Prospects for Hydrogen in APEC

by

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Abstract

There is an increasing interest in the potential use of hydrogen as a clean energy source, due to the need for effective measures of decarbonization to combat climate changes. APEC is an important region in the future global energy mix as it consumes approximately 60% of the world's energy. Our modelling suggests that hydrogen could satisfy around 4% of APEC's final energy demand by 2050. Additionally, APEC's member economies have access to different energy sources which, in turn, can enable the production of different types of hydrogen according to their characteristics. Furthermore, some member economies have published documents that show their visions and goals regarding hydrogen while others do not have such plans.

This paper presents the prospects for hydrogen in two scenarios, estimates potential demand, identifies economies that potentially can produce hydrogen, and analyses the implications that such demand represents for those economies. Our work indicates that APEC economies can play important roles in the future global hydrogen market as consumers and producers.

1 Introduction

In a world that is increasingly aware of the risks attributed to climate change, the sustainable development of the energy sector is key to achieve any environmental goal set to limit the effects of global warming on human life. The use of hydrogen as an energy carrier has been considered as potential measure to mitigate greenhouse gases (GHG) emissions because it can be used as an alternative to fossil fuels to power hard-to-decarbonize sectors such as transport and industry.

Despite being called the fuel of the future, hydrogen is not new as it is an important industrial feedstock: hydrogen is widely used in refineries and in the production of ammonia. However, the use of hydrogen as an energy carrier is still marginal although with great potential to grow in the coming decades. The experience on the use of hydrogen provides a glimpse of the challenges that the future use of hydrogen as an energy carrier might face: dependency on fossil fuels, long-distance reliable transportation, safety issues at the end-use point, among others that require important technological innovations, the development of adequate regulatory frameworks, and substantial investments that incentivize the development of a global hydrogen market.

The Asia-Pacific Economy Cooperation (APEC) region is important in the future global energy mix because it is responsible for 60% of the world's energy demand and (APEC, 2021). Therefore, APEC needs reliable and affordable energy to satisfy its demand and, simultaneously, develop adequate strategies to mitigate the environmental impacts of its energy sector. In 2018, fossil fuels provided more than 70% of final energy demand in APEC, a figure which does not include electricity generated using fossil fuels.

Figure 1: APEC Final Energy demand in PJ from 2000 to 2018

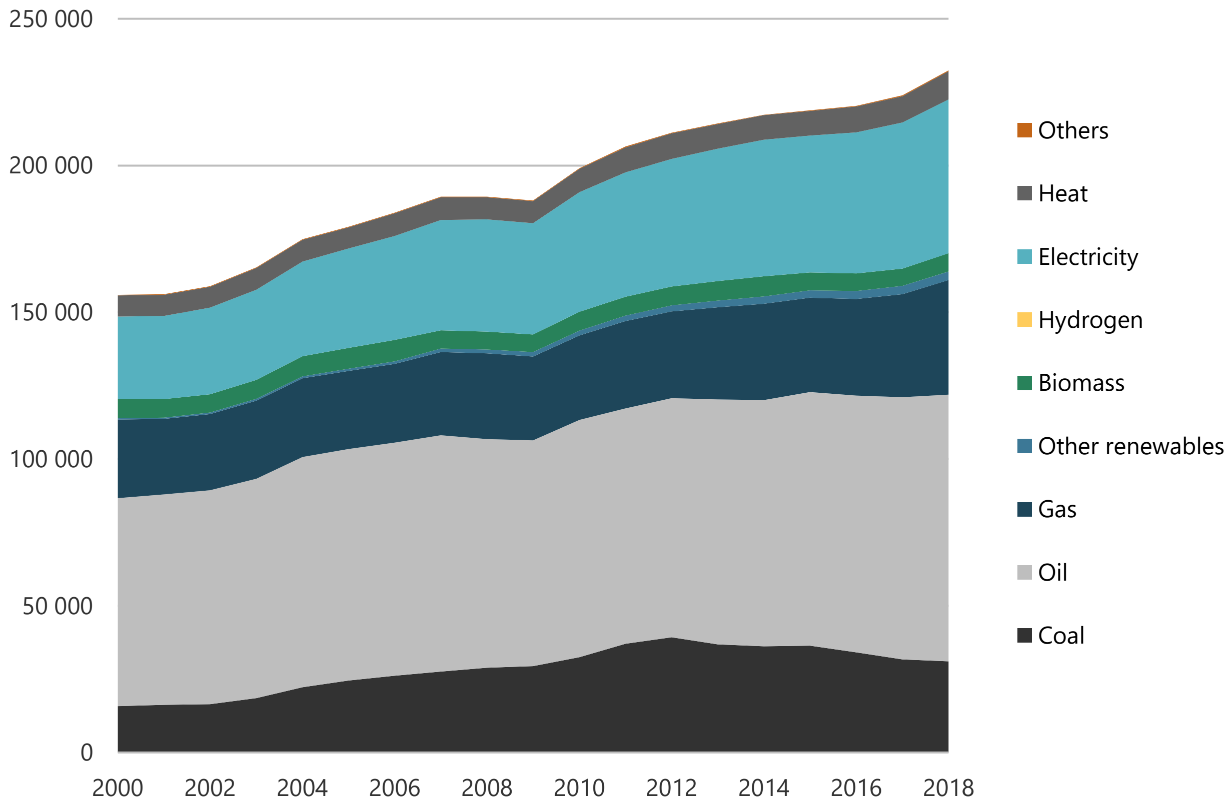


Figure 1 illustrates not only APEC's dependency on fossil fuels but also how rapid the share of electricity and natural gas in the final energy mix grew in the past two decades, giving an indication on the usual pace to change the energy mix. Coal, natural gas, and oil satisfied 73% of the demand in 2000 and 69% in 2018.

Some APEC economy members have launched strategies for development of a hydrogen industry in the coming years. These documents show their vision of building internal demand and supply chains that support the development of related infrastructure that improves efficiency and reduces costs making hydrogen more cost-competitive with respect to other fuels. Some economies highlight the role of exports in their strategies.

Table 1 Hydrogen strategies launched in economy members of APEC

Economy	Document	Date
Republic of Korea	Hydrogen Economy Roadmap of Korea	January 2019
Japan	The Strategic Road Map for Hydrogen and Fuel Cells	March 2019
People’s Republic of China	White paper of hydrogen energy and fuel cell industry in China 2020	June 2019
New Zealand	A vision for hydrogen in New Zealand	September 2019
Australia	Australia’s National Hydrogen Strategy	November 2019
United States	Hydrogen Strategy Enabling A low-carbon Economy	July 2020
Russia	Roadmap for Development of Hydrogen Energy for 2020-24	October 2020
Chile	National Green Hydrogen Strategy	November 2020
Canada	Hydrogen Strategy for Canada	December 2020

2 Hydrogen Production

Almost all hydrogen that is currently produced comes from natural gas, also known as grey hydrogen, and coal, also known as brown hydrogen. In 2020, 59% of the globally produced hydrogen came from natural gas through a process called steam methane reforming (SMR) and 19% from coal in a process called coal gasification, while 21% was produced as byproducts, mainly in refineries (IEA, 2021). Brown hydrogen is relevant mainly in PRC, although there are important pilot projects such as the Hydrogen Energy Supply Chain (HESC) that creates a supply chain of liquefied hydrogen between Australia and Japan, that is in Australia and is based on brown hydrogen.

Producing hydrogen from fossil fuels can generate high emissions. For example, steam methane reforming emits approximately 9 kg CO_2 / KgH_2, while coal gasification emits 19 kg CO_2 /KgH_2. Consequently, the addition of technologies that can capture most of the emissions generated is necessary to use hydrogen as an effective emissions mitigation measure. Carbon capture and storage (CCS) technologies for fossil fuel-based hydrogen generation has been proposed as a transition step towards carbon-free hydrogen. Hydrogen produced from SMR with CCS is known as blue hydrogen

On the other hand, some studies have found that green hydrogen, that is produced via electrolysis and that uses renewable energy electricity, can be more competitive than blue hydrogen by the end of this decade (BloombergNEF, 2022). Chile, an APEC economy member with high solar and wind energy potential, has launched a strategy focused on this type of hydrogen. However, in the same way that natural gas resources are not evenly distributed, renewable energy potentials are not evenly distributed throughout APEC, therefore, some economy members may have some comparative advantages to produce some type of hydrogen over others.

Nevertheless, hydrogen is one option among others that will compete to satisfy energy needs in the future. Consequently, it is important to perform an integrated analysis of different fuels to grasp the potential of hydrogen to displace other fuels and to effectively help to reduce emissions in the APEC energy sector.

2 Methodology

To answer the question about the potential role that hydrogen can play in energy strategies that integrates all fuels, a prospective analysis was performed. Projections of energy demand and supply were estimated using a model implemented in the Open-Source Energy Modelling System (OSEMOSYS), an open-source systems optimization model for long-run energy planning. The projections timeline covers from 2018 to 2050 and each APEC member economy was individually modelled. This analysis is circumscribed to the energy use of hydrogen, therefore, demand for hydrogen as an industrial feedstock was not considered.

Hydrogen was divided into brown hydrogen, grey hydrogen, blue hydrogen, green hydrogen, and hydrogen produced as by-product of industrial activities. Information such as hydrogen domestic plans, roadmaps, strategies, etc. were incorporated if they were available. The conditions of each member economy, such as natural energy resources availability, were incorporated into the model as restrictions for each type of hydrogen production in each economy.

Considering the low social acceptability that surrounds nuclear energy projects, pink hydrogen, hydrogen produced via electrolysis using electricity from nuclear plants, was not considered. Additionally, yellow hydrogen, the one that is produced via electrolysis but using grid electricity, was also not considered because of the big share of fossil fuels in the electricity grid.

The developed scenarios were the following: the Reference (REF) scenario and the Carbon Neutrality (CN) scenario. REF is a pathway where existing tendency in technology development and deployment, and policy frameworks are known and follow historical trend such as continues improvement in energy efficiency and fuel economy standards. Hydrogen demand in REF considers exclusively domestic demand with emphasis in transport and industrial sector.

In contrast, CN present a potential pathway where energy efficiency, fuel switching, and technology advance to reduce CO_2 emissions from fossil fuel combustion by 2050. CN reflects higher ambitions for hydrogen consumption in final energy demand sectors and incorporates potential exports. Additionally, more stringent environmental standards for bunkers are implemented in the CN.

Finally, the OSEMOSYS model solves for the optimal mix of different types of hydrogen for each individual member economy in both scenarios.

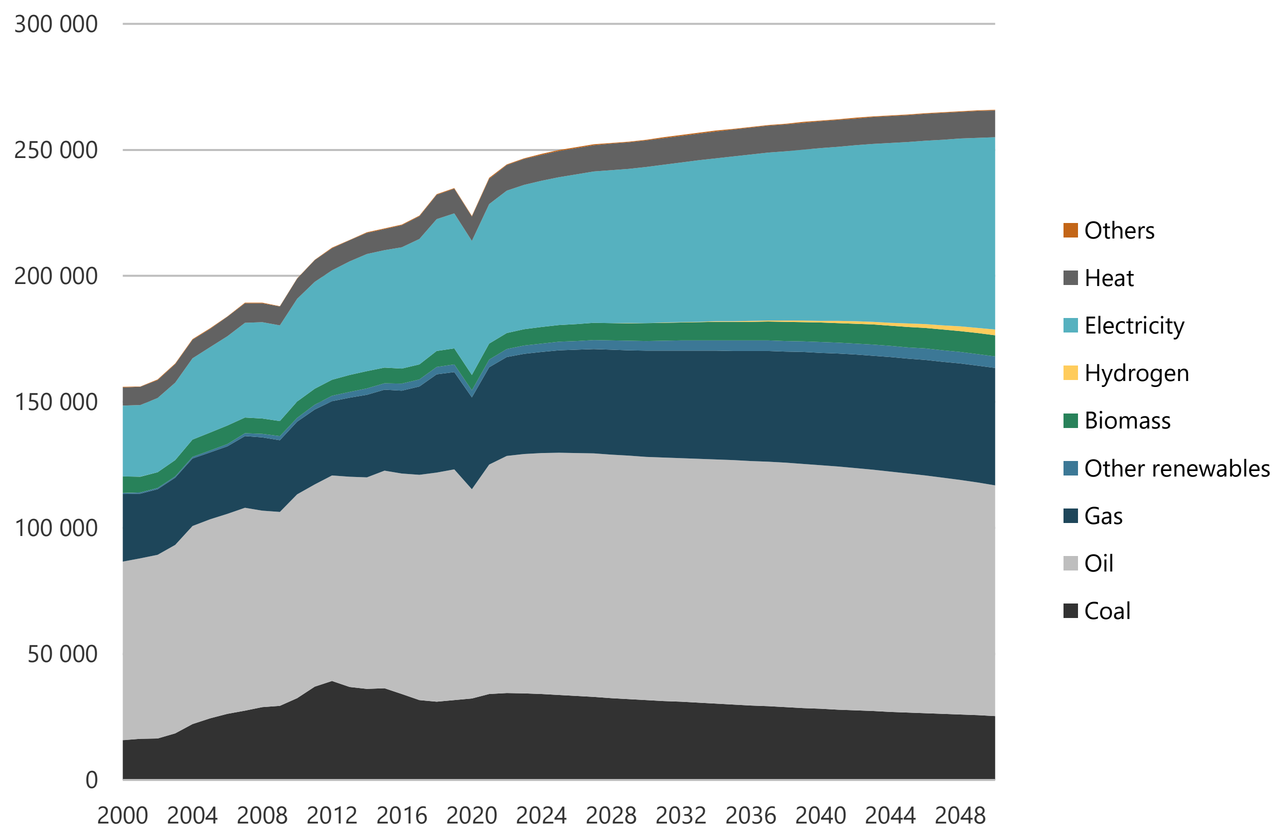
3 Results

3.1 Reference Scenario

Japan and the United States of America (USA) are largest hydrogen for energy consumers in APEC, mainly in the transport sector with some electric fuel cell vehicles projects. In REF, hydrogen for energy demand starts to grow in APEC after 2025 when the implementation of the hydrogen strategies to build demand begins to show effects. Between 2025 to 2030, hydrogen demand goes from around 10 PJ to more than 70 PJ. By then, Japan and USA represent almost two thirds of APEC's hydrogen demand, meanwhile the demand in People's Republic of China (PRC) start to grow. By 2050, hydrogen demand reaches 2200 PJ and PRC becomes the main hydrogen consumer in APEC with more than a half of the hydrogen demand. USA remains a top hydrogen consumer with almost 30% of the demand in 2050.

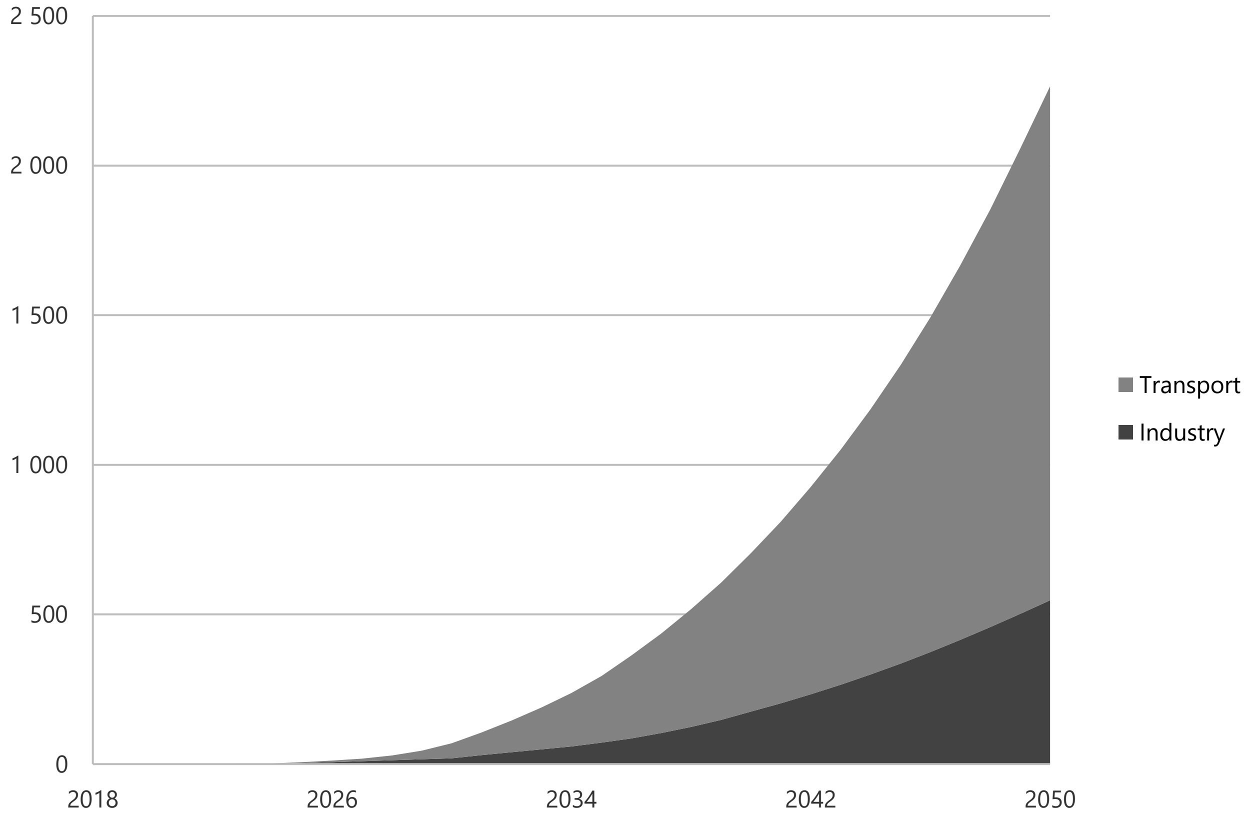
Despite its substantial increase, hydrogen accounts for just around 1 % of APEC's final energy demand by 2050. The demand of oil and oil products, the main target for the use of hydrogen as an alternative fuel, is curbed by energy efficiency improvements and the electrification of the demand.

Figure 2: APEC's final energy demand by fuel in REF 2018-2050



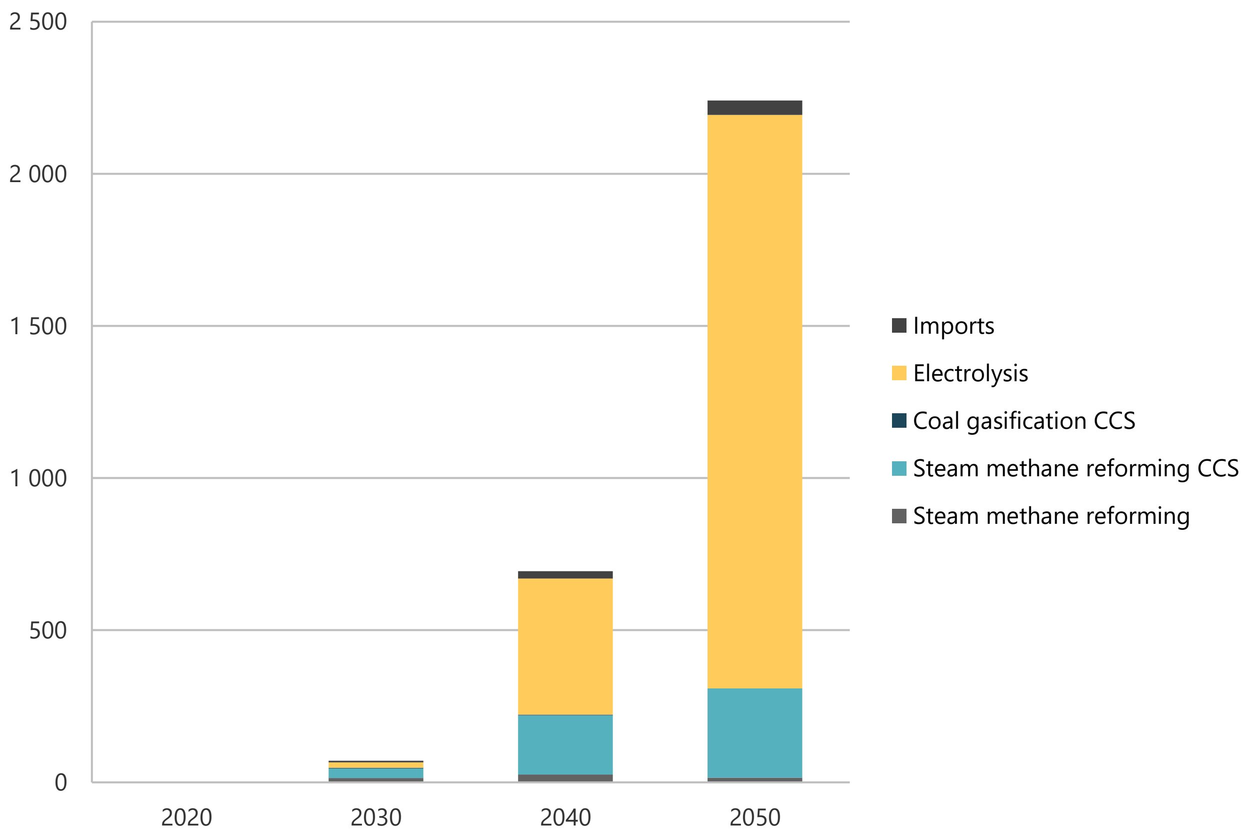
Hydrogen is expected to be consumed mainly in transport for long-distance heavy-duty transport. This consumption of hydrogen represents 3% of the total energy demand in transport by 2050. On the other hand, hydrogen is also used in industry mainly in steel production. These sectors are considered the demand hubs in several launched strategies.

Figure 3: Hydrogen demand by sector in PJ in REF



Until 2030, hydrogen produced from fossil fuels, grey hydrogen initially and later blue hydrogen, is the dominant type of hydrogen in APERC due to production costs, however, after 2030, the competitiveness of green hydrogen makes this type of hydrogen the dominant type throughout APEC.

Figure 4: Sources of hydrogen demand in PJ in REF



Grey hydrogen production growth from 0.3 PJ in 2018 to 25 PJ in 2040, then there is a decline of production reaching 15 PJ in 2050 because of the increase of blue hydrogen capacity. Blue hydrogen capacity grows faster between 2030 and 2040, going from 30 PJ to around 200 PJ. Later, blue hydrogen capacity keeps growing and reaches almost 300 PJ in 2050. This blue and grey hydrogen production capacity requires 410 PJ of natural gas by 2050.

Coal-based hydrogen increases from 0.1 PJ to 2.2 PJ by 2040, then competitiveness of other sources of hydrogen replaces this hydrogen with other types by 2050.

By 2050, green hydrogen production is estimated in around 1900 PJ requiring electrolyser capacity of 140 GW[1]; this is a substantial growth from the 300 MW of global capacity by mid-2021 (IEA, 2022). PRC is an important contributor to this trend as green and low carbon hydrogen in China play an increasingly important role as green hydrogen displaces coal-based hydrogen from the early years.

Additionally, imports are essential for some economy members such as Japan and Republic of Korea to satisfy their domestic demand.

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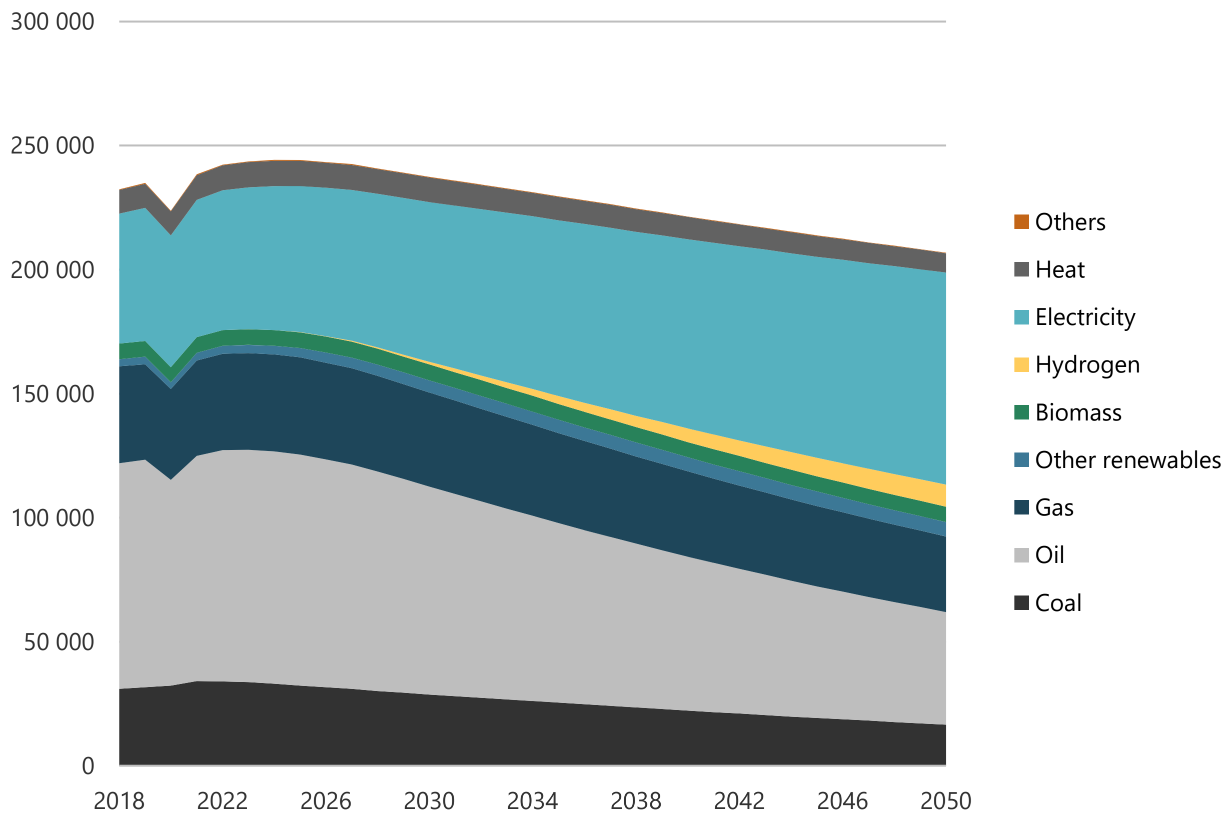
[1] Assuming 75% of efficiency and capacity factor of 57%.

3.2 Carbon Neutrality Scenario

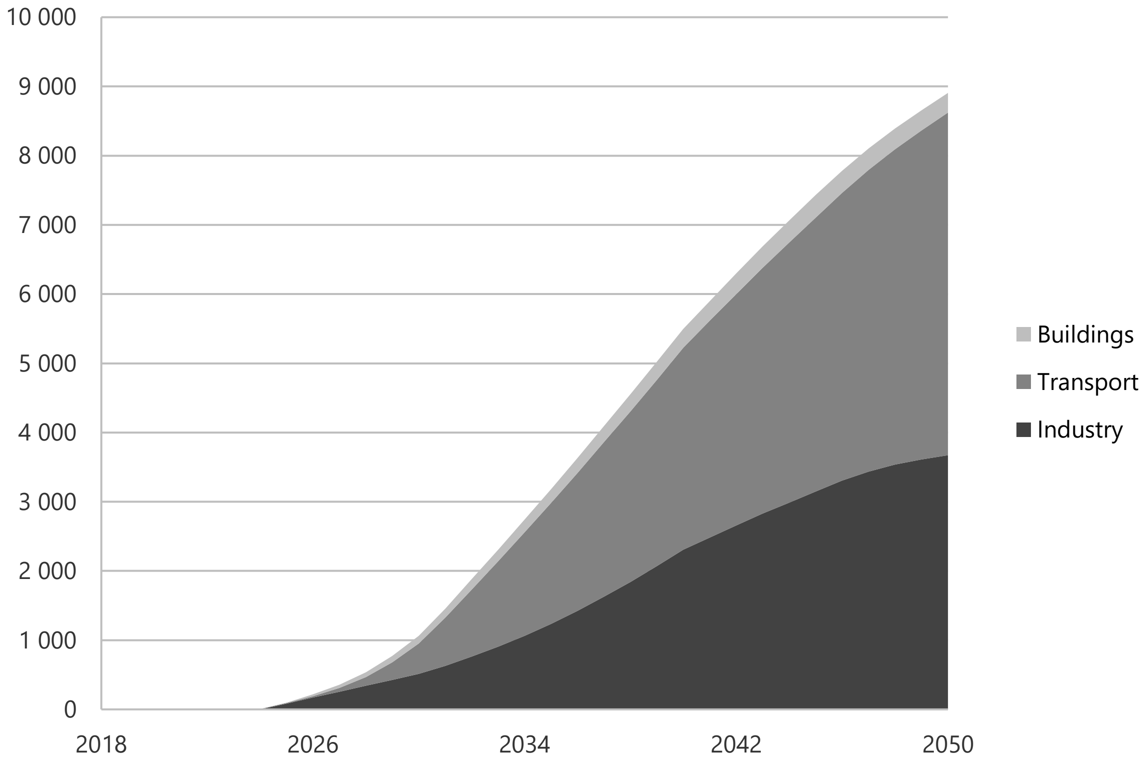
Demand for hydrogen energy in CN is higher than REF at around 9000 PJ or 4% of APEC's energy demand in 2050 even though final energy demand is 20% less than final energy demand in REF, indicating that there is higher penetration rate of hydrogen. This can be observed by the increase of hydrogen participation in all APEC economy members. Other economies -excluding PRC, USA, and Japan- represents one third of the APEC's hydrogen demand in CN.

Figure 5: APEC's final energy demand by fuel in CN 2018-2050



This increase of hydrogen demand is due to higher consumption in fuel cell vehicles, six times more than in REF, and more dynamic growth of hydrogen in industry that demands around seven times more than in REF. Additionally, hydrogen is used in building sector, mainly as part of the mixture hydrogen-natural gas, up to 20 vol %, that is used to reduce natural gas consumption and, consequently, CO_2 emissions from buildings.

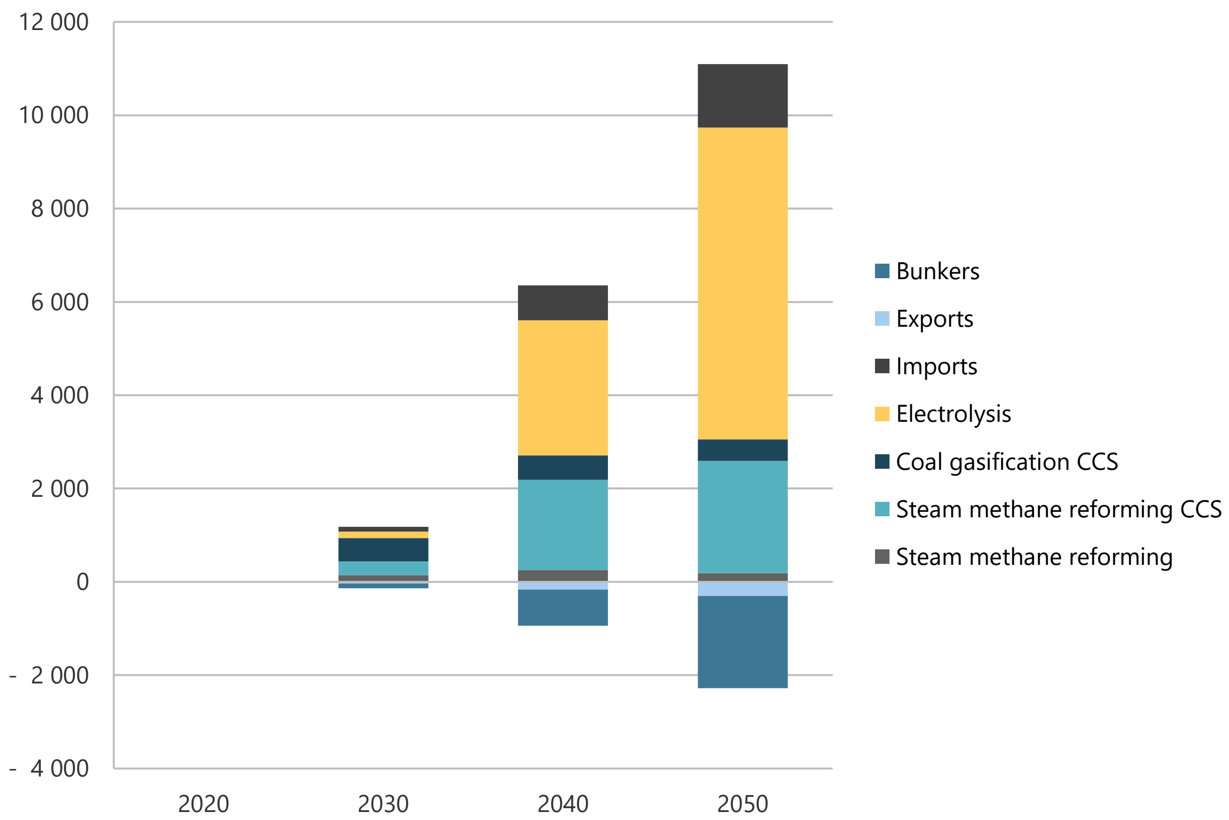
Figure 6: APEC's final energy demand by sector in PJ in CN 2018-2050



In CN, hydrogen capacity production increases significantly. Grey hydrogen capability produces 260 PJ by 2040, more than ten times the production in REF. Blue hydrogen production reaches 2400 PJ by 2050, six times more than in REF. This increase requires 3400 PJ of natural gas for hydrogen production, around 10% of the final energy demand of natural gas in APEC by 2050 in CN.

On the other hand, hydrogen produced by electrolysis is 250 % more in CN than in REF. This capacity requires 350 GW extra in electrolyser capacity. To supply to green electricity, additional renewal energy capacity must be built at around 800 GW. In this regard, hydrogen is not only an energy carrier but also an incentive for investment in renewable energy infrastructure.

Figure 7: Hydrogen supply in PJ in CN. Bunkers and exports are represented with negative values



Almost a quarter of APEC hydrogen production is exported or used by international marine and aviation bunkers in CN. It was assumed that very stringent environmental standards were imposed to international transportation, so hydrogen with very low or zero carbon can be used in this application. Imports satisfy almost 15% of APEC hydrogen demand, and a quarter of these imports are satisfied by exports within APEC.

4 Conclusions

APEC will continue to be an important player in the global energy sector. After initial leadership by Japan and Korea in building hydrogen demand, PRC and US will lead hydrogen for energy consumption in the long run. The importance of their vision regarding hydrogen can shape the future of hydrogen market in APERC. In a world that follows a path closer to CN, the participation of other APEC's economy members will grow.

Although the share of hydrogen in final energy demand may seem modest in the projections, hydrogen demand growth is very substantial, several-fold higher than in the past, even in the REF. This growth requires increased investments in hydrogen production capacity, namely blue hydrogen, at the beginning, and, in later years, green hydrogen.

Transport, the second largest CO_2 emitter after power, is the sector that leads hydrogen consumption, particularly in long distance heavy freight and passenger transport. Industry is the second biggest hydrogen for energy consumer. Energy strategies focused on these sectors will affect the development of hydrogen demand in the economies greatly.

Hydrogen is not only a source of energy but also a driver for investment in other sources of energy such as natural gas and renewable energy. The requirements of energy supply from those sources to produce hydrogen will be important and can be comparable with other uses in the APEC's final energy demand.

Even though exports were implemented in CN because there are member economies such as Australia and Chile that are studying potential export markets, the estimated APEC hydrogen demand still requires additional imports from other sources. These results show potential opportunities for trading, especially in economies that have not yet developed a vision regarding hydrogen.

5 References

Asia-Pacific Economic Cooperation (2021) *Energy* Energy|APEC. https://www.apec.org/groups/som-steering-committee-on-economic-and-technical-cooperation/working-groups/energy

Asia Pacific Energy Research Centre, *APEC Energy Demand and Supply Outlook 8th Edition* [scheduled to be published in June 2022]

BloombergNF (2021) *"Green Hydrogen to Outcompete Blue Everywhere by 2030"*. Retrieved from https://about.bnef.com/blog/green-hydrogen-to-outcompete-blue-everywhere-by-2030/

Chile's Ministry of Energy and Mines (2020) *National Green Hydrogen Strategy.* Retrieved from https://energia.gob.cl/sites/default/files/national_green_hydrogen_strategy_-_chile.pdf

China Hydrogen Alliance (2020) *White Paper of Hydrogen Energy and Fuel cell Industry in China*. Retrieved from http://www.szguanjia.cn/article/2435

COAG Energy Council (2019) *Australia's National Hydrogen Strategy*. Retrieved from https://www.industry.gov.au/sites/default/files/2019-11/australias-national-hydrogen-strategy.pdf

Hydrogen Council (2020) Path to hydrogen competitiveness A cost perspective. Retrieved from https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf#:~:text=A%20path%20to%20hydrogen%20cost%20competitiveness%201%20TCO,how%20to%20best%20take%20on%20this%20unprecedented%20challenge.

Hydrogen and Fuel Cell Strategy Council (2019) *The Strategic Road Map for Hydrogen and Fuel Cells*. Retrieved from https://www.hydrogenenergysupplychain.com/wp-content/uploads/2021/07/0312_002b.pdf

International Energy Agency (2019) The Future of Hydrogen, Seizing today's opportunities. Retrieved from https://www.iea.org/reports/the-future-of-hydrogen

International Energy Agency (2020) Tracking Hydrogen 2020. Retrieved from https://www.iea.org/reports/tracking-hydrogen-2020

International Energy Agency (2021) Global Hydrogen Review 2021. Retrieved from https://www.iea.org/reports/global-hydrogen-review-2021

Korean Ministry of Trade, Industry and Energy (2019) Hydrogen Economy Roadmap

Ministry of Business, Innovation & Employment (2019), *A vision for hydrogen in New Zealand*. Retrieved from https://www.mbie.govt.nz/assets/a-vision-for-hydrogen-in-new-zealand-green-paper.pdf

Morgan Lewis (2020) *Summary of Russia's proposed roadmap to develop the hydrogen economy.* Retrieved from https://www.morganlewis.com/-/media/files/document/2020/russia-hydrogen-roadmap-table.pdf

Natural Resources Canada (2020) *Hydrogen strategy for Canada, Seizing the Opportunities for Hydrogen. A call to Action*. Retrieved from https://www.nrcan.gc.ca/climate-change-adapting-impacts-and-reducing-emissions/canadas-green-future/the-hydrogen-strategy/23080