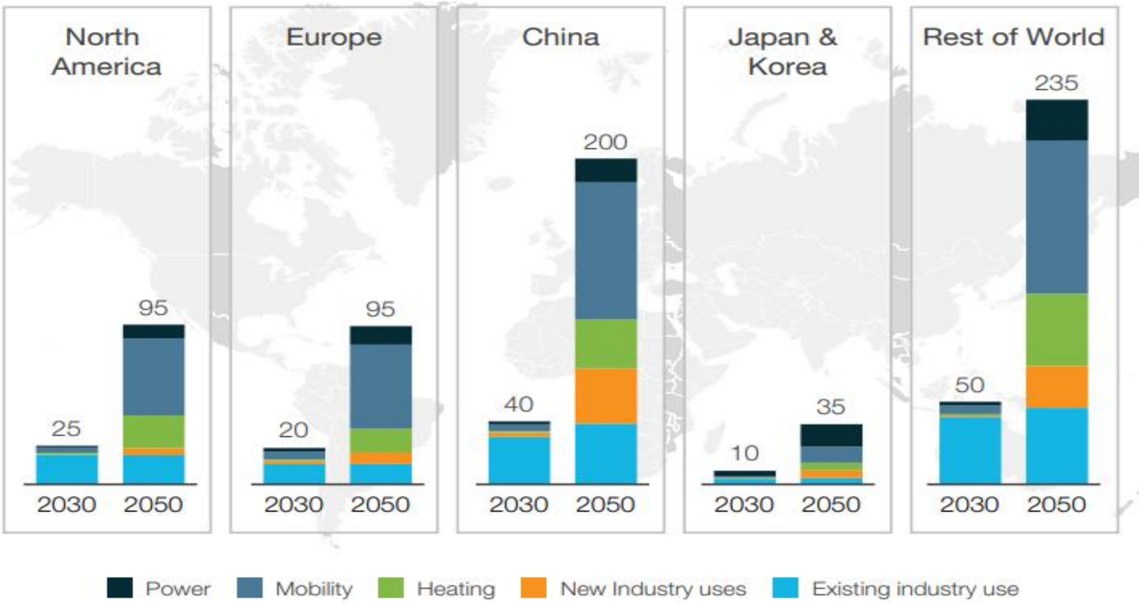
2021-IP28
Hydrogen for Net-Zero
A critical cost-competitive energy vector

The Hydrogen Council in collaboration with McKinsey & Company authored a report entitled the Hydrogen for Net-Zero in November 2021. This publication appraises the role that clean hydrogen (which is in the published study defined as either renewable, produced from water electrolysis with renewable electricity or low-carbon hydrogen, produced from fossil fuel reforming with carbon sequestration) could play in the energy transition from now through to 2050. It addresses a knowledge gap by presenting an industry-derived, comprehensive outlook on hydrogen, and its indispensable role as a cost-effective decarbonization enterprise. Further, it outlines the long-term role of hydrogen and the measures that must be taken in the coming decades to achieve the net-zero targets. This publication delivers a high-level context for the industry and governments to make an informed decision with regards to initiating and advancing the hydrogen-based economy.

The momentum behind the hydrogen economy is unprecedented with government policy announcements to corporate commitments, and consortia and projects synergies. There is currently a global consciousness with regards to how hydrogen is critical to achieving the climate goals. In a net-zero economy, demand for clean hydrogen could be up to 660 million metric tons (MT) in 2050 (see Figure 1). This accounts for about 22% of the global final energy demand and an annual abatement potential of 7 gigatons (GT) of CO_2 which is equivalent to about 20% of the CO_2 emissions if the world remains on its current global warming trajectory. By 2050, clean hydrogen could abate a cumulative total of 80 GT of CO_2 from 2020 (i.e. 11% of the emissions reductions required to stay within the carbon budget of 420 GT needed to limit global warming to 1.5 - 1.8°C). This is about twice the current amount of annual anthropogenic emissions.



660 MT	22 %	80 GT	7 GT
Hydrogen required p.a. in 2050 for net zero	Of global energy demand	Cumulative abatement by 2050	Abatement in 2050, with ~4GT CO2 p.a. in 2040

Figure 1. Hydrogen demand by region in 2030 and 2050

Figure 1 lays bare the significant scale up campaign for clean hydrogen supply that is required by 2050 to meet the net-zero targets. 690 MT of low carbon and renewable hydrogen supply in net zero 2050 is needed to satisfy the 660 MT hydrogen demand in 2050. The energy cap is as a result of losses in the supply chain, for instance those from conversions to or from carriers, leakage in pipelines, or boil-off from liquid hydrogen storage or distribution.

Meeting the demand of 660 MT by 2050 to end-uses will entail 3 to 4 TW of electrolysis capacity and about 4.5 to 6.5 TW of renewable capacity (about twice the total renewable generation capacity of 2.8 TW installed by 2020) devoted to about 400 to 550 MT of hydrogen production in 2050. Whereas low carbon (CCS-abated) hydrogen is projected to provide about 140 to 280 MT of hydrogen supply in 2050. This amounts to about two to three times today's unabated fossil fuel hydrogen capacity. There are currently seven commercial facilities producing CCS-abated hydrogen, their total combined production capacity is 1.3 to 1.5 MT p.a., i.e., less than 1% of the required capacity three decades from now. This stark capacity gap underscores the necessity for the commercial deployment of carbon capture, usage, and storage (CCUS) in a net zero 2050 scenario. CCUS must play a critical role to unlock the huge potential of low carbon hydrogen. Assuming all the hydrogen were to be produced via renewables, about 5.5 TW of electrolysis and 8 GW renewable energy capacity would be required. Such a scale-up of renewable generation, and electrolysis, would be extremely challenging and may heavily draw on still-scarce renewable power resource, thus requiring stronger commitments and an even faster scale-up of supply chains. By comparison, supplying the demand with only low-carbon hydrogen will require about 5.5 GT of annual carbon storage capacity, note 0.036 of CO_2 GT has been stored in 2021.

Scaling through 2030 is critical for meeting long-term hydrogen targets. Demand for hydrogen is projected to increase to 140 MT by 2030 (see Figure 2), which equates to a ~50 MT increase in the coming decade. 75 MT of clean hydrogen is needed by 2030 to be on track for a net-zero 2050 (see Figure 3). About 25 MT and 50 MT of the clean hydrogen supply is projected to come from converted grey (hydrogen from unabated fossil fuel reformation) capacity and newbuilt renewables or low carbon hydrogen respectively. These climate targets are achievable via gradual phasing out of current unabated hydrogen production capacity (i.e., associated with processes that release CO_2 straight to atmosphere) and replacing with clean hydrogen supply towards 2030. Phasing out of unabated hydrogen capacity will see existing hydrogen applications in ammonia, methanol, and refining experience, both an increase in demand of 13 MT of clean hydrogen for new capacity coming online, as well as the conversion of 25 MT of existing unabated hydrogen capacity into clean hydrogen. This would result in 40 MT of clean hydrogen demand by 2030.

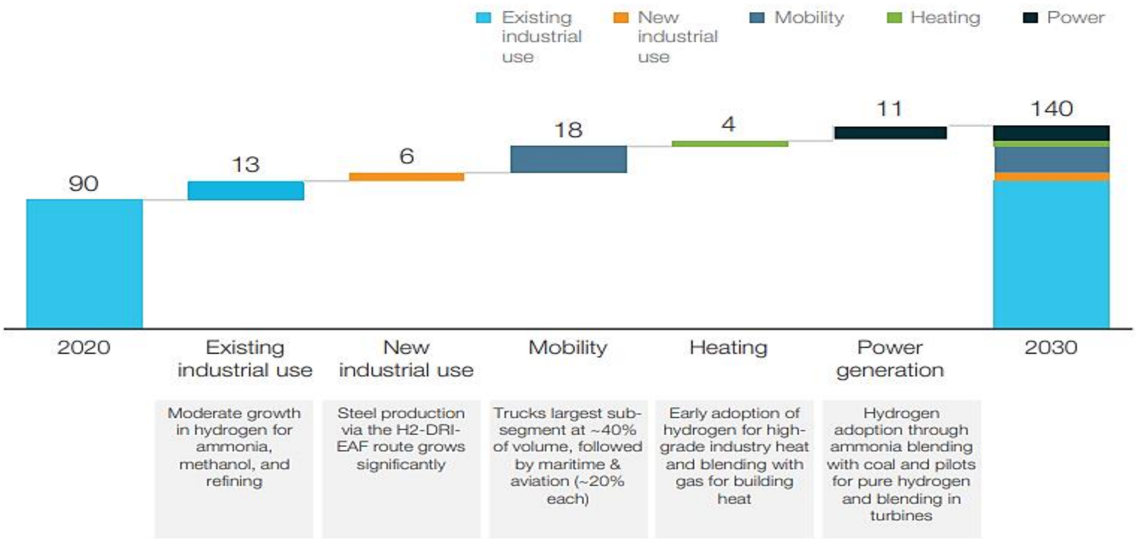


Figure 2. Global hydrogen end use demand build 2020-30, MT p.a.

Deploying 75 MT of clean hydrogen by 2030 will attract substantial investments in about the 45 to 55 MT of low carbon (annual abatement potential of 730 MT of CO_2) and 20 to 30 MT renewables hydrogen production infrastructure. 200 to 250 GW of electrolysis capacity is required to meet this supply in 2030. This is much higher than the approximate 90 GW cumulative capacity announced today. Rapid scale up of production lines by manufacturers must be met to meet the climate goals. This electrolyser capacity will necessitate the deployment of about 300 to 400 GW of new solar, wind and hydro capacity devoted to hydrogen production by 2030, if these sources supply all the demand. Assuming only renewable hydrogen were deployed, the electrolyser volume needed would be about 600 GW, supported by about 1 TW renewable generation capacity by 2030.

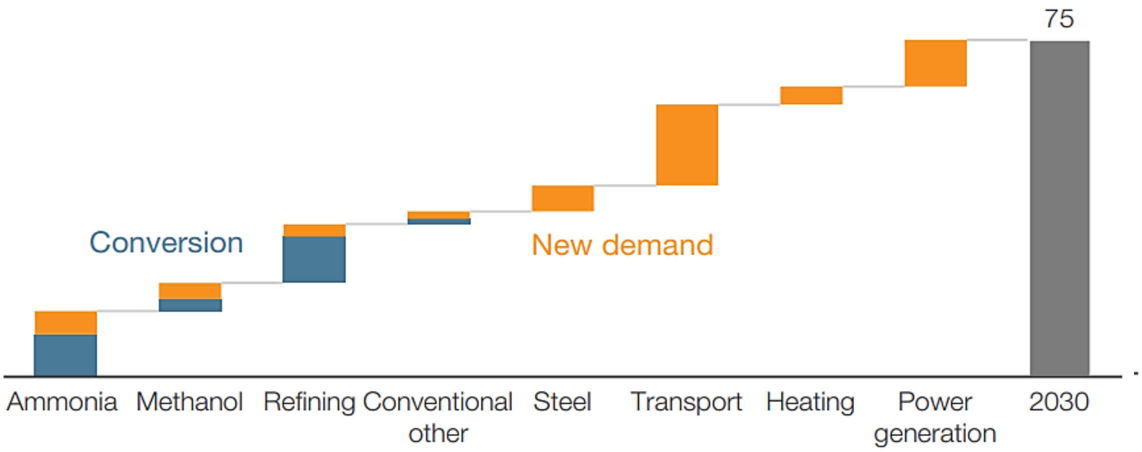


Figure 3. Clean hydrogen end use demand in 2030, MT hydrogen p.a.

Clean hydrogen can deliver up to 3.5 GT of CO_2 abatement by 2030 and annual abatement potential from clean hydrogen in 2030 is estimated at 730 MT of CO_2, i.e., almost 2% of the emissions today. To place in context, these emissions equate to taking about 200 million passenger vehicles off the road. Significant amounts of this abatement potential in 2030 is projected to emanate from conventional industrial uses (270 MT of CO_2 per annum) and steel (130 MT of CO_2 per annum). Further, notable contributors to hydrogen's abatement potential in 2030 include transport (180 MT of CO_2 per annum) and power generation (100 MT of CO_2 per annum). The existing hydrogen industry, as well as new hydrogen applications in transport, power, steelmaking, and heating, are expected to be jointly responsible for the unprecedented growth in hydrogen demand. Further, it is expected to set the aforementioned 2030 abatement potential on track to net zero by 2050.

Investment momentum in hydrogen projects is developing with more than 520 large-scale projects announced globally to date, representing a 100% increase since January 2021 (see Figure 4). 150 projects have been added in the past three months alone. Approximately 70% of the projects have announced full or partial commissioning before 2030, with the remainder coming online after 2030 or not having announced a commissioning date yet. The total clean hydrogen production volume announced now exceeds 30 MT i.e., more than 30% of current global hydrogen demand. Renewable hydrogen capacity accounts for half the total announced capacity and accounts to 93 GW of announced electrolysis capacity globally.

The development of hydrogen projects through 2030 represents a total direct investment of US$ 160 billion. A significant part of the investments is in low carbon hydrogen production and renewables, which accounts for about US$ 95 billion. Investment in end-use applications follows with about US$ 45 billion and US$ 20 billion channelled for transmission, distribution, and storage. 75% of the total investments announced for end-uses are in the transport and steel sectors, signifying their attractive market base. The lowest announced funding schemes are for the power and heating applications.

The development of a hydrogen pipeline infrastructure is needed for heating requirements whereas hydrogen for power technology is at its early stage of deployment.

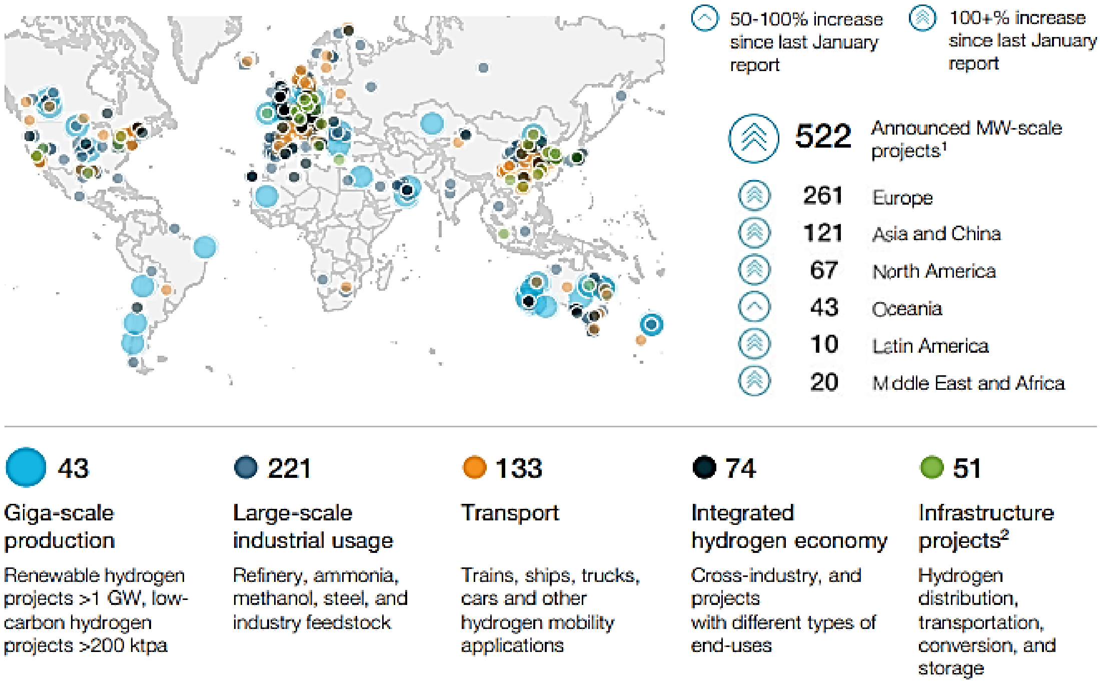


Figure 4. Hydrogen project announcements

Achieving net zero by 2050 and decarbonising 22% of the global final energy[1] demand will require 75 MT of clean hydrogen supply and demand by 2030. To attain this feat, a total direct investment of US$ 700 billion is required across the hydrogen value chain by 2030 with US$ 300 billion for hydrogen production. US$ 200 billion for hydrogen shipping, pipeline, local distribution, conversion and refueling infrastructure. A further US$ 200 billion for end-uses investment with transport and new hydrogen industry use requiring 75% of the end-use application investment. A substantial investment gap exists across the hydrogen value chain, despite the observed momentum and project announcements. Achieving net zero by 2050 will require an additional investment of US$ 540 billion by 2030, in essence closing the gap between the US$ 160 billion announced projects and the US$ 700 billion in required investments as illustrated in Figure 5.

[1] Total final energy demand (consumption) is the sum of energy consumption in each sector. In each sub-sector or end-use, at least six types of energy are shown: coal, oil, gas, electricity, heat, and renewables. (https://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-outlook-from-iea)

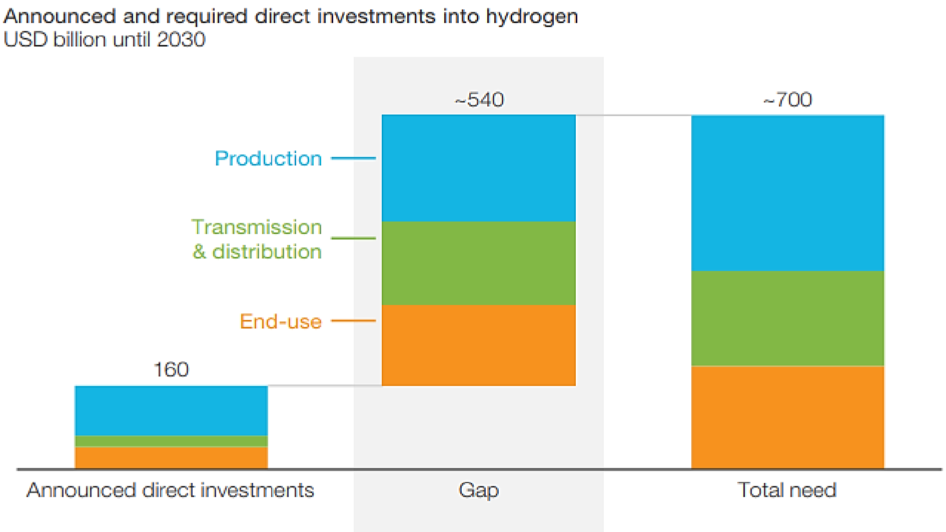


Figure 5. Investment gap in hydrogen value chains

Net zero 2050 is challenging, with 690 MT of clean hydrogen supply required to meet demand for 660 MT in hydrogen end-use applications. Estimates of the **total required investment are around US$ 7 to 8 trillion** across the hydrogen value chain by 2050, generating about USD 3 trillion revenues in 2050 across the hydrogen economy. While the investments required are significant they are comparable to investments of USD 5.7 trillion made in upstream oil and gas in the past decade i.e., from 2010 to 2019 and investments in renewable energy surpassed US$ 2.5 trillion from 2010 to 2019.

If the decarbonisation of the global economy to achieve net zero by 2050, and restrict global temperatures to 1.5 – 1.8°C (equivalent to the abatement of 80 GT of CO_2), then hydrogen is pivotal to achieving these goals. **Three key levers to unlock the hydrogen economy** must be met: **creating demand** via incentivizing decarbonization through clean hydrogen; **ensuring access** via making hydrogen accessible through the infrastructure; and **lower cost** via creating economies of scale to reduce cost and open new markets.

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02/12/2021