# Chapter 1

# Introduction

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# Chapter 1

# Introduction

## 1. Background

In the past 2 years, the Economic Research Institute for ASEAN and East Asia (ERIA) has identified a significant potential for hydrogen energy supply and demand in the East Asian Summit (EAS) region. China is one of the biggest potential producers and consumers of hydrogen energy in the near future (ERIA, 2019).

As of May 2021, out of 34 Chinese provincial administrative regions, 18 (plus at least 22 municipal administrations) have published policies to develop hydrogen energy-related industries and infrastructure; this is complemented by 18 relevant policy documents issued by the central government.[1,2] Among the provincial and municipality administrations, Guangdong province issued the most policies.

There are currently over 8,000 fuel cell electric vehicles (FCEVs) operating in China, mostly supported by demonstration projects, together with over 80 hydrogen refueling stations (HRSs) (IEA, 2021). It is expected that the number of FCEVs will reach 1 million units and HRSs will increase to 1,000 units by 2030 (Li and Kimura, 2021).

Leading economies around the world have also announced or upgraded their plans about hydrogen in recent years, as summarised in Table 1 and Table 2.

**Table 1.1: Announced Plan/Estimation for Hydrogen Station Infrastructure Development**

| Country | 2020 | 2025 | 2030 |
|---|---|---|---|
| China | 100 stations | 300 stations | 1,000 stations |
| France | 100 stations (2023) | 355 stations | 1,000 stations (2028) |
| Germany | 100 stations | 400 stations | 1,000 stations |
| Japan | 160 stations | 320 stations | 900 stations |
| Rep. of Korea | 310 stations (2022) | N.A. | 1,200 stations |
| UK | 65 stations | 300 stations | 1,100 stations |
| US | 115 stations | 320–570 stations | 1,500–3,300 stations |

N.A. = not applicable.
Source: Li and Kimura (2021).

[1] Source: http://www.sohu.com/a/327206089_618917 (accessed 23 May 2021).
[2] Source: https://www.qianzhan.com/analyst/detail/220/210329-199cd898.html (accessed 23 May 2021).

**Table 1.2: Announced Plan/Estimation for Hydrogen Fuel Cell Vehicles**

| Country | 2020 | 2025 | 2030 |
|---|---|---|---|
| China | 5,000 FCEVs | 50,000 FCEVs | 1,000,000 FCEVs |
| Germany | 10,000 FCEVs | 100,000 FCEVs | 1,800,000 FCEVs |
| Japan | 40,000 FCEVs | 200,000 FCEVs | 800,000 FCEVs |
| Rep. of Korea | 80,000 FCEVs (2022) | N.A. | 6,200,000 FCEVs |
| US | 20,000 FCEVs | 90,000–200,000 FCEVs | 1,800,000–4,500,000 FCEVs |

FCEV = fuel cell electric vehicle, N.A. = not applicable.
Source: Li and Kimura (2021).

## 2. Research Questions: Barriers Faced in Developing Green or Clean Hydrogen Energy

However, it is surprising to find that most of these demonstration projects currently source hydrogen from conventional natural gas reforming and petroleum refineries' by-products. An ERIA study published in 2020 identified two main barriers to developing green or clean hydrogen energy. First, there is a lack of comprehensive and valid feasibility studies on the potential projects to produce hydrogen from renewable or clean energy sources, as well as their associated energy infrastructure network for transportation and distribution. Second, there is a lack of consensus among stakeholders regarding who should resolve the standing institutional and regulatory barriers to said projects. For example, in China, under the current regulations, power grid companies have no redundant capacity to transmit curtailed renewables, as well as nuclear energy to hydrogen production facilities near the demand market; neither do they have incentives to build dedicated new lines. Furthermore, the current power sector regulations in China do not allow onsite production of hydrogen at the renewable power stations, using the curtailed electricity.

Feasibility studies and implementation plan studies are thus called for to accelerate the development of large-scale green or clean hydrogen energy demonstration. Aiming at shaping a roadmap for stakeholders of hydrogen energy development, these studies collect information and ideas from field experts in industry, government, and academia to comprehensively identify solutions to both economic and non-economic barriers. By doing so, the studies significantly reduce the potential risks involved with the proposed large-scale renewable to hydrogen energy demonstration projects in China. They also serve to summarise the best practices and experience from existing and successful demonstrations and share the lessons in China as well as around the world.

## 3. Component Studies: Methodologies and Main Findings

This ERIA research project report covers the technical, economic, financial, institutional, regulatory, and policy issues related to enabling large-scale hydrogen energy demonstration projects in China. The research processes involve collaborations and interactions with industrial entities, government bodies, and research institutes in China, in order to identify key barriers as well as proper and practical solutions in the above-mentioned dimensions, and deliver a roadmap to realise large-scale green or clean hydrogen demonstration projects.

Chapter 2 is contributed by the Institute of Energy Economics, Japan, which provides ***a high-level outlook of the demand and supply of hydrogen as energy in China***, under the background of the carbon neutrality target recently announced by the Chinese government. Accordingly, this implies that the demand for hydrogen energy from China's road transport and power sectors will reach 58 Mtoe by 2040. On the supply side, it is estimated that green hydrogen produced using curtailed variable renewable energy could reach 140 Mtoe. Theoretically, then, green hydrogen alone has the potential to meet hydrogen energy demand in China, while the remaining potential capacity could be used to further decarbonise other sectors of the Chinese economy. However, such a vision depends on the micro-economics, namely in each hydrogen energy project, as well as how policies and institutions enable and facilitate such a transition.

Chapter 3 is contributed by a research team led by Prof. Long from Huazhong University of Science and Technology. It presents a ***technical and economic feasibility study of hydrogen sourced from renewables in Southern provinces*** such as Fujian, Jiangxi, Guangxi, and Hunan for supply to Guangdong province, an emerging demand center for hydrogen energy. It is found that small-scale liquefied hydrogen production, such as in the case of Hunan-Guangdong scenario, delivers the lowest supply cost. In the case of large-scale hydrogen production, such as in Fujian-Guangdong scenario, natural gas pipelines adapted for mixed hydrogen and natural gas offer the most cost-effective solutions. The cost of hydrogen supplied from these four provinces to Guangdong ranges between CNY31–41/kg, under the current circumstances.

Chapter 4 is contributed by a research team from Dalian University of Technology. It presents a study on the ***economic feasibility of a cooling - heating - power - hydrogen multi-generation***, applied in a specific case in an urban community of Dalian city of Liaoning province in China. The study found that the integration of renewables-to-hydrogen into a grid-connected Combined Heat and Power system could help minimise the latter's cost to meet the energy demand of the community. The costs of hydrogen production and delivery are US$2.48/kg and US$3. 35/kg, respectively, in such a case.

Chapter 5 is contributed by a research team from Guangdong Electric Power Design Institute of China Energy Engineering Group. It studies the ***technical and economic feasibility of hydrogen production from offshore wind power***, in the context of Guangdong province. The cost of hydrogen produced from offshore wind farms located in Guangdong and transported by pipeline to land ranges between CNY33–42/kg, after considering the government subsidy on offshore wind electricity at CNY0.45/kWh, about 50% of the actual cost.

Chapter 6 is contributed by a research team led by Prof. Tagizadeh-Hesary from Tokai University. This study addresses the financial feasibility of hydrogen energy projects in China to identify ***appropriate financing solutions***. Gradient sensitivity analysis was adopted to assess the impact of financial costs on the net present value of hydrogen energy projects. The method was applied to three hydrogen projects in Guangdong province (two cases) and Jiang Xi province (one case). It is found that lowering financing risk, for example, through green financing mechanisms, could improve profitability of hydrogen energy projects.

Chapter 7 is contributed by a research team lead by Dr. Sun, former executive director of the International Energy Forum. It surveys the current status, challenges, and opportunities of developing hydrogen energy in China. In doing so, lessons from leading economies around the world are also drawn. Correspondingly, a comprehensive set of ***policies and strategies*** are proposed to accelerate the development of hydrogen energy in China. Importantly, systematic demonstrations in various application fields, as well as the strategic importance of developing green hydrogen, were emphasised.

Chapter 8 is contributed by a research team lead by Dr. Wang from Green World Low-carbon Economy & Technology Center, China. It analyses the feasibility of large-scale development of the hydrogen energy industry in China from the perspective of ***safety laws and regulations***, some of which appear to be overly stringent, such as the restriction on the land property in the process of making hydrogen production. Some regulations need to be improved, such as the lack of regulatory requirements for long-distance hydrogen pipelines. International experience from the US, the European Union, Japan, and Republic of Korea is summarised. It is concluded that China should improve the top-level design as soon as possible and speed up the technical basic research to support the continuous improvement of safety standards, especially in the areas identified in this chapter.

Chapter 9 is contributed by a research team lead by Dr. Liu from Guohua Energy Investment Co., Ltd., a member of the China Hydrogen Alliance. It analyses ***key factors of the global green hydrogen standards***, and how to establish a quantitative evaluation system of low-carbon hydrogen, clean hydrogen, and renewable hydrogen by using life cycle assessment. The issue is essential in promoting the role of clean and green hydrogen and thus enabling carbon neutrality, which is the ultimate motivation of developing hydrogen energy.

Chapter 10 is contributed by a research team lead by Prof. Youngho Chang from Singapore University of Social Sciences. It ***estimates the potential of carbon emissions reduction that could be achieved*** if curtailed electricity from intermittent renewables in both the Association of Southeast Asian Nations (ASEAN) and EAS context by 2050. EAS consists of the 10 ASEAN countries, along with Australia, China, India, Japan, New Zealand, and Republic of Korea. Importantly, it is found that if carbon prices are higher than

US$20/tonne of $CO_2$, then producing hydrogen from curtailed electricity from renewables via electrolysis could be cost effective, even under a low electrolyser utilisation rate, such as 1,000 hours per year.

Chapter 11 is contributed by a research team led by Dr. Shi from University of Technology Sydney. ***Strategies and policy frameworks leading to a shift to green or low-carbon hydrogen*** have not been explored in depth nor identified clearly in the context of China. This study aims at bridging such gaps. A survey method and roadmapping technique have been applied to survey experts on hydrogen energy from government bodies, industries, and academia and achieve basic consensus on strategically enabling large-scale green hydrogen demonstration, followed by commercialisation in China. A strategic roadmap is thus derived based on these findings, with recommendations on policy principles and tools at each phase of the development of hydrogen energy in China.

## 4. Conclusions and Policy Recommendations

With the above-mentioned studies, in the context of China, this report concludes the following:

First, as hydrogen and fuel cell technologies are maturing commercially, it is important to identify scenarios and applications that could make these technologies cost-competitive as low-hanging fruits to enable initial penetration of the technologies. More studies on the technical and economic feasibility of large-scale renewable and clean energy to hydrogen projects in such scenarios and applications are thus called for, so as to comprehend whether any technical and economic barriers and gaps exist.

Second, technical and economic feasibility of hydrogen infrastructure and supply chains is equally important, especially in the sense of determining what kind and scale of infrastructure network and supply chain capacity should be developed to enable large-scale development of green and clean hydrogen energy in China.

Third, on the one hand, the safety of large-scale hydrogen energy projects is a precondition and thus calls for updated or newly developed legislation, regulation, and standards; on the other hand, the existing institutional and regulatory system may not be a good match with the characteristics of the new hydrogen and fuel cell technologies, especially as technologies are still developing fast. Therefore, continuous research in this regard is called for.

Fourth, systematic and comprehensive policy frameworks are called for in order to develop the abovementioned dimensions. In the meantime, it is important that policies help forge a series of market mechanisms for large-scale renewable and clean hydrogen energy projects, such as those in the power market, the carbon market, and green financing. In this regard, this report contributes a strategic roadmap for policies, as well as other stakeholders' strategies and actions in line with the proposed policies.

Lastly, international cooperation is critical in achieving accelerated adoption of hydrogen and fuel cell technologies and the development of green and clean hydrogen energy. There are at least three major dimensions of international collaboration: (1) international coordination in policy support for hydrogen energy, especially in market creation and international trade of hydrogen energy, with special emphasis on green and clean hydrogen; (2) international collaboration in hydrogen and fuel cell supply chains, with lowering trade barriers in technologies and equipment, transfer of and joint research and development in technologies being the key in this regard; and (3) sharing best practices and lessons from existing and ongoing hydrogen energy demonstration projects globally.

With these, this study thus presents a high-level strategic overview and assessment on the feasibility of green and clean hydrogen energy in China. It is hoped that this project serves as a starting point for research institutes and experts in and outside of China to look further into more details of the issue of how to implement and accelerate the development of green and clean hydrogen energy in China.

**References**

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