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| FUEL CELL INDUSTRY ANALYSIS REPORT |
| 01/01/2015 |

Bambu, the team

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# Introduction

## Intentions

This report wants to inform about the state of the fuel cell industry. It wants to address a vast group of people, those who are in contact with fuel cells for the first time as well as those who already have a profound expertise in this field. Therefore the report gives a short introduction of history and also explains the different types and working mechanisms of fuel cells but also shows threads and chances by linking the gathered knowledge with new topics like blockchain.

The underlying informations for this report was gathered by a broad literature and internet research. Knowledge from previous Industry Reports as well as research paper, newspapers and press releases were used to show a broad spectrum of facts.

## History of fuel cells

The beginnings of fuel cells reach back to 1838. At this time William Robert Grove worked on what was later called fuel cell. Grove, who is credited with the invention of the fuel cell, used platinum together with hydrogen and oxygen to create a constant current. Several scientists including Christian Schönbein tried to show how exactly fuel cells are working. Although great discussions and large efforts it took several years to explain the system fully. In the early years there no practical device emerged. In the early 20th century the first molten carbonate fuel cell was built by Emil Baur. Further investigations were made by Francis Thomas Bacon who developed first fuel cells with a practial use. His work was promisable enough to be licensed by Pratt & Whitney for the Apollo missions[[1]](#footnote-1). At General Electric Willard Thomas Grubb and Leonard Niedrach invented the first PEMFC which was later refined and used by NASA for the Gemini Mission in the 1960s. International fuel cells developed other systems for the Apollo missions. Also in the Soviet Union there was research in this field of technology, mainly for military purposes, later also for space missions. Driven by the oil crisis in the 1970s nearly all major car manufacturer had developed a FCEV. Another effect of the oil shortage was progress in the development of PAFC which are featuring higher possible outputs. Although high growth rates are predicted in the 1980s, there was just a slow adaption of the new technology[[2]](#footnote-2) [[3]](#footnote-3)

PEMFC: proton exchange membrane fuel cell

FCEV: fuel cell electric vehicle

PAFC: phosphoric acid fuel cells

## Fuel cell as an alternative

Fuel cells can be used as a substitute as well as a complementing technology. The applications can be divided into the three categories stationary, transport and portable. The area of stationary fuel cells includes systems like plants or one household systems. In this area it is possible to complement for example regenerative energies with fuel cells to store the energy during the time it is not needed and by doing so building a smart network. As it is a clean and very fast reacting technology it can be also used in cities, for example instead of gas plants. Portable systems in different scales can be used for example as a supplement for diesel generator to support of grid systems with energy. Micro systems compete with traditional batteries. The transport sector is probably the most competitive area as fuel cells are in direct competition with traditional fuel as well as battery cars. Further discussion about these topic will be hold in part 5.

## Short industry overview

As pointed out in the history section above the fuel cell market for customer is quite young and therefore still shaping itself rapidly. On the market there are several big players as well as niche producers. In general big stationary systems (e.g. plants) are built by bigger companies whereas the portable systems are mostly distributed by smaller companies. The fuel cell market is strongly related to different regions, which was the reason to divide the analysis in three main regions

# Product description

## Introduction

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## Technologies

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### PEMFC

### AFC

### PAFC

### SOFC

### MCFC

### DMFC

### Summary

## Applications

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### Categorisation choices

### Transport

### Portable

### Stationary

## Infrastructure

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### Distribution facilities

#### Delivery

#### Hydrogen storage

### Hydrogen production

#### Introduction

#### Electrolysis

#### Steam reforming

#### Summary

# Market Perspective

## Introduction

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## Investment Cost Reduction

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## Research and Development Fundings

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## Top Investors

## Quantity of Fuel Cells shipped

## Hydrogen Refuelling Stations

## Major Companies

### Public Companies

### Private Companies

# Law and governmental regulations

It is shown that innovations in their early stages need technology specific support, to prevent lock-in effects of earlier technologies from only incentivizing incremental innovations[[4]](#footnote-4). When developing such innovations new products or entering markets, firms are acting in a network of governmental influence, universities and customer. The actors, which are engaging in this network, can be classified as the role of the government and the interaction between firms and non-firm. This chapter will discuss the different influences of the institutional framework, which influence the development of technologies, by framing policies, opportunities and capabilities[[5]](#footnote-5).

Support of new technologies may happen through R&D funding, support for demonstration trials, testing etc. Another form of influence can be planning incentives on a regional level, for example incentives for the use of fuel cells in new buildings[[6]](#footnote-6).

The targets of stimulating the fuel cell industry vary from region to region. In the US they are mainly driven by national security issues, in Europe by environmental targets and in Japan economic as well as environmental targets. As shown in part 2 there are several technologies, policies may vary from technology to technology depending on which focus is set and therefore create competition between those. Also other technologies compete or complement fuel cell. Incentives can be a high influence on creating the wanted effects[[7]](#footnote-7). One of the main indicators of political influence are the expenditures for R&D in this area. In the following the situation in the three countries which are ranked highest with regard to expenditures are analyzed[[8]](#footnote-8). Other possible influences are subsidies or public support.

Although often seen together hydrogen and renewable energies have some distinctions, which influence the policies, as it is unlikely that the same policies will work. Hydrogen is an energy carrier and therefore need infrastructure for production and distribution. Hydrogen has to be made compatible for the existing infrastructure and cannot be blended. The future development is heavily relying on critical issues like storage where technological progress is necessary. Therefore a successful policy has to connect market requirements, climate requirements and the hydrogen technology development.[[9]](#footnote-9)

A study in Germany has shown that the political conditions influence the adoption of FC. There is a difference in the adoption thorugh commercial and private users. For commercial user the investment decision is influenced by feed in laws for CHP systems and the oil and energy price. Private consumers are positively affected by a future oriented energy policy and clear law statements. Whereas commercial users deny subventions, because they are unreliable, private users endorse subventions to cover expenses which arouse by the use of FC[[10]](#footnote-10).

METI : Ministry of Economy, Trade, and Industry (Japan)

JHFC : Japan Hydrogen and Fuel Cell

FCV : Fuel Cell Vehicle

## Situation in Japan

Due to the lack of fossil fuel sources Japan’s government is heavily investing in fuel cells and their research during the last years through R&D funding[[11]](#footnote-11)[[12]](#footnote-12)[[13]](#footnote-13). Already in 1974 the sunshine project was started to examine hydrogen power among other renewable energy sources. Around 1980 the development was pushed by the moonlight project who aimed to develop fuel cells. With the new sunshine project of 1993 the effort on PEMFC was increased. All the efforts culminate in the millennium project from 2000. This is including R&D for PEMFC for use in automobile and residential application. This project is flanked by another program to develop tests and evaluation for safety and reliability standards which is stated to be a critical factor for the adoption of a new technology[[14]](#footnote-14). As a result of the announcement of Daimler-Benz of their failed plan to commercialize fuel cells, the government developed a strategic plan. According to this a partnership between METI and several Japanese fuel cell companies is established and called JHFC project. The intention of this project was mainly focused on the development of a FCV and surrounding infrastructure like hydrogen production, storage and filing. The development is characterized by a high degree of cooperation between government and industry, which is significant for high corporatist countries. The plan was divided in three phases. The first phase from 2002 to 2005 was intended to develop a hydrogen infrastructure and to determine performance statistics. The aim of the second phase from 2006 to 2010 was to develop standards investigate about policies and reduce costs. Besides this plan there was an agreement of the Japanese car manufacturers to release fuel cell vehicles by 2015[[15]](#footnote-15). In 2002 the Japanese government announced the target to reach 15 GW produced by stationary fuel cells in 2030. Besides funding, another influence of the government, is the research on the practical use of fuel cells. Japan has a clear focus on creating new markets for fuel cell CHP. The Japanese effort is among the highest[[16]](#footnote-16).

Using FCV and stationary appliances Japan intends to use 4 billion $ for hydrogen usage and is expecting that by 2020 all road vehicles are powered by hydrogen fuel cells. In 2000 a funding of 25 billion Y were made for R&D on FC, in 2004 another 31 billion Y were spend. The government is also funding manufacturers and an estimated value of 380 million $/year is done for research and commercialization of FC.

**Japan: $380 million in 2008 for R&D and commercialization[[17]](#footnote-17)**

## Situation in the USA

The electricity market in the US is decentralized. In contrast to Germany or Japan there is less support for creating a market for fuel cell CHP. The SECA program which is focusing on SOFC for small stationary use, SOFC may be the best choice for electricity generation but is lacking behind PEMFC. Besides the US Department of Defense is also investigating about residential fuel cells in military related fields. [[18]](#footnote-18).

US department of energy Hydrogen Program. Furthermore there is a direct subsidy support for manufacturing facilities.[[19]](#footnote-19)

**USA: $640 million annually to 2014 plus; $3,000/ kW purchase incentive tax credit [[20]](#footnote-20)**

## Situation in Germany

As a part of the EU the German policies have also to be seen in the context of the European framework, as the national framework is largely shaped by the European context. The general consent within the EU is that the “further development and market introduction” is desirable, as it can be a carbon neutral substitute for fossil fuels. One of those projects which empower fuel cell is the JTI in which frame 1 billion € will be spend from 2008 to 2017 [[21]](#footnote-21) It was shown that Germany is one of the most innovative regions regarding fuel cells[[22]](#footnote-22)[[23]](#footnote-23). The public federal funding amounts 8-10 million every year. For the time 2001-2003 additionally 15 million were added in the “program on investment into the future”. The Helmholtz foundation, which undertakes basic research is supported with 15 million annually. In addition in 2006 a program containing another 500 million was announced. Besides financial support, politicians reinforce hydrogen, e.g. by presenting newest technologies[[24]](#footnote-24). The German government often proved to create new markets for new energy forms, e.g. with the “feed in law” from 1991 which guarantee a specific price for electricity generated by renewable energies. Germany is creating a market for fuel cell CHP within a broader range of technologies. To further develop fuel cells for the residential market there is an extensive ZIP program. Another indicator is how much new technologies are encouraged as this is creating an atmosphere in which firms will experiment more. Japan and the US may have the highest spendings for R&D, but the highest use of renewable energies is reached in Germany. A main reason for this is the feed-in law.[[25]](#footnote-25). Another influence is the taxation, in Germany hydrogen is taxed when used as a motor fuel[[26]](#footnote-26)

JTI : Joint technology initiative

Furthermore there is the NOW program. Germany also make use of subsidies for capital cost and give feed in tariffs for fuel cell CHP[[27]](#footnote-27)

**Germany: $1.1 billion until 2017[[28]](#footnote-28)**

## Conclusion

Most of the policies are facing the same problem. On the one hand they have to be broad enough to create new markets and encourage firms to enter, but on the other hand they are focused on specific technologies where there is the greatest chance to success. A proposed solution includes to keep regulatory measures flexible while focusing R&D on special technologies[[29]](#footnote-29).

# Comparison to other technologies

## Alternative technologies

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### Introduction about different technologies

### Trend of these technologies in different regions

## Advantages and disadvantages of fuel cells

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### Advantages

### Disadvantages

### Challenges

## Different elements of settling a technology

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### alternative elements

### policy as an important element

# Future perspectives

## Opportunities

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## Limitations and risks

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## Forecast

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# Conclusion

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