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Fuel cells and the hydrogen revolution: Analysis of a strategic plan in Japan

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ABSTRACT

Japan may be the least likely country to start a revolution, but its new energy policy, if implemented successfully, will revolutionize Japan's economy, society, and energy infrastructure. The new energy policy calls for the creation of a "hydrogen society" in which citizens will use hydrogen as their primary energy source. Hydrogen fuel would be produced from renewable sources and used to generate electricity at home and to power vehicles via fuel cells. The policy came into force in April 2015 and will guide Japan's energy development for the next 25 years and perhaps beyond. The new policy is a determined response to the twin disasters faced on March 11, 2011, when Japan was struck by a Magnitude 9 earthquake and then a catastrophic tsunami, which devastated Japan's economy, energy security, and environmental well-being. The new energy policy would substantially reduce Japan's dependence on nuclear power as well as oil and gas-fired thermal power plants and would greatly strengthen the development of fuel cell systems that use hydrogen. Implemented in three broad phases over several decades, the policy would promote the development of fuel cells that are less costly, more efficient, and more durable, and it would develop hydrogen production, storage, and transport as well as fueling systems to support the widespread use of fuel cells. Over the long term, the hydrogen society could be integrated into Japan's concept of a "smart community" that uses digital technologies and information and communication technologies to more efficiently generate and regulate the use of power. This paper examines how Japan laid the policy and legal framework in the 1990s to promote fuel cell and hydrogen development, compares Japan's investment and policy strategies to those in the United States and the European Union, identifies the challenges Japan will face in broadly establishing a hydrogen society, assesses the potential economic benefits it might enjoy if the hydrogen society policy succeeds, and recommends that the new energy policy be more fully integrated with other initiatives to promote economic growth, more efficient communities, and a cleaner environment.

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1. Introduction

Japan is a country of long-term planning and steady policy implementation programs that might not yield immediate results but that ultimately prove to be prescient and foundational. The policies discussed in this paper are two examples of such programs. They encompass two interrelated, multiphase policy initiatives intended to (1) broadly establish practical fuel cell technologies for a variety of applications and (2) embed these technologies in a "hydrogen society" that relies on hydrogen as a primary source of energy to generate electricity and power vehicles. The two initiatives are mutually complementary. The first initiative will not become practical unless hydrogen production, storage, transport, and fueling technologies are developed and widely deployed. The second initiative will not be realized if the first initiative does not yield practical and inexpensive fuel cell technologies that can provide a hydrogen fuel source that is sufficient to meet demand.

Both initiatives will take decades to play out. The first initiative, which began with a few modest initiatives in the early 1990s, has already taken more than two decades to yield preliminary results; the second, which kicked off this year, will require at least two to three decades before a hydrogen-fueled society can become widely available. Despite the long wait, Japan's government and industry are enthusiastic about the two initiatives because achieving these goals is of vital national importance. These policies, if successfully implemented, will ensure Japan's future economic growth, energy security, and environmental health.

2. Competencies in fuel cell science and technology

It is something of a paradox that Japan has put in place a policy to promote fuel cell systems, given that Japan historically has not been a technology leader in this field. Indeed, a detailed review of some 180 government and private sector fuel cell programs indicates that until the 1990s, Japan had not been credited with significant fuel cell accomplishments, nor had it successfully brought fuel cell products to market (Behling, 2012a,b). In contrast, Europe and the United States have had a long record of scientific discoveries and technical developments pertaining to fuel cells. Indeed, European scientists and engineers invented or discovered all of the first fuel cell types that are known today, and the United States developed and brought almost all of the first fuel cell products to market (see Table 1). One exception to the rule, and of particular import, was the proton exchange membrane fuel cell (PEMFC). The PEMFC was invented by General Electric in 1955. Ballard, a Canadian company, started to develop it in 1984, and the world was surprised by its rapid progress. By 1994, Ballard and Daimler had introduced the world's first fuel cell vehicle, NECAR 1, triggering a global fuel cell race among major industrialized governments (Behling, 2012a,b).

Profoundly impressed by the technical advances in Europe and the United States, Japan enacted a series of laws to foster innovation, inventiveness, and entrepreneurship. The first and most important was the *Science and Technology Basic Law*, enacted in November 1995. The law identified the most important science and technology areas upon which Japan should focus its efforts, and it provided a solid bureaucratic foundation on which Japan could build scientific and technological competence. To flesh out the implementation of the Science and Technology Basic Law, Japan also enacted the Law Promoting Technology Transfer from Universities to Industry (referred to as the TLO Law) in May 1998. Its purpose was to facilitate technology transfer and encourage industry-academia R&D collaboration. Moreover, in 1999, Japan enacted Article 30 of the Law on Special Measures for Industrial Revitalization—a Japanese "Bayh-Dole Law". The law permitted inventors to retain plan sets out Japan's energy mix for 2030s derived from government-funded projects. It made it easier for the holder of such patents to engage in entrepreneurial activities. Previously, all patents derived from government projects reverted to the government.

More recently, Japan enacted the *National University Corporation Law* of 2004, which changed the status of national universities from a government entity to a special corporation to make it easier for universities to engage with businesses. Japan also enacted the *New Education Basic Law* in December 2006, which included supporting industry as an appropriate university mission. These laws have worked well to enhance universities' inventiveness and creativity as well as to provide them with the necessary flexibility to engage in collaborative R&D with businesses (Behling, 2012a,b).

- As a result of these efforts, by the middle of 2013, approximately 200 University-Industry Collaborative Research Centers had been established and approximately 2000 venture companies created, demonstrating the private sector's increasing interest in seeking R&D assistance from universities (see Fig. 1) (Behling, 2014).

3. Fuel cell R&D program in 1992

In the early 1990s, Japan's Ministry of Economy, Trade, and Industry (METI, formerly MITI) took note of significant fuel cell developments in Canada and implemented a modest 8-year fuel cell R&D project in 1992. The project had two phases: Phase I (1992–1995) (a total budget of $6.6 million)[1] focused on the development of 1 kW modules for stationary and portable applications, and Phase II (1996–2000) (a total of $33 million) focused on the development of 5–10 kW portable, residential,

[1] In this paper, an exchange rate of $1/¥ 100 is used.