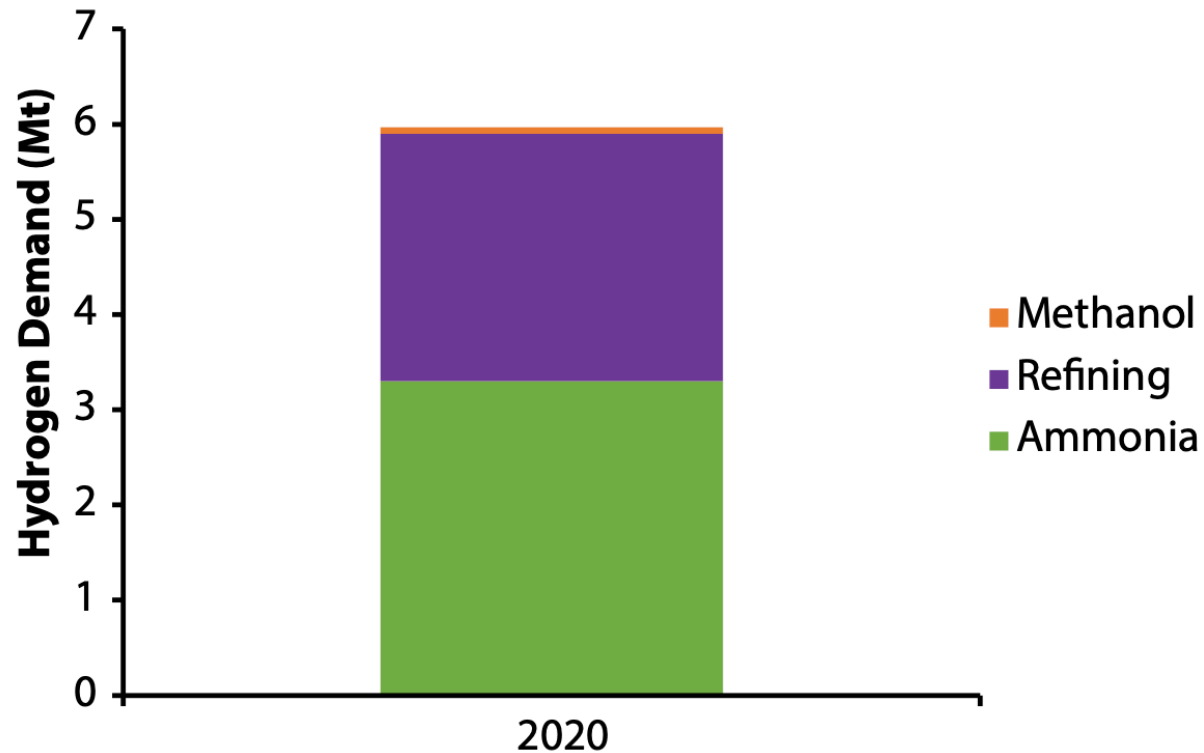


Figure 5: Hydrogen demand by sector, 2020