Mission-oriented R&I policies: In-depth case studies

Case Study Report

Hydrogen Society (Japan)
Case Study Report: Hydrogen Society (Japan)

European Commission
Directorate-General for Research and Innovation
Directorate A — Policy Development and Coordination
Unit A.6 — Open Data Policy and Science Cloud

Contact
Arnold Weiszenbacher
E-mail arnold.weiszenbacher@ec.europa.eu
RTD-RISE@ec.europa.eu
RTD-PUBLICATIONS@ec.europa.eu

European Commission
B-1049 Brussels

Manuscript completed in February 2018.

This document has been prepared for the European Commission however it reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.


Luxembourg: Publications Office of the European Union, 2018


Reuse is authorised provided the source is acknowledged. The reuse policy of European Commission documents is regulated by Decision 2011/833/EU (OJ L 330, 14.12.2011, p. 39).

For any use or reproduction of photos or other material that is not under the EU copyright, permission must be sought directly from the copyright holders.
Mission-oriented R&I policies: In-depth case studies

Case Study Report

Hydrogen Society (Japan)

Ville Valovirta

A Study coordinated by the Joint Institute for Innovation Policy

February 2018

Directorate-General for Research and Innovation
Table of Contents

1 Summary of the case study ................................................................. 3
2 Context and objectives of the initiative ............................................. 5
   2.1 Contextual factors and origins of initiative ..................................... 5
   2.2 Strategic and operative objectives and milestones of the initiative .......... 9
3 Resources and management ............................................................... 12
   3.1 Governance and management model ............................................. 12
   3.2 Financing model ........................................................................... 13
   3.3 Key actors and key technologies and platforms involved in the initiative .... 14
   3.4 Monitoring system and evaluation of the initiatives ............................ 17
   3.5 Level and type of citizen engagement in the initiative .......................... 17
4 Policy instruments and wider policy-mix used for implementing the initiative. 17
   4.1 Description of the R&I policy instruments ....................................... 17
   4.2 Connection with other policies ..................................................... 20
   4.3 International cooperation ............................................................ 20
5 Realised or expected outputs, outcomes and impacts ............................. 21
   5.1 Outputs ..................................................................................... 21
   5.2 Outcomes ................................................................................... 25
   5.3 Impacts ....................................................................................... 26
6 Conclusions and lessons learned ........................................................ 28
   6.1 Identification and assessment of key strengths and weaknesses of the initiative 28
   6.2 Lessons learned and key messages for European R&I policy .................. 29
References: ......................................................................................... 30
1 Summary of the case study

This document presents an analysis of a mission-oriented research and innovation policy initiative from Japan concerning Hydrogen Society. It covers the origin of the policy, the present state-of-play, and future directions extending several decades ahead.

The following table describes the main components of the case study:

<table>
<thead>
<tr>
<th></th>
<th>Hydrogen Society</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title:</strong></td>
<td>Hydrogen Society</td>
</tr>
<tr>
<td><strong>Country:</strong></td>
<td>Japan</td>
</tr>
<tr>
<td><strong>Thematic area:</strong></td>
<td>Energy, transportation</td>
</tr>
<tr>
<td><strong>Objective(s):</strong></td>
<td>Transform the Japanese energy supply, distribution and use towards wide-scale uptake of fuel cell technology and hydrogen as an energy carrier and ultimately as a renewable source of energy through carbon free hydrogen production technology. By 2040, the Japan aims to have established a completely CO2-free hydrogen supply system.</td>
</tr>
<tr>
<td><strong>Main Governing Body</strong></td>
<td>Ministry of Economy, Trade and Industry (METI)</td>
</tr>
<tr>
<td><strong>Timeline:</strong></td>
<td>1991-2040</td>
</tr>
<tr>
<td><strong>Budget:</strong></td>
<td>The government budget for the fiscal year 2017 is EUR 310 million. Throughout the entire duration of the strategy until 2040 the expenditure is expected to amount to several billions Euro.</td>
</tr>
<tr>
<td><strong>Brief description of the case (250 words)</strong></td>
<td>Japan’s government and industry have jointly decided to implement a Hydrogen Society plan, starting in 2015, with completion by or beyond 2040. This decision was made in the aftermath of the 2011 Earthquake and Tsunami disaster, which forced Japan to look for alternative sources of sustainable energy. The Hydrogen Society plan consists of three phases: Phase 1 is an extension of the current fuel cell programme, which includes broader diffusion of fuel cells into the global market accompanied by dramatic cost reduction of both hydrogen and fuel cells. Phase 2 envisions the large-scale introduction of hydrogen power generation and the establishment of a wide-spread hydrogen supply infrastructure. Phase 3 would establish a zero-carbon emission hydrogen supply system throughout the manufacturing process.</td>
</tr>
<tr>
<td><strong>Implementation and organisation (a brief description of the governance and policy instruments used)</strong></td>
<td>Cross-ministerial oversight; a Council for a Strategy for Hydrogen and Fuel Cells bringing together government, industry, academia representatives; public and private funding directed both at R&amp;D and financial incentives for stimulating market uptake.</td>
</tr>
<tr>
<td>Main elements of mission-oriented R&amp;I initiative¹</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>--</td>
</tr>
<tr>
<td>Directionality (links to societal challenges, industry transformation):</td>
<td><strong>Yes.</strong> The Hydrogen Society initiative responds to several of the Sustainable Development Goals defined by United Nations²: affordable and clean energy (goal 7), sustainable cities and communities (goal 11) and climate action (goal 13).</td>
</tr>
<tr>
<td>Intentionality (specific, well-articulated targets):</td>
<td><strong>Yes.</strong> Targets are focused and measurable.</td>
</tr>
<tr>
<td>Clearly set timeline and milestones:</td>
<td><strong>Yes.</strong> Strategic Roadmap sets a clear timeline with milestones for the upcoming years.</td>
</tr>
<tr>
<td>Mobilises public and private investments:</td>
<td><strong>Yes.</strong> Strongly public-private with significant engagement from the industry.</td>
</tr>
<tr>
<td>Focused on new knowledge creation (basic research, TRLs 1-4):</td>
<td><strong>Yes.</strong> R&amp;D on missing elements in the comprehensive hydrogen-based energy system: renewable methods to produce hydrogen, storage and transportation solutions (energy carriers), and more efficient fuel cell technologies.</td>
</tr>
<tr>
<td>Focused on knowledge application (applied research, TRLs 5-9):</td>
<td><strong>Yes.</strong> The major focus is on accelerating the market uptake. Also, close-to-market development to decrease the production costs and increase reliability.</td>
</tr>
<tr>
<td>Demand articulation (involves instruments for inducing demand):</td>
<td><strong>Yes.</strong> The demand is influenced through changes in regulation, provision of subsidies on purchasing price and investment costs, use of local public procurement, and promotion of standardisation.</td>
</tr>
<tr>
<td>Multi-disciplinary (inter-disciplinary and/or trans-disciplinary):</td>
<td><strong>Yes.</strong> To certain degree; science and engineering dominate, but other disciplines are also involved.</td>
</tr>
<tr>
<td>Joint coordination (multi-level and/or horizontal governance of policies/finance):</td>
<td><strong>Yes.</strong> Cross-ministerial coordination covers the key government departments and agencies.</td>
</tr>
<tr>
<td>Reflexivity (flexible policy design, timely monitoring):</td>
<td><strong>Yes.</strong> The later stages of the strategy are loosely defined in order to specify them as the technology evolves and markets shape up.</td>
</tr>
<tr>
<td>Openness (connected to international agenda and networks):</td>
<td><strong>Yes.</strong> Partnerships established at global level, bilateral R&amp;D partnerships, and bilateral hydrogen supply chain development relationships.</td>
</tr>
<tr>
<td>Involvement of citizens:</td>
<td><strong>To certain degree.</strong> The citizen involvement is mainly related to improving the social acceptance of fuel cells and hydrogen, with the main focus on safety.</td>
</tr>
</tbody>
</table>

¹ Assessment: Yes, To certain degree, No or Not known.
2 Context and objectives of the initiative

This Chapter contains an analysis of the initiative since the beginning until today, as well as an overview of the major milestones and main objectives. Also, the analysis describes the key barriers and drivers influencing the initiative, classified according to their nature.

2.1 Contextual factors and origins of initiative

The massive earthquake and tsunami in 2011 causing the Fukushima Daiichi nuclear reactor meltdown resulted in an immediate energy crisis in Japan. All 50 nuclear power plants were shut down necessitating substitution of 29% share of nuclear energy production with alternative sources. This led to drastic increase of fossil-based energy use from natural gas and coal in thermal power plants. It pushed Japan’s greenhouse gas emissions back on a fast-growing track offsetting earlier efforts to increase energy saving and carbon free energy. Increased dependence on imported fuels resulted also in considerable trade deficit.³

Soon after the incident the Japanese government undertook a comprehensive review of energy options for the future considering the radically changed energy landscape.⁴ Together with other drastic measures on a new energy policy, a long-term vision of transformation towards a hydrogen society was presented. There were several factors which supported considering it as a viable long-term energy solution.

First, Japan has few domestic sources of primary energy and its energy dependence on imports is the highest among major nations (Figure 1). Its energy independence ratio (without nuclear energy) is only 4%⁵. Being an island nation, it also has little potential to purchase power across the border from neighbouring countries, unlike many European nations such as France or Germany. Diversification of energy sources was considered having high importance.

![Figure 1. Energy import dependency of major energy consumer countries. Source: Hashimoto 2015.](image)

³ Behling et al. 2015.
⁵ Onoue et al. 2012.
Second, while renewable energy sources are recognised as having tremendous potential it was considered insufficient to substitute nuclear energy. Relying on expanding capacity of solar, wind and geothermal power sources is estimated to be insufficient and unreliable due to several factors: restricted generation potential, fluctuation of production, vulnerability to natural disasters, and limited land space in a densely populated country.

Third, the intermittent nature of solar and wind energy production and low maturity of energy storage solutions prevent expansion of renewable energy sources in large scale. The risk of massive power blackouts increases when electricity demand and supply become more variable. There is thus a need to develop decentralised energy supply system which can function to some degree independently of the centralised energy network operating at the level of a city or community.

Fourth, long-term technology development in fuel cells had advanced considerably bringing it closer to market maturity and wide scale deployment. Being able to stimulate market uptake of these new technologies would create industrial renewal, economic growth and employment.

Based on these considerations, a future relying on hydrogen energy and fuel cell technology deployment was assessed to be a viable path towards comprehensive energy transformation - along with other radical means to safeguard Japan’s energy supply and transform it towards a more sustainable direction.

The preconditions for the transformation had been created through major investments on fuel cell and hydrogen energy R&D during earlier decades. In the next section, a brief retrospective review of Japan’s technology development is presented.

Until 1990s Japan did not have internationally recognised competences in the fuel cells. Major technological inventions regarding various types of fuel cells had been made in Europe and the United States. In order to catch up with other major economies the Japanese government initiated an eight years R&D programme on fuel cell and hydrogen energy development in 1991. In 1999, an ex-post evaluation of results and outcomes concluded that Japan had caught up with global leaders.

With the encouragement from the positive results, the Japanese government launched another phase in the fuel cell technology development. The Millennium Project targeted developing fuel cell vehicles and residential cogeneration energy systems and bring them to the market by 2015. The early 2000s involved further development of fuel cell technology prototypes and applications. The first phase ran between 2002 and 2005 and aimed to develop the H2 infrastructure and to determine performance statistics from a small fleet of FCV. Between 2005 and 2008 a large-scale demonstration programme was conducted. More than three thousand fuel cell units were installed in Japan by several companies. The demonstration was carried out to verify system performance under various fuels and load patterns. System suppliers and energy providers worked together which contributed to establishing a new market. The demonstration was able to show that electrical efficiency of fuel cells is higher than conventional electricity generation

---

6 Behling et al. 2015.
7 NEDO 2015.
(over 45% compared to 25–35% for conventional combustion), and when the heat is used total efficiency of fuel conversion can approach 98%. This means that carbon dioxide emissions can be significantly reduced.

When Japan was hit by the 2011 earthquake and energy crisis, a strong technological basis was thus available for inclusion of fuel cells and hydrogen energy in the long-term energy planning scenarios. Japan was well positioned to craft a comprehensive strategy to harness hydrogen as an energy carrier and promote adoption of fuel cell technologies.

The Hydrogen Society Plan emerged from several policy planning activities between 2011 and 2014. In October 2011, the Ministry of Economy, Trade and Industry (METI) set a goal in its Energy White Paper to conduct a complete review of Japan’s energy situation. The review was made by a committee at the Agency of Natural Resources and Energy (ANRE), resulting in publishing its results in the Energy White Paper in June 2012.

In 2013, Prime Minister Abe promoted the use of hydrogen in his second Economic Growth Policy Strategy. The policy involves deregulation of legislation governing the use of hydrogen distribution, storage and refuelling stations. Abe’s reform plan was approved by the Cabinet in June 2013. At the end of 2013, ANRE appointed a Council for a Strategy for Hydrogen and Fuel Cells (CSHF). The committee comprises 23 members from government, industry and academia. In 2014, the Council outlined measures along the route towards a hydrogen society. This roadmap was published by METI in June 2014.

The hydrogen society was further endorsed in the fourth Strategic Energy Plan outlining a comprehensive national energy strategy. The plan, approved by the Cabinet in April 2014, positioned the use of hydrogen as a secondary energy structure, which contributes to diversifying and stabilising energy supply and reducing global warming. CO2 free hydrogen was recognised as a key medium for energy storage in the future in the Outlook on National Energy & Environment Strategy for Technological Innovation towards 2050 (NESTI 2050). The first budget for the new hydrogen society plan involved the fiscal year 2015 for which a budget of EUR 400 million was allocated.

The strategic roadmap was revised in March 2016. In the revision, further emphasis was put to develop approaches to create a hydrogen-based energy system with low carbon dioxide emissions. This includes promotion of using hydrogen as an energy carrier that can store renewable energy in large-scale reserves for a long time. The technical advancement of power-to-gas technology electricity from renewable sources can be converted to hydrogen enabling energy storage and distribution.

The latest government statement is the Basic Hydrogen Strategy, published in December 2017. The strategy is the result of an investigation responding to Prime Minister Abe’s call for the government and stakeholders to come up with a formulation of a plan to realise the hydrogen society. As structural issues surrounding the energy supply and demand, the strategy takes note of the low energy self-sufficiency rate, dependence on fossil fuels, and long-term targets to reach the carbon dioxide reductions by 80% by

---

8 Behling et al. 2015.
2050 made in the Paris Agreement. Compared to earlier roadmaps, the latest strategy makes more specific targets regarding energy supply system, more diverse inclusion of economic sectors as users of hydrogen, recognition of other hydrogen-based energy carriers (methane, organic hydride, ammonia), and role of hydrogen infrastructure in enabling expansion of renewable energy systems. The key is to reduce cost of hydrogen to the same level as conventional energy such as gasoline and liquefied natural gas (LNG). It also sets targets for more diverse set of fuel cell applications such as fuel cell buses, forklifts, and buses, in addition to revising the targets for fuel cell passenger vehicles and residential fuel cells.

The following table summarises main external drivers and barriers for the hydrogen society strategy:

<table>
<thead>
<tr>
<th>Drivers</th>
<th>Barriers</th>
</tr>
</thead>
</table>
| • Political | • The energy crisis following the Great East Japan Earthquake and the subsequent nuclear power accident.  
• Pressures to diversify energy sources and improve security of energy supply.  
• Meeting international climate commitments without the nuclear energy option | • High price of fuel cells and hydrogen supply infrastructure  
• Overcoming the chicken-and-egg problem between uptake of fuel cell appliances and hydrogen supply infrastructure  
• Low price level of fossil fuels, particularly oil, has slowed down investments on new energy sources and reduced their price competitiveness in energy investments. |
| • Economic | • The aspiration to capitalise on Japanese industry’s leadership in fuel cell technology, established in earlier decades (1990s and 2000s).  
• Maintaining a favourable trade balance. |  
| • Societal | • The need to provide backup power supply during earthquakes and other natural disasters in case of electricity outages. Fuel cell electric vehicles may provide a power outlet which can be used to power up a standard household for a few days. | • Public concerns over the safety of hydrogen storage and distribution systems. |
| • Technological | • Japan’s global leadership with fuel cell development  
• Maturation of fuel cell and hydrogen energy technology in | • Infrastructure for large-scale hydrogen supply distribution does not exist yet. |
2.2 Strategic and operative objectives and milestones of the initiative

The main target of the Hydrogen Society plan is to transform the Japanese energy system towards hydrogen-based energy system in order to diversify energy sources, cut carbon dioxide emissions, and cope better with natural disasters. The government aims to maintain the global leadership of Japan in the nascent fuel cell technology industry and create economic growth.

The following strategic objectives were set in the 2014 plan:\textsuperscript{14}

\begin{itemize}
  \item The complexity of the technological system involved with the large-scale transformation to hydrogen-based energy system.
  \item Cost efficient production of carbon free hydrogen at a large scale is not yet available.
  \item Inhibiting or lacking regulation concerning the use of hydrogen as a new energy source (e.g. regulation prohibits hydrogen stations in dense urban areas).
  \item Stringent regulation governing hydrogen fuelling stations. Establishing a station in Japan may cost two or three times the price in Europe. Original regulations were written for the purpose of chemical production.\textsuperscript{13}
  \item Being emission free at point of use (emits only water) makes fuel cells an attractive solution in various applications, eliminating harmful local emissions.
  \item Hydrogen has higher energy yield per weight unit than other fuels.
  \item Potential to create a truly carbon free hydrogen supply system over the long term with power to gas (PtG) technology and carbon capture and storage (CCS) solutions.
  \item Until the primary production of hydrogen is based on renewable sources, the application of fuel cells shifts the CO2 emissions from the point of use to the site of hydrogen production.
  \item While hydrogen has high efficiency per weight unit, its transportation and distribution systems require higher environmental footprint decreasing the total sustainability over the life cycle.
\end{itemize}

\textsuperscript{13} Financial Times, October 24, 2017. \url{https://www.ft.com/content/98080634-a1d6-11e7-8d56-98a09be71849}
1. **Energy saving**: Use of fuel cells enables high energy efficiency contributing to energy saving targets;

2. **Energy security**: Hydrogen can be produced from various primary energy sources, including unutilised energy sources such as by-product hydrogen, flaring gas, and brown coal; and renewable energy sources. Procuring these energy sources from areas of relatively low geopolitical risk leads to enhancing energy security, and using renewable energy promotes energy self-sufficiency;

3. **Environmental load reduction**: Hydrogen does not emit CO2 when consumed. Applying Carbon Capture and Storage (CCS) technology to hydrogen production or using renewable energy enables a completely CO2-free system;

4. **Industrial promotion**: Japan ranks first in patent applications regarding fuel cells and holds global technology leadership in this field.

The hydrogen society involves a large-scale transformation framework involving the production, supply chain and use of hydrogen in various economic sectors (Figure 2). Hydrogen can be produced from several sources, including renewable energy and fossil fuels. The use sectors involve transportation, residential housing, commerce and businesses, as well as industrial production.

The Hydrogen Society plan consists of three phases (Figure 3). The first phase involves dramatic expansion of **hydrogen use and widespread diffusion of fuel cells**. This involves further dissemination of residential fuel cells earlier introduced to market,
commercialisation of fuel cells for commercial and industrial use, and introduction of fuel cell vehicles and achieving considerable reduction of vehicle price and hydrogen fuel price. These measures are aiming to bring about significant energy savings and leadership in the global market for hydrogen and fuel cells. Phase 1 is an extension of the earlier fuel cell programmes, which includes broader diffusion of fuel cells into the global market accompanied by dramatic cost reduction of both hydrogen and fuel cells. The first phase is to a large degree an extension of the earlier fuel cell R&D programmes resulting in introduction of residential fuel cells for combined heat and power in 2009 and fuel cell vehicles in 2014.

Figure 3. Strategic Road Map for hydrogen and fuel cells. Source: ANRE 2014.

The second stage targets introduction of **hydrogen power generation** and establishment of a large-scale system for **hydrogen supply**. Between 2015 and 2020 development and demonstration of these solutions are accelerated through R&D and demonstration. Building the supply requires establishing strategic partnerships with hydrogen suppliers overseas by tapping into unutilised energy sources (e.g. brown coal). By the mid-2020s, the inexpensive sources of hydrogen are expected to be available permitting the building up a commercially operating hydrogen distribution system. Around 2030, a fully-fledged system to use hydrogen for manufacturing, transportation and storage should be in place.

The third phase targets establishing a **carbon free hydrogen supply** system using renewable energy sources and using carbon capture and storage (CCS) technologies for fossil-based hydrogen. This capability is to be developed and demonstrated between 2015 and 2030s leading to putting the technology into practice around 2040. The ultimate goal is a CO2 free hydrogen supply system.
Japan is examining technologies to ship renewable energy to Japan from overseas sources (Figure 4). Hydrogen produced via water electrolysis from wind power in South America or hydropower in Russia could thus be transported for consumption in Japan.

With the phased progression of the roadmap, Japan intends to source hydrogen first from existing by-products of industrial processes, then extract it on the mid-term from unused overseas energy sources such as low grade coal (lignite, crude petroleum), and finally transform the hydrogen production to renewable energy sources on the long term once technology advances.

3 Resources and management

3.1 Governance and management model

The Hydrogen Society plan is a public-private undertaking with cross-sectoral political governance together with intensive private sector and academic involvement. The implementation relies on a collaborative science and technology policy implementation structure (San-Kan-Gagu Renkei Taisei) which was consolidated in the 1990s when the Science and Technology Basic Law was enacted. The collaborative structure was already a key factor in the early fuel cell and hydrogen implementation and has been further strengthened after 2014.

The overall policy coordination resides with the Ministry of Economy, Trade and Industry (METI). In 2013 METI appointed a Council for Strategy for Hydrogen and Fuel Cells (CSHF). The Council has 23 members from government, industry and research community. It maintains the strategic road map and reports to METI’s Agency of Natural Resources and Energy (ANRE). The Council functions as an advisory group for the government. In addition, a regulatory reform committee operates within the cabinet office. The group’s role is to identify regulatory reforms necessary to implement the hydrogen society plan.
3.2 Financing model

The government budget for the fiscal year 2017 was EUR 310 million (JPY 39 billion).\textsuperscript{15} The budget consists of research and development grants and support for fuel cell and hydrogen infrastructure deployment.

<table>
<thead>
<tr>
<th>Item</th>
<th>Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D of fuel cells</td>
<td>EUR 23 million (JPY 3.1 billion)</td>
</tr>
<tr>
<td>R&amp;D of hydrogen refuelling stations</td>
<td>EUR 31 million (JPY 4.1 billion)</td>
</tr>
<tr>
<td>R&amp;D for producing, transporting and storing hydrogen derived from renewable energy</td>
<td>EUR 7.5 million (JPY 1.0 billion)</td>
</tr>
<tr>
<td>Demonstrations for global hydrogen supply chain</td>
<td>EUR 35 million (JPY 4.7 billion)</td>
</tr>
<tr>
<td>Subsidies for stationary fuel cells</td>
<td>EUR 70 million (JPY 9.4 billion)</td>
</tr>
<tr>
<td>Subsidies for hydrogen refuelling stations</td>
<td>EUR 34 million (JPY 4.5 billion)</td>
</tr>
<tr>
<td>Support for fuel cell vehicles</td>
<td>EUR 91 million (JPY 12.3 billion)</td>
</tr>
</tbody>
</table>

\textsuperscript{15} METI 2017.
As the government R&D grants are typically provided as 50% co-funding, there is an equal amount of money invested by the private sector. In addition, it has been estimated that industry invests a further EUR 300 million each year on fuel cell and hydrogen technology.\(^{16}\) There is no precise information publicly available on private investments, but an estimate can be made on the basis of total R&D investments which indicate that 77% of Japanese R&D spending is made by private companies. For instance, Toyota Motor Corporation has announced that it has invested EUR 4 billion in fuel cell vehicle R&D by 2015.

Some private endowments also provide funding for research related to hydrogen energy. The Toyota Mobility Foundation (TMF) has established the Hydrogen Research Initiative to provide grants for original, innovative, and ambitious research by next generation scientists, and thereby support fundamental research on technological breakthroughs that will aid in establishing a hydrogen society.\(^{17}\) The research should contribute significantly to producing low-carbon and CO2-free hydrogen, as well as to reducing the cost of hydrogen systems, and expected to offer the potential to yield practical results between 2025 and 2030. The proposals are expected to focus on hydrogen generation, storage and transport, hydrogen applications (such as conversion to chemicals or fuels) and energy systems.

3.3 **Key actors and key technologies and platforms involved in the initiative**

**The Ministry of Economy, Trade and Industry (METI)**\(^ {18}\) is responsible for policy formulation and governmental steering of the hydrogen society strategy. As METI guides the government’s energy policy, it also implements the fuel cell and hydrogen energy deployment. Operating under METI’s supervision, the Agency for Natural Resources and Energy (ANRE) drafts Japan’s energy plans and oversees their implementation. Under ANRE, the operative responsibility lies with Hydrogen and Fuel Cells Strategy Office.

**The Council for a Strategy for Hydrogen and Fuel Cells (CSHF)**\(^ {19}\) was appointed by ANRE to advice the government on hydrogen energy deployment. The council is a cross-sectoral advisory group composed of 23 members representing government, industry, and academia.

**New Energy and Industrial Technology Development Organisation (NEDO)**\(^ {20}\) is a semi-public organisation promoting technology development in the field of energy solutions. It is positioned as an intermediary between government and the industry and

---

\(^{16}\) Behling 2016.


research organisations. Fuel cells and hydrogen is one of NEDO’s focus areas in the field of new energy technologies. NEDO’s role is to coordinate and integrate the technological capabilities of private enterprises and research abilities of universities instead of hiring researchers. NEDO organises technology development activities as national projects to realise fundamental technologies (including technology demonstrations) that are difficult for private enterprises to develop by themselves due to the high level of risk before practical application.

The National Institute of Advanced Industrial Science and Technology (AIST)\textsuperscript{21} is one of the largest public research organisations in Japan. The institute hosts several research groups working on fuel cell and hydrogen energy research within domains of materials research, energy systems and networks, and heat utilisation.

Ministry of Education, Culture, Sports, Science and Technology (MEXT) supports education and basic research activities in the field of hydrogen energy. For instance, in 2010 they supported establishment of International Institute for Carbon Neutral Energy Research in Kyushu University.

Japan Science and Technology Agency (JST)\textsuperscript{22} promotes science and technology innovation through strategic research programmes and promotion of industry-academia collaboration, international collaboration and intellectual property commercialisation. One of JST’s programmes is CREST under which hydrogen energy carrier programme has been funded since 2013. It also manages the Cross-Sectoral Strategic Innovation Programme (SIP) which has also funded a programme on hydrogen energy carriers since 2014.

The Association of Hydrogen Supply and Utilisation Technology (HySUT)\textsuperscript{23} is involved with technology development guidelines and standards, training and information dissemination related to safety and reliability issues, public awareness campaigns and international collaboration activities. The association has 42 member companies and organisations including the leading fuel cell vehicle manufacturers (Toyota, Honda, Nissan), energy companies (Iwatan, Osaka Gas, Tokyo Gas, Toho Gas), energy equipment manufacturers (Kawasaki Heavy Industries, Mitsubishi) etc. The HySUT has coordinated industry engagement with R&D programmes such as the large-scale fuel cell and hydrogen demonstration programme.

Fuel Cell Commercialisation Conference of Japan (FCCJ)\textsuperscript{24} is an association consisting of 134 firms in fuel cell-related business fields and is responsible for communication between the government and industry and fuel cell commercialisation.

Next Generation Vehicle Promotion Centre\textsuperscript{25} - The centre promotes adoption of clean vehicles, including electric vehicles, plug-in hybrid vehicles, clean diesel vehicles and fuel cell vehicles. The centre also promotes installation of the charging facilities necessary to power electric vehicles, as well as hydrogen fuelling stations for fuel cell vehicles. It provides subsidies for vehicle purchase and investments in hydrogen fuelling

\textsuperscript{21}http://www.aist.go.jp/index_en.html
\textsuperscript{22}https://www.jst.go.jp/EN/
\textsuperscript{23}http://hysut.or.jp/en/index.html
\textsuperscript{24}http://fccj.jp/eng/index.html
\textsuperscript{25}http://www.cev-pc.or.jp/english/
stations. Various public relations activities are also undertaken by the centre in order to expand use of next generation vehicle and related infrastructure.

**Key industrial players** include a large number of major technology corporations in various parts of the emerging hydrogen economy:

- Residential fuel cells: Panasonic, Toshiba, Aisin Seiki;
- Fuel cell vehicles: Toyota Motor Corporation, Honda Corporation, Nissan Motor Corporation;
- Heavy vehicles: Hino (fuel cell buses), Toyota (fuel cell forklifts), Toyota (hydrogen trucks);
- Fuel cells for commercial/industrial application: Denso, Miura, Fuji Electric, Hitachi Zosen, Mitsubishi Hitachi Power Systems, etc.;
- Fuel cell manufacturing: Kyocera, NGK, Murata, Mitsubishi Hitachi Power Systems, TOTO;
- Local energy companies e.g. Tokyo Gas, Osaka Gas, Toho Gas, Saibu Gas;
- Combined-cycle power generation technology (a combination of thermal power and fuel cell power generation) to replace large-scale thermal power stations: Mitsubishi Hitachi Power Systems.

Other stakeholders include regional and local governments which are collaborating in various hydrogen energy demonstrations. **Tokyo Metropolitan Government** plans to showcase a hydrogen-based society in 2020 Olympic Games. The metropolitan government supports fuel cell vehicle buyers with additional JPY 1 million subsidy on top of the JPY 2 million provided by the central government. Also, hydrogen stations are supported up to 80% of total costs bringing the capital costs down to the level of conventional gasoline station.²⁶

A regional government intensively involved with hydrogen society development is **Fukuoka Prefecture** (in Kyushu) which has since 2004 promoted collaboration with academia and industry to create a local hydrogen-based economy.²⁷ Some of the early demonstrations include Fukuoka Hydrogen Town, Kitakyushu Hydrogen Town and Hydrogen Highway.

There are a large number of universities which undertake research and development activities related to fuel cells and hydrogen energy. Kyushu University hosts a centre of excellence for hydrogen energy, the **International Research Centre for Hydrogen**

---

²⁷ Aso 2013.
Energy. The institute manages an extensive portfolio of research and educational programmes on fuel cells and hydrogen energy. The centre also hosts the Hydrogen Energy Test & Research Center (HyTReC) which was set up in 2010 to assist small companies and start-up ventures to enter new hydrogen industries. HyTReC provides testing services for hydrogen-related products such as valves, pipes and tanks. Kyushu University provides human resource development within their business manager and engineering programmes.

Other key universities and research institutes include Tokyo Institute of Technology, Tohoku University, Kyushu University, Kyoto University, University of Tokyo, Nagoya University, Hokkaido University, Osaka University, and Nagoya Institute of Technology, many of which host several research groups focusing on fuel cell and hydrogen energy research.  

3.4 Monitoring system and evaluation of the initiatives

The cross-sectoral mechanism for coordination and progress monitoring takes place through the Council for a Strategy for Hydrogen and Fuel Cells (CSHF). The Ministry for Economy, Trade and Industry oversees the general progress and reports to the Cabinet.

3.5 Level and type of citizen engagement in the initiative

Citizen engagement has not played a very visible role. The safety of hydrogen has been a subject of public debate. The government has launched initiatives to validate the safety through demonstrations, regulatory means, and information dissemination.

Two issues are causing public debate: the safety of hydrogen power must be clearly demonstrated; and fears that the extensive subsidies might lead to tax increases.

Although detailed information about citizen engagement issues was not found, it appears some hydrogen infrastructure projects are going ahead without little citizen and neighbourhood involvement thus backlashing as public fears for safety.

According to a public survey conducted in 2015, Japanese people have become a little more positive about hydrogen infrastructure in the baseline but more cautious about the risk and benefits. Generally, acceptability of utilisation technology, for example FCVs, is mostly positive, but people are found to be more prudent about hydrogen station placement at least partially due to the perception of risk in hydrogen transfer and storage.

4 Policy instruments and wider policy mix used for implementing the initiative.

4.1 Description of the R&I policy instruments

---

28 Information about the centre: http://h2.kyushu-u.ac.jp/english/
29 Haslam et al. (2012)
The central government uses a variety of policy instruments to promote innovation and transformation towards hydrogen society. The main policy instruments are financial support for R&D and deployment subsidies for consumers and businesses.

Supply side instruments:

- R&D grants and loans - Financial support for research and development projects follows regular financing forms used in Japan.

- Japan Science and Technology Agency (JST) provides funding for strategic research under the CREST programme. A programme with the title ‘Creation of Innovative Core Technology for Manufacture and Use of Energy Carriers from Renewable Energy’ has been running since 2013. The projects funded by JST focus on synthesis and use of new energy carriers superior in hydrogen content, conversion efficiency, and safety to organic hydrides and ammonium.31

- Cross-Ministerial Strategic Innovation Promotion Programme (SIP) has funded a flagship on energy carriers 2014-2018.32 The programme studies liquid hydrogen (LH2), methylcyclohexane (MCH), and ammonia (NH3) as hydrogen energy carriers in order to create carbon free hydrogen value chain (Figure 5). The programme has ten projects related to hydrogen production using solar energy, ammonia-related research topics and organic hydrides as hydrogen carriers. The total budget over five years is around EUR 130 million.33 The SIP was launched by the Council for Science, Technology and Innovation in 2014.

![Figure 5. Development of carbon free hydrogen value chain. Source: Hamaguchi 2016.](https://www.jst.go.jp/kisoken/presto/en/research_area/ongoing/1112064.html)

Demand side instruments:

---
33 The exact total budget volume is not available over the five year programme period. The budget has been estimated on the basis of the budget for the fiscal year 2017 which was JPY 3.66 billion.
Public subsidies for establishing hydrogen fuelling stations. METI subsidises 50% or 67% of installation costs depending on the type of station;

Purchase subsidies for stationary fuel cells. This covers both residential and commercial buildings;

Purchase subsidies for fuel cell vehicles are provided by the central government. Some local governments (e.g. Tokyo) provide additional financial support to accelerate the uptake;

Subsidies for hydrogen fuel: the goal is to reduce the price to EUR 10 per kilogram, because early station fuel revenues are unlikely to offset costs for at least several years;

Development and revision of a variety of codes and standards for fuel cells and hydrogen infrastructure are supported by the government. NEDO coordinates development of codes and standards for hydrogen station quality assessment, metering, filling and inspection;

Regulatory means to remove barriers for hydrogen use and infrastructure construction (e.g. safety standards, see Figure 6). Regulatory changes are also made to change the requirements which are initially very strict due to original purpose of regulating hydrogen storage and distribution in chemical plants. These requirements make instalment of a hydrogen station very costly in Japan compared with some other countries;

Local and regional government procurement is also used to create initial demand for fuel cell vehicles. An example is fuel cell bus procurement by Tokyo metropolitan government transportation bureau.

Systemic instruments:

Facilitation of public-private cooperation: roadmaps, shared target setting, coordination of large demonstration projects;

National / regional policy cooperation and communication: land use for demonstration sites for hydrogen renewable hydrogen production and fuelling stations.
4.2 Connection with other policies

Due to its highly systemic nature touching upon a variety of sectors, the hydrogen society initiative has connections and synergies with several other policy programmes and initiatives. The following are the most notable policies interfacing the hydrogen society plan.

- The hydrogen society plan is part of a larger energy policy plan of Japan with an emphasis on transformation towards renewable energy sources. Production of renewable hydrogen and its potential role in balancing the energy network caused by fluctuating production of solar, wind and other primary sources, creates many links to the larger energy agenda.

- The **smart community** policy aims to create cities and urban environments where various next-generation technologies and advanced social systems are effectively integrated and utilised, including the efficient use of energy, utilisation of heat and unused energy sources, improvement of local transportation systems and transformation of the everyday lives of citizens.\(^3^4\) Carbon free hydrogen towns are part of the smart community trials, bringing the hydrogen society into a component in the local energy system.

- A concerted effort is underway to transform the whole Fukushima Prefecture into a new energy society system as part of reconstruction efforts after the nuclear power plant accident. Hydrogen plays a role in the overall scheme to connect multiple sources of renewable energy production in a local distributed energy network. The Fukushima New Energy-Oriented Society Scheme is coordinated by a dedicated council.\(^3^5\) Several demonstrations are taking place in the region. For instance, a grid balancing demonstration with hydrogen is taking place in the town of Namie. The project aims to promote the expanded use of renewable energy in the electricity grid in order to balance supply and demand and process load management.\(^3^6\)

- Prime Minister Abe’s government has launched a **Smart Society 5.0** strategy in 2016 as part of Japan’s 5th Science and Technology Basic Plan.\(^3^7\) The strategy aims to boost the integration of digital systems such as artificial intelligence, big data and robotics, with physical systems into cyber-physical systems. The strategy is Japan’s equivalent to Germany’s Industry 4.0 strategy. It likewise aims to update the Japanese industry into the digital era. The hydrogen society plays a role in this digitally connected space as one priority area where distributed energy systems are managed by smart technologies.

4.3 International cooperation

- Leading research institutes have made collaboration agreements with globally leading research organisations in the United States and Europe.

---


Japan has established official cooperation with the United States Department of Energy in safety standardisation of fuel cells and hydrogen infrastructure.

Japan is one of country members in the International Partnership for Hydrogen and Fuel Cells in the Economy.\(^{38}\)

Hydrogen supply development with Australia: in May 2017 the Australian government announced that exporting renewable energy in the form of hydrogen, ammonia or embodied in mineral exports is one of its four new investment priorities.\(^{39}\)

Experiments with green hydrogen supply produced by hydropower from Norway.

Hydrogen Council - 13 global major industrial corporations advocate the hydrogen economy to lead the global energy transition. The international companies currently involved are Air Liquide, Alstom, Anglo American, BMW, Daimler, ENGIE, Honda, Hyundai Motor, Kawasaki, Royal Dutch Shell, The Linde Group, Total and Toyota.\(^{40}\)

4.4 **Key turning points of the initiative and policy adaptation measures.**

The hydrogen society policy has transformed from the earlier fuel cell diffusion policy into a more comprehensive energy system transformation initiative.

<table>
<thead>
<tr>
<th>Major changes / turning points of the initiative</th>
<th>Description of the flexibility mechanism / policy adaptation measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Japan Earthquake 2011</td>
<td>The 2011 earthquake and Fukushima Daiichi nuclear power plant accident gave major leverage to the hydrogen society vision as a credible option on the long term.</td>
</tr>
<tr>
<td>Roadmap 2014 and launch of the Hydrogen Society initiative 2015</td>
<td>A comprehensive roadmap, crafted and shared by the key stakeholders, aligns expectations and facilitates coordination of activities towards the common goal.</td>
</tr>
<tr>
<td>Basic Hydrogen Strategy 2017</td>
<td>Extending the timeline towards 2050; shifting the focus away from fuel cell diffusion policy towards introducing hydrogen as an energy carrier; more focus on structural issues surrounding hydrogen supply, infrastructure development, and development of technology and sources for carbon-free hydrogen production. The increased emphasis on hydrogen society strategy is accentuated by Japan’s commitments to the Paris Agreement.</td>
</tr>
</tbody>
</table>

5 **Realised or expected outputs, outcomes and impacts**

This section is focused on the outputs, outcomes and impacts.

5.1 **Outputs**

- **Patenting** volume in fuel cell technology has come down considerably from the heyday in the 2000s (Figure 7). This reflects maturing of the technology and shift towards market diffusion stage in the technology life cycle.\(^{41}\) Hydrogen energy experienced a

\(^{38}\) https://www.iphe.net/
\(^{40}\) http://hydrogencouncil.com/
\(^{41}\) Chen et al. 2011.
global technological hype cycle, in which expectations in the technological development peaked at around 2002, followed by a disappointment phase at the end of the decade, as the development of the technology turned out to be slower than originally foreseen.

Figure 7: Fuel cell technology patenting in Japan. Source: WIPO.42

- The biggest patent holders in fuel cell technology are automotive companies (Toyota Motor, Honda Motor, Nissan Motor) followed by energy system manufacturers (Toshiba, Matsushita/Panasonic, and Aisin Seiki).43

- Toyota has announced the royalty-free use of approximately 5680 fuel cell related patents until the end of 2020, including critical technologies developed for the new Toyota Mirai fuel cell vehicle.44 Toyota argues that in order to boost the first generation of hydrogen fuel cell vehicles between 2015 and 2020 unconventional collaboration between car manufacturers, government, academia and energy providers is needed. Free utilization of key technology knowledge is expected to speed up technology diffusion and market uptake.

- The focus in scientific publications and patenting has shifted away from fuel cells more towards hydrogen production, distribution and storage technology, and CO2 free hydrogen production. These fields are technologically less mature than fuel cells, although there is great variation between types of technology.

---

42 The data comprises Japanese patents and PCT applications with Japanese inventor; data retrieved from the WIPO patent database by VTT.

43 Ibid.

44 Toyota 2015 http://blog.toyota.co.uk/toyota-makes-5600-fuel-cell-related-patents-available
The introduction and diffusion of fuel cell technology up to January 2018:

- The uptake of **residential fuel cells** has progressed with 40 000 - 50 000 new units sold annually. The total number of Ene-Farm fuel cell units sold after the initial market introduction in 2009 until 2016 is 195 000 units.\(^{45}\) During that period the unit market price has dropped more than 50%. The 2015 model is claimed to achieve 95% combined heat and electrical efficiency thus significantly reducing carbon emissions, as compared to gas boilers conventionally used by households.

- Since 2014 when the first hydrogen **fuel cell vehicles** were introduced to the market by Toyota and Honda 6000 cars in total have been sold globally. Japan and California lead the deployment with also the widest hydrogen fuelling networks in place. In Japan, until the end of March 2017 there were 1800 units sold. Some 60% of the sales have come from government agencies.

---

\(^{45}\) Hashimoto 2015.
- **Fuel cell bus** demonstrations have been undertaken in Japan already since 2006. The first commercially produced fuel cell bus was delivered by Toyota Motor Corporation to the Bureau of Transportation of the Tokyo Metropolitan Government in 2017. Toyota plans to introduce over 100 fuel cell buses in the Tokyo area ahead of the Tokyo 2020 Olympic and Paralympic Games. The fuel cell bus can be used as a power source in the event of disasters such as at evacuation sites (e.g. local schools) to provide emergency electricity supply. According to available estimation a fuel cell bus with a full hydrogen tank could power a school gymnasium for some five days.46

- Other hydrogen-powered devices introduced include fuel cell forklifts (Toyota Tsusho), hydrogen-powered train (Japan Railways), and hydrogen truck (Toyota Motors).

- The hydrogen refuelling station network is expanding. In 2017, there are 100 refuelling stations in Japan. The industry has made commitments to expand the network up to 160 stations by 2020. Eleven major industry players, including key automotive manufacturers and energy providers, have made an agreement to establish a new company in spring 2018 to develop hydrogen fuelling infrastructure.47

- The hydrogen supply chain development (Phase 2 of the roadmap) is progressing towards first demonstrations. (1) A project is developing sourcing of hydrogen from lignite (brown coal) from Australia and shipping it in gas tankers to Japan. The plan involves a carbon capture and storage in underground deposit in order to improve the carbon footprint of the supply.48 (2) In another project hydrogen gas is procured in Brunei and transformed to methylcyclohexane (MCH) liquid form. The MCH can be transported under ambient temperature and atmospheric pressure by using organic

---

46 Fevre d'Arcier & Lecler 2014.
chemical hydride method. The MCH will be shipped to Japan by ocean transportation in 2020 and hydrogen will be extracted for use in Kawasaki city bay area. The maximum supply volume is planned to be 210 tonnes, equalling full charging of approximately 40 000 fuel cell vehicle units. (3) Possibilities are explored to source hydrogen from carbon-free sources overseas. One option is hydrogen produced in Norway using power from hydroelectric dams and wind farms.

- Several demonstrations are undergoing for locally produced carbon free hydrogen include: (1) Hydrogen production from biogas in wastewater treatment facilities in Fukuoka involving Mitsubishi, Toyota and Kyushu University; (2) Wind power to hydrogen (power-to-gas) technology for carbon-free hydrogen production is demonstrated in Keihin coastal region near cities of Yokohama and Kawasaki. Hydrogen is produced through a water electrolysis system and will be used by local logistics services to power fuel cell forklifts operating in warehouses. The hydrogen supply chain is expected to reduce CO2 emission by 80% compared to forklifts powered by gasoline or grid electricity; (3) Tomiya city is demonstrating hydrogen production from solar power. An electrolyser transforms electricity to hydrogen gas to be delivered to households, supermarkets and community services; (4) In the Fukushima region suffering from the tsunami and nuclear accident a local ecosystem based on renewable energy is set up; this involves a plan to build a hydrogen production plant with 10 MW capacity which is enough to supply hydrogen to 10 000 fuel cell vehicles; (5) a power to gas demonstration is taking place in Hokkaido with the goal of using the unstable part of wind power production to produce hydrogen while providing steady electric output to the grid; the demonstration is coordinated by NEDO and involves five industrial partners.

- The Japanese fuel cell producers are making efforts to export their devices to overseas markets. Residential fuel cells have been marketed mostly to German markets with local industry partners (Viessman, Bosch). Fuel cell vehicles are exported to the US and Europe, with California being the lead market with a widespread hydrogen fuelling network, strict emission regulation and purchase subsidies.

5.2 Outcomes

The cost decrease of fuel cell and hydrogen energy technology has progressed steadily. For each doubling of residential fuel cell production volume, the price has dropped by 15% (see Figure 4).

51 Asia Biomass Energy Cooperation Promotion Office. https://www.asiabiomass.jp/english/topics/1510_06.html
The cost has not decreased quite as fast as desired. How soon residential fuel cell technology can survive without subsidies on the mass market is still uncertain.

Japan has undoubtedly gained a global market leadership in residential fuel cells for combined heat and power production market. This leadership has not yet generated significant export revenue since demand in overseas markets has not taken off yet.

5.3 Impacts

As for economic, environmental and social impacts, it is still quite early to assess the overall effectiveness of the hydrogen society initiative. The potential is obviously enormous, but risks of difficulties with reaching sufficient scale are also considerable. Nevertheless, it is possible to observe some early indications of impacts.

As for environmental impacts, the residential fuel cell deployment results in 35-50% reductions of CO2 emissions. This is still offset to some extent by the higher carbon footprint of fuel cell manufacturing compared to conventional gas boilers (Dodds et al. 2015). Application of a micro CHP system would reduce carbon dioxide emissions of a residential home by 19%.

Residential fuel cell lowers local emissions of nitrogen oxides considerably. This is expected to improve the local health conditions of dwellers leading to positive social impacts.

As for fuel cell vehicles, a similar price reduction trend is expected. The leading manufacturer Toyota declares that they have already been able to reduce the price by 95% since the early prototypes. Based on a literature review of several studies, fuel cell vehicle costs are expected to decrease by more than 70% from 2015 to 2030 due to economies of production scale and fuel cell stack innovations. As a benchmark,

---

55 Elmer et al. 2015.
56 Ito 2016
57 Isenstadt & Lutsey 2017.
Japanese industry is looking at the example of gasoline-electric hybrid car which took 20 years to establish on the marketplace as an industry standard. A similar pattern and long-term time horizon are expected from fuel cell vehicles.

- New product niches are being experimented with fuel cell forklifts, hydrogen powered trains, hydrogen trucks, and small marine vessels. In the latest strategy revision, policy targets for new product demonstrations and market uptake have been set for these new product categories.58

- The hydrogen supply chain development as well as demonstrations for production of renewable hydrogen are still at very early stage. There is no data available to assess economic and social impacts. Various simulations exist pointing out potential for net improvements in sustainability of the energy system. However, due to the complexity of the energy system and high carbon footprint of many hydrogen supply and transportation sources, it is not at all evident that significant net reductions to CO2 emissions are expected immediately. Using hydrogen would remove CO2 emissions at the point-of-use but would only reduce emissions across the energy system if low-carbon hydrogen production technologies and feedstocks were used. Technology for production of renewable hydrogen is still at immature stage as regards its cost competitiveness.59 If development of economically efficient large-scale production of renewable hydrogen succeeds the environmental footprint will be very low.

- When assessing the early impacts of Japan’s hydrogen society plan, it must be remembered that decreasing carbon emissions is not the only societal mission involved. Improving energy security and diversification of energy sources is an equally important goal. The short and mid-term impacts of the initiative should not be evaluated solely on the grounds of net carbon emission reductions achieved, but on the basis of establishing an energy supply and delivery system with capacity to diversify energy sources while at the same time holding great long-term potential in transitioning towards a carbon neutral energy production.

5.4. Summary of the key indicators

<table>
<thead>
<tr>
<th>Key indicators</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Timeline:</td>
<td>2015-2040</td>
</tr>
<tr>
<td>Objective and targets:</td>
<td>Transform the Japanese energy supply, distribution and use towards wide-scale uptake of fuel cell technology and hydrogen as an energy carrier and ultimately as a renewable source of energy through carbon free hydrogen production technology. By 2040, Japan aims to have established a completely CO2-free hydrogen supply system.</td>
</tr>
<tr>
<td>Total budget:</td>
<td>EUR 4 Billion (estimated total; precise figures are not available)</td>
</tr>
<tr>
<td>Annual budget:</td>
<td>Year 2017: EUR 310</td>
</tr>
<tr>
<td>Share of budget, public funding:</td>
<td>35% (estimated)</td>
</tr>
<tr>
<td>Share of budget, private investment:</td>
<td>65% (estimated)</td>
</tr>
</tbody>
</table>

59 Dodds et al. 2015.
Leverage effect (additional public/private investments the initiative has triggered):  
Public investments are assessed to have leveraged private funding considerably, but no precise estimate is available.

Key (official/public) indicators applied for monitoring the progress towards the targets:  
- Number and price of fuel cell units (residential, vehicles)
- Number of hydrogen stations
- Reduction of hydrogen cost (to around 30 yen / Nm 3)
- Development and demonstration of hydrogen supply chain
- Development of carbon-free hydrogen production methods

Other key indicators (e.g. outputs/outcomes/impacts):  
Long term impacts:
- Improvement of energy self-sufficiency rate
- Reduction of greenhouse gas emissions by 80% by 2050, based on the Paris Agreement
- Growth of Japan’s fuel cell and hydrogen energy technology industries

6 Conclusions and lessons learned

6.1 Identification and assessment of key strengths and weaknesses of the initiative

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Underpinning the initiative was long technical R&amp;D undertaken since 1990s on developing fuel cell technology. The investments to fuel cell R&amp;D have been largest in Japan, as compared US and Europe.</td>
<td>- The price of fuel cell products has not decreased as fast as expected which is why generous subsidies continue to be provided by the government. The market uptake has not developed very rapidly.</td>
</tr>
<tr>
<td>- A highly systemic view of hydrogen society covering the whole chain from hydrogen production, storage, and transportation to utilisation in various applications.</td>
<td>- Accomplishing the policy targets requires inexpensive sources of hydrogen, whether through electrolysing water with renewable energy sources or extracting it from fossil energy sources (e.g. natural gas, lignite coal). The system requires pipelines and shipping methods to transport hydrogen and then fuelling stations to distribute it to end users like cars, households and industries. Driving the costs of this infrastructure down far enough to compete with fossil fuels depends on a global economy of scale. International transformation is necessary and cooperation with other countries is very important.</td>
</tr>
<tr>
<td>- Government support: willingness to lead R&amp;D and market development</td>
<td></td>
</tr>
<tr>
<td>- Use of a large variety of supply and demand side policy instruments as well as systemic coordination mechanisms.</td>
<td></td>
</tr>
<tr>
<td>- Cross-sectoral coordination across policy domains and between government, industry and academia.</td>
<td></td>
</tr>
<tr>
<td>- Stable policy on R&amp;D and subsidy with sunset options in place for phasing out subsidies.</td>
<td></td>
</tr>
<tr>
<td>- Consensus-building among stakeholders to develop a long-term roadmap and deploy it jointly.</td>
<td></td>
</tr>
<tr>
<td>- While Japan has invested heavily in deploying fuel cells on the mass market to gain sufficient demand volume, it might have neglected another route to develop the market and scale-up through high-value niche markets. Some American and European companies have been able to find market opportunities for fuel cells in specialised customer segments such as defence, oil and gas</td>
<td></td>
</tr>
</tbody>
</table>
6.2 Lessons learned and key messages for European R&I policy

- Emphasis on long term gains at the system transformation level vis-à-vis short-term benefits.

- SMEs play a relatively small role as product development is dominated by large technology corporations.

- Emergency power supply, drones, or data centres where small-scale demand is maturing without big government subsidies.

The hydrogen society initiative relies on a broad-based innovation policy combining R&D push and market pull policy instruments to bring about a system level transformation.

In order to overcome the chicken-and-egg problem related to fuel cell technology and hydrogen distribution infrastructure the government has seen it necessary to provide substantial investment and purchase incentives. Making adoption of fuel cell appliances attractive a hydrogen station network of sufficient scale needs to be in place, which does not emerge without a sufficient number of vehicles demanding the fuel.

Broad-based collaboration between government, industry, and academia within an established structure of science, technology, and innovation coordination mechanisms. Also, cross-sectoral coordination mechanisms exist between the key government departments.

The stakeholders have committed to a long time horizon and are not expecting only quick wins. A long-term roadmap involves a highly systemic view on connecting various sectors into a hydrogen economy: energy production and distribution, electricity, transportation, and housing. The most recent Basic Hydrogen Strategy from 2017 further expands the plan to set targets for inclusion of industrial production and commerce as user of hydrogen-based energy.

When moving towards large scale deployment of fuel cell technology, Japan has been able to tap into the results of earlier decades of fundamental research. Scientific and engineering leadership relies on large R&D investments on this radically novel technology.

The implementation of the hydrogen society initiative takes advantage of the well-established Japanese science and technology coordination system involving the government, industry and academia. Various coordination mechanisms are in place, most notably the Hydrogen and Fuel Cell Council as the leading advisory body. Through these mechanisms the governance system has capability to address policy issues related to regulation, standardisation and public awareness - issues outside the core of science and technology policy.

The government leadership of the hydrogen society initiative has been strong. The Prime Minister has endorsed the initiative very visibly providing it leverage and visibility at the highest political level.
Local and regional governments are important partners in various local demonstrations. They play an essential role in implementing the plan to strengthen the distributed renewable supply of hydrogen energy.

References:


Getting in touch with the EU

IN PERSON
All over the European Union there are hundreds of Europe Direct Information Centres. You can find the address of the centre nearest you at: http://europa.eu/contact

ON THE PHONE OR BY E-MAIL
Europe Direct is a service that answers your questions about the European Union. You can contact this service
– by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
– at the following standard number: +32 22999696 or
– by electronic mail via: http://europa.eu/contact

Finding information about the EU

ONLINE
Information about the European Union in all the official languages of the EU is available on the Europa website at: http://europa.eu

EU PUBLICATIONS
You can download or order free and priced EU publications from EU Bookshop at: http://bookshop.europa.eu. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see http://europa.eu/contact)

EU LAW AND RELATED DOCUMENTS
For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex at: http://eur-lex.europa.eu

OPEN DATA FROM THE EU
The EU Open Data Portal (http://data.europa.eu/euodp/en/data) provides access to datasets from the EU. Data can be downloaded and reused for free, both for commercial and non-commercial purposes.
The Hydrogen Society initiative is an ambitious policy by Japan to transform its energy landscape to utilize hydrogen as a major source of energy in transportation, housing, heat and power production, and industrial processes. Earlier investments to fuel cell technology has provided Japan with industrial leadership which it aims to benefit from by accelerating the adoption of fuel cells vehicles and residential fuel cells on the mass market and building associated distribution infrastructure. The second phase of the hydrogen society roadmap involves developing global supply chain of hydrogen from untapped energy sources overseas, thus diversifying Japan’s energy portfolio. Research and development efforts are needed to develop reliable, safe and economically feasible technologies for hydrogen storage, transport and distribution. The third phase of the roadmap involves developing methods for carbon free production of hydrogen. This may involve conversion of solar and wind power to hydrogen gas or combination of fossil based hydrogen with carbon capture and storage solutions. Hydrogen energy has the potential to provide an important carrier for excess renewable energy contributing to balancing off fluctuating production of renewables and Japan meeting its commitments to the Paris Agreement. This ambitious policy mission is not without hurdles, but coordination mechanisms have been established to involve all necessary stakeholders to enable a system-wide transformation across the society.

*Studies and reports*