Chapter 1

Introduction

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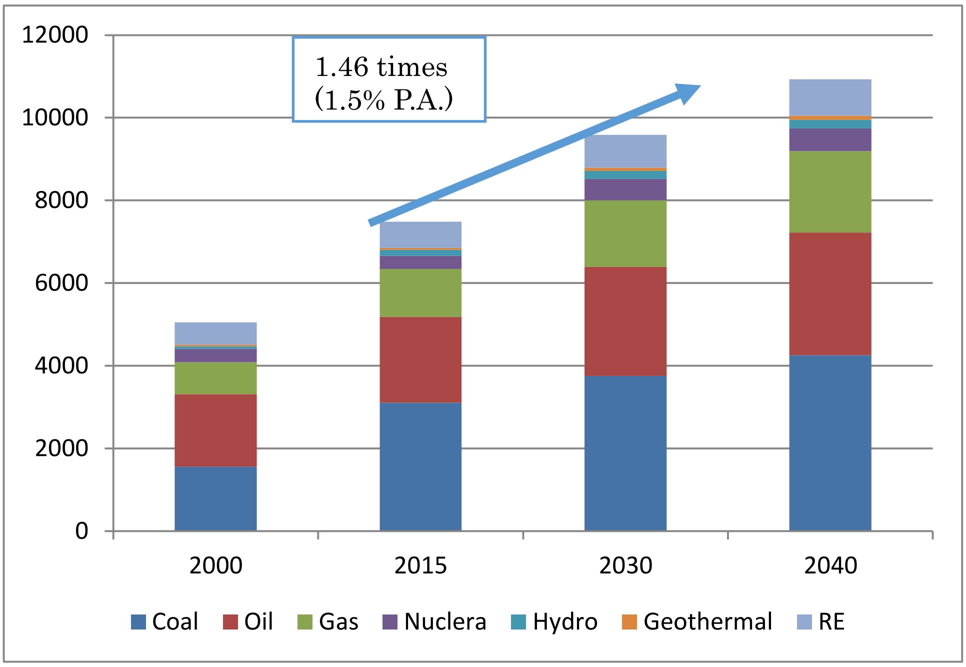
Chapter 1
Introduction

1. Energy Outlook in the East Asia Summit Region

According to the East Asia Summit (EAS) Energy Outlook produced by the Economic Research Institute for ASEAN and East Asia (ERIA), which covers ASEAN 10 countries plus Australia, China, India, Japan, Republic of Korea, New Zealand and United States, the total primary energy supply (TPES) will increase from 7,487 Mtoe in 2015 to 10,931 Mtoe in 2040. The annual growth rate will be 1.5% (1.46 times), two percentage points lower than the 3.5% per annum GDP growth rate in the same period. The share of fossil fuels will remain at more than 80% from 2015 to 2040, as shown in Figure 1.1. In this regard, CO_2 emissions will also increase 1.5% per annum, following the TPES.

Figure 1.1 Future Projection of TPES (in Mtoe)



Mtoe = million tonnes of oil equivalent, PA = per annum, RE = renewable energy, TPES = total primary energy supply.
Source: ERIA EAS Energy Outlook 2017 (2019).

Consequently, most energy policies in the EAS region promote efficiency and conservation (reduce fossil fuel consumption) and shifting to such low-carbon energies as nuclear and renewables (reduce CO_2 emissions). As a renewable energy source, hydrogen is highlighted to reduce CO_2 emissions for the following reasons:

a. **Zero CO_2 emissions**. Hydrogen bonds with oxygen to generate electricity/heat, with water as the only by-product.

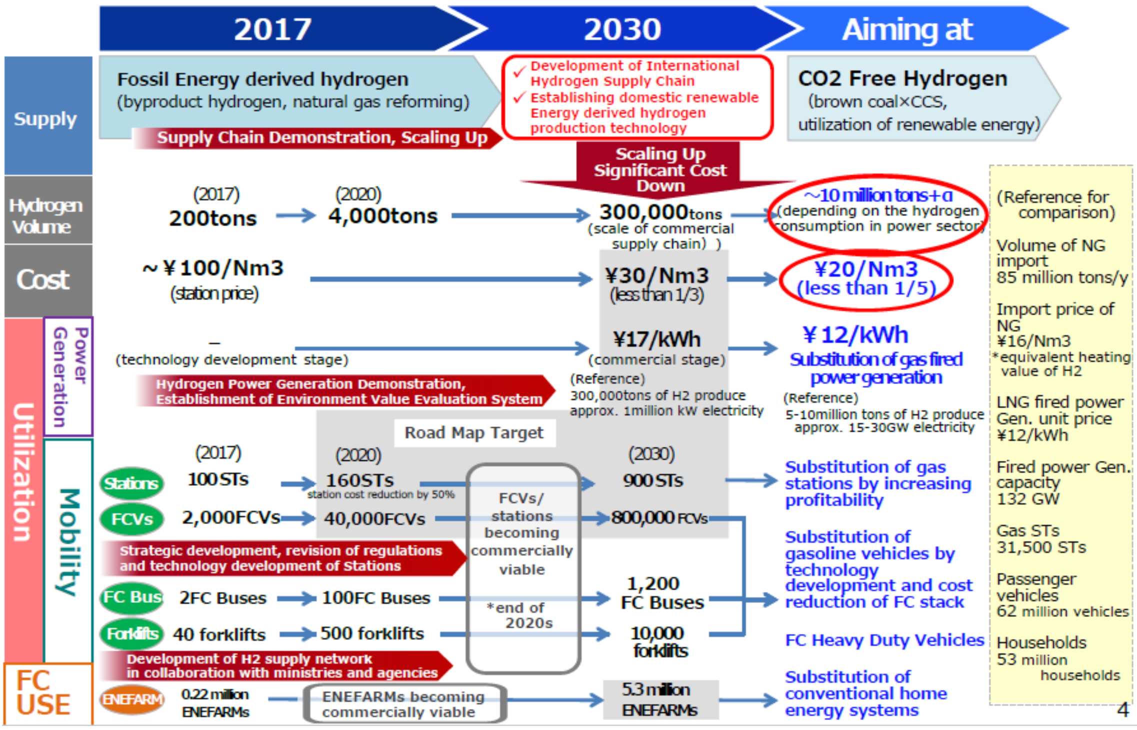
b. **Unlimited Supply**. Hydrogen can be extracted from a wide range of substances, including oil, natural gas, biofuels, and sewage sludge, and can produce unlimited natural energy by water electrolysis.

c. **Storage and transportation**. Hydrogen is able to store energy beyond the seasons and be shipped over long distances.

2. Current Trends of Hydrogen

The Ministry of Economy, Trade and Industry (METI), Japan, launched the Basic Hydrogen Strategy, as summarised in Figure 1.2. It was approved by the cabinet in December 2017, and details the action plans through 2030, as well as the future vision through 2050.

Figure 1.2 Basic Hydrogen Strategy in Japan



CCS = carbon capture and storage, FC = fuel cell, FCV = fuel cell vehicle, LNG = liquefied natural gas, NG = natural gas, STs = stations.
Source: METI, Japan (December 2017)

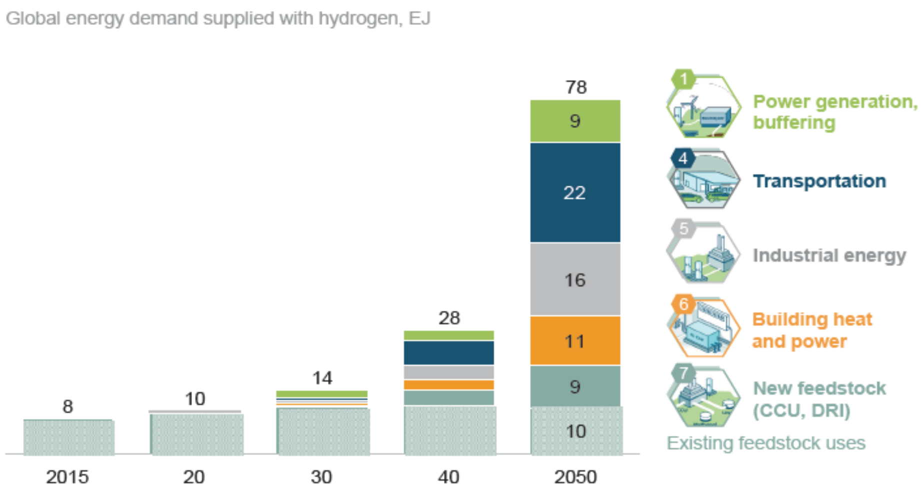
METI, Japan, also organised the First Hydrogen Energy Ministerial Meeting in Tokyo, held on 23 October 2018 (see Figure 1.3 for photo). More than 300 people from 21 countries, regions, and organisations met to discuss both demand and supply penetration of hydrogen.

Figure 1.3 Group Photo of the First Hydrogen Energy Ministerial Meeting

Source: Ministry of Economy, Trade and Industry, Japan.

In addition, the Hydrogen Council released the publication, 'Hydrogen Scaling Up' in November 2017, which mentioned that 20% of total final energy demand in 2050 will be covered by hydrogen, bringing such economic effects as more than US$2.5 trillion per year in revenue and more than 30 million people employed, as shown in Figure 1.4.

Figure 1.4 Expected Hydrogen Demand in 2050



CCU = carbon capture and utilisation, DRI = direct reduced iron.
Source: Hydrogen Council (November 2017).

In addition, Chiyoda Corporation (Chiyoda), in collaboration with Mitsubishi Corporation, Mitui & Co., Ltd., Nippon Yusen Kabushiki Kaisha, has started the world's first global hydrogen supply chain demonstration project using SPERA Hydrogen technology, funded by the New Energy and

Industrial Technology Development Organization, which will produce hydrogen in Brunei Darussalam for power generation in Japan. A maximum of 210 tonnes of hydrogen will be brought from Brunei Darussalam to Japan in 2020.

a. Scope of Work

Referring to the Energy Outlook results and the current hydrogen trends, ERIA conducted a hydrogen research study in collaboration with Chiyoda and The Institute of Energy Economics, Japan. The research contents are:

a. Review of renewable energy policies, including hydrogen
b. Forecasting future hydrogen demand potential
c. Forecasting future hydrogen supply potential
d. Well-to-wheel analysis
e. Site survey

i. Review of renewable energy polices, including hydrogen

This part reviews the existing polices on climate, renewables, and hydrogen (if available) of the following countries:

a. ASEAN 7 countries, except Cambodia, Lao People's Democratic Republic, and Myanmar due to the small potential of hydrogen demand and supply
b. Australia, China. India, Japan, Republic of Korea, New Zealand

Renewable energies, which consist of hydro power, geothermal power, solar photovoltaics and wind power, are potential sources of zero-emissions hydrogen, as detailed in chapter 4.

ii. Forecasting future hydrogen demand potential

Hydrogen will be used mainly in the following sectors:

a. Road transport (vehicle)
b. Power generation
c. Industrial heat

(1) Road transport (vehicle)

In July 2018, Japan introduced over 2,700 fuel cell vehicles (FCVs), serviced by 100 hydrogen stations, with an eventual 2025 target of 200,000 cars and 320 stations. Current FCV trends in Japan include the following:

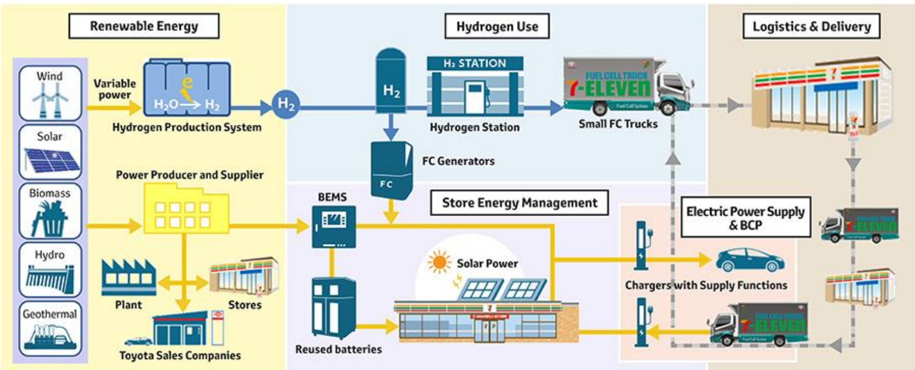
a. Joint venture for hydrogen stations

In March 2018, 11 companies (Toyota, JXTG, Tokyo Gas, etc.) established the 'JHyM' joint venture to promote an H2 station network.

b. Fuel cell trucks in '7-Eleven'

- 7-Eleven Japan and Toyota will jointly launch a next-generation convenience store project in autumn 2019.
- Small fuel cell trucks, fuel cell generators, solar panels, rechargeable batteries and BEMS will be made available in their stores and distribution.

Figure 1.5 New BEMS of '7-Eleven' Store



BCP = Business Continuity Planning; BEMS = Building Energy Management Systems; FC = fuel cell.
Source: Press release by 7-Eleven/Toyota.

c. Tokyo fuel cell buses

Tokyo introduced two fuel cell buses in March 2017 with the goal of increasing the number to 100 by the Tokyo Olympic Games in 2020.

For forecasting FCV deployment through 2040, three scenarios are applied in lieu of a single model:

a. Scenario 1: 2% of gasoline cars will be replaced by FCVs by 2040
b. Scenario 2: 10% of gasoline cars will be replaced by FCVs by 2040
c. Scenario 3: 20% of gasoline cars will be replaced by FCVs by 2040

(2) Power generation

To introduce hydrogen into power generation, gas turbine manufacturers have started demonstration/R&D for hydrogen combustion, and electric power companies have started feasibility studies to introduce hydrogen into their power plants.

a. Hydrogen gas turbine (MHPS)

   MHPS has successfully fired with a 30% hydrogen fuel mix in 2018 and will move to 100% hydrogen combustion in 2023.

b. Feasibility study for hydrogen power generation

   Japanese electric power companies KEPCO and Chuden conducted a hydrogen power generation feasibility study from 2018 to 2019.

   i. **Technical evaluation of hydrogen mix combustion**. Maximum ratio of hydrogen mix using combustor of existing gas turbine, Performance of combustion/power generation and impact for environment/durability/reliability by hydrogen mix combustion, Technical/risk analysis, related laws and regulations.

   ii. **Study of the hydrogen supply system**. Study hydrogen supply system regarding receiving, storage, supply, and fuel mix, and execute basic design at expected site.

   iii. **Basic design for hydrogen mix combustion system**. Execute basic design of hydrogen mix combustion system, based on results of technical evaluation.

   iv. **Economic evaluation**. Clarify technical challenges and evaluate future economics of hydrogen-mix power generation.

For forecasting power generation from hydrogen through 2040, three scenarios of hydrogen mixing ratios are applied in lieu of models;

a. Scenario 1: 10% hydrogen and 90% natural gas

b. Scenario 2: 20% hydrogen and 80% natural gas

c. Scenario 3: 30% hydrogen and 70% natural gas

(3) Industrial heat

We assume heating boilers and furnaces using natural gas can be replaced by hydrogen and consider one scenario:

Scenario 1: 20% natural gas will be replaced by hydrogen

iii. Forecasting future hydrogen supply potential

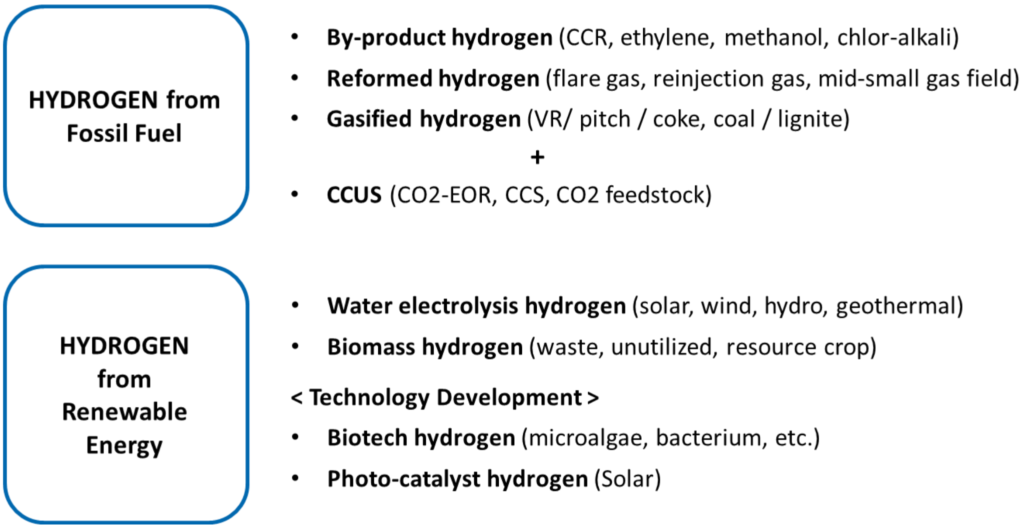
There are mainly two hydrogen sources:

a. Fossil fuel

b. Renewable energy

The detailed production processes are shown in Figure 1.6.

Figure 1.6 Hydrogen Production Method



CCR = Conradson carbon residue, CCUS = carbon capture, utilization and storage, EOR = enhanced oil recovery, VR = vacuum residue.
Source: Author.

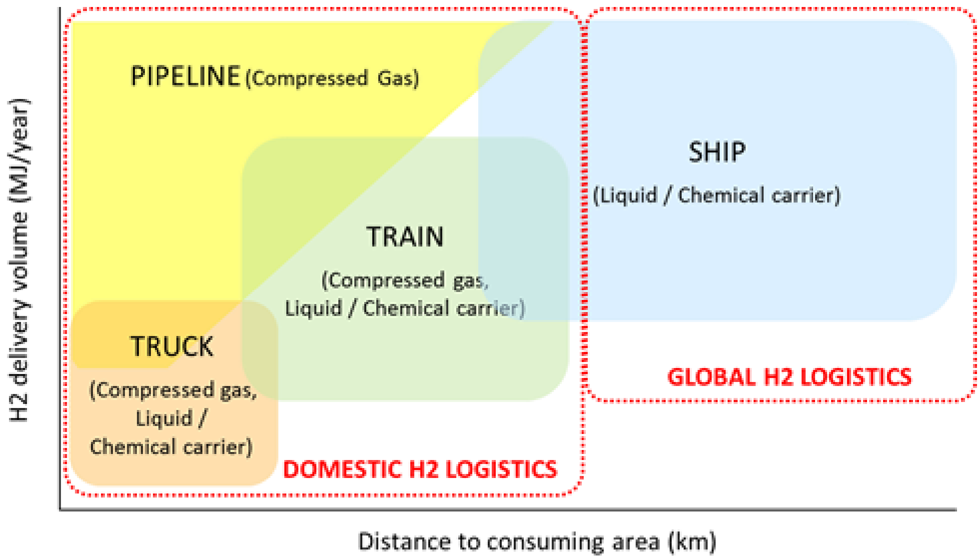
Gauging hydrogen supply potential based on proven reserves of coal (lignite), oil, and natural gas (mainly flare and mid-small size gas field) is linked to production potential forecasts. On the other hand, solar and wind potentials are forecasted using weather information such as solar radiation and wind speed. Nonetheless, some of the potentials will be used directly for electricity, so that the remainders will be used for production of hydrogen.

There are three transportation measures:

a. Ship
Liquid hydrogen tanker, chemical tanker, container vessel, barge, etc.
b. Train
Freight train, container train, etc.
c. Truck
Liquid hydrogen truck, chemical/gasoline tank truck, etc.
d. Pipeline
Hydrogen gas pipeline, natural gas pipeline, etc.

The choice of the measures depends on distance and volume, as shown in Figure 1.7:

Figure 1.7 Image of Hydrogen Logistics Portfolio



Source: Author.

In addition, the supply cost of hydrogen, including production and transportation, is examined.

iv. Well-to-wheel Analysis

Several types of vehicles, including internal combustion engine vehicles (ICEs), plug-in hybrid electric vehicles (PHEVs), battery electric vehicle (BEVs), and FCVs are compared in terms of energy consumption, CO_2 emissions, and total cost. The total cost consists of the capital cost (price of vehicle) and fuel costs (gasoline, diesel, electricity, as well as hydrogen). The energy consumption, CO_2 emission, and cost of hydrogen supply are built into the analysis based on the well-to-wheel concept. This study uses accurate cost data, but this is very difficult due to confidentiality constraints and a lack of agreed-upon measurements. For example, the FCV price in 2040 fully depends on technology development and market size.

v. Site Survey

Site surveys, i.e., information exchange meetings, were conducted with several organisations and offices regarding fossil fuels, renewable energy, and hydrogen. We visited Ministries of Energy (Policy, Oil and Gas, Renewables, including hydrogen), and national oil companies such as Pertamina, Petronas, and PTT, plus coal-mining companies and private hydrogen companies. The site survey covered the following six countries:

a. ASEAN

   Indonesia, Malaysia, Thailand

b. +6 Countries

   Australia, India, New Zealand

The meetings covered the following items:

a. introduction of this hydrogen research study, including the results
b. comments on the results
c. data collection regarding the production potential of fossil fuels, potential of CO_2/EOR & CCUS
d. power development plan, especially renewable energy
e. hydrogen policies