China Analysis 83
December 2010
www.chinapolitik.de

Comparative Studies in Innovation Policy:

The Role of Public Policy in the Development of Alternative Vehicles in Japan

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Contents

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List of abbreviations

ACE	Advanced Clean Energy (Vehicle Program)
AFCC	Automotive Fuel Cell Corporation
AIST	National Institute of Advanced Industrial Science and Technology
ANRE	Agency for Natural Resources and Energy
BPEV	battery-powered electric vehicle
CAFE	Corporate Average Fuel Economy
CARB	California Air Resource Board
CVCC	compound vortex controlled combustion
EA	Environmental Agency (now: MoE)
DPJ	Democratic Party of Japan
FCCJ	Fuel Cell Commercialization Conference of Japan
FCEV	fuel cell electric vehicle
GHG	greenhouse gas(es)
HEV	hybrid electric vehicle
IAA	independent administrative agency
ICEV	internal combustion engine vehicle
INTARDA	Institute for Traffic Accident Research and Data Analysis
IT	information technology
JHFC	Japan Hydrogen & Fuel Cell Demonstration Project
LDP	Liberal Democrat Party
LEV	low emission vehicle
LEVO	Organisation for the Promotion of Low Emission Vehicles
LGRI	local governmental research institute
LiIon	lithium-ion
MCFC	Molten carbonate fuel cell
METI	Ministry of Economy, Trade and Industry
MEXT	Ministry of Education, Culture, Sports, Science and Technology
MHLW	Ministry of Health, Labour and Welfare
MITI	Ministry of International Trade and Industry (now: METI)
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
MNC	multi-national corporation
MOC	Ministry of Construction (now: integrated into MLIT)
MOE	Ministry of Education (now: MEXT)
MoE	Ministry of Environment
MOF	Ministry of Finance
MOT	Ministry of Transport (now: integrated into MLIT)
NEV	neighbourhood electric vehicle
NiMH	nickel-metal hydride
NISTEP	National Institute of Science and Technology Policy
NEDO	New Energy and Industrial Technology Development Organisation
PAFC	Phosphoric acid fuel cell
PEFC	Polymer electrolyte fuel cell
PEMFC	Proton exchange membrane fuel cell (identical with PEFC)
PHEV	plug-in hybrid electric vehicle
R&D	research and development
RD&D	research, development and demonstration
SME	small and medium-sized enterprise
SOFC	Solid oxide fuel cell
S&T	science and technology
STA	Science and Technology Agency (now: integrated into MEXT)
ZEV	zero-emission vehicle

Introduction

The aim of this thesis is to analyse public policy on alternative vehicles in Japan in order to elucidate the processes and functions of the Japanese national innovation system as well as to investigate interaction between the state and industry concerning those new technologies.

Innovation is the driving force behind global competition and its impacts will shape future industries and societies, as well as the environment. The capability to foster innovative products, processes and services is of vital interest for states, especially for already highly developed ones. This is because those national economies cannot compete successfully in areas like cheap labour costs with less developed countries. Therefore, national innovation systems become more important as they play a crucial role in the future economic and social development. Although the term suggests that it is first and foremost a domestic affair, this analysis intends to highlight international influences on the Japanese innovation process to exemplify that policies and business decisions are becoming increasingly interdependent. Indeed, the notion of national innovation system could be misleading, if taken literally, which is stressed by this pointed remark:

> "Like the Holy Roman Empire, which was not holy, Roman, or an empire, innovation systems may be international, rather than national, in scope and structure; they may influence diffusion as much as innovation; and they often are ad hoc, rather than strategically conceived, in origin." (Mowery/Oxley 1995: 80, 2n)

Nevertheless, this observation is not to imply that national politics are irrelevant: the case study represents new technologies, maybe even an emerging industry, but its development is dominated by a small, highly concentrated number of large multi-national companies (MNCs) of an established business. It could be concluded that MNCs do not recognise national borders and therefore, national innovation systems are irrelevant under those conditions. This study will follow the argument that MNCs carry out most of their research and development (R&D), the heart of innovative activity, in their home nation (Hu 1992: 119). This line of reasoning is backed up by the finding that among industrialised countries, Japanese firms have the least internationalised R&D structure (Meyer-Krahmer/Reger 1999: 761-765), so that the national framework conditions actually play an important role even for MNCs.

The choice of the case study was made for the following reasons: Japanese automobile manufacturers were the first to develop and commercialise alternative vehicles, e.g. hybrid-electric vehicles (HEVs) like the Toyota Prius or Honda Insight. A relatively new development is so-called plug-in hybrid electric vehicles (PHEVs): Toyota announced in December 2009 that its

PHEV, the Prius PHV, would be introduced to the market in 2011.[1] An alternative that has been around for about 40 years, but not yet successfully developed, is battery-powered electric vehicles (BPEVs). Also, the Japanese car industry is considered to be leading in the field of fuel cell electric vehicles (FCEVs). All alternatives are regarded as possible long-term options for replacing the standard internal combustion engine vehicles (ICEVs) as they are more fuel efficient and their harmful exhaust emissions are considerably lower.[2]

The case study is supposed to demonstrate that the Japanese approach towards environmental issues has been largely technological, which is the reason for the environmental image of the country being internationally divided: on the one hand, it is applauded for developing low-emission vehicles, while being criticised on conservation issues on the other hand (most prominently whaling (Wong 2001: 89-143). Politicians, bureaucracy and industry alike try to promote an environmentally progressive image of Japan, e.g. the EXPO at Aichi 2005 or the recently failed bid for the Olympics 2016 by Tokyo, which put forward the idea of sustainable "Green Games" (Tokyo 2016).

The aim of this study is to investigate the policies that led to the successful development of new eco-friendly technology and its commercialisation. Most important will be to investigate the role of the Japanese government policies on this issue and to ask if those policies contributed to the aforementioned positive results.

The theoretical framework of this paper will be a policy analysis as the development of alternatives vehicles in Japan is surrounded by various issues, rivalling interests and different actors. It is critical to point out that by the time alternative automobiles first came on the political agenda, the topic was highly contested by economic interests of the industry, national energy security, environmental conservation as well as public health. All stages of the policy cycle will be investigated, but areas of special interest will be the tactics of different actors in the decision-making stage, the choice of instruments for implementation and learning processes in the evaluation of policy. The element of learning is most critical to judge the innovation process, because the fact that technological innovation is hard to predict does not allow state agencies to put forward a single option. Technology development forces agencies to revisit the subject, evaluate the achieved advancement and maybe alter or readjust their programs.

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1 Financial Times Deutschland, 14.12.2009, "Toyota fertigt Steckdosenhybrid"; see also: Spiegel online video: Durchbruch für Hybrid-Autos? Toyota stellt "Plug-In-Prius" vor , 14.12.2009

2 There exists the debate about how much more efficient grid-charged vehicles like BPEVs and PHEVs really are as the production of electricity also includes carbon dioxide emissions, which is arguably true. The same observation is made for hydrogen production, questioning the efficiency of FCEVs. However, then it is also necessary to add the emissions of petrol and diesel refining to the ecological balance sheet of ICEVs, which is usually forgotten.

Therefore, first, an introduction of the theoretical approach will be necessary to clarify the analytical framework. Second, this will be followed by a brief overview on Japanese environmental policy, its origin and characteristics. Third, a description of special features of the national innovation process will follow to place the case study in the context of Japanese innovation and environmental framework. The case will illustrate how policy influenced the development of new technology, which is carried out by the industry. Therefore, this study will also allow some insight into the public-private interaction in Japan.

1 Theoretical framework

1.1 Policy analysis and national innovation system

This study will apply the analytical framework of the policy cycle as put forward by Howlett and Ramesh (Howlett/Ramesh 2003). It should be pointed out that there exists a plethora of other methods to study public policy, however, the model of the policy cycle has the following merits: first, this model explicitly states that it is studying policy subsystems instead of covering the full spectrum of public policies. The proposed model states that actors and institutions have a mutually defining relationship (ibid.: 53). This means that individuals are influenced by their environment but at the same time they are capable of affecting the institutions through interaction. Putting it different, both entities "are mutually constitutive, yet ontologically distinct" (Evans/Davies 1999: 371), so that policy analysis represents a combination of actor-orientated and structural approaches. The large framework, which is called the policy universe, is made up out of the international system, the state and its society. All those actors can be present in the policy subsystem, which is at the centre of analysis. A subsystem includes all relevant actors that engage in influencing and determining policies according to their interests in specific issue areas. Second, as the subsystems include a broader variety of actors in those subsystems, analysis is not exclusively limited to government activity. Further, it follows that policy subsystems are influenced from decisions made in other subsystems. Therefore, subsystems are only partially autonomous and the impact of policies generated in other subsystems has to be regarded as a major dynamic element which drives intra-subsystem activity and debate (Sabatier 1988: 137). This is very similar to described processes of fragmentation and accommodation of policies (McCool 1989: 266; 271f.): policies and subsystems get more specialised, which enhances the chances that subsystems are captured by vested interest groups. At the same time, there is a greater need for coordination upon subsystems, because their authority and expertise is becoming narrower. Hence, there appears to be a trend towards greater differentiation and interdependence between subsystems. Third, it is acknowledged that there is no sequential order in the policy cycle, although the model might suggest the opposite. The insight that sometimes stages are left out or that evaluation can influence a new round of the cycle is adaptable to innovation policy.

A similar flexibility can be noted in the interactive innovation model. This model replaced former linear and sequential linear innovation strategies. Older policy approaches to the topic of innovation, back then frequently labeled science and technology (S&T) policy, followed the logic of linear or sequential linear models: innovation was thought to evolve in a fixed and sequential order, which could be described as a chain of events. The prime example for the linear model is the Manhattan Project, a large-scale R&D program resulting in the development of the atomic bomb. The success of this project quite literally embodied the power of science, more precisely “big science”. Because the development of the first nuclear weapon appeared to have resulted from a “chain reaction”, starting with basic physics, followed by large-scale development in big science laboratories and ending in the application in the form of the atomic bomb (Freeman 1995: 9). Following this logic, a state basically had to provide the R&D budget and innovation would more or less automatically evolve. Consequently, R&D budgets were the most prominent tool of technology policy. However, later scientific work demonstrated that innovation was also linked to the application into products by firms, the diffusion of those products as well as the exchange of knowledge between companies and academic scholars and the capacity of the education system (ibid.: 10-12). This means nothing less than a shift from mainly focusing on quantitative factors towards incorporating qualitative ones.

The linear and sequential linear models were replaced by the interactive innovation model, because it became apparent that innovation is subject to many different economic and social influences, so that it rarely evolves in a linear fashion. Uncertainties of the innovation process therefore necessarily influence any policy trying to foster innovative products or processes. Addressing technological innovation policy-making, it is also crucial to realise that a large number of innovative approaches will fail and that technical advances, if they do occur, not necessarily translate into innovative products or services. Putting it different, most innovation experiments fail. Interestingly, this high rate of failure and the related perceived wasted resources of unsuccessful trials could be regarded as the starting point of social planning or innovation policy (Metcalfe/Georghiou 1997: 5). However, the belief that planning can improve the process by making it more efficient and targeted is questioned, because the generated technological variation also needs to be selected by firms and consumers, which also creates a feed-back to the variation respectively innovation process (ibid.: 5f.). This perspective has several consequences (ibid.: 9-12; 17-23): innovation policy-making must be adaptive, meaning that a high capability of policy learning and will to policy experimentation, including the use of many instruments, are deemed more likely to succeed than following an orthodox, standard operation procedure approach. Also, companies are at the centre of innovation as they posses the knowledge which products will be valued by the market and therefore, technological innovation policies need to encourage firms to use this potential or assist companies in enhancing their capabilities. Therefore, it has been emphasised that the framework of a national innovation system ideally should focus on the conditions that enable or drive innovation, rather than pursuing the achievement of individual innovations (Metcalfe 1995: 31).

The flexibility of the interactive innovation model and the plea for adaptive policy-making both suggest a view that is compatible with the policy cycle model. They emphasise that the processes of innovation are open-ended and uncertain. The cycle also acknowledges this observation, as it is impossible to determine if a topic raised through agenda-setting will eventually be dealt with in a state-implemented policy or if it fails to go through the stages of the cycle. Thus, as an innovation may never be used or commercialised, policy proposals may never enter decision-making or become implemented. Also, both perspectives stress that innovation could occur in a non-linear fashion, e.g. through a combination of already existing items, a new way of using technology and also feedback from different development stages or the market that influences development of a particular product. A very similar idea is immanent to the policy cycle model, because of the possibility that stages are left out and that evaluation can initiate a new cycle, which is basically another method of feedback utilisation. In general, innovation can be described as a cumulative process, which is path- and context-dependent (Lundvall/Barrás 2005: 615). Therefore, the concept of (international) best-practice must be doubted, because institutions or procedures that work successfully in one path- and context-specific national innovation system might not achieve similar performance in another system, which operates under its own unique conditions. This general observation is also found in the policy cycle as the subsystem resembles the path- and context-dependency in many ways: investigating the open or closed structure of a subsystem, the level of state capacity or a preference for certain policy tools are just a few examples which obviously acknowledge the distinct features inherent to each system.

1.2 The policy cycle model

As already stated, the following model represents an ideal type, but later analysis may present a differing sequence of government action.

The first stage is agenda setting, which involves the circumstances and processes that lead governments to the conclusion that there exists a problem which has to be addressed by politics. Although it appears to be a problem-solving approach, this process can also be reversed: politicians, bureaucrats or interest groups often already advocate a policy, but do not find support. Thus, the policy proposal has to be related to a problem. This linking of a policy proposal and a perceived problem has been called coupling (Kingdon 2003: 172-179). Also, it is possible to relate a policy to various problems: if an attempt to couple fails, this does not mean that the policy will never appear on the agenda. The proposed policy may be linked to another problem, highlighting the importance of persistent advocacy by the actors interested in a particular policy. Therefore, successful coupling of problem and policy is crucial for agenda-setting. However, it needs to be stressed that setting a topic on the agenda does not equal control over the following stages of policy-making or outcomes. Despite coupling, a completely different policy might be the result of raising concern about a perceived or real problem. Further, timing is crucial as the perception of a problem may pass rapidly or be replaced by a even more pressing concern. This is the reason why Kingdon describes the timely limited possibility to link problems and policies as “window of opportunity” (ibid.: 165-170).

Another way to understand policies is to place them in political environments. It has been argued that there is a dual causality between politics and policies, meaning that the way policies are formulated and implemented will depend on the level of public involvement (May 1991: 189). To define environments, it is advocated to apply a continuum which extends from “policies with publics” to “policies without publics” (ibid.: 190-197). There are several important insights can be drawn from this approach: first, in case of “policies with publics” due to high level of public interest, formulation and implementation will be largely influenced through the process of agenda-setting:

> “It is unlikely that an issue would reach sufficient prominence to place it on the policy agenda without some sense of problem definition and at least an implicit set of policy responses.” (ibid.: 193)

This perspective is very similar to Kingdom’s approach. However, if there are rivaling understandings of the problem addressed, policy-making can be conflict-ridden (see below). Second, in case of “policies without publics”, policy-making will be dominated by expert opinions and conflict will usually be absent. However, there is the danger that those policies or whole subsystems will be captured by vested interest groups. Thus, both extremes of the continuum present differing challenges for policy-makers. Third, towards the issue of learning, it is argued that under conditions of “policies without publics”, learning will be limited, because there is little debate, in general about technical details rather than fundamental convictions, and consequently less pressure to explore different solutions (ibid.: 202f.). Last but not least, in regard to the topic of this paper, May states that in the USA innovation policy falls into the category of “policies without public” while industrial policy is subsumed under “policies with public” (ibid.: 190f.). Whether or not this observation can be applied analogously to Japanese policies must be doubted (see: 4.1).

Key elements that determine if and how a problem will appear on the political agenda are the nature of the respective subsystem, because this affects if a problem is initiated by the state or societal actors, and the level of public support for a resolution (Howlett/Ramesh 2003: 140f.). From the combination of these dimensions, four styles of agenda-setting are possible: If there is a problem affecting society on a whole, outside initiation of the problem is likely to occur as societal actors will demand a solution and become actively involved in promoting a policy. However, if a societal group has close ties to the present administration it may also be able to initiate policy from the outside, nevertheless this behaviour is termed inside initiation. However, if the problem is narrower, government can also practice a form of internal initiation. When a government wants to address an issue, but support is scarce, the administration must resort to mobilisation of the public. If the administrative initiative finds broad support, the likely result is consolidation of the topic. Further, agenda-setting is the only stage of the cycle were non-members of the policy subsystem can play an influential role, because identifying an issue and calling for its solution does not require specialised knowledge in the subject, so that the entire policy universe may participate in this process.

The second stage is called policy formulation, meaning that different policy options are developed. Although formulation may be directly linked to agenda-setting, in the way that an identified problem is already put on the agenda coupled with a specific solution, usually policies are formulated in the specialised subsystems. Most issues require expertise, which is embodied in subsystem members. A division inside a subsystem can be made into policy networks and communities (Howlett/Ramesh 2003: 150f.). Whereas networks are characterised by the promotion of participants material interests, the category of policy community shares political ideas. However, networks and communities can co-exist and even if their motivation is of a different nature, they may advocate the same policies. Related to the notion of a policy community is the idea of an advocacy coalition:

> “These are people from a variety of positions (elected agency officials, interest group leaders, researchers) who share a particular belief system - i.e. a set of basic values, causal assumptions, and

> problem perceptions - and who show a non-trivial degree of coordinated activity over time." (Sabatier 1988: 139)

This framework is highlighting the importance of beliefs and ideas in politics. Advocacy coalitions pursue their goals exactly because they share a common understanding of their environment. Also, these coalitions are more inclusive than the older concept of "iron triangles" (see: 3.2) as they not only incorporate state officials and interest groups, but also journalists or researchers (ibid.: 131). Further, this concept realises that a common problem perception is crucial. Indeed, a problematic condition may persist for some time, but only if it is perceived as problematic, it will be addressed by groups and individuals through policies. However, the negative aspect of belief-based perception certainly is that information which is incompatible with one's belief-system is resisted and not acknowledged (ibid.: 133). Therefore, policy learning (see below) of an advocacy coalition or an entire subsystem may be impossible or very limited due to prevailing dominant ideas.

Another aspect is the relation of state and societal actors inside networks or to a lesser extent in communities. The position of the state inside those networks is important, because it indicates if politicians and bureaucrats can influence social and economic actors or if they are subject to pressure by those members. Yet another significant dimension of a policy subsystem is the ability to integrate new actors and ideas. With regard to the styles of policy formulation, entrance of new ideas and actors influences the mode of formulation (Howlett/Ramesh 2003: 156-159): if new ideas and actors are blocked from entering the formulation process, the result is instrument tinkering, meaning only minor adjustment of already existing policy tools. If actors are excluded, but ideas welcomed, or the opposite, medium adjustments in programs or instruments can occur, the former called program reform, the latter policy experimentation. If both, actors and ideas, are included, the outcome is likely to be a complete change in goals and instruments, labeled as policy renewal.

From the perspective of the author, this distinction between entrance of ideas and actors is somewhat problematic: although analytically elegant, separating an actor from the ideas he or she is inherently holding might be impossible in reality. No actor has exactly the same set of ideas or interests as another. Further, if the view held by an actor would already be advocated by members of the policy subsystem, the actor would have little reason to enter the deliberation. Moreover, this separation may not be generating a better understanding of the policy formulation process, because the consequences of receptiveness to only actors or only ideas are almost identical (ibid.: 158). However, the distinction made is very useful to explain the extreme types, policy renewal and instrument tinkering, as well as the related ramifications for policy formulation.

This stage is followed by the third step, decision-making, which refers to the selection among the previously formulated policy options. It needs to be stressed that the process of decision-making is inherently political, not a limited technical choice between options. The options are the result of the formulation process and as described, those can be subject to the influence of actors furthering their own, often economic, interests. Therefore, decisions are not necessarily rational in the sense of rational for the public good. Decision-making is the domain of actors that possess authority (Howlett/Ramesh 2003: 163f.). In democratic states those actors are politicians or bureaucrats that have the legal authority to initiate action on behalf of the public. Of course, other actors from society or foreign countries might actually influence decision-making through lobbying or pressure, but the formal power to make legally binding decisions rests with the governmental and bureaucratic office-holders. However, non-action is also a possible alternative of decision-making. This leaves three possible types of decision-making: positive, negative and non-decision. Positive decisions are those which become implemented and alter former policies. Negative decisions are characterised as an arrested policy cycle, since they are options that appeared in the previous stages, but are discarded in order to maintain the status quo. This separates negative from non-decisions, which represent options that are consciously blocked from entering the cycle altogether, because they represent an undesired change of the status quo. Because decision-making is taking place under complex conditions, models seek to combine rational and incremental approaches. Howlett and Ramesh suggest that the complexity of the policy subsystem and the severity of constraints the decision-makers face are the most critical indicators to understand the nature of the decisions made (ibid.: 182f.): If the subsystem is highly complex and the constraints severe, resulting decisions will be limited to incremental adjustment. If the situation is opposite, a simpler subsystem and low constraints, decision-making will be comparatively easy, so that a more rational search for policies occurs. If the subsystem is complex, but facing low constraints, the likely result is optimising adjustment. Optimising adjustment is related to so-called mixed-scanning models, which stress that rationality is limited to areas perceived most crucial for addressing a problem. It is also differentiated between fundamental and incremental decisions: fundamental decisions only explore the main alternatives without much concern about the details or possible effects. Incremental decisions occur within the context of fundamental ones. Further, it is argued that both types are each others corrective, so that there is constant interplay (Etzioni 1967: 390). The context-rational fundamental decisions address long-term perspectives, which are often ignored due to incremental conservatism. In turn, incremental decisions correct rational ones by focusing on the detailed effects of policies and seek to optimise the used tools. Critisising the incremental approach for lacking any guiding principle to determine the direction of decisions, Etzioni makes a very important observation: [an] "accumulation of small steps could lead to a significant change" (ibid.: 387). This means that many incremental decisions could have the same changing impact than one fundamental decision. A very similar logic is presented in volume edited by Wolfgang Streeck and Kathleen Thelen: studying changes in social institutions, several case studies demonstrate that transformative change can result from incremental change, identifying five types of gradual transformation (Streeck/Thelen 2005: 16-33). The concept of transformative and incremental change put forward by the authors can be closely related to the idea of fundamental and incremental decisions by Etzioni. Although mixed-scanning is labelled a decision-making approach it is clear that close links to policy formulation are present in the process of scanning on different levels. Further, the model has later been extended to incorporate strategies for implementation and review (Etzioni 1986: 9), so that almost the complete policy cycle is covered by this model. The approach realises the role of structural factors such as the position and relative power of the actors that affect decision-makers (ibid.: 11), which is similar to the idea of the policy subsystem. Because of the incremental aspect of continuing scanning and re-evaluation, it is noted that the mixed-scanning model can become a "quasi-satisficing approach" (ibid.: 9). If the subsystem is simple, but constraints are high, satisfying search will occur, meaning that search is likely to end as soon as a solution is likely to address the problem in a viable way. However, the satisfying search will resort to this solution even if it is quiet distant from being optimal. It could be said that satisfying search will result in an effective resolution of the issue, but not in an efficient one. As pointed out before, the distinction between satisfying search and optimising adjustment could be regarded as being quiet blur and therefore difficult.

In turn, the fourth stage of implementation describes methods or strategies by which decisions are put into practice. Implementation is the domain of bureaucracy, but some qualifications are put forward (Howlett/Ramesh 2003: 187): bureaucracy is never a monolithic block, but rather consists of many agencies, sometimes even bureaus, with different agendas and interests on their own. Further, members of a policy subsystem will try to influence implementation, because this function determines the actual outcome of all other stages. In this stage the choice of the instrument of implementation takes place, because decision-makers seldom provide a clear goal or direction, nor prescribe a specific instrument (ibid.: 189f.). The instruments can be divided in substantive and procedural types, the former delivering or affecting the delivery of goods and services in society, while the latter alter aspects of policy deliberations (ibid.: 91). Thus, substantive instruments deal with the question of how to deliver policies whereas procedural instruments are concerned with the question of how these policies are born out of interaction patterns by the political process. Also, tools may be categorised by the type of resource governments use to implement their policies. Organisation, authority, treasure and nodality are the main governmental power resources and the instruments can be assigned to one of these categories (ibid.: 91-116). Especially if decision-makers and implementing bureaucrats are confronted with complex issues, it is likely that a policy combines the use of several tools from different categories to address the problem from various angles. Despite this observation, a model of implementation styles can be applied. Using the nature of the policy target and the severity of constraints on the state as indicators, the following categories exist (ibid.: 203f.): if a policy target is highly specific and constraints on the governmental decision-makers are low, directed provision policy is an often observed approach. Owing to the specific nature of the issue, the state can use its organisational capacity to address it, while low resistance reduces the need to persuade or include societal actors. If the target is narrow, but the government is confronted with various limitations, e.g. legal, monetary or societal opposition, policies are likely to rely on regulation, which is combined with provision of financial incentives for the organisation of targeted actors in the policy subsystem. Such an approach, using the carrot and the stick, exemplifies that different, i.e. negative and positive incentives, may be employed simultaneously in order to achieve the specified goal. This way of implementing policy is called representative legalism. If a broad issue has to be addressed while decision-makers face multiple constraints, they will tend to use information-based substantive tools and the procedural tool of reorganisation. This approach, which on the one hand seeks to promote policies by speech-based acts like exhortation or persuasion and, on the other hand, utilizes governmental authority to change interaction structures, is called institutionalised voluntarism. If a broad target is pursued without significant constraints, implementation is likely to employ treasure-based policy tools and communicate goals towards stakeholders. Further, this channeled consultation could be used to establish a dialogue to ensure continued flow and exchange of information between the state and relevant societal (interest) groups. This method of implementation is labeled directed subsidisation and with regard to the case studies, it should be highlighted that this type is commonly found in industrial policies.

The fifth stage of policy evaluation refers to the processes of judging the effects of particular policies and conclusions from evaluation can set off a new cycle by identifying remaining problems or ineffective measures of implementation. There are three basic types of evaluation

(Howlett/Ramesh 2003: 210-216): judicial, administrative and political. Judicial review first and foremost judges the legality of governmental and bureaucratic action. In this process, the judiciary assesses if policies conform to constitutional principals and administrative bodies act in the boundaries of their legally prescribed jurisdiction. Moreover, in states like Germany, courts may play a influential role as they are not limited to strictly legal, procedural parameters. Administrative evaluation is more concerned with economic or budgetary cost-benefit assessment. The aim is to establish how efficient or effective the implementation process was conducted, analysing the costs and performance of a policy or program. However, administrative units also have organisational self-interest in continuing programs, which equals jurisdiction and command over financial resources. Thus, if the administrative body performing the program and its evaluation are identical, evaluation is likely to be biased. Therefore, dividing project administration and its evaluation between separate agencies may be sensible. Moreover, it is also important that administrative review may be subject to influence of political actors, who wish to portray their policies in a positive fashion and therefore lobby for evaluation with favourable indicators. Thus, administrative review processes can be manipulated to arrive at a desired, predetermined conclusion about the evaluated policy. In this case, the distinction between administrative and political evaluation becomes blurred due to political interference. Political evaluation is most likely to be biased as the interests of the evaluator guide the assessment. Judging policy is a very political process, because there are usually no clear or fixed criteria of evaluation, so that the establishment of indicators will significantly shape the following analysis and its results.

Possible outcomes of policy evaluation are continuation, alteration and termination. Upon these, termination is most rare. Possible explanations are a tendency towards stability and persistence of organisations. Termination of longer existing policies has been compared to human relationships:

> "Have we not heard of those who stick to a relationship just because they have grown used to the institutional inertia, are better off financially, or will not face the cost or legal complexities of ending it? […] Till death do us part… how nice to cleave to the oath. But at what price? […] While the oath above is not officially sworn in public policy and public management, organizational survival patterns, as well as legal and cost-benefit concerns, are analogical to their equivalents in human affairs." (Geva-May 2001: 265)

According to this perspective, termination is avoided because of the political, financial, legal as well as emotional costs. While judgments seldom declare flawless success nor complete failure, continuation and termination only occur as exceptions, but most evaluations will arrive at the conclusion that improvement of a policy is possible or necessary. Therefore, alteration of the program or parts of it is likely to appear. The level change tends to be incremental due to path dependency of the policy subsystem and its policies.

Related to evaluation is the question of policy learning. Learning can be interpreted as conscious attempt to improve existing policies, but also as a mere reaction to changing conditions affecting the policy under review. Therefore, learning can be initiated endogenously or exogenously. With regard to the former, it needs to be stressed that learning or lesson drawing must be an intentional exercise directed towards changing policy to distinguish it from the effect or reliance of policy-maker's past experience (Evans/Davies 1999: 365-367). This point is crucial, because otherwise almost all decisions could be labeled as lesson drawing as experience will often be included subconsciously. Another aspect is who is learning and what is learned. Learning may be limited to a subsystem or occur on a larger scale, namely the policy universe while the object of the process may be restricted to specific instruments, but also extend to a redefinition of the problem addressed by a policy. One special type of organisation which has been credited as influential are so-called epistemic communities (Haas 1992: 2-4): these networks of knowledge-based experts are said to play an important role as advisors on increasingly complex policy issues that confront decision-makers. It should be stressed that the idea of an epistemic community is highly idealistic. This ambition is reflected by the differentiation between them and administrative bodies: epistemic communities are said to operate on the basis of normative objectives, whereas bureaucracies further their own interests, embodied in their missions and budgets (ibid.: 19).

The relation between evaluation and learning can be investigated by assessing the level of administrative capacity of a state and investigating if a subsystem is dominated by state or societal actors. Those indicators generate the following evaluation styles (Howlett/Ramesh 2003: 222-224): If state capacity is high and state actors dominate, the likely result is endogenous lesson-drawing, also called instrumental learning. If capacity is high, but societal actors are more influential than state-centered ones, the process is called social learning as learning emanates from non-governmental actors. If administrative capacity is weak and the state dominates the subsystem, learning effects will be very limited and it is likely to arise from technical evaluations. If state capacity is low and societal actors more influential, the result will be non-learning, because evaluation does not even follow some limited rationality as in the former case, but is mainly subject to political interests. All in all, it stands out that state administrative capacity is critical for any substantial learning process. State capacity is necessary to absorb any evaluation, regardless of its origin, and transform the results into improved policies.

Finally, students of public policies seek to identify long-term patterns of policy-making in subsystems. This idea is embodied in the so-called policy regime, which combines persistent patterns of policy processes and contents (ibid.: 233f.). While the processes, represented through the already put forward policy styles, deal with the question how policies are made, prevailing contents, called policy paradigms, define ideas and issues addressed through these policies. Moreover, although regimes are examples of lasting processes dealing with persistent or reoccurring contents, regimes are also subject to change. Change can be of incremental or fundamental nature, but the former is more common than the latter, which is the reason why they are also labeled as normal and atypical respectively (ibid.: 234-242). However, it must be underlined that both modes may be interlinked, e.g. that long periods of incremental change are followed by a brief phase of fundamental shift, which then is a newly established, dominant set of ideas and processes, but in turn also will become subject to many incremental changes. Further, policy processes like learning represent the openness to a certain degree of change via regime-internal functions, so that regimes should not be misinterpreted as frozen structures. On the contrary, they have inbuilt features that enable modulation. However, as already pointed out, learning tends to be embedded in existing belief-systems and structured through institutions that seek continuity. Exactly for these reasons, the level of change tends to be rather evolutionary and path-dependent than revolutionary.

2 Japanese environmental policy

It has been noted that the Japanese environmental policy approach tends to be largely technological, so that environmental problems have usually been framed as “brown” issues instead of “green” ones (Vinger 2008: 5f.). The reason for this as well as a hypothetical connection with the Japanese cultural concept of nature has not been explored so far (Vollmer 2006: 15f.).

Japan was, together with the USA and Sweden, among the pioneers of environmental policy. However, this cannot be attributed to any special Japanese concern about nature, but rather to an increasing impact of pollution. Japan’s priority after the Second World War was clearly on economic growth while environmental concerns were virtually absent (Fukui 2002: 3f.). Air pollution and water contamination increased rapidly and began to affect public health: in the 1960s, diseases caused by mercury and cadmium poisoning - Minamata and itai-itai (meaning: it hurts, it hurts) - initiated citizens’ protest and put the problem on the political agenda. Therefore, environmental policy in Japan started out in 1967 with the enactment of the Basic

Plan for Environmental Pollution Control. The step to institutionalise environmental policy in a government branch was the establishment of the Environmental Agency (EA) in 1971. It should be pointed out that the EA did not have the rank of a ministry, resulting in a comparatively weak regulatory authority vis-à-vis other bureaucratic bodies. However, EA could promote its policies through several channels (Wong 2001: 51-57; Graham 2002: 126-130): it was established as an agency in the Prime Minister's Office, which granted access to the head of the executive and allowed EA some informal influence. EA was headed by a minister of state, who was a member of the cabinet. Further, it was designed as a coordinating agency, which included the right of recommendation. Although, this right does not grant power, it can be utilised to initiate debates and to promote the view of the agency. The only other government body that possessed this right was the Ministry of Finance (MOF). However, EA needed the consent of other ministries to issue guidelines or to present bills to the Japanese diet. This means that EA was forced to compromise with ministries in policy-making, because its jurisdiction was extremely limited, mainly centered around water and air pollution. Last but not least, EA was newly created in 1971 and its staff was pooled together from various ministries. These ministries intentionally installed their staff to influence EA positions and policies, so that many officials had dual loyalties. Not until 2001, this arrangement was changed: during the major institutional reorganisation (see: 3.5), EA was upgraded to the Ministry of Environment (MoE).

The role of local governments in pollution control has helped to reduce environmental degradation and negative impacts on public health. The tools which local authorities frequently used were so-called local governmental research institutes (LGRIs). These organisations were especially important for SMEs as many small businesses could not afford to conduct their own pollution control research or buy expansive equipment. Main tasks of LGRIs were technical guidance and testing on request for regional firms as well as conducting their own R&D activities (Ito 2007: 73). Although LGRIs seem to have a positive influence on the diffusion of environmental technology in the past, these institutes face problems that might undermine their capability to provide technical guidance in the future: the number of LGRIs decreased, their staff has been reduced and coordination between industry and academia is a new, additional task (ibid.: 84f.).

A factor that has significantly contributed to the continuing commitment to environmental issues is the so-called Kyoto-Protocol of 1997. The Japanese industry lobbied against it, especially after the US administration of George W. Bush had abandoned the protocol. Therefore, on the one hand, there was understandable concern about losing competitiveness on the global market, but on the other hand there was support for ratification by NGOs and the media, so in the end the Koizumi administration chose to commit the country to the protocol by ratifying the bill on May 17, 2002. It has been suggested that the Kyoto-Protocol has been transformed into a powerful symbol of Japanese concern about environmental issues like global warming and the dedication to resolve those problems (Tiberghien/Schreurs 2007: 78-82). Last but not least, it is noteworthy that since the beginning of the new millennium, there is a tendency in Japan to combine environmental and economic topics. The former Prime Minister Koizumi Junichiro and his Environmental Minister Koike Yuriko repeatedly emphasised the role of environmental technology as the key to revive the national economy after the stagnation of the 1990s (Tanaka/Ahlner 2003: 9). MoE even promotes the “Environmental Revolution” as the next step after the “Industrial” and “IT Revolution” (Guilamo 2007: 12).

On the whole, a strong interaction between environmental and economic policy is visible in Japan. The willingness of Japanese industries to engage in emission reduction is exemplified through the 1997 Voluntary Action Plan by Keidanren (now: Nippon Keidanren), Japan’s largest business federation. In order to avoid regulation, Keidanren committed itself to reduce CO^2 emissions at a level lower than 1990 by 2010. This aim was achieved every year since 2000 (Andersson/Widegren 2006: 17). Nevertheless, Japanese GHG emissions actually increased by 8,1% in 2005 (ibid.: 18), which was a further gain compared to 7,4% in 2004 (Guilamo 2007: 19). Enhanced emissions are largely due to increased energy use by consumers (Wieczorek 2007: 60). This trend is thought to be caused by intensive use of electric household and office appliances as well as the internet. Thus, while the emissions of the production processes have been lowered, increased utilisation combined with constant energy demand of appliances has led to more emissions. The issue of energy end-use is addressed through the so-called top-runner program of 1999, which sets energy-efficiency parameters (Nordqvist 2006: 5-10). This step is yet another example of the technical approach towards environmental problems, but the rationale behind it is coming under scrutiny. The Science Council of Japan (SCJ), a special organisation under the jurisdiction of the Prime Minister since 1949, which is representing the interests of Japanese scientific community, stressed in a report on future development:

> “In the 21st century, however, sustainable development will be possible only if we are prepared to change individual and group values.” (SCJ 2004: 6)

Thus, although there are doubts about solely continuing this practice, the largely technological approach of problem solving in environmental issues seems to have been quiet successful in the past. Today, Japan is the most energy-efficient economy, if the indicator primary energy use per unit of GDP is used (ANRE 2008: 29; Ushiyama 1999: 1174). The newly elected Hatoyama administration entered the failed negotiations at the Copenhagen summit with the highly ambitioned goal to reduce emissions by 25% by 2020 (SZ online, 10.12.2009). With regard to the problems Japan experiences to reach the current reduction target, combined with the already achieved energy-efficiency in production, this goal could be said to be overly ambitious. However, with regard to the case study, as 21% of Japanese emissions stem from transportation (Saito 2005: 6), mass diffusion of alternative vehicles would enable major reductions. Therefore, the aim of the Hatoyama administration may reflect optimism towards the possibility to introduce and commercialise new, environmentally-friendly technologies, like co-generation systems and alternative vehicles in the near future.

However, there seems to be a lasting effect: the Japanese industries learned during the oil crises that environmental protection efforts also could lead to less resource consumption equal with decrease in production cost. It must be pointed out that those cost reduction effects usually are only realised over a longer period as initial development and installation of technologic pollution control can be expansive. However, in the long run, technologies or production processes that require fewer resources help companies in competition as they are more cost-efficient. Also, today eco-friendly production and low energy consumption of the finished product are features that firms can use in marketing their goods and for creating a positive brand image. Japanese companies regard environmental technology as an increasingly important factor for their future competitiveness (Guilamo 2007: 19), which has been demonstrated in several short case studies, e.g. about Toyota, Hitachi and Sanyo (Andersson/Widegren 2006: 18-25) or Toshiba (Tanaka/Ahlner 2003: 28-33). It is noteworthy that all these firms are established, large-size MNCs and that their activities started at the early or mid-1990s, which gives them the role of a trendsetter for companies like BMW, who advertise that they want to run their production plants only with renewable energy in the near future.

Last, and with regard to the theoretical framework, the role of (environmental) non-governmental organisations (NGOs) in Japan should be clarified (Wong 2001: 69-74; Danaher 2002): in general, NGOs are comparatively weaker than their Northern American or European counterparts. This is mainly rooted in bureaucratic disapproval and the perception of NGOs as a threat to administrative authority. Therefore, the legal conditions are unfavourable, e.g. funding and donating is constraint as tax deductions depend on the function (as defined by state officials) of the specific NGO. Thus, donations are limited and NGOs do not command large sums. Further, NGOs in Japan tend to focus on local issues, so that there are no influential national umbrella organisations. Preoccupation with local problems tends to result in “not-in-my-back- yard” (NIMBY) politics. As NIMBY politics rather express unwillingness to bear a burden by oneself than fundamental conviction that the issue at hand is generally problematic and undesirable, public environmental concerns stop short of manifesting themselves on the national level. Thus, they can become influential in local affairs, but there is a lack of national (as well as international) cooperation between NGOs. This may also partially explain why there is no Green Party on the national level in Japan. This is even more noteworthy as despite long prevailing single-party rule and a recent tendency towards a more concentrated party system, Japan still has a multi-party system. Although NGOs are comparatively weak, they are becoming more influential, especially in the field of environmental politics since the agreement on the Kyoto- Protocol in 1997. Thus, it can be claimed that NGOs were usually not included into policy subsystems in Japan and they were kept weak by structural constraints. The more recent trend towards cooperation now seems to allow NGOs some influence in selected policy subsystem. However, it appears that NGOs are perceived as useful tools and not as equal partners or embodiment of social expertise.

All in all, Japan has been labeled as one of the leading countries in what is called eco-innovation (OECD 2008: 22), which is described as a way to achieve sustainable, environmentally-friendly economic growth. Japanese industry and government seek to uncouple growth from resource use, mainly because the country lacks an own natural resource base.

3 The Japanese national innovation system

3.1 Long-range planning

An outstanding feature of the Japanese innovation policy process is the utilisation of technology foresight surveys by the so-called Delphi method. Japan has continued to carry out Delphi surveys from the 1970s while most European countries ended their Delphi studies after the first oil crisis and restarted national Delphi surveys around the 1990s (Cuhls 1998: 26). The surveys were carried out by the Science and Technology Agency (STA). first by its planning bureau, later by the National Institute of Science and Technology Policy (NISTEP), which was under the aegis of STA. STA was fused with the Ministry of Education (MOE, known as Monbusho) into the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2001, but the surveys are still conducted by NISTEP.

The Delphi method is based on a selected panel of experts and a structured questionnaire. The timeframe of all Japanese surveys has been 30 years: The experts are asked to indicate at which point in time the stated objectives of future technology could be realised or if they thought it was impossible to achieve a goal in the next 30 years. From the second survey of

1976 onwards, those who thought that realisation was not possible in the given timeframe were asked to elaborate their reasons. Further, it was asked which - state or private organisation - could promote R&D, by which methods and by what means (ibid.: 102). The participants' anonymous responses to the questions are evaluated and the results are entering into a second (and possibly third) round of the survey, where the experts again are asked to comment on the same questions. The point is that in the first round the judgment is only based on the experts´ knowledge while following rounds confront the experts with the answers of their colleagues. Thereby, the experts get a feedback to their opinion, a statistical overview of all responses and often they are asked to state reasons if their judgment is extremely different to the mean average.[3] Therefore, the participants can change their mind or confront the rest of the panel with their own assessment and critique. Furthermore, it is usually asked which nation is currently the most advanced in a certain field of technology, so that the level of other countries is viewed as a benchmark to be achieved (Cuhls 2007: 38). A useful differentiation has been introduced in the eighth Japanese study: the topics are assessed towards the time of technological realisation and social application (e.g.: NISTEP 2005: 340). This should be valuable information for decision-makers as it highlights the fact that innovative products will need a certain timeframe to diffuse into the market and society. Such information could raise questions about state measures that could support diffusion or help identifying obstacles blocking social application. Moreover, there exists a variety of other forecast activities at different levels in Japan, ranging from ministries with an own R&D structure to private businesses. Kuwahara Terutaka, former head of the Technology Forecast Research Team at NISTEP points out:

> "Among these activities, the STA Delphi survey is designed considering the Japanese science and technology administrative background and provides a basis for all other forecasting activities. As Japanese science and technology administration is distributed in many government ministries and agencies that have their own research institutions budgets, government R&D programs as a whole are implemented through STA's coordination." (Kuwahara 1999: 6)

The utilisation of Delphi surveys is also mentioned in the third S&T Basic Plan (Government of Japan 2006: 18). Another aspect should be mentioned here: although the survey strongly focuses on technological foresight, there are sometimes also political measures explored. One exemplary topic is the introduction of an environmental tax (NISTEP 2001: 386). This is clearly a political or administrative tool, which utilisation is not connected to or dependent on

[3] From the second round of each survey a graphic was illustrating the points in time when 25%, 50% and 75% of participants were expecting realisation of the subject. Example of this visualisation, see: Irvine/Martin 1984: 112

technological innovation. However, the Japanese Delphi-surveys serve the main purpose to inform decision-makers or decision-making institutions about the judgment of technical experts. E.g., the eighth survey was planned and timed for 2003/04, so that the results could enter the discussions on the Japanese third S&T Basic Plan which covers the years 2006-2010 (Kuwahara 2004: 34). This point needs to be stressed here: the purpose is first and foremost that of information, because there is no automatism that the identified future topics are getting priority attention or funding from the state institutions (Cuhls 2007: 47). Political decision-makers themselves will select which issues they regard as being of critical interest for Japan's future and international competitiveness. It is also reported that Japanese companies use Delphi-surveys even more often than in-house, external organization's or industry forecasts to identify future trends (Kuwahara 1999: 11). The utilisation of Delphi foresight studies in different countries varies greatly (Metcalfe/Georghiou 1997: 22f.) which can be explained by the underlying administrative culture of individual states. This planning activity of the state appears to have stood in stark contrast to private company attitudes: an analysis of Japanese economic development since the Meiji Restoration even arrives at the pointed conclusion that prior to the 1970s, more precisely before the oil crisis, Japanese private companies did not posses a corporate strategy and did not employ strategic R&D planning (Yamauchi 1983: 328-335).

3.2 Political framework conditions

Innovative development often takes place inside firms, but the political environment is able to provide conditions that support or discourage research. Besides monetary incentives, a high quality education system and stable, reliable conditions for R&D are being attributed to positively affect innovation. An outstanding feature of the Japanese political system is the dominance of the Liberal Democrat Party (LDP): for most of time covered by this study the LDP held power, the only exceptions being 1993/1994 and the loss to the Democratic Party of Japan (DPJ) under new Prime Minister Hatoyama Yukio last year. With such ongoing influence the LDP decisively shaped the framework under which Japanese innovation policy operated.
Long-term success provided a stable and reliable set of conditions. Industry, bureaucrats and LDP-politicians were able to establish close relations, sometimes referred to as "iron triangles" (鉄の三角/tetsu no sankaku). Here is not the place to enter into the discussion on if or

how much these informal networks or its respective actors dominated Japanese politics[4], but one aspect is nevertheless important for the policy analysis: the position of the LDP minimised the role of other parties in those "iron triangles", which should be regarded as policy subsystems, or at least as their respective cores.

Benefits or side-effects of such stable environment could be mutual information exchange and close cooperation based on trust, the already mentioned foresight-based long-range planning and general reliance on political promises. With the LDP in power, societal members of the subsystem could rely on the continued commitment to a taken course of action. Possible pressure and demand for change by new state subsystem members due to shifts in governmental power were more or less absent.

Extraordinary close ties were created between the LDP and the ministerial bureaucracy. An inter- and intra-agency procedure of consultation for legislative projects, called "ringi sei" (稟議制), was mirrored by an intra-party structure, so that the politicians in the respective groups were incorporated into legislative planning by the bureaucracy before a formulated bill entered the diet. This system was informally called "pre-appraisal system" (事前審査制/jizen shinsa sei) (Klein 2006: 290). Politicians who take strong interest in particular topics and industrial sectors, known as "zoku giin" (族議員)[5], are especially active in their respective sector - "zoku giin" are organised along ministerial sections - and the system allowed those politicians to be influential in the respective branches (ibid.: 97-99; 290) Further, it is possible that a single politician is active in more than just one zoku-network. It has been noted that these politicians also use their ties to the bureaucracy to protect sectors from deregulation (Kusano 1999: 69) or misuse their networks for personal enrichment (Choi 2007: 935f.). With respect to the analysis, (automobile) industry and transport "zoku giin" must be accounted as the political members of the policy subsystem. This is in line with the observation, that legislatures in parliamentary systems - like Japan - are not significant actors in the policy process, but individual legislators may be subsystem members due to their expertise and thereby command considerable influence (Howlett/Ramesh 2003: 67). However, the problem is that little is known about how the relationship between legislators and industries works and the actual number of "zoku giin" is unclear. This is due to the informal and opaque nature of these connections. The only numbers available are from a Japanese study made in 1986 (quoted by: Klein 2006: 99): according to this source the "zoku" on industry and trade, related to MITI,

4 Thorough discussion of revisionist, counter-revisionist, neo-pluralist and rational choice approaches towards the question which group dominates Japanese politics, see: Wright, 1999

5 "zoku" means tribe or family, but in this context it is used for political factions. "giin" means member of parliament. "Industry sector assemblyman" or "special interest legislator" might be proper descriptions of their function in the Japanese political system.

was the largest with 34 members from the House of Representatives and seven from the House of Councilors, followed by agriculture and construction. Transportation was a middle-sized group which consisted of 19 legislators from the lower and six from the upper house. The obvious problem is that the data is outdated. Further, as these networks mirrored the ministerial structure, the administrative reform of 2001 (see: III.5.) may have also altered the organisational form of the "zoku". Therefore, it can only be speculated that the number of METI related "zoku giin" roughly remained the same, while the merger of the Ministry of Construction (MOC) and Ministry of Transport (MOT) may have caused a fusion of their respective "zoku"-networks.

Another feature that influences the interaction inside the policy subsystem is relations between the bureaucracy and private companies. One particular connection is called "amakudari" (天下り), literally meaning "descending from heaven". This term describes the transfer from retired bureaucrats into private companies or politics. One clear effect of "amakudari" is the establishment of informal ties between bureaucracy, politicians and industry. As these networks are opaque it is hard to determine how influential these connections are and if they strengthen just one side of the "iron triangle". Therefore, two diverging interpretations of "amakudari" exist: older assessments stress that bureaucrats are often employed by middle-sized firms, which seek to gain access to the bureaucracy via "amakudari" in order to equal the structural disadvantage they have in this matter against large MNC competitors (Calder 1989). To this rather positive function could be added that the experience of ex-bureaucrats in politics enhance the ability of parties to monitor the administration. After several corruption scandals involving former bureaucrats were disclosed in the 1990s, the phenomenon has been increasingly regarded as a form of structural corruption (Choi 2007: 933-935). Regulation was legislated, which set a two-year ban before companies could employ officials that held administrative authority over their business sector. However, it should be pointed out that such practice is not exclusive for Japan. Very similar procedures can be found in many countries, e.g. in France, where it is called "pantouflage", or the "revolving door" in US politics. The more recent and probably more problematic, opposite phenomenon that private company personal is seconded to administrative bodies is called "amaagari" (天上がり/ascending to heaven) and so far not subject to academic analysis.

3.3 Governmental R&D funding and strategy

Another aspect that deserves attention is government R&D spending: Japanese governmental R&D funding has been comparatively low in comparison with other advanced economies (Wakabayashi et.al. 1999: 3). However, it should be pointed out that is mainly due to the virtual absence of military research (Stenberg 2004: 28). The pattern changed since the end of the 1990s, when the overall percentage of R&D compared to GDP has significantly increased (Shiozawa/Ichikawa 2005: 140; Cuhls/Wieczorek 2008: 45; see: Fig.7). Another step to stimulate more private sector R&D was the overhaul of tax credits for R&D in 2003. Since then, 2-3% additional deductions can be made, but additional to this permanent change, some timely limited extra incentives were granted (Tanaka 2006: 1). So, while the government increased its R&D budget, it also improved the conditions for private sector R&D investment.

However, looking back at the long lasting practice of limited government R&D funding, it is essential to note that this was intentional. The logic or philosophy behind this was that government R&D should induce industrial R&D spending in the targeted area (Watanabe 1995: 243). Further, it has been noticed that government-initiated R&D consortia are an often utilised tool of administrative intervention in Japan. Empirical studies demonstrated that participation in consortia was related to higher R&D spending of the firms, an increase in research productivity as well as augmented knowledge spill-over effects (Branstetter/Sakakibara 1998: 231). These positive results have been qualified: Not questioning the past success, but emphasizing the impact of structural change, the argument suggests that the former virtuous cycle between spill-over effects and the quality of participants has degenerate to a vicious one, where reduced effects lead to decreasing quality of participants (Watanabe et.al. 2004: 406; 415-417). Moreover, the relative success of Japanese consortia in generating knowledge spill-over might be a result of the differing method of patenting, combined with diverse utilisation pattern of patents by Japanese companies (Cohen et.al. 2002: 1364-1366). Also, the specific problems of cooperative research in consortia like asymmetry of information, protection of property information and distribution of rewards, profits and patents must be kept in mind (Aldrich et.al. 1998: 274).

Stating how many funds are actually provided is also complicated: research on government subsidised consortia points out that even if data is accessible, it does not allow identification of the amount received per firm per project per year (Branstetter/Sakakibara 1998: 213). This situation still remains: although annual budget figures for headline topics are available (e.g.: NEDO 2008a: 1f.), it is not specified how much money individual projects will receive and how these sums will be divided between the participating companies, government science laboratories and universities (ibid.: 3-23). Hence, R&D funding is opaque rather than transparent and it is difficult to state how many subsidies are channeled towards the Japanese industry and for which research projects.

The emphasis on the encouragement of creativity is also new. While Japan has well-educated human resources, they are often said to lack originality. In order to change this situation, especially young researchers should be supported and given greater independence (Government of Japan 2006: 22-24). Now the government promotes people who think outside the box, the so-called 'nail that stands out' (Cuhls/Wieczorek 2008: 84). This is noteworthy reference to a Japanese proverb: the nail that stands out, gets hammered down (出る釘は打たれる/deru kugi wa utareru). This means that unorthodox behaviour gets sanctioned, which indicates that a dramatic departure from this social principle is desired in science. Advancing behavioural change in order to generate more creativity is going to be a long-term objective, but it must be doubted whether this sort of socio-cultural transformation can be limited to the realm of science.

3.4 Administrative guidance

The practice of administrative guidance also has influence on innovation policy. Administrative guidance should also be placed in the Japanese political context of one-party dominance and the established close ties between state and societal actors. This form of state intervention has been much discussed ever since it was described by Chalmers Johnson, mostly concerning government ability to direct and create economic growth via targeting key industries and allocating preferential credits through a state controlled banking system, export-promotion and import restrictions. It is interesting to note that even those scientist who argue that the system has broken down in the 1970s or 1980s, do not deny positive impacts of MITI policy in the past (Callon 1995: 4). Later, Johnson qualified his approach and pointed out that it is crucial to realise that it is time specific, especially US tolerance of protectionists´ practices and that Japan was catching up to the advanced industrial economies (Johnson 1999: 54-56).

Again, it needs to be emphasised that the Japanese state is far from being a single, monolithic unit, which miraculously steers the development towards a desired end. Interaction between agencies and companies is influenced by the relative strength of the respective units. The recent scandal involving Toyota might be a good example: the Japanese agency in charge of transportation safety is reportedly staffed by 16 personnel, of which 15 are only employed in part-time jobs (Spiegel, 01.03.2010: 80). Obviously, the office is under-staffed, so that it is difficult to prevail if confrontation with other agencies or automobile companies occurs.

Although there exists an orientation towards consensus-building, Japanese bureaucracy is described as competitive, conflict-ridden and lacking cooperation. This situation is portrayed in the phrase: “There are no ministries, only bureaus.” (Klein 2006: 291) However, critics who focus on this feature of Japanese politics and argue that this makes the system incapable of consensus and inefficient miss the following: the existence of diverse interests, intra- or inter-agency conflicts does not inhibit consensus-building, but rather make it necessary to arrive at some kind of mutual understanding. Consensus is not a continuous status, rather something that has to be reached through ongoing struggle over the diverging options.

One tool of administrative guidance in the field of innovation policy is the so-called S&T Basic Plan. Established through the S&T Basic Law of 1995, from 1996 onwards, five-year plans have been drawn up to target key technologies. Regarding the first S&T Basic Plan, it was been criticised that it applied the logic of the linear innovation model (Harayama 2001: 20). This approach was discontinued as the successive Basic Plan put more emphasis on interaction with and feedback from society (ibid.: 20f.). Since the second S&T Basic Plan, the priorities are determined through the newly founded Council for Science and Technology Policy (CSTP) (see: 3.5). Targeted technologies or fields, partly identified via foresight surveys, receive the lion’s share of funds in order to accelerate the invention process, which in turn should explicitly ensure the competitiveness of the Japanese economy (Government of Japan 2006: 20). Four priority fields - life sciences, information technology (IT), environment and nanotechnology - and four additional areas - energy, manufacturing technology, social infrastructure and frontiers, i.e. ocean and space - have been selected for the second S&T Basic Plan. As a result, government-funding is highly focused, the fields received 45% of national R&D funds, the areas another 38% (Stenberg 2004: 14f.). The concentration of the R&D budget became even higher, e.g. the 38% spent on the areas in 2001 reached 46% in 2005 (Government of Japan 2006: 4). As some topics are interrelated, e.g. environment and energy or manufacturing and nanotechnology, synergies are possible so that effects of targeting could be even stronger than the figures suggest. In the third S&T Basic Plan the fields remained unchanged and minor adjustments or additions were made in the areas (ibid.: 17). So, the Japanese government reemphasised the support towards those subjects by concentrating the R&D budget. However, there is also the downside of focusing, namely the risk that other technological developments are overlooked.

It has been stressed that METI lacked any legal basis to enforce its directions. Using a law of resource utilisation as an example, the following can be stated (Lorenz 2006: 160-171): The use of guidelines as a means of administrative guidance is based on legal grounds, but is usually limited to measures falling short of enforcement such as recommendations, advice or public announcement. However, public announcement is already considered to be an indirect sanction and companies are said to be afraid of being openly singled out as an underperformer. This may explain why sharper legal instruments like a legal requirement or even an administrative fine are seldom utilised, although these are available bureaucratic tools. Further, utilisation of each specific instrument is based on the formulation that it can be employed, which allows the administration a wide area of discretion. A possible reason for the prevailing influence of the mainly informal institutions in Japan is tradition: METI's past and continuing reliance on consensus building and informal sanctions could be regarded as based on the value system of the Tokugawa period (Hill 1995: 121-125). At the same time, cultural explanations should be applied very cautiously: while Confucianism was long said to be reason for the backwardness of Asian states, today it is often identified as the cause of economic success and dynamic development (Johnson 1995: 38-50).

3.5 Administrative reform

It is also necessary to investigate the impact of administrative reform[6] on the national innovation system. The reforms passed the diet in 1999 and became effective in 2001. Four aims were pursued (Klein 2006: 324): First, with regard to law-making, the cabinet and the legislature should gain strength vis-à-vis the ministerial bureaucracy. Second, intra- and inter-agency sectionalism should be reduced. Third, the work of ministries and agencies should become more transparent in order to increase accountability. Fourth, the administrative body should be reduced. Clearly, the first three targets are qualitative. Interestingly, they all stress that politicians should play a more active role in the policy process and that the controversial and largely opaque dealings of ministerial bureaucracy should become more transparent. This also seems to indirectly verify the view that Japanese bureaucrats command significant influence on legislation. The fourth goal is much easier to measure: The number of ministries and government agencies has been reduced from 23 to 13 (ibid.: 323). The already mentioned merger

[6] Administrative reform was preceded by electoral reform. In 1994, the former single non-transferable vote system in multi-member constituencies was replaced by a mixed system of single seat districts, which are combined with proportional representation districts (for details: Lin 2006; Yamaguchi 2001). Both seem to have been a reaction to the loss of power by the LDP in 1993. The relation between the two and the combined impact on the Japanese political system on the whole can not be discussed in detail.

of MOE and STA into MEXT and the upgrade of EA to MoE were part of the structural changes that were made. MITI was reorganised into Ministry of Economy, Trade and Industry (METI). The former MOC was merged with the MOT, the so-called Hokkaido Development Agency and the National Land Agency into the Ministry of Land, Infrastructure, Traffic and Tourism (MLIT).

Apart from this major restructuring, reforms in the innovation system were also made. With the foundation of the Council for Science and Technology Policy (CSTP), a new and strong institution emerged. The Prime Minister chairs the CSTP, six of the 14 seats are held by ministries related to S&T policy, one for the President of the SCJ, while other members have a background in Japanese industry or academia (Cuhls/Wieczorek 2008: 51). Improving coordination among ministries and agencies and their different innovation strategies is CSTP's main purpose. Since each ministry operated its own R&D system in the past, unnecessary duplications and rivalry should be reduced. This situation even has been given an own name: tatewari (縦割り), which means vertical division (Stenberg 2004: 14). However, it is also critical to point out that despite all divisions, agencies used similar tools, labeled administrative guidance, to implement their policies. Formerly existing turf wars are examples for this kind of sectionalism, which should be curtailed by the council: MOE and STA were not allowed to fund industry directly, while MITI could not fund universities directly (Shiozawa/Ichikawa 2005: 159). Such legal restrictions were limiting the innovation strategies of the respective agencies and inhibited cooperation between industry and academia. With the establishment of CSTP and the reorganisation into METI and MEXT, both ministries are now forced to cooperate within the new framework of the council. A good example for the new approach is the cooperation of these ministries in cluster policies: because there remain legal barriers, each started its own, MEXT the knowledge cluster initiative and METI the industrial cluster program, but collaboration between project managers is taking place regularly as both projects seek to establish new university spin-offs (Kondo 2006: 170-172).

Further, CSTP also plays a role in the budgetary process. CSTP defines the priority fields through the Science and Technology Basic Plan. According to those predefined areas, the ministries develop budgets and policy measures, so that responsibility still rests in their hands. However, CSTP reviews those budget proposals and passes its evaluations on to the MOF (Stenberg 2004: 14f.). Therefore, CSTP is probably the most powerful actor in innovation policy, but there is also the question remaining how conflict resolution works internally. In the worst case, formerly existing conflicts between ministries and bureaus have just been relocated to higher political echelons. Thus, the efficiency and effectiveness of CSTP is likely to depend on the willingness of ministry representatives to cooperate and the leadership of the Prime Minister as chair of the council. In general, administrative reform has strengthened the position of the cabinet and the Prime Minister towards the bureaucracy[7]. Nevertheless, using this potential still is a question of leadership: whereas Prime Minister Koizumi utilised this power comparatively often, his short-lived successors Abe Shinzo, Fukuda Yasuo and Taro Aso, all from the LDP, showed less inclination to do so.

With regard to the theoretical framework, CSTP is mainly involved in policy formulation and decision-making. By defining the technological areas to be targeted, CSTP clearly decides which focus and direction the national innovation system is pursuing and it also structures the formulation, which is still carried out by the various ministries. This is an example that demonstrates that policy is made in a non-linear fashion: CSTP decisions largely influence formulation, decision-making and partially implementation of government agencies. Here, decision-making of one high-ranking council precedes the formulation of concrete, specific policies and programs by subsidiary organs. Further, this body is active in evaluation as it reviews the budget proposals as well as it utilises evaluations and foresight surveys when defining targets and identifying key technologies. This partly resembles Kingdon's observation that control over the agenda - here, identifying the targeted areas - does not give full control over the policy outcomes - the actual policies developed by the ministries and passed by the Japanese diet. Etzioni might state that CSTP is making the fundamental decisions of innovation policy and the ministries and agencies are enacting many incremental decisions in the context of or towards the aim of achieving these fundamental goals. With regard McCool's observation, CSTP could be regarded as a forum to ensure accommodation between fragmented policy subsystems. Indeed, the whole administrative reform process in Japan confirms another aspect of subsystem specialisation: it is stated that sub-governments are unable to reform themselves and that change has to be initiated by exogenous forces (McCool 1989: 277). The efforts aimed at administrative reorganisation were mainly promoted by political parties, largely opposition and LPD-secessionists, not by bureaucrats, so that it could be claimed that reform originated from those politicians on the outside.

Another important change related to innovation policy is the status of government agencies. Also enacted in 1999, agencies formerly attached and more or less directly controlled through ministries have been transformed into independent administration agencies (IAAs) from 2001 onwards, which is the reason why this transformation has been labeled as "agencification" (Shiozawa/Ichikawa 2005: 160-175). Agencification aims at improving efficiency through

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[7] Exploring foreign policy, a detailed description of the changes is included in: Shinoda 2007: chap. 1

granting more independence to the respective agencies. The ministries continue funding, but give up the detailed micromanagement of the agencies. Agencies set self-formulated goals, which are evaluated externally and the results should be the basis of future budget processes. Further, bureaucratic red tape in funding processes should be cut back, but analysis highlights that the degree of simplification also depends on the specific task of an agency: while a research orientated IAA like the 2001 reorganised National Institute of Advanced Industrial Science and Technology (AIST) enjoys more flexibility, an actor like New Energy and Industrial Technology Development Organization (NEDO), which main task is project planning and coordination, will continue to be closely monitored by its supervisor METI (ibid.: 168-170). This means that IAAs which decide, design and implement policies will probably remain closely controlled, but agencies addressing technical and therefore rather apolitical tasks are likely to profit from this reform. However, it is widely overlooked that the reform also has some negative aspects. Concerning AIST, the positive perception from Shiozawa and Ichikawa, who formerly worked for METI and NEDO respectively, should be balanced by a mixed assessment:

> "Clear merit of the transformation to an IAA is that we now have more flexibility and freedom in our organisation than before. Now we can collaborate with companies, universities and other institutes more freely. But, on the other hand, because we are still getting considerable amount of subsidy from government, including salary, we are forced to decrease number of employees. We are now busy to write proposals and to get funding from various sources. And, because our R&D activity largely depends on short term intermittent project funding and direct funding from the private sector, it is more difficult to keep or raise our own scientific research potential, which is our reason of existence. (Owadano, personal communication, 24.03.2010)

According to this assessment from AIST staff, it is necessary to realise that greater freedom and less bureaucratic paperwork towards other government agencies is partly counterbalanced by the need to raise funds for science projects. Further, more competition, project-based instead of staff-based funding and the rationale that basic research already should consider future application have some drawbacks. Despite those issues, the overall evaluation is positive, because the higher degree of operational freedom outweighs the caused additional work.

Placing NEDO and AIST in the policy cycle model also clarifies their roles. While the former possesses limited authority to formulate, decide and implement policies in the field of renewable energy, the latter operates within the predefined context of CSTP, METI and NEDO decisions. AIST's operational freedom only permits to conduct research in designated areas as deemed best, but it cannot pursue an own R&D agenda.

National Japanese universities have also been transformed into IAAs since 2004. It must be stressed that there is also a very high number of private universities that absorb most students in the Japanese higher education system (Cuhls/Wieczorek 2008: 59). Before the reform, national universities were controlled by MEXT and links between industry and academia were weak. To improve this situation, the Japanese government made several reforms. The US Bayh-Dole provision, which allows private companies to own intellectual properties rights generated in government-contracted research, was adopted in 1999 (Shiozawa/Ichkawa 2005: 148). Further, so-called technology licensing organisations (TLOs), were promoted to allow universities to profit from their research results through patenting and TLOs are seen as an extra monetary incentive for university lecturers (ibid.: 147; Nabor 2007: 56). All in all, higher education reform aimed at improving competition between universities and fostering industry-academia cooperation, e.g. via regional clusters. However, the results of this reform measures are not yet visible. There is also general doubt about the effects of the Bayh-Dole provision and science parks, claiming that universities play a much more complex role in national innovation systems than purely performing economic functions (Mowery/Sampat 2005).

To sum up and to relate to the theoretical framework, administrative reform in Japan from 2001 onwards aimed at reshaping the national innovation system. The reorganisation clearly is a procedural tool to reconfigure the interaction patterns between various actors active in the innovation system. Reform works in two, seemingly opposite, directions: centralisation and decentralisation. Centralisation is pursued through the installation of the CSTP, which main task is providing more coherence through coordination. Since tatewari minimised coordination, linking R&D measures of different agencies together in order to focus on priority fields, which are defined by CSTP, is resulting in more inter-agency communication. However, the reorganisation of government agencies and national universities into IAAs is going in the opposite direction. Both are now enjoying more operational freedom and are able to act less constraint by supervising ministries and bureaucratic procedures. This step is obviously meant to spur more competition between universities themselves, but also vis-à-vis research orientated IAAs like AIST. At the same time, deregulation and incentives like royalties via TLOs aim to increase cooperation and exchange between IAAs, academic scientists and industry. So, the logic behind the reorganisation seems to be about streamlining the targets in the central forum of CSTP, while at the same time encouraging the actual performers of R&D to search for their own approach towards meeting the those goals. Thus, despite some steps towards decentralised research agencies and universities, the Japanese innovation system remains highly centralised and continues the practice of targeting key technologies.

4 Alternative vehicles in Japan

4.1 Regulative framework conditions of alternative vehicle development

Regulation of automobiles in Japan is divided, so that several government agencies play a role in the development and regulation of alternative vehicles. The MoE implements emission standards to limit environmental degradation as well as negative effects on public health. MLIT is responsible for maintenance programs, vehicle inspections and safety. The METI is in charge of industrial and energy policy. Further, METI administers a substantial part of Japanese R&D expenditure and therefore is the main bearer of technological innovation promotion in Japan. METI combined industrial and innovation policy through its well known "visions". Due to this interlinked approach and the extensive exclusion of societal interests other than industry, the distinction of industrial and innovation policies into "policies with publics" and "policies without publics" respectively, may not be useful for Japanese politics. Important agencies under the aegis of METI are AIST and NEDO. During the course of administrative reform, AIST became an IAA in 2005. AIST reorganised formerly existing research institutes to concentrate R&D efforts on the following fields: sustainable society, industrial competitiveness, local industrial development and industrial technology policy (AIST 2007: 3). It could be said that AIST is an umbrella organisation, which coordinates the specialised research facilities, currently seven laboratories and 21 research centres. With regard to the inner workings of AIST (ibid.: 7): the strategic goals are determined in a top-down process through discussions with METI and industry representatives. At the same time, the actual research themes are developed bottom-up, planned and carried out by research units. So, after the reform, AIST is still connected to METI and the industry in order to serve their needs, but the organisation of research is left to the scientists working in the laboratories. It could be said, that the goals are still predefined by political and business actors, but finding a way to this goal rests with the science teams. NEDO was established in 1980 to develop alternative energies. As it uses tools like contracted research and competitive loans or research subsidies to private companies or research consortia, it has been labeled a R&D management and funding agency (Shiozawa/Ichikawa 2005: 168). At the same time, NEDO received more administrative authority as METI largely targets and plans policies, but leaves implementation to NEDO (ibid.: 166). Therefore, it might be best to characterise NEDO as METI's specialised branch for alternative energy technologies and AIST as a semi-public basic research service provider. However, this theoretically clear distinction can become quite blur, e.g. the so-called PEFC Cutting-Edge Research Center, a project started by AIST in 2005 is been managed by NEDO since 2008, but remains a unit under AIST (AIST website, 19.03.2010). Further, the change in power from the LDP to DPJ in 2009 also could influence the roles of the agencies:

> Due to the big political change, which took place last year, role of NEDO as a funding agency is now being reviewed. AIST is expected to contribute and to promote “Green Innovation” much more than ever. We have to behave as a useful tool for METI. (Owadano, personal communication, 24.03.2010)

This statement also indicates that despite agencification, METI still influences the work and organisation of IAAs. Hence, the degree of independence enjoyed by IAAs should not be overestimated. As the review of agency status is an ongoing process, it is unclear if and how further reorganisation will take place, but since the Hatoyama administration strongly promotes environmental issues, some degree of change is likely to take place.

4.2 Battery-powered and hybrid electric vehicles

4.2.1 Brief history of battery-powered electric vehicles

Although there is the widespread perception that electric vehicles are a fairly new innovation, those cars already have a long history. The first BPEV was built in 1834, predating the first ICEV, which was constructed in 1885, by more than 50 years (Chau/Wang 2005: 737). Around the year 1900, consumers had the choice between BPEVs, ICEVs and steam-powered vehicles, which all had an almost equal share of the limited yet quickly expanding market, because every type had specific advantages and problems. The strengths of BPEVs were no exhaust emissions and silent operation, which made them particularly popular for taxi fleets, but the problems were high initial costs as well as the need for electric charging infrastructure. Therefore, the use of BPEVs was concentrated in urban areas: By 1904 one-third of all vehicles in New York, Boston and Chicago were electric (Anderson/Anderson 2005: 3). However, at the beginning of the 1920s, the improvement of ICEVs in starting time, their superiority in cruising range, combined with higher taxes on BPEVs resulted in the establishment of ICEVs as the standard technology in personal transportation (ibid.: 8f.; 86).

4.2.2 Government support for battery-powered and hybrid electric vehicles

The first step Japan took in supporting BPEV-development came in 1971 with a five-year government-industry R&D program, sometimes referred to Electric Vehicle Project, with a total budget of JPY 5.7 billion by MITI (Åhman 2004: 11). The program was mainly carried out by AIST and was organised as a large-scale project. This kind of project could be characterised as a standard operation procedure of that time. So-called Large Scale Industrial Research and Development Projects, also referred to as large-scale or big projects, were established by the Japanese government in 1966 (Harayama et.al. 2009: 196). Primary objective was to support expensive, long-term and thus high-risk R&D projects and the state was the driving force behind those projects. Thus, the Electric Vehicle Project was conducted under the leadership and full sponsorship of the Japanese government, but in close cooperation with industry and academia (AIST 1977: 2). Cooperation was established in the following way (ibid.): two AIST research institutes, namely the Mechanical Engineering Laboratory (MEL) and the Governmental Industrial Research Institute at Osaka, developed test and evaluation methods. R&D on specific BPEV components such as the battery, motor and control device, vehicle body, utilisation system and charging method was performed by working groups, consisting of one to five private firms. So, this approach represents government research contracted to and carried out by private businesses. Government agencies coordinate the participating companies and evaluate the results, but the actual product is developed by various firms. The constructed BPEVs could be described as early prototypes or experimental vehicles. Five different vehicle types were developed: lightweight and compact passenger car and truck respectively as well as an electric route bus (ibid.: 4-15). The performance of the experimental BPEVs with regard to maximum speed, between 68 and 94 km/h, was already promising. The main problem was that the mileage per charge, ranging from 150 to 330 km could only be realised at 40 km/h constant speed. Further, starting and accelerating were problems, so that combination of different battery types, one to increase the cruising range and another to provide satisfactory acceleration, called hybrid battery system was designed. Several vehicles already featured regenerative braking (see below). All in all, the results of the five-year Electric Vehicle Project could be said to be quite impressive and innovative, but the invented BPEVs still had seriously flaws compared to ICEVs.

However, strong interest of Japanese politicians, bureaucrats and industry in vehicles with electric power trains and motors was only sparked by the economic shockwaves resulting from the first oil crisis in 1973. Back then, BPEVs were regarded as an option to reduce the dependence on foreign, mostly Middle Eastern, oil and harmful exhaust emissions from transportation (Åhman 2006: 436).

Consequently, in 1976, MITI drew up a basic market expansion program for BPEVs. It was originally designed to cover 10 years, but the plan was altered and expanded several times. First changes were made in 1983, due to slow technological development and falling oil

prices. If the market expansion program was initiated because of the promising initial results of the large-scale BPEV R&D project is unclear.
Also, research was conducted under the Moonlight Project[8], which main purpose was R&D on energy conservation technology. One theme under the project was on flywheel power vehicles and the research was carried out between 1978 and 1981 by the MEL, back then part of MITI subsidiary AIST (JETRO 1990a: 8f.). The concept of flywheels is applied in what became known as regenerative braking: during braking, a part of the kinetic energy is converted into electric energy which is used to recharge the battery of the car. To illustrate the importance and usefulness of this concept it must be stressed that this mechanism can extend the driving range of an electric vehicle up to 25% (Chau/Wang 2005: 748).

4.2.3 Renewed emphasis

The second restructuring was implemented in 1991 when energy and environmental issues reappeared in world politics. The Iraqi invasion of Kuwait and the following liberation by US-led forces again triggered higher oil prices. At the same time, California drafted the so-called Zero-Emission Vehicle Mandate (see below) and preparations for the Rio summit put environmental issues back on the political agenda. All these factors contributed to increased awareness of problems like global warming and continuing oil-dependency. Therefore, alternative vehicles resurged as a resolution to mitigate both problems. MITI’s target of 200000 BPEV units by 2000 was very ambitious as a large number of barriers for market expansion was identified: in comparison to the standard ICEVs, the batteries, motors and control systems needed to improve their performance, there was a lack of recharging or battery changing infrastructure and probably most important, the costs were too expansive (Iguchi 1992: 62f.).
The impact of the market expansion program must be regarded as limited, but not completely unsuccessful. Between 1977 and 1996 a mere 655 BPEVs have been put on the roads of Japan. Over 400 BPEVs have been deployed by small-size vehicle specialist Daihatsu, which is a part of the Toyota group since 1998 (Åhman 2006: 438f.), which is the reason why the company has been labeled as the standard bearer of electric vehicles (Patchell 1999: 1003). Although the number of supplied cars is small, the program’s continuity signaled vehicle

[8] Another term frequently used in the literature instead of program is project. The Japanese word 計画 (keikaku) can be translated in both ways or as plan. Official Japanese documents speak of the Sunshine Program and Moonlight Project, but there exists no uniform translation for the merger of the two, which is referred to as New Sunshine Program or Project.

companies the future relevance of alternative drivetrains. From 1976 to 1993 government funding of BPEVs appeared to have been scarce, for the following reason:

> "No comprehensive data exists on how much this support actually was but in the plans of the MITI, this was supposed to be a commercialisation phase were targeted support was offered to vehicles produced. As the number of vehicles actually produced was very low, the targeted support also became low." (Åhman 2006: 438)

The beginning of the 1990s is marked by a more comprehensive strategy. The support was no longer limited to produced cars, but became broader: In 1992, the Lithium Battery Energy Storage Technology Research Association (LIBES) was founded with the goal to develop more advanced batteries that could be utilised in mobile and stationary applications (Patchell 1999: 1013). One year later, LIBES was incorporated as a part of the so-called New Sunshine Program, which was fused out of already existing R&D projects, namely the Sunshine Program, the Moonlight Project and the Global Environmental Technology Project.

Further, support for necessary infrastructure was initiated. The ECO-Station Project was started in 1993 and targeted the construction of 2000 alternative refueling stations by 2000. About 50% of these were projected as recharging stations for BPEVs. However, this aim was widely missed as there existed a mere 36 BPEV charging facilities in 2002 (Åhman 2006: 440).

Another project also tried to speed up BPEV-development: In 1994, EA brought together a group of automobile supplier firms and Daihatsu to build the Eco-vehicle (Patchell 1999: 1002). This project was remarkable, because it differed from other government programs in many ways: First, EA orchestrated this project through the Global Environment Research Fund (GERF), which was created in 1990 to carry out EA research activity. EA took the initiative despite MITI's role as the main actor in technology development policy. Second, the object of support was not a single component, but a fully integrated, marketable vehicle. This is in marked difference towards the initial R&D project of 1971: although private firms from various industries co-developed BPEVs under the supervision of AIST, these were clearly not marketable prototypes. Third, all different participants had to collaborate directly in design and production in order to reach this goal. The Eco-vehicle project alone cost 61 million yen and ended in 1996 when a prototype was developed (GERF 1996: 163; 170f.). However, additional 19.867 million yen were used for the development of a battery management system (ibid.: 173).

Although the reports indicate that the prototype could reach a reasonable range of 140km at 80km/h (ibid.: 171) and one of the smaller car companies, Daihatsu, participated in the Eco-vehicle development, the prototype never was commercialised. The reasons are unknown, but it stands to reason that production costs were too expansive, the limitation to two passengers and its concept as a commuter car was not marketable.

Again in 1997, the plan was reshaped in another way: from then on BPEVs were not the only target, but also HEVs, FCEVs, methanol-fulled and compressed natural gas vehicles were supported. It has been suggested that the inclusion of HEVs was adopted due to the reduction targets of the Kyoto-Protocol. Further, it must be pointed out that this could be regarded as a significant shift in alternative vehicle policy: as the previous goal is said to have been energy independence (Åhman 2004: 9), after the negotiations in Kyoto, this aim was complemented with lower emissions.

The term market expansion plan might indicate something larger than what was actually initiated, but it surely provided the car industry with a niche-market to test and gradually improve their BPEVs. Also, the reoccurring adaptations of the plan exemplify the flexibility of Japanese administration: the aims were sometimes overambitious, but failure to meet was not sanctioned with the termination of the program.

4.3 Policy transfer and learning: Influence of US environmental regulation

Today there are various international influences on national innovation systems, most notably international competition and foreign regulation. For export-oriented companies and national economies, regulation in key markets is of vital interest: In the case of automobiles, these are emission standards, fuel efficiency and safety requirements.

4.3.1 The 'Muskie Law'

Japan's first vehicle emission standards were introduced in 1960, but they were not particularly strict and could easily be met. However, this changed when the USA adopted the so-called 'Muskie Law', a section of the Clear Air Act of 1970. The regulation required large cuts in carbon monoxide (CO), hydrocarbons and nitrogen oxide (NOx) emission levels. The EA reacted to this legislation from their US counterpart by calling for stricter exhaust regulation as well. The major Japanese carmakers Nissan and Toyota - like their American competitors - opposed EA's proposal of 92% of NOx reduction by 1976, stating that it was not technically possible. At the same time, seven Japanese municipalities commissioned an own team to investigate possibilities to improve air quality, as this issue was of public concern of local residents (and voters). Back then, Honda and Mazda, which were relatively small challengers of the two large archrivals Toyota and Nissan, set out to attack their competitors on the field of emission technology. Originally, Honda developed a new type of engine called compound vortex controlled combustion (CVCC), which alone met the standard, but the CVCC was soon abandoned (Yarime et.al. 2008: 193). Instead, Honda and Mazda introduced the three-way catalyst converter and early prototypes achieved benchmarks in fuel economy (Wallace 1995: 143). Both companies shared information with domestic institutions in order to prove their market-dominating rivals wrong by showing that the EA's reduction targets could be achieved. Based on this evidence the exhaust emission standard was implemented as proposed by the EA, but the deadline was postponed to the year 1978 (Fujii 2007: 56f.).

This case provides an interesting insight into the Japanese political and bureaucratic process of policy learning: US lead to stricter emission levels had to be coped with, because of the importance of the American market for car exports. However, it is critical to notice EA's strategy in this particular case. The EA had just been formed in 1971 and its rank as an agency reflects that by this time, the environmental issues were comparatively new to politics and that EA was not on the same level with other established ministries like MITI. Being the main advocate of tighter regulation, but without a strong position in political and bureaucratic system, EA's chances of success appeared limited. Therefore, EA as well as the city's inquiry team based their argumentation on the evidence obtained by Honda and Mazda. The interest of the general public and EA in improving air quality coincided with the interest of the relatively small competitors to gain market-shares from their established rivals and to demonstrate technical expertise to the public and state institutions. EA's resort to competitors´ expertise seems to have been a skilful move to overcome limited resources and bureaucratic standing with the aim to achieve its political objectives. The position and argument were backed up by data from relatively small car manufacturers, so no ministry or rivaling company could argue the contrary. It is also noteworthy that the Japanese administrative body as a whole was under the misperception that the US government was committed to enforce the 'Muskie Law' (Åhman 2004: 7), but the US car industry successfully lobbied for a postponement of the regulation to the year 1983. Even more, these companies argued the US administration into viewing the Japanese requirement as a non-tariff import barrier, so that the US government pressured the Japanese to exempt imported vehicles from compliance until 1981 (Wallace 1995: 144). In the same year, the USA pressured Japan to limit automobile exports to the US market via "voluntary restraint", a practice that continued until 1994 (Shimizu 2003: 126f.).

All in all, the strategy of EA seems to be based on gathering information and its utilisation in bureaucratic negotiations. Being able to prove the technical feasibility of their emission targets coupled with strong public concern about air quality provided the EA with enough bureaucratic muscle to largely implement its original goals. The fact that the compliance date was delayed until 1978 must be regarded as a concession EA had to make towards the established car manufacturers and their supporters in powerful ministries.

This case is also interesting with regard to the theoretical framework: EA, the municipalities and their citizens as well as the smaller car manufacturers shared the goal of stricter air pollution standards. Consequently, they all worked towards enacting this legislation. However, this alliance does not fit the type of an advocacy coalition (Sabatier 1988: 139): Honda and Mazda certainly did not share a common belief system with EA and municipal officials about negative impacts of emissions, but furthered their business interests nor was this alliance stable. This case exemplifies the useful distinction between policy networks and communities. It could be said that EA and municipalities shared the political idea to limit hazardous emissions. For EA, emission regulation was its main administrative authority and therefore this issue was more or less its raison d'être. The problems like poor air quality, related health issues and smog manifested themselves first and foremost in large municipalities, which is the reason why citizens and politicians supported regulation. Thus, these actors could be described as an advocacy coalition or a policy community. Honda and Mazda must be assigned to a policy network as their action is based on economic interests. Therefore, the adoption of the 'Muskie Law' demonstrates that despite different motifs, networks and communities may actually support the same policies. Although Nyland (1995) explores relationships between government and non-profit organisations, her findings could be used analogous to idea-centred communities and interest-based networks: if they share interest, they may cooperate for a limited span of time. Later, this alliance will dissolve as these groups normally pursue different interests. Also, it is clear that even inside communities, actors may hold various interests. Although they share the perception of emissions as a problem, EA and municipal officials pursue their organisational and political interests at the same time. This case further shows that subsystems are interrelated: emission control is an issue of what could be labeled environmental protection subsystem, but the decisions made influenced the automobile transportation and innovation subsystems.

4.3.2 The Impact of the Californian Zero-Emission Vehicle Mandate

In 1990 the Californian Air Resource Board (CARB) created the so-called Zero-Emission Vehicle Mandate (ZEV Mandate) with the aim to improve air quality. The ZEV Mandate required car manufacturers with more than 35.000 sales to conform to the mandate. The regulation required those companies to sell a certain percentage of ZEVs out of their total sales: 2% in 1998-2000, 5% in 2001-2002, 10% in 2003 and beyond. The fine for every vehicle sold above of the quota was US$ 5.000.

The resort to this approach seems to have different backgrounds: First, Californian air pollution was serious. Cars were at the heart of the problem, as in 1992, vehicles emitted 75% of NOx and 50% of hydrocarbons (Wallace 1995: 126). The presentation of General Motors (GM) Impact, an electric vehicle, in January 1990 influenced CARB to regard this car as a solution for the pollution issue (ibid.: 161-163; Larrue 2003: 5). Second, California was going through a recession and the end of the Cold War brought cuts to military defense spending, which effected the high-tech industry and an emerging electric vehicle industry appeared to be a probable replacement for the slumping defense sector (Larrue 2003: 5; Schot et. al. 1994: 1065).

The ZEV Mandate effected the American "Big Three" - GM, Ford and Chrysler - as well as all major Japanese car manufacturers, namely Toyota, Nissan, Honda and Mazda. The regulation did not prescribe any specific solution, but by the time of enactment, BPEVs were regarded as the only option for compliance (Schot et. al. 1994: 1065). The importance of the North American market to the Japanese car industry can be exemplified by the fact that over half of Toyota's overseas sales went to this destination since 1970 (Shimizu 2003: 121f.). Therefore, Toyota, Nissan and Honda started to invest heavily in the development of BPEV-technology (Åhman 2004: 14), while the US firms put up strong resistance to the mandate. They argued that the necessary battery-technology for BPEVs did not yet exist: the requirement would have forced them to adopt available lead-acid batteries, because the more advanced lithium-ion (LiIon) and nickel-metal hydride (NiMH) batteries had not been successfully scaled-up (Larrue 2003: 10). As the battery is the core of a BPEV, the car has to be built around it, which means that the ZEV Mandate required the producers to integrate the battery technology of 1994 into their models for the first mandate year of 1998 (ibid.: 11).

The Californian ZEV Mandate had a technology-forcing character at the beginning, but CARB had to acknowledge in 1995 that necessary advanced batteries needed more time to be developed and integrated. The regulation was amended in 1996 through a memorandum of understanding, in 1998 HEVs and in 2001 so-called neighbourhood electric vehicles (NEVs) were awarded with partial ZEV credits. This means that the companies could lower the number of full-ZEVs by selling HEVs or NEVs. Interestingly, CARB already put forward the option of compliance through HEVs in 1994 (ibid.: 20n). The Japanese manufacturers were very successful with selling HEVs: Honda and Toyota did not anticipate the positive response to the Insight and Prius models from the US-consumers and could not satisfy the demand (Parker 2001: 103f.). The strategy of GM was rather different: As NEVs could not be sold in the US market, they were given away freely to non-profit businesses, hospitals or schools in 2002 with the option for the operators to buy them in 2003 or return them (Larrue 2003: 17f.). GM’s strategy was obviously to introduce the NEVs before the mandate´ s deadline in 2003, but without the intention to make a business.

The ZEV Mandate can be regarded as largely failed. At the beginning, CARB’s deadline was too optimistic and simply technically not feasible. After reaching this conclusion in 1995 the regulation has been watered down and especially the US manufacturers appeared to be more active in legal struggles over regulation than trying to improve their technological expertise. The US automobile companies also could have pursued the development of HEVs like their Japanese rivals, but they did not. Even more telling is the following background: According to Joseph J. Romm, who worked for the Clinton administration on different posts in the Department of Energy, there was an informal agreement between the administration and the “Big Three” that gas-mileage efficiency requirements, known as Corporate Average Fuel Economy (CAFE), would not become stricter and the industry would in return concentrate on the development of hybrid technology. He also suggests that the ZEV Mandate got the Japanese manufacturers so nervous that they would lose the race for alternative vehicles, so that they committed themselves much more to realisation than their US counterparts.[9] The US automobile industry did not produce HEVs and abandoned the informal bargain when the new administration of George W. Bush was elected. At the same time, US companies questioned the partial credits for HEVs, obviously because the Japanese successfully developed and commercialised the technology while they were lagging behind.

The first phase was a poorly informed attempt of technology-forcing, while the second phase after 1995 was dominated by a market-driven regulation. Looking back, it appears that CARB went from one extreme to another with amending the ZEV Mandate by and large in line with the wishes of the automobile industry. Critical assessments of the ZEV Mandate point out that

[9] Interview in the documentary: *“Who killed the electric car?“, time index: 1.03.00-1.04.30*

it has been hollowed-out, e.g. that NEVs should be regarded as “golf carts” as they could not operate on the road, but were limited to closed campus environments (Larrue 2003: 17f.).

The influence of California’s ZEV Mandate on the Japanese innovation process can be divided into two areas: the response of the automobile manufacturers and the reaction of the administration. First, as been mentioned before, the Japanese car producers responded to US regulation by investigating ways to integrate an electric motor into a vehicle. As full-fledged BPEVs faced serious troubles in the areas of driving-range, acceleration, reliability and cost, especially if compared to standard ICEVs, the development of HEVs was a promising option. However, in line with the already mentioned topic of framing environmental problems as “green” or “brown” issues, the question arises, why Japanese companies were actively searching for a workable solution while the US firms were more concerned with stopping or delaying implementation. Therefore, these two hypotheses should be put forward: First, the Japanese carmakers were also active in lobbying for a more flexible, “softer” mandate, which would allow them to fulfill the required proportion of sales with HEVs. Especially the behaviour of Nissan and Honda, which waited with engaging full-scale R&D on HEV-technology until the regulation was amended in 1996 (Yarime et.al. 2008: 207; see below: Development strategies). The several amendments of the ZEV Mandate, together with the successful efforts of the Japanese manufacturers to develop the necessary technology enabled them to comply. Second, it could be reasoned, that the Japanese saw the requirement as a way to gain an advantage towards their international rivals, if they were the first to master the technology. Further, a successful development could be advertised as ecologically friendly.

The reaction of administration was very different from the one to the ‘Muskie Law’. As already mentioned before, the target numbers for BPEVs were aimed high and more support was given to R&D projects. However, there was no transfer of the strict technology-forcing approach used by CARB in Japan, meaning that a similar requirement was never enacted. To the knowledge of the author, the reason for this has not been investigated, but he would like to suggest that unlike regulation of NOx emissions, there was no clear proof that the technology could be introduced to the market, so that no agency could argue the necessity of regulative emulation. BPEVs were - as still today - not attractive enough for consumers since they are unable to compete against ICEVs in the combination of driving-range, acceleration and speed. Given these features and a higher price, Japanese decision-makers could have concluded that such a product could not be forced into the market. It needs to be stressed that this is just a possibility, which also underlines a gap in policy analysis as well as many other approaches:

description and analysis of positive decisions are at the centre of research, but negative and non-decisions are seldom investigated since information is scarce.

4.3.3 Enter the hybrid

In December 1997, shortly after the Kyoto summit, Toyota released the Prius, the first HEV entering mass production. However, prior to this event, HEVs have attracted little attention from the public as well as policy-makers.

Tracing the development of the hybrid, it has been reported that Toyota already developed the technology in 1977 for a sports car (Yarime et.al. 2008: 203). The following questions arise: Why did it take 20 years to introduce the technology into the market? What was the role of Japanese policy in this development?

To begin with, it appears that there was no intention to utilise hybrid technology for the mass production until 1992 when Toyota's new president, Toyoda Tatsuro, took over. This means that although the basic knowledge was around for 15 years, Toyota never took any serious step to commercialise their invention. However, this changed after 1992: the original goal was an introduction by December 1998, but when Toyoda learned about the climate summit in Kyoto, he pressured for market readiness by the time of the conference (ibid.: 204). As already stated before, the increase of oil prices and the Californian ZEV Mandate will also have contributed to the rediscovery of hybrid technology.

Turning to the political background: The announcement of the Prius release took MITI and NEDO by surprise. Also in 1997, the Advanced Clean Energy (ACE) program was planned, without any knowledge of Toyota's plans. This conclusion is based on the fact that ACE was changed when the Prius was introduced: more advanced research in hybrid and bus concepts, ceramic engines and flywheels was supported (Åhman 2006: 440). Further, the administration responded quickly to the development: HEVs became included in the Clean Energy Vehicles Introduction Program, covering the years from 1998 to 2000. The HEVs took the lion's share of subsidised cars under this program, totaling 12.242 HEVs which overshadowed 276 BPEV units that also were supported (ibid.).

The Japanese government kept providing incentives for alternative vehicle acquisition. Besides giving incentives to Japanese consumers, the government also moved forward to set an example. Since 2001, alternative vehicles - among a list of a total 101 items - are procured by the Japanese government under the so-called Law on Promoting Green Purchasing (Tanaka/Ahlner 2003: 24-26). One aim was that all government automobiles would be LEVs by 2004 (Tiberghien/Schreurs 2007: 87).

The latest are the “Green” Vehicle Purchasing Promotion Measures, which passed the diet on May 29, 2009. The measures simultaneously aim for two objectives (JAMA 2009: 1): stimulating vehicle sales in Japan and at the same time promoting the reduction of Greenhouse Gases (GHG). The first aim is pursued for economic reasons, as the recent financial crisis again led to economic recession and this slowdown also resulted in lagging car sales. Although not stated openly, the second goal seems to be promoted, because of the difficulties Japan experiences in complying with the Kyoto Protocol. The measures were timely limited, since the incentives were only granted to automobiles sold from April 10, 2009 through March 31, 2010. Measures can be divided into two parts: a replacement and a non-replacement program. To count as a replacement, the subsidised model must comply with the latest fuel efficiency standards and the old vehicle must have been registered for at least 13 years (ibid.). Further, the amount of the subsidy depends on the type of vehicle purchased: standard and small cars are eligible for JPY 250,000 (US$ 2,500) while mini-vehicles (the so-called kei-cars) are rewarded with JPY 125,000. The non-replacement part subsidies are smaller, JPY 100,000 for standard and small vehicles or JPY 50,000 for mini-cars (ibid.: 2). Also, the purchased model must have fuel efficiency at least 15% better than the latest standard of 2010 to be eligible. The overall funds allocated by the Japanese government are 370 billion Yen (or US$ 3,7 billion), so that a limit of 690,000 cars could be subsidised (ibid.). It must be pointed out that this is an additional incentive: press reports stress that depending on the vehicle type purchased, the top amount of subsidies could reach € 11,500 (Spiegel online, 08.01.2010). The “Green” Vehicle Purchasing Promotion Measures are just tools next to tax abatement and subsidies provided by regions or municipalities.

The latest move towards alternative vehicle commercialisation on a larger scale aims at standardising charging machines for BPEVs and PHEVs. For this purpose a joint-venture called CHAdeMO has been founded by Toyota, Nissan, Mitsubishi, Fuji Heavy Industries, which sells its cars under the Subaru brand, and Tokyo Electric Power Company (TEPCO), the largest electric power producer of Japan. These five companies are the executive members of CHAdeMO and a total of 158 government bodies and private firms are expected to join the association (Toyota website, 16.03.2010). As the formulation shows, these numbers are preliminary and the final list of members does not exist yet. According to Shiga Toshiyuki, Nissan Chief Operating Officer, despite fierce competition between car producers, standardisation is a task of the whole industry in order to serve the convenience of consumers (Japan

Times, 16.03.2010). Also, Katsumata Tsunehisa, president of TEPCO, stated that the standard also must be established outside Japan, which is probably the reason why the Japanese government supports the consortium with US$ 13.7 million (Spiegel online, 16.03.2010). CHAdeMO is also a prime example how closely - internationally as well as intra- and inter-industry - interwoven the subject of electric mobility is. Other Japanese partners are electronic MNC Toshiba and telecommunication company KDDI, further, Bosch, German supplier connected to many automobile firms around the world, French car producer PSA (Peugeot and Citroen) and Italian energy provider Enel are also collaborating through CHAdeMO (ibid.).

Thus, very different factors contributed to the diffusion of HEV technology. There was obviously strong leadership of the Toyota president that led to commercialisation. The last minute altering of ACE underlines that Japanese bureaucrats and politicians do not steer the development of the industry. Individual companies, especially vast MNCs like the car manufacturers are capable to protect their plans, act independently and follow an own agenda. But policy also should be attributed its share: continued governmental measures towards BPEVs greatly helped HEV development. So, although R&D efforts aimed at a breakthrough of BPEV technology, these measures actually supported HEVs, too. As both types share many components like motors, advanced NiMH- or LiIon-batteries and control equipment, HEVs profited from the knowledge gained in BPEV development. Hence, it can be stated that HEVs are an unintended outcome of BPEV support. Adapting the research scheme and including HEVs into a market expansion plan must be regarded as positive impulses. Earlier studies pointed out that HEVs only accounted for 1% of newly registered passenger cars in Japan (Åhman 2006: 440), but this has completely changed, because the Prius reached the top position in national sales in 2009 (Spiegel online, 08.01.2010).

Another aspect that helped the introduction of HEVs is the development of electric drivetrains, control equipment, power electronics and battery technology. As mentioned before, the LIBES project supported the development efforts towards advanced batteries that began replacing the old lead/acid battery technology. As already mentioned earlier, the research on flywheels also could have helped HEV breakthrough as the concept of flywheels is utilised in what is called regenerative braking (see above). Another very crucial point must be stressed: BPEV and HEV development depended (and continues to depend) on more than just advanced battery technology. Although batteries are central, electric motors, power and control electronics are almost equally important. Engines and control equipment are essential parts that form the electric drivetrain, which transforms or delivers the power of the motor to the wheels. Japanese car producers have developed these technologies in-house or in cooperation with their suppliers (Patchell 1999: 1010). That manufacturers set out to develop these components in-house demonstrates the fundamental importance of these devices in shifting towards alternative vehicles. Despite their relevance for electric vehicles, development of the mentioned parts was not funded through governmental R&D projects (Åhman 2004: 15). Thus, although the Japanese approach towards developing alternative vehicle types was broad, not all necessary components were supported.

Another factor that most likely enabled the success of HEVs is the fact that those automobiles do not need a new fuelling infrastructure, which means that the car industry did not need to wait with commercialisation until a sufficient number of recharging stations was installed or to worry about the question of how to provide an infrastructure like that. Also, consumers did not need to change their behaviour, as their vehicles still needed refueling at a petrol station while the battery was being charged through the combustion engine or regenerative braking. This means that car companies could introduce HEVs without consensus-building with other branches, namely the oil and electricity industry.

All in all, this case reflects the usefulness of the interactive innovation model and the merits of adaptive policy-making.

4.4 Development strategies

After investigating the incentives and requirements that aimed at the introduction of BPEVs and HEVs by the Japanese and US governments it is time to look at the development strategies of the Japanese carmakers to investigate which tools had an impact.

It appears that the first applied tools, monetary incentives in form of the 1971 government-sponsored R&D program together with the market expansion program of 1976, had a limited influence on the R&D activities of the automobile industry. Analysis of alternative vehicle patent data from the Japanese Patent Office show that first applications were filed during the mid-1970s, but that their number was small and remained limited through the 1980s (Yarime et.al. 2008: 196f.).[10] It appears that the programs did not induce intensive interest by Japanese manufacturers in BPEV-development. Notable exceptions are Daihatsu, labeled the standard-bearer of electro-mobility, and Suzuki[11], another producer specialised in small cars and vans,

[10] Yarime et.al. point out that the analysis and their figures are based on the time patents got published and that applications of the patents were made 18 months earlier, which reflects the period from filing until a patent is granted by the Japanese Patent Office.

[11] Although not directly related to the topic of this paper, it should be pointed out that both companies are recently successful in the field of so-called Kei-cars (軽自動車/keijidousha), meaning mini or light vehicle. This

but well known for its motorcycles. Both companies continued development processes, while other producers basically froze their R&D activity (ibid.). Also, it appears that technological development did not immediately translate into new products as the Toyota hybrid exemplifies: although it was invented and applied in racing cars as early as 1977, this progress was not introduced to the market and mass production for about 20 years. This underlines the argument that innovation is more than just technical progress, but also the diffusion of a product into the market (Metcalfe/Georgiou 1997: 5-10).

A noticeable increase in patent applications occurs from the 1990s onward (Yarime et.al. 2008: 196f.), which indicates that the issue of alternative vehicles was taken more seriously by the Japanese automobile industry. This corresponds with intensified and more comprehensive support by the Japanese government, but also with CARB's ZEV Mandate and increasing oil prices. The latter two factors influence on the former will be addressed later, but the external shocks followed by promptly support measures of the state appear to have convinced private firms to regard electric vehicles as a future key technology.

The state as well as the industry realised that the batteries were the central component of BPEVs and therefore, development of advanced batteries was a top priority. The government tried to induce development via LIBES, but it seems that companies preferred another approach: major manufacturers allied with companies from the electro-chemical industry to develop advanced batteries that fit their specific needs. Toyota and Honda both cooperated with Matsushita in developing NiMH-batteries. These batteries were integrated into the first HEVs, the Prius and the Insight, the companies marketed. Another development should also be mentioned: Toyota strengthened its own electronic know-how, seemingly to be less dependent on Denso, which is a major Japanese supplier. Denso supplied most of electronic components in the past, but Toyota increased its in-house capabilities, partly to become more independent, partly because electronics increasingly develop into key technologies in vehicles (Ahmadjian/Lincoln 2001: 685-689). It also should be pointed out that Toyota intentionally did not purchase its long-time affiliate, because Denso had relationships to other companies, equal to a better picture of the whole automobile industry, which according to Toyota would strengthen Denso's ability to innovate (ibid.: 690). This logic stresses that those relationships would end if Denso became a subsidiary of Toyota. This means that the various ties of the supplier are also perceived as an insurance, which guarantees that Toyota will indirectly profit from innovation channeled through an important supplier. However, by employing this the-

segment is the only one with growing sales in Japan, while standard and small cars registrations stagnate or decrease (JAMA 2009: 4).

ory, Toyota also accepts that business rivals will profit from its technological inventions through Denso.

Nissan took a different approach: LiIon-batteries were judged as the more advanced type and worked together with Sony. Slow progress limited the ability to introduce BPEVs or HEVs and after the alliance with Renault in 1999, hybrid R&D was halted (Yarime et.al. 2008: 208). After the unexpected success of HEVs, Nissan announced an alliance with Toyota in 2002. Even before this step and despite its collaboration project on LiIon-batteries, the company procured NiMH-batteries from the Toyota-Matsushita joint-venture (Ahmadjian/Lincoln 2001: 692). Thus, the alliance could be regarded as a formalisation of the already existing cooperation between the car makers. Nevertheless, this transfer of technology is a remarkable step since both firms are archrivals. Indeed the purchase of NiMH-batteries was the first time Nissan procured technology from a Toyota subsidiary (Patchell 1999: 1004). Nissan later also collaborated with NEC in LiIon battery development. The recently arranged collaboration between Nissan-Renault and Daimler is centred on cooperation in small and light-duty vehicles as well as joint parts procurement for these types. However, joint development of a new small vehicle platform should also be commercialised with an all-electric, meaning BPEV, version and further, cooperation in battery- and electric vehicle components will be considered (Daimler website, 07.04.2010). As this rather vague formulation suggests, it is unclear if co-development in these future key components will be carried out. Thus, if this limited cooperation is going to be expanded cannot be stated. Consequences for alternative vehicle R&D of these manufacturers are not predictable, because they will be subject to assessment and possible future agreements between members of this triple alliance. Also, the effects on the participants are by no means obvious: so far, the alliance of Nissan and Renault is judged to be the only successful example of cooperation, whereas Daimler’s past merger and collaboration projects with Chrysler, Mitsubishi and Hyundai demonstrated the risks of such enterprises.

An important influence on R&D activity again must be attributed to regulation in California: Nissan and Honda only entered full-scale HEV development after the ZEV Mandate was amended in 1996 (Yarime et.al. 2008: 207), now awarding partial credits to HEVs. Only when it became possible to comply with the requirement through HEVs instead of BPEVs, both companies intensified research in this particular vehicle type.

The smaller Japanese producers are all situated within alliance frameworks. Daihatsu is a subsidiary of Toyota since 1998. Although the company seems to concentrate on low-emission mini ICEVs, Daihatsu sells HEV and BPEV versions of its mini van, the Hijet. Recently Suzuki strengthened its ties to Volkswagen (Suzuki, 2009). Other producers like Fuji Motors, Mazda and Mitsubishi entered in cooperation with foreign manufacturers. Fuji collaborated with GM, Mazda shares were held by Ford and Mitsubishi entered into an alliance with DaimlerChrysler. There seems to have been little cooperation towards joint development of alternative vehicles inside this alliance, so that its disintegration did not have significant impact on Mitsubishi's R&D towards BPEVs. Mitsubishi engaged a very different approach on its own. Development focussed on the i MIEV series, mini vehicles with in-wheel rotary motors, which would need less mechanical components and should be applicable to BPEVs, HEVs or ICEVs (Mitsubishi website, 03.03.2010). However, this innovative approach was not applied for the i MIEV, which is sold in Japan since last year, announced for sale in the UK from 2011 and is currently tested in various locations, e.g. Hong Kong (Government of Hong Kong website, 03.03.2010). This commercialised BPEV version of the i MIEV utilises LiIon- batteries, developed in a joint venture with GS Yuasa, a specialised Japanese automotive-battery producer, and a permanent magnet motor (Mitsubishi website, 03.03.2010). The case of Mitsubishi is interesting as the original concept concentrated on developing an energy efficient motor design that would be applicable for all vehicle types. Thus the idea was not to develop a powerful yet durable battery or fuel cell, but to construct a vehicle body and motor, which would need little energy, regardless if supplied by a internal combustion engine, a battery or a fuel cell. Nevertheless, the commercialisation as a "normal" BPEV suggests that this idea needs further development efforts before it is market-ready.

With regard to general development strategies, one observation should be emphasised: Taken together with the Toyota-Denso relationship, Nissan's battery procurement from Toyota-Matsushita shows that the new technologies partially overcome the keiretsu divisions in Japanese automobile industry, because companies seem to fear that their business rivals reach a breakthrough before they do. Thus limited cooperation appears necessary to ensure competitiveness. Another related aspect is that intra-industry cooperation, whether in Japan or with international partners, appears to continue. Since most mergers proofed to be ineffective and soon were dissolved, limited, strategic cooperation or take-over and integration into a clear hierarchy seem to be preferred. Ties between Renault-Nissan and Daimler are an example for the former, while Toyota's acquisition of Daihatsu for the latter. However, the cooperation of Suzuki and Volkswagen shows that both forms may be practiced at the same time. Further, Japanese car producers regularly enter cooperation with electro-chemical companies like Matsushita or specialised auto-battery producers like GS Yuasa. This is in sharp contrast with

Chinese BYD, a battery producer who entered automobile manufacturing in order to develop BPEVs since 2003 (Spiegel online, 14.03.2010).

4.5 Battery-powered and hybrid electric vehicle innovation policy analysis

Although MITI launched a R&D program for BPEVs in 1971, it can be claimed that the attention of Japanese officials and industry towards BPEV-development was initiated by an external shock, namely the first oil crisis of 1973. The topic of energy efficiency and what today is called sustainable development was already discussed among scientists and MITI also addressed the problem with an own ecological research group prior to the crisis (see below). However, the crisis set the issue on the political agenda as Japan's strong dependency on Middle Eastern oil became apparent. Industries and citizens alike were suddenly realising the problem as they experienced shortage and rising prices, so state officials were now forced to deal with the issue.

Turning to policy formulation, it is first necessary to identify the members of the concerned policy subsystem. The state actors are made up by politicians and officials from the bureaucracy. No names can be provided, but nevertheless, it is possible to specify their function. Bureaucrats from the ministries with legal administrative power and interest in the issue must definitely be included. As the various programs indicate, METI took the most active role, even before the oil crisis increased attention to BPEVs as a future, less resource intensive demanding mode of transportation. METI adopted an approach that supported private company R&D investment and a rather limited role of state institutions in the research process. This is in line with the concept, which ascribes the role of future-orientated planning through "visions" to METI, but leaves the transformation into marketable products and services to Japanese industry. Guiding and inducing desired development of private firms is preferred over direct state action and it also should be noted that METI usually stands at the side of industry when conflict with other ministries or agencies occurs. Other members from the bureaucratic apparatus were also involved, but to a lesser degree: Being in charge of vehicle inspections and safety, MLIT also has close relations to the automobile companies as well as with industry associations. Further MLIT cooperates with intermediaries or special interest organisations, e.g. the Institute for Traffic Accident Research and Data Analysis (INTARDA) or the Organisation for the Promotion of Low Emission Vehicles (LEVO). However, MLIT plays a rather complementary role, acting in cooperation with other agencies on the topic of alternative vehicles. MoE naturally supports vehicles with low or zero emissions, but because of its formerly lower status, it does not command administrative powers and funds similar to other agencies. Therefore, MoE could not promote alternative vehicles on its own, but needed to cooperate with other ministries.

The politicians active in the subsystem are those LDP-diet members with interest in the economic and industrial development, transportation or the automobile industry, the already mentioned “zoku giin”.

The societal members come first and foremost from the car manufacturers, but also from the electro-chemical industry. As batteries are the centre of a BPEV, which influences all other components, they are also important for HEVs if only to a lesser extent. Battery-development is a key problem for both vehicles types and so, the expertise from the electro-chemical industry needs to be incorporated. It should be pointed out that there was no national environmental organisation in Japan for most of the time investigated by this study that could influence political decisions. The absence of a social interest group like that left the policy subsystem filled with representatives from business and the Japanese state.

Regarding the actual process, it could be said that formulation partially preceded agenda-setting and decision-making followed formulated options in this particular case. The ecological research group drew up plans and policy suggestions before the oil crisis put the topic on the public and political map. Thus, at least to a certain degree, there were already some options for more efficient energy utilisation formulated. The timely response in form of the Sunshine Program should be attributed to this fact. However, it is necessary to point out that BPEV development was only one way to reduce dependency among various options. The steps taken suggest that BPEVs were regarded as a long-term target, not a solution with immediate effect. The government-industry R&D program of 1971 was a first move to start the development of a new technological option. Large-scale projects like the initial BPEV R&D program employed the logic of inducing private sector activity. The role of the state agencies was limited to organisation, coordination and funding, while actual R&D was conducted by the selected companies. Also, it should be realised that with the end of the initial large-scale project, state-funding on BPEVs became more limited to the market expansion program. It seems that R&D and the following subsidisation of BPEVs were thought to provide enough incentives for the private sector. The market expansion program only started in 1976 and was not included in the Sunshine Program just as little as the later Moonlight Project. Those research programs were the core of the Japanese reaction to the energy crisis and they focused on nuclear and solar energy. The development of BPEVs seems to have been judged as a less important source of possible energy saving measures.

The implementation of innovation policies towards the development of BPEVs and HEVs can be divided into two phases. The first stretches from the mid-1970s until the early 1990s, when the second phase starts. The first phase is characterised by two policy instruments: rather limited, but nevertheless influential state funded research, e.g. on flywheels and the market expansion program. With regard to the style of implementation, directed subsidisation fits this policy: Both tools can be classified as subsidies, the former for development and the latter for diffusion of new technology. The constraints must be regarded as low: the issue was not publicly debated nor was there pressure or demand to spur the development of alternative vehicles. Also, it can be claimed that the policy subsystem of this era only consisted of LDP politicians, bureaucrats and the Japanese car industry, while opposition parties or environmental interests groups did not play any significant role. Failure was therefore not likely to result in pressure on the government or the manufacturers. The nature of the policy target should be regarded as broad. It could be argued that the development of a single technology is a narrow target, but for the following reasons the author argues the opposite: by the time the decisions for R&D and purchasing subsidies were made, there was no clear trajectory of development. Although prototypes existed, developing an automobile capable of competing against the standard ICEVs was a project with many unanswered questions: many technological components had to be combined. The car companies needed to develop electric engines and drivetrains in place of mechanic ones as well as to power their systems from a battery instead of the internal combustion of gasoline. Also, the historic development showed that there was also the question, which battery type could be applied. With regard to HEVs, it was unclear which of possible options - series, parallel or series-parallel hybrids - was to be applied for the future mass production. Later, as the development proved to be slower than expected, there was also the option to avoid direct competition against more powerful ICEVs by promoting BPEVs as commuter cars. Given this bulk of uncertainty, stating that HEV or BPEV development is a narrow target is shaped by today's experience that HEVs have entered mass production and more detailed plans for BPEV development exist. Portraying the situation of the mid-1970s as having a clear idea about the future development of alternative vehicles is anachronistic. Therefore, as the first phase is characterised by low constraints and rather broad policy target, the style of implementation can be described as directed subsidisation.

The second phase that started at the beginning of the 1990s is marked by a more comprehensive approach: while continuing subsidisation of vehicles, the research projects included more topics deemed critical for a breakthrough in BPEV development, e.g. battery and infrastructure development. However, implementation only varied slightly. Constraints have increased through the increasing oil price, the perceived danger from Californian regulation and new awareness of ecological problems, but overall remained low. Also, the aim of policy was not altered. Although BPEV and to a lesser extent HEV technology got more attention and support, directed subsidisation implementation remained firmly in place. The treasure-based tools were still at the heart of policy, but LIBES, the ECO-Station and Eco-vehicle projects exemplify that there was more emphasis on cooperation between firms and industries. This more comprehensive approach is promoting the recognition of new technological solutions to energy and environmental problems, but still it mainly focuses on providing funds.

The rather active role the EA appears to have played in bringing together different companies as well as its aim of developing a market-ready product through the Eco-vehicle project is very different from usual Japanese industrial or technology policy. Moreover, the intention of EA indicates that the subsystem seems to have extended or that it became more contested. It must be pointed out that the activity of EA appears at the same year the LDP suffered a loss of power, which would explain the introduction of new ideas and actors to the subsystem, which in the end increases tensions and constraints. However, another alternative could be that the rather slow progress of "classical" industrial innovation policy led the government to the conclusion that a different approach could be utilised. Then, the Eco-vehicle program could be regarded as a new tool or a policy experiment. From this perspective, a new approach was simply tested without causing any major change of the general technology innovation policy. As this experimental approach failed to perform significantly more successful than established forms of administrative guidance, it seems to have been terminated. The aim of developing a marketable product is absent in later R&D projects in the automobile sector, programs rather seek to improve or develop specific components deemed critical to boost overall performance. At least for both case studies explored in this paper, no similar program was carried out afterwards, so that this policy experiment must be regarded as failed.

Also in the second period, the case of the ACE program is highlighting a connection between phases of the policy cycle. As pointed out before, the program had to be suddenly altered when METI and NEDO became aware of the Prius release. Thus, formulation and decision-making were already completed and implementation was imminent. Therefore, the quickly applied changes show two things: first, Japanese state capacity must be described as high, because other technology options could readily be identified and replaced HEVs. Second, this resembles adaptive innovation policy-making as information could be processed in two ways. Not only was the ACE program altered without going through another cycle, but further, the subsidisation program also aimed at the diffusion of hybrid vehicles. Thus, with regard to

ACE, it could be stated that implementation was adapted due to novel information. Further, knowledge about the commercialisation started a new cycle, which resulted in an extended subsidisation program. Another aspect should also be mentioned: opposite to the Eco-vehicle program, broadened subsidisation followed already existing procedures and therefore was quickly formulated, decided and implemented. Hence the particular case represents instrument tinkering, optimising adjustment and directed subsidisation. However, this may also be connected to the chosen instrument: using a limited treasure-based distributive policy tool in a subsystem that is quite stable and not subject to much public concern and therefore unconstrained is unlikely to meet a lot of resistance.

This issue also is related to the evaluation phase of the policy cycle. The change towards more comprehensive support of alternative vehicles, now also including infrastructure build-up, extended subidisation as well as stronger state-sponsored and promoted research on critical components is remarkable. The question arises, why this shift occurred. Among the three basic types of evaluation outcomes, two are identifiable in the development of BPEVs: the first type is continuation, the second one alteration. Continuation is embodied in the market expansion program that was never abandoned. Even despite slow progress, the decision-makers prolonged the program several times. There are two possible reasons, why the originally timely limited programs were not terminated: firstly, although progress was slow and the cars were not able to penetrate the consumer market, some companies like Daihatsu kept researching and developing BPEVs, because the program practically created a niche market with guaranteed support by the state. Therefore, the program worked as an incentive for interested companies to engage in development of a possible future technology and product. Secondly, as stated before, the fact that only produced vehicles were subsidised resulted in comparatively small state expenditure for BPEV support. The rationale of the Japanese R&D policy is said to aim at exactly this effect: limited state funds should induce private firm investment and research activity. So, if one does not follow the official wording, but interprets the market expansion program as an incentive or quasi niche market for car manufacturers the program fulfilled its mission of continued attention by producers towards electric vehicles.

Alteration seems to have taken place at the beginning of the 1990s. Possible triggers towards this broadened approach are the resurfacing issue of energy security or shortage and the perceived pressure from the important market of California. Those challenges forced the automobile industry to intensify their efforts in alternative vehicle development. At the same time, Japanese politicians and bureaucrats must also consider these issues since the companies represent one of its domestic key industries. Both, the state and industry members of the subsystem, were therefore forced to find methods that would speed up the slow progress in BPEV development that occurred until then. Consequently, the alteration of the former subsidisation and limited R&D funding took place. The support for key components such as more powerful and durable batteries and installation of necessary infrastructure were more costly, but necessary if the firms wanted to meet the ZEV Mandate in California. The approach seems to follow the logic that the former practice of largely treasure-based instruments worked satisfactory and that more funds would translate into accelerated technological progress. This means that the alteration took the form of expansion into related, complementary subject areas to achieve a technological breakthrough.

Another kind of alteration must also be observed: the administrative reforms carried out since 2001. Of course, this reorganisation did not aim at any specific policy subsystem, but at general structures and processes. However, these major changes affect the national innovation system and are tangent to R&D projects. Although the overall approach of inducing private sector activity in targeted areas is continued, cooperation between IAAs, universities and companies is promoted. In order to achieve this objective several procedural changes - agencification, adoption of the Bayh-Dole provision, TLOs, etc. - have been made. It appears that the Japanese state tries to remain the practice of centrally identifying key technologies, while minimising the micromanagement of R&D performers by granting greater operational freedom and fostering collaboration as well as competition.

The question of learning or evaluation style is rather complicated. Undoubtedly, the capacity of the Japanese bureaucratic apparatus is high in comparison to other states. Identifying the role of state and societal, here by and large industry-based, actors is difficult. The close informal relations between politicians, bureaucrats and private enterprises are quite opaque. As pointed out before, their interests in BPEV development were very similar and it is therefore hard to prescribe dominance of the subsystem to only one side. It can be argued that the state initiated and dominated the subsystem at the beginning of the 1970s and that societal actors gradually became more influential and replaced the state as the dominant side at the beginning of the 1990s, when automobile producers increased their efforts and demonstrated more interest. However, this must be qualified as the leading role of the state did not cause any dedicated attempts of private firms to achieve a technological breakthrough. This step only occurred when external shocks - most likely the fear of losing the main export market - forced the companies to innovate new vehicle types.

The latest move to support standardisation of charging stations rather shows that now that PHEV- and BPEV-technology is reaching the commercialisation stage, Japanese industry and government act in concert. Consequently, the evaluation style must be said to be between instrumental and social learning or that both occurred at the same time, caused by the external shocks of Californian legal requirements and increasing oil prices due to the Second Gulf War. This could also be put different: instrumental learning by CARB can be said to be the single-most influential factor. Then, the state of California is the dominant actor, because the Japanese automobile manufacturers reacted to the legislation. This case illustrates that a national innovation system is embedded into an international context. Furthermore, in this case, the international dimension of the policy universe seems to have been more influential than Japanese state actors and the business decisions of the societal members have been shaped by Californian legislation. Indeed, it could be said that the automobile policy subsystem is international, because of the global operations of producers, the alliances between companies and the outstanding importance of the triad markets. It should be highlighted that this is an exception to the norm, which may be explained by the global yet oligopoly structure of the car industry. Firms sell their automobiles worldwide in fierce competition, so that they can not risk losing an important market if they want to ensure their future presence in the market and survival. Under these conditions, complying with regulation in a key export market is just as critical for firms than with domestic legislation. Thus, if all state actors from the triad - Europe, Japan and the USA - form the state dimension of the policy subsystem, the state dominated and it is a case of instrumental learning. If one rejects this view and emphasises the national structure of an innovation system and subsystem, then it is a case of societal learning, because the Japanese companies intensified R&D activity, while politicians and bureaucrats incrementally broadened their subsidisation approach.

4.6 Fuel cell electric vehicles

4.6.1 Short history of fuel cell electric vehicles

Although there are some similarities between the historic development of battery-powered and fuel cell vehicles, there are distinct differences. The oldest and quite simple version of a fuel cell was created in 1802, but the working principle was studied by Christian Friedrich Schönbein between 1829 to 1868 (Stambouli/Traversa 2002: 437) while most textbooks ascribe fuel cell development to Sir William Grove’s invention in 1839 (Verspagen 2007: 103). For a long time, fuel cell development was not pursued. Only the utilisation in the NASA spaceflight missions of the Gemini and Apollo projects pulled attention to other possible applications (Anderson/Anderson 2005: 109f.). These were mainly energy generation and storage, while the integration into automobiles was not high on agenda. But around the beginning of the 1990s, when global environmental problems got more pressing coinciding with the again surfacing issue of energy security, FCEVs became something like the embodiment of a clean energy future and a society based on hydrogen consumption instead of oil or coal. The history of fuel cells is a fine example for the distinction between invention and innovation: the initial development was not practically applied for a very long time and it can be claimed that innovation will occur when FCEVs or co-generation systems are commercialised. This illustrates that innovation is linked to diffusion and is not the same as invention.

4.6.2 Regarding fuel cells

First, it is necessary to point out that fuel cells have a wide range of possible applications and their use it not limited to the automobile industry. Today, mobile and stationary fuel cells are subsumed as "new energies" (shin enerugii/新エネルギー), which are part of renewable energies (saiseikanou enerugii/再生可能エネルギー) (Fülop 2006: 147f.). Fuel cells can be utilised for decentralised power generation systems, but now they are also considered as a power source for portable devices like laptop computers and mobile phones (Kunimi 2007: 250f.). In fact, FCEVs were not considered as a viable solution up until the 1990s (Åhman 2003: 2). This is the same time when polymer electrolyte fuel cells (PEFCs) reached highest prominence of all fuel cell types. The interest in PEFCs as a probable solution are due to their distinct features: PEFCs operate at around 80-90°C which is significantly lower than the other types of fuel cells (Stambouli/Traversa 2002: 6-8) - namely solid oxide (SOFC), molten carbonate (MCFC) and phosphoric acid (PAFC) - as well as higher energy density. These characteristics make PEFCs the most viable solution for automobile and portable applications. It should be added that there are two kinds of polymers that are applied in PEFCs (Bae et.al. 2001: 189f.) which also underlines that the technology is not yet standardised.

Therefore, it is hard to attribute PEFC development only to transportation issues. Rather, promotion of fuel cell technology is at the crossroads of energy, economic and environmental policies (Weidner et.al. 2003: 1f.) All following issues are related to the political interest in PEFCs (Maeda 2003: 2-6): Firstly, automobile regulations like the already discussed ZEV Mandate in California put pressure on automobile companies to come up with eco-friendly vehicles and FCEVs were becoming a possible resolution. Secondly, Japan's lack of domestic energy resources is an ongoing concern and technology-intensive solutions like fuel cells are seen as a way out of energy dependency. This follows the logic that a constraint production factor, in this case oil, is substituted by an unconstraint one, namely technology (Watanabe 1999: 722-225). Thirdly, environmental concerns also influence the development and public interest in the technology. Last but not least it should be emphasised that fuel cells posses a multi-purpose usability so that a number of industries, e.g. automobile, electronics, chemical or energy take interest in development and commercialisation of PEFCs. This wide range of stakeholders could be seen as an advantage but also as a stumbling block. A large number of interested industries could provide a larger amount of R&D funds and a high number of applications - and therefore potentially high returns - could make the market more attractive for investors. However, similar to discussions around the introduction of BPEVs which is described as a technology shift (Schot et.al. 1994: 1060-1064; Patchell 1999: 998-1000), this situation can also create problems: if there are many stakeholders with varying technological expertise, different interests and absence of clear development trajectories for components can also result in uncertainties. These are perceived as risks by many companies and this can lead to a standstill in development as no firm or industry is willing to make the first move. To prevent a scenario like that the role of the state is crucial: financial and infrastructural supports are important, but coordination of the different stakeholders and consensus-building is maybe even more relevant, because this communicative process mitigates the emergence of uncertainties.

4.6.3 Foresight of fuel cell technology in Japan

As fuel cells can be utilised in various applications, it is necessary to investigate the history of the state-sponsored development and also to clarify when and why the technology was being considered for transport applications.

As pointed out earlier, Delphi method foresight surveys are an important source of information for policy-makers. The first Japanese Delphi survey of 1970/71 already proposed the development of fuel cells, however, it only examined the subject area of energy, not transportation issues (Cuhls 1998: 167f.; 207; 228). Fuel cells were regarded as promising in energy generation, especially as a possible storage for energy produced by solar power. At the same time, MITI released its vision for the 1970s and declared that Japan should shift from a resource-intensive to a knowledge-intensive industrial structure (Watanabe 1995: 240).

Options of fuel cell technology utilisation continued to focus on energy generation systems. The fourth Japanese Delphi survey - being the first of these studies to be translated into English[12] - discusses the future utilisation of fuel cells, but only for large-scale power generation or co-generation systems (IFTECH 1988: 130). This foresight survey does not contain any topic related to FCEVs. Alternatives discussed back then were alcohol or methanol fuel (ibid.: 130; 202). The fifth survey is the first to include the topic of fuel cells in cars, but remains rather vague:

> "Widespread use of methanol and other fuel cells as highly efficient, environmentally safe, portable power sources, e.g. for electric vehicles." (NISTEP 1993: 170)

Further, the fifth Delphi survey discusses hydrogen motorcars (ibid.), but its formulation is rather unspecific as FCEVs or ICEVs using hydrogen as an alternative fuel could be subsumed under this term. Together with the aforementioned topic, this indicates that technological development trajectories were unclear at the time of the fifth survey. First, hydrogen and methanol were regarded as options for fuelling. Indeed, FCEV prototypes often used methanol reformers to obtain the hydrogen needed, because methanol is easier to store and considered as safer than pure, compressed hydrogen. Second, the method of utilising hydrogen, either in FCEVs or in ICEVs, was not clarified. Also, the study suggests fuel cells for co-generation systems for residential power supply (ibid.: 29; 166-169), which is in line with the original focus on power generation.

Analysing the development of the subsequent series of surveys elucidates interesting aspects of the Japanese expertise in fuel cell as well as battery technology. First of all, the bulk of topics relating to these technologies is concentrated in the energy section of all reports. Sections dealing with environmental and transportation topics regularly refer to the connection between the areas (e.g.: NISTEP 2001: 371; 527). This may indicate that the most important reason for the political and scientific interest in those issues is energy, or more precisely energy scarcity in the country and that environmental or transport problems are regarded as secondary. Further, it is possible to capture the technological progress through the changes that are made in topic formulation. Thus, while the fifth survey only mentions fuel cells as power source for automobiles (NISTEP 1993: 170), the next survey already links fuel cells and batteries for practical use in vehicles (NISTEP 1997: 262). Also, while the fifth report is rather vague, simply referring to fuel cells in general, the seventh survey states which type of fuel cell is perceived as suitable for the task (NISTEP 2001: 366). The eighth survey is the most specific, because hydrogen energy systems and fuel cells are introduced as subsections of the energy chapter (NISTEP 2005: 350-353): MCFCs and SOFCs are linked to stationary and large-scale energy production while PEFCs could be applied to automobile or stationary use.

[12] The Japanese Delphi survey consists of a report on the findings and a catalogue of the topics and questions respectively. While the report has been shortened, the catalogue has completely been translated.

Being able to ascribe a particular type to a certain practical utilisation indicates that past R&D efforts have resulted in advanced insight in possibilities and limitations of different fuel cell types. Also, such accumulated knowledge may allow decision-makers to focus on one certain type deemed to be in the national interest or critical in global competition. Another example clarifies one particular technological innovation process: the fifth survey regards the future for practical use of advanced NiMH or LiIon batteries (NISTEP 1993: 170), while the sixth and seventh already assesses their widespread use (NISTEP 1997: 261; 2001: 364) and the eighth even discusses low cost secondary batteries (NISTEP 2005: 354). The language reflects the growing maturation of the technology as the assessment shifts from technical innovation towards diffusion and the related issue of cost.

4.6.4 Promotion of fuel cell technology

Government-funded R&D on fuel cells already started in the early 1970s: in May 1971, MITI set up an ecology research group, which purpose was to determine the impact of human and industrial activity on the environment and to come up with a way to limit those effects, especially with regard to an eco-friendly energy system. After drafting two research reports, the oil crisis hit the country and now MITI was even more interested in new, alternative energy sources as a resolution to the serious problem. Based on the proposals of the ecology research group, the Sunshine Program was initiated with the aim to substitute technology for energy, including hydrogen energy (Watanabe 1995: 240-242). Thus, fuel cells and hydrogen energy were among the targeted technologies of this research project, but renewable energies, especially solar, as well as clean coal technology, were at the centre of interest.

Unfortunately, there is no source indicating that the ecology research group used the Delphi survey as a source of their work. However, it should be noted that the focus on solar energy and the rather complementary role of fuel cells adopted by MITI is also present in the foresight study (Cuhls 1998: 207). In this respect, the similarity between the survey and the Sunshine Program is remarkable, but it is not clear if the decision-makers relied on the expertise of the survey.

During the 1980s, R&D was focused on PAFCs, shifted towards MCFCs at the beginning of the 1990s, before attention was focused on PEFCs around the end of the decade (Weidner et.al. 2003: 58). Under the Moonlight Project and at the start of the New Sunshine Program, the Japanese government sponsored mainly types suitable for large-scale power generation and co-generation like MCFCs (Fukasaku 1995: 1067; 1074, 15n; JETRO 1990b: 10).

4.6.5 Promotion of fuel cell vehicles

At the beginning of the 1990s, the Japanese government started to support FCEV development. Research on PEFCs was among the themes of the already mentioned New Sunshine Program. However, the funds for R&D on automobile applications of PEFCs were limited: the R&D budget for this type was less than 10% of the overall state-sponsored fuel cell funding and only a not specified part of this was spent on automotive use (Harayama et.al. 2009: 203), because PEFCs may also be used for stationary applications.

Again, the timely connection between the Delphi survey and the inclusion of fuel cells suitable for automotive use in the New Sunshine Program is peculiar.[13] While its predecessor did not explore mobile applications, when this possibility was however vaguely discussed, its investigation became state-sponsored through the newly merged R&D program. Therefore, some hints lead to the conclusion that the Delphi survey supported or even initiated state activity towards FCEVs: the very purpose of the studies is to inform decision-makers about future key technologies, the close linkage between the publishing of the survey and the inclusion, but also the limited funds spent on automotive PEFCs under the program (see above). This could reflect the fact that PEFCs were relatively new, so that other types received more attention and capital. But for the sake of clarity, this evidence is only circumstantial and does not prove that the scientific expertise embodied in the surveys influenced decision-making. It is also possible that powerful societal subsystem members from the Japanese car industry lobbied for state assistance and funding for this particular technology.

Nevertheless, it can be claimed that the approach towards FCEVs was not solely focused on this new vehicle type, but was rather holistic. However, the following confirms the rather slow pace in utilising PEFCs in FCEVs: during the first phase of the PEFC-centred R&D activities under the New Sunshine Program, only residential applications were produced and during the second phase (1996-2000) only two companies, Mitsubishi Electric and Aishin Seiki[14], worked on automobile applications (Avadikyan/Harayama 2003: 190). Further it has been claimed that FCEV technology was included in the ACE program in 1997 (ibid.). This would be consistent with ACE´s notion of promoting future technology and the fact that HEVs, the original targets of this project, were already commercialised by Toyota and Honda. However, FCEVs seemingly were not supported through the Clean Energy Vehicles Introduc-

[13] The Japanese version of the survey was published 1992, so that it preceded the New Sunshine Program, which was started in 1993.

[14] Aishin Seiki is a supplier which is usually described as a part of the Toyota keiretsu. However, shares are also held by companies affiliated to Mitsubishi and the firm is not exclusively supplying Toyota.

tion Program, because Åhman (2006: 440) reports exact numbers for BPEVs and HEVs, but does not mention FCEVs.

As another part of this comprehensive program, the World Energy Network (WE-NET) was initiated by NEDO, focusing on hydrogen infrastructure, production, storage and utilisation (Watanabe 1995: 268; 270). WE-NET was originally planned to cover 28 years, which indicates that hydrogen based mobility was rather a long-term development project than being considered ready for market entry. The project was divided in three stages: a first phase of basic R&D 1993-1998, the second demonstration phase 1999-2003, followed by early commercialisation phase from 2004 onwards (Åhman 2006: 437). However, in 2002 WE-NET was stopped and replaced by the Japan Hydrogen and Fuel Cell Demonstration Project (JHFC). Like its predecessor, JHFC aims at the realisation of FCEV mobility. It is divided into an infrastructure demonstration study and a FCEV road testing study, which are both subsidised by METI. The infrastructure is currently limited to twelve hydrogen stations, from which nine are located at the agglomeration of Tokyo and Yokohama (see: Fig.6). There is a wide range of possible hydrogen sources: electrolysis, liquid hydrogen, liquefied petroleum gas (LPG), methanol, kerosene, naphtha or spare hydrogen from industrial production processes amongst others. All of these are tested in the different stations which are constructed and operated by different companies from the energy, oil or gas industry (Kunimi 2007: 267f.). Although the firms operate the stations, the costs are entirely covered by JHFC (Weidner et.al. 2003: 65). It appears that the state is funding all the possibilities, because there exist no data which could determine options that will secure a safe and steady supply or about the costs of operation. Therefore, given this variety of rivaling options, companies will be reluctant to open testing stations themselves. Confronted with this situation, funding the installation of a testing and demonstration infrastructure respectively is a necessary step to gather information and overcome the standstill, which is caused by the fear of financial loss by the companies. If the same principal of full coverage of expanses also extends to the FCEV demonstration study is unknown. However, since 2002 the Japanese have initiated leasing programs, so that automobile firms could begin road testing of their vehicles. In Japan, the automobiles require certification through MLIT and participate in JHFC (JETRO 2006: 6). Currently, only fleet operators use FCEVs, as they are the only customers that can support the expensive technology as well as the necessary infrastructure. Therefore, the state government or municipalities are the main operators of FCEVs. This is in line with the already mentioned Law on Promoting Green Purchasing, which passed the diet in 2001 (Tanaka/Ahlner 2003: 24-26). Examples of such fleet testing are the fuel cell buses that were used for public transport at the EXPO 2005 at Aichi (EXPO website, 08.03.2010) or a bus trial at Tokyo, carried out 2003 and 2004 by Toei Bus (Kunimi 2007: 254), which is a bus service operated by the Tokyo Metropolitan Bureau of Transportation. Both examples demonstrate that testing does not need to be lasting a long time - in case of the Aichi EXPO only half a year - or require a large fleet of vehicles.

As these examples indicate, although R&D support started in the mid-1990s, the level of activity became increasingly higher around the year 2000. Notable is the increase of budget and research projects since that time (Avadikyan/Harayama 2003: 187; Maeda 2003: 18; see: Fig.1) and official sources point out that the Japanese government has committed itself to PEFC promotion since 1999 (NEDO 2008a: introduction). One particularly interesting step that underlines this strong support is the initiation of a fuel cell project team of Senior Vice Ministers from METI, MLIT and MoE by Prime Minister Koizumi in 2002 (Ishitani/Baba 2008: 73). The aims were not limited to technological issues, but also included creation of public awareness and promotion. One example for this is the joint publication of a Low Emission Vehicle Guidebook by the three ministries, which was distributed to parties, including central and local authorities, interested in introducing alternative vehicles like FCEVs, BPEVs and HEVs among others (MoE 2004). This illustrates that Japanese politicians realised the cross-cutting nature of fuel cell technology and therefore a strong need to coordinate and promote activities. However, although joint promotion and awareness campaigns are visible, FCEV R&D seems to remain the domain of METI (as an industrial key technology).

Support of FCEV development is increasingly addressing problems that could hamper commercialisation. Projects towards standardisation and safety are included into the strategy. Safety measures are rarely addressed in Europe, but if one keeps in mind that Japan frequently experiences natural disasters like earthquakes, the attention towards save hydrogen use is certainly understandable.

Related to this process is increased emphasis on cooperation between academia and industry. In order to overcome the historically weak links between those spheres several regulative measures were enacted. In 2008, NEDO initiated several new PEFC R&D projects, which all incorporate national and private universities, institutional actors like AIST and private industries (NEDO 2008a: 2-24). It is the declared aim to leverage the know-how and expertise of the scientific and industrial communities in order to achieve a breakthrough of PEFC technology, which is also the reason why NEDO organises meetings to the project leaders to achieve synergies (ibid.: introduction).

Another particularly interesting issue is links between fuel cell technology and other priority fields of the Japanese Science and Technology Basic Plan. Although it became included rather late into the Basic Plan, nanotechnology is regarded as an important factor. The reason for this is that nanotechnology has come to intersect with the major priority fields, namely life science, IT and environment (Stenberg 2004: 16). Advancement of the latter three fields will largely depend on applying nanotechnology, so that it could be said that nanotechnology is complementary to or enabling progress in the other sectors. With regard to the possible synergies between those fields, the question arises if assigning priority to all of them was made intentional by the decision-makers. Owadano Yoshiro, Research Coordinator for Energy and Environment at AIST stated:

> "In general, environmental/energy were used to promote nanotechnology, but, things are changing the other way round. Now, nanotechnology may be used if it contributes to solve environmental/energy issues. In the case of fuel cell R&D, because cost barrier is very high for automobile application, breakthrough by basic research was intended." (Owadano, personal communication, 28.12.2009)

This opinion is underlined by a recent R&D program, planned from 2008 until 2014: utilisation of nanotechnology - in form of nanomaterials for polymer electrolyte membranes, catalysts or membrane electrode assemblies, for advanced fuel cells - is explicitly included (NEDOb 2008: 86).

However, the statement also highlights another aspect. It exemplifies again that innovation policy-making has to deal with a high level of uncertainty. Synergies between environmental and energy research respectively and nanotechnology can be observed, but opposite to previous thought, the trade-off seems to stem from nanotechnology, which means that the intersecting relationship between these technologies is reverse. Moreover, this case shows that differentiation of research into subsections might be sensible with regard to political or budgetary purposes, but may not reflect the actual work. Putting it different, much of advanced research projects will be at the nanoscale, but is aiming to achieve a breakthrough in another scientific discipline. So, it might be best to think about the budgetary item nanotechnology as basic research in this field, while other sectors, e.g. fuel cells, are a kind of applied nanotechnological research.

Another aspect highlights the role of the Japanese bureaucracy and its close ties to the Japanese industry: In December 1999, the Director General of the Agency for Natural Resources and Energy (ANRE), a METI subsidiary, founded the so-called Fuel Cell Commercialisation Strategy Study Group as a private study group (Maeda 2003: 11). However, other sources claim that the impulse to set up this group actually came from MITI (Avadikyan/Harayama 2003: 200), while others even claim that the study group was a government committee, organised within MITI (Ishitani/Baba 2008: 64). If this was true, the initiation of this committee could be regarded as a type of administrative guidance, because the state itself organised a body to foster a goal of economic and technologic development. It consisted of 28 people, which were largely from industry or academia: nine university professors, four automakers, three each from petroleum suppliers, electric utilities and electronics manufacturers, two from gas utilities and one material manufacturer, a national research institute, a NEDO representative and a journalist (Maeda 2003: 12). The main purpose of this circle of selected individuals was the identification of obstacles hindering fuel cell commercialisation and the formulation of policy recommendations that could take on those problems. When the group finished this task in 2001, the report was published by METI. One step was the expansion of the group and so in March 2001, the Fuel Cell Commercialization Conference of Japan (FCCJ) was created. Today FCCJ has 114 members, mostly companies from the manufacturing and energy sector (FCCJ website, 29.01.2010). With the notable exception of Mitsubishi and Suzuki, all Japanese car producers are members of FCCJ as well as GM, Ford, Mercedes-Benz and Hyundai. The absence of Mitsubishi Motors is particularly striking, as a total of nine companies[15] from the Mitsubishi keiretsu participate in FCCJ (ibid.). Further, Toyota subsidiaries Hino and Daihatsu are upon the members and together with the example of Mitsubishi, this may qualify the seemingly long list of participants. Large conglomerates are still very influential, so that the actual number of players may be considerably lower.

It is crucial to realise that neither the study group nor FCCJ held any official status and that their recommendations were not legally binding, because they both were established by private initiative, not by legislation. Nevertheless, the impact of the report must not be underestimated: The Japanese government has adopted the target numbers for FCEVs as well as fuel cells in stationary use, mostly co-generation systems (Weidner et.al. 2003: 60). The scenario for fuel cell technology diffusion proposed by METI seems to have solely been modeled after the report of the study group (Avadikyan/Harayama 2003: 202). At first, the target of FCEV commercialisation was set between 2010 and 2020, but a revised roadmap was published in 2008, now aiming to start this process at 2015 and enter full commercialisation around 2020 (FCCJ 2008; see: Fig. 5). Interestingly, a NEDO pamphlet published three months after FCCJ's revised scenario, also states that practical use, which is equal to mass diffusion and therefore commercialisation, should be achieved between 2020 and 2030 (NEDO 2008a: 3). Similarly, a JHFC brochure featured the same graph FCCJ had used in its official press release for illustrating the altered commercialisation scenario (FCCJ 2008; JHFC 2008b: 8).

[15] Asahi Glass, Mitsubishi Corp., Mitsubishi Electric, Mitsubishi Gas, Mitsubishi Heavy Industries, Mitsubishi Kakoki Kaisha, Mitsubishi Materials, Mitsubishi Rayon and Nippon Oil.

Even more important, all RD&D activities on PEFCs were adjusted to the recommendations given by FCCJ in 2001 (Ishitani/Baba 2008: 64). However, despite the seemingly close connection between FCCJ on the one side and METI and NEDO on the other, it is reported that FCCJ did not accept financial assistance from the Japanese government (ibid.: 70).

The differing characterisations of the study group exemplify the opaque nature of Japanese bureaucratic action. Although clear evidence is missing, the author tends to share the perspective of Avadikyan and Harayama, that the government initiated the Fuel Cell Commercialisation Strategy Study Group, because MITI realised the potential of fuel cell technology, but did not leave the foundation to an individual high-ranking bureaucrat or gave the group any official status. Nevertheless, all authors agree that the group had significant influence on policy-making, so that it might be best to regard the study group as a quasi-official government body. The fact that METI published the report of the group under its own name and policy was largely modeled after the recommendations seems to support this view. Also, when FCCJ revised its commercialisation scenario in 2008 this was soon adopted by NEDO. However, this could just indicate that FCCJ and NEDO drew the same conclusions, as they both have insight into the latest technical developments, FCCJ directly through its members and NEDO indirectly through the organised and funded R&D projects as well as the through communication between these two actors. Therefore, both organisations are also aware of the remaining problems that hinder commercialisation.

Further, all authors point out that the report assigned specific roles for each actor in the development of FCEVs (ibid.: 67; Avadikyan/Harayama 2003: 201; Maeda 2003: 15f.): industry should be the main actor in development and commercialisation, while government and academia play supporting roles. Japanese industry wants to invent the technologies for FCEVs and co-generation systems on its own, with government support for basic R&D, initial infrastructure build-up and standardisation, and limited support of academia through contracted, mostly basic, research and education of engineers. Comparing this plan to the actual development, it appears that all three actors fulfill their prescribed function. Unlike the case of the Eco-vehicle, there is no government agency trying to reach a breakthrough via a state organised consortium. The Japanese government supports infrastructure, demonstration and standardisation measures as well as basic R&D, but refrains from actively influencing the research process of private companies, which is also confirmed by the varying approaches of the individual automobile manufacturers (see below). Measures promoted by the team of Senior Vice Ministers were exactly the same as recommended by the study group report and the respective ministries increased activities (Ishitani/Baba 2008: 73-75). The contribution of research agencies like AIST and universities is limited and mostly in the realm of basic research. As stated before, many projects are organised and co-financed by NEDO, but conducted by AIST and researchers from universities and companies. This reflects the status as a funding agency and intermediary research service provider. The relatively high level of collaboration between AIST and industry is concentrated in the field of basic research and therefore at a pre-competition stage. However, even under these conditions cooperation can stay limited:

> "Usually, our public projects stay in pre-competitive stage, but, some companies decide not to participate in a project because they do not like their higher potential leak to competitors." (Owadano, personal communication, 28.12.2009)

Interestingly, this is much in line with research about motives for participation in Japanese R&D consortia (Sakakibara 1997: 151-155): although cost sharing and economies of scale in R&D are reasons for cooperation, the most frequently stated motive is to gain access to complementary knowledge of other participants. This demonstrates that firms use cooperation to monitor the technological capabilities of their business rivals. This is very similar to the already described cooperation between Toyota and Denso, where the former seeks to profit from the latter's strong network throughout the whole Japanese automobile industry.

Another possible reason for this is that industry-academia cooperation has historically been weak and that regulative changes like the adoption of the Bayh-Dole provision, which should increase collaboration, will need time to overcome this division. Furthermore, industry has created its own R&D apparatus and relied on its own innovative capabilities, so that it can act quite independent. However, as pointed out before, the Japanese state is now actively bringing together industry and academia, e.g. in NEDO projects, to promote collaboration. Since this is a recent trend, it could be claimed that success of these projects will foster cooperation, while limited progress will discourage it.

All in all, it appears that recommendations of the study group and the FCCJ, its successor, had tremendous influence on fuel cell R&D projects. All actors contribute to the development process in the prescribed roles accordingly. Private companies are the main R&D performers, the state assists with funding basic R&D, standardisation, infrastructure and demonstration projects, while academia, although becoming more integrated, still remains a supporting actor. With the expansion and reorganisation into FCCJ, the question of status is much clearer: the network has integrated international stakeholders so that it can function as a forum for discussion of important intra-industry issues, but FCCJ first and foremost functions as a lobby group. Rejecting financial assistance from the government could be interpreted as a gesture to highlight its independence towards administrative guidance. Although it is not exclusively addressing FCEV development, but a wide range of possible applications, FCCJ is a powerful societal member of the policy subsystem.

Summing up, there appears to be a strong interaction between state institutions and industry on the issue of fuel cell development and commercialisation. However, the question arises, if this really exemplifies a case of state guidance: although the state set up those groups, its role is limited to the creation of this forum. The direction of guidance rather appears to have been reversed, because the various industries addressed the state and the administrative body seems to have largely followed industry's recommendations. The Japanese state has created this particular forum as a nexus to those companies interested in fuel cell utilisation to obtain information about barriers of market introduction and strategies to overcome those obstacles. With regard to the policy subsystem, it could be said that FCCJ is the collective actor representing the societal part of the subsystem. It appears that the various industries utilise FCCJ to establish a consensus and formulate their policy recommendations. In this case the state institutions seem to have adapted the recommended steps to pave the way for Japanese firms to develop and market fuel cell technology, because it is regarded as a solution for energy and environmental issues as well as being economically profitable.

4.7 Development strategies

Japanese automobile companies follow three different approaches towards fuel cell development: In-house manufacturing, cooperation with or technology transfer from other car producers and procurement from specialised fuel cell system developers (JETRO 2006: 6f.). Before exploring company strategies, these models need some clarification. Although the term in-house may be interpreted as completely independent development, it rather means that manufacturers procure components from different fuel cell device manufacturers and utilise these devices to construct the fuel cell stack for their vehicles on their own. The fuel cell stack is the central component of a FCEV and influences the other modules of the car. Therefore, the fuel cell stack is the central piece of technology inside a FCEV, which could be regarded as the core or heart of the vehicle. The second and the third approach is more straightforward as the fuel cell stack is jointly developed with other car producers or simply bought from specialised firms.

Another issue should be mentioned before exploring the different development strategies. Expertise from other electric vehicle types is adaptable as all alternative vehicle types explored in this study share many components: electric motors, electronic control systems as well as batteries. To be clear, batteries in FCEVs are mainly used to enable regenerative braking, they are not the main power source as in BPEVs, but nevertheless FCEV schematics usually include batteries as one important component (e.g.: JHFC 2008a: 10; see: Fig.3). Therefore, all car producers with experience in BPEVs and HEVs could be considered to profit from the expertise they have gained by developing electric drivetrains in present FCEV development.

As will be shown now, these are idealised types, which may be combined in the actual technology development process. First, it should be pointed out that all Japanese car producers are currently engaged in fuel cell development in one or the other way. This is noteworthy as the German automobile companies VW and BMW have aborted their fuel cell R&D programs and instead plan to concentrate their efforts on HEV, PHEV and BPEV development as both firms believe that FCEV development is too expansive and is not going to result in marketable products (Auto Bild online, 08.12.2009). On the one hand, this termination and concentration on other alternative vehicle types could be an advantage, as BMW and Volkswagen can focus their R&D instead of dividing their resources, but on the other hand this step could result in serious problems if their business rivals successfully construct and commercialise FCEVs.

Developing the fuel cell stacks[16] and hydrogen tanks on its own, Toyota by and large falls into the first category. The producer started its R&D activities on fuel cells in 1992 (Kunimi 2007: 253), the same year Toyoda Tatsuro became company president and initiated a more environmentally conscious vehicle design and brand image. It can be claimed that Toyota successfully transferred knowledge it gained in BPEV and HEV development to FCEV construction as its first FCEV was a modified RAV4L-EV, an all electric sport utility vehicle (SUV), which was presented to the public in 1996 (Yarime et.al. 2008: 205). The company continued its R&D efforts and improved the technology, so that different development steps became visible. An example is the joint development of fuel cell buses with its subsidiary Hino Motors, a manufacturer specialised in trucks and buses (Kunimi 2007: 253). Although both companies have been cooperating since the 1960s, Toyota formalised the relationship through increasing its shareholding from 11% to 21.1% in 1998 (Shimizu 2003: 138f.) and acquiring the majority in 2001, so that Hino became a subsidiary (Hino website, 10.03.2010). The second generation of the so-called FCHV-BUS has been developed before the 2005 EXPO at Aichi (EXPO website, 08.03.2010), while its predecessor was already tested in Tokyo. This step of fuel cell bus development could be regarded as a way to test a limited number of vehicles in a segment which is suitable to function as a fleet market. However, Toyota also coop-

[16] A fuel cell stack consists of several layers of individual fuel cells, which are combined in the stack to increase the total electrical output. See: Fig. 4

erated with GM since 1999, which could be regarded as a reaction to the alliance between DaimlerChrysler, Ford and specialised fuel cell system developer Ballard Power Systems (Yarime et.al. 2008: 207). Thus, while focusing on in-house development, Toyota partially follows the second approach.

Honda adopted a very different strategy, which could be described as a dual approach. The company combined the first and third type. The first, third and fourth generation of Honda's FCEV were originally equipped with fuel cell stacks of Ballard and shortly after the respective presentation integrated its in-house developed stack (ibid.: 210). The second generation utilised an in-house stack. Since the year 2003, all following generations, called Honda New FCX are equipped with in-house developed fuel cell stacks (Honda homepage, 03.12.2009). This suggests that Honda had limited experience at the beginning of the development process, so that the company chose to integrate Ballard's technology. However, it is also apparent that Honda understood the centrality of the fuel cell stack for its future vehicles and therefore intensified in-house development. Outside technology integration from fuel cell system developer Ballard stopped in 2003, which indicates that Honda had accumulated enough expertise through its own R&D efforts to continue the internal FCEV development process without external technology.

The development strategy of Nissan can be described as a mixture of all three ideal types: analyses of the patent data suggest that Nissan conducted limited R&D on FCEVs from the 1980s until the mid-1990s, before an increase occurs at the end of the decade (Yarime et.al. 2008: 209f.). However, the first FCEV of the company, the 1999 R'nessa, was based on a methanol steam reformer jointly developed with Mitsubishi Kakoki Kaisha, the chemical engineering section of Mitsubishi, a LiIon battery and a PEFC stack from Ballard. With regard to the battery, it is likely that it is the result of the collaboration between Nissan and Sony. One year after the partnership with Renault was formed in 1999, Nissan announced that it would invest JPY 85 billion until 2005. It is unclear, how this development is conducted. The alliance is said to jointly develop fuel cells with UTC Power, formerly UTC Fuel Cells (Kunimi 2007: 257), a specialised fuel cell system developer. UTC Power is originally a subsidiary of the American corporation United Technology, but it collaborates with Toshiba, which invested in UTC Power. Further, there was cooperation through the firm HydrogenSource with Shell Hydrogen, but in 2004 both companies decided to dissolve this joint-venture (HydrogenSource website, 09.03.2010). If the description of Kunimi is correct must be doubted as UTC Power officially states that it provided fuel cells to Nissan, which the company also did for BMW and Hyundai-Kia (UTC Power website, 09.03.2010). This is confirmed by Nissan: the companies FCEV, the X-Trail, was powered by UTC fuel cell stacks in older versions, but the New X-Trail model of 2005 is equipped with an in-house developed stack (Nissan website, 09.03.2010). According to Nissan, this stack was the first one to be independently developed by the company (ibid.). So, relying on the information of the involved companies, it appears that Nissan has chosen a strategy similar to Honda. At the beginning, joint development and integration from external developed components occurred. When the R&D activities of Nissan translated into sufficient technology the company did not need to borrow components from specialised fuel cell system developers like UTC Power or Ballard anymore and consequently stopped procurement.

Smaller car producers´ approaches are very different. Mitsubishi Motors ended its R&D on FCEVs in 2006 in order to focus on other alternatives (Yarime et.al 2008: 213). As pointed out before, Mitsubishi Motors also does not cooperate through the FCCJ. The case of Mitsubishi is also important with regard to the aspect of learning and technology transfer or application. Mitsubishi Motors terminated efforts towards FCEV development, although Mitsubishi Heavy Industries is among the leading companies in commercial and industrial applications of PEFCs (JETRO 2006: 5). It is necessary to qualify this position, because according to measurements, only 5 units were sold in 2005, but high growth potential was estimated (ibid.). Nevertheless, the fact that one part of Mitsubishi group could start selling PEFCs for power generation, while another section of this keiretsu stops R&D on PEFCs for automobile use questions transferability of knowledge in the field of fuel cells. As it seems, knowledge transfer is difficult, even inside a company group like Mitsubishi. About the possible causes can only be speculated: application or miniaturisation of power-generation equipment towards automobile utilisation might be an issue. Also, the problem could be that transferability might be limited due to very distinct requirements of the specific end-use. Industrial units must perform less complex tasks than automobile ones, which are more subject to environmental effects like temperature or vibration and have to rapidly adjust their power output - due to acceleration and braking - while operating. Therefore, construction of transportation fuel cells might actually only gain limited expertise from insights into stationary applications.

Having conducted R&D on FCEVs on its own earlier, since Ford acquired a controlling interest in 1997, Mazda is linked to the alliance surrounding Ballard (see below). This business relationship seems to have been weakened as Ford sold about 20% of its shares in 2008, apparently because the company suddenly needed capital to withstand the financial crisis. Although Ford sold a substantial amount of shares, with 14.9% it remains the single-largest shareholder of Mazda (Mazda website, 09.03.2010). It is unclear how giving up the controlling interest is going to affect the intensity of collaboration between these car producers, including Mazda's access to fuel cell technology through Ford. Mazda is exploring a rather unique approach towards alternative vehicles: instead of FCEVs or BPEVs, the company wants to use hydrogen to fuel its internal combustion engines. This idea is only pursued by Mazda, since the only manufacturer that also experimented with this approach, BMW, has ended its R&D on hydrogen-based propulsion systems altogether. Mazda seems to believe that its Wankel engines[17] possess superior capabilities for this task than the standard Otto engines (Nieuwenhuis 2009: 142).

Suzuki cooperated with US manufacturer GM in FCEV development since 2001. This joint effort continues despite the GM sale of Suzuki stock in November 2008 (Suzuki 2009: 27), like in the Ford-Mazda case, caused by the financial crisis. Suzuki is also developing fuel cell-powered scooters (ibid.), thereby applying this technology to one of its own key products, motorcycles.

Summing up, the most noticeable aspect is that only the major Japanese automobile manufacturers conduct FCEV R&D while the smaller competitors rely on technology transfer inside alliances. The reason for this might be economic and not subject to political factors. In the case of subsidiary firms like Daihatsu or Hino, there is simply no need to duplicate the efforts of the parent company, because the technology can be transferred internally from the parent to its subsidiaries or co-developed. R&D on FCEVs is a costly process and therefore, smaller, independent companies simply might not be able to afford the necessary capital to engage development on their own. Thus, entering into alliances and joint-ventures to develop fuel cell technology may be the only realistic option for smaller car producers to get access to key technologies like fuel cell stacks. Further, with the noted exception of Mitsubishi, all companies discussed here are members of FCCJ and participate in JHFC (JHFC 2008a: 3).

Another aspect that stands out, is that there are basically two options for companies with regard to technology development. The first is to rely on in-house development, maybe combined with integration of externally developed components at the beginning of the process. All Japanese producers, except Mitsubishi, engage this development strategy. To a certain degree, Mazda follows this path with the use of hydrogen fuel for ICEVs, but it is also linked to the following approach. The second option is to include specialised system developers, e.g. the alliance between Daimler, Ford and Ballard: in 2008, this alliance founded a joint-venture

[17] Mazda is the only mass producer using Wankel engines in a larger number of models. While conventional Otto engines are based on reciprocating pistons, Wankel engines utilise a rotary piston.

called Automotive Fuel Cell Corporation (AFCC), which is based in Vancouver, Canada.[18] Daimler holds 50,1% of the shares, Ford 30% and Ballard 19,9% (Ballard website, 09.03.2010). With the formation of AFCC, Ballard transferred its automotive division to the new company (Daimler website, 09.03.2010), so since then Ballard Power Systems is engaged in stationary fuel cell applications. A third, but arguably risky option is abandoning fuel cell development and the possibility to use hydrogen as an alternative fuel in an internal combustion engine altogether like Volkswagen and BMW.

4.8 Fuel cell electric vehicle innovation policy analysis

The way FCEV development occurred on the Japanese government agenda appears quite similar to the case of BPEV and HEV technology. Like the energy production application of fuel cells, the idea of transport utilisation was discussed in Delphi foresight surveys. However, hydrogen-based mobility was only vaguely discussed at the beginning of the 1990s and as the most suitable type, PEFCs, was a relatively new invention, other factors contributed to raise attention of this technology. Like other alternatives, FCEVs became more interesting against the background of increasing oil prices. CARB's ZEV-Mandate must be ascribed a significantly lesser influence than in the BPEV and HEV case, as FCEV development clearly was a long-term option, but not considered as a possible compliance option by any manufacturer. Thus, the appearance of FCEVs on the innovation agenda should be regarded as caused by a combination of factors. Increasing energy prices provided the main cause for politicians and industry to consider alternatives. This search was partially directed by scientific expertise and advice.

The implementation of the New Sunshine Program allows drawing some conclusions. As described, PEFCs as an option for FCEV development were a relatively new idea. Consequently, the projects on PEFC applications were included into the New Sunshine Program. However, the automobile applications received limited attention while residential use attracted more research activity. Further, excluding FCEVs from the Clean Energy Vehicles Introduction Program underlines that this technology was not considered as market-ready, rather a long-term option. New Sunshine Program's subsection, the WE-NET project, addressed the necessary construction of hydrogen supply infrastructure. However, in line with the uncertainties coupled to this novel fuel cell type, measures were limited.

[18] Daimler's merger with Chrysler was dissolved in 2007. According to Ballard's website, Chrysler is not among its strategic partners and not included in the alliance's formed joint-venture AFCC.

With regard to policy evaluation and learning, policy on FCEV development mirrors the BPEV and HEV case. It can be stated that learning originated from those examples. The adaptation of a more comprehensive approach towards those vehicle types, which included infrastructure and enabling technologies right from the beginning of the 1990s, was also applied for the relatively new concept of FCEVs. No direct proof such as a statement of a decision-maker or bureaucratic personal for policy learning can be presented here, but the utilisation of indirect evidence is possible: PEFC R&D was carried out under the New Sunshine Program, which is a result of a learning process. This R&D program integrated three already existing energy R&D projects in order to achieve more efficiency (through possible spill-over effects) and comprehensiveness (Watanabe 1995: 258). Arguably, against the background of these goals, linking together formerly separated R&D on new energy technology (Sunshine Program), energy conservation technology (Moonlight Project) and environmental technology (Global Environment Technology Project) is the result of learning. The alteration towards this approach coincided with the invention of PEFCs and the idea that fuel cells could also be used for transportation and mobile applications. Further, the need for hydrogen infrastructure was and is not limited to automobile use, but for all possible applications. It should be pointed out that the multiple applications of fuel cells have elevated the awareness for necessary hydrogen infrastructure, so that FCEVs are not the sole cause for its build up. Thus, adopting a comprehensive approach stemmed from learning that new energy options should be coupled together instead of explored in an isolated manner plus the simultaneously occurring shift towards supporting infrastructure for BPEVs.

Although a holistic approach like that characterises state policy towards FCEVs from the beginning, intensified support is visible since 1999. A new round of agenda-setting must be related to the foundation of the Fuel Cell Commercialisation Strategy Study Group in 1999. Unfortunately, the above described versions of the group's genesis make an evidence-based determination of agenda-setting in this important case inconclusive.[19] Nevertheless, a classification of the two possibilities will be made, as the group and FCCJ were important for the policy process: If Maeda is right and ANRE's Director General initiated this group without any consultation with its supervising ministry, the large number of societal actors in this study group plus the low involvement of the general public represent inside initiation. If the versions of Avadikyan and Harayama as well as Ishitani and Baba respectively are correct, the case would rather resemble mobilisation as the state set the impulse of foundation. However, the whole process could be regarded through another perspective: although mobilisation and

[19] The author requested the groups report, which was originally published by METI, and e-mail communication with its successor, FCCJ, but did not receive any answer.

inside initiation appear as being clearly separated, this case suggests that the distinction can actually be blurred. Inside initiation of a small, well connected interest group towards a desired policy could also be reversed. If state actors want to address a certain issue, but lack information or expertise, they can mobilise (and organise) certain groups or individuals that possess this particular knowledge or are likely to be affected by policy decisions in order to develop proposals. Here it is useful to apply the continuum of public involvement as suggested by May: innovation policies take place in an environment (equal to subsystem) that largely discusses and acts without significant public attention. This could be attributed to a lot of reasons: the inherent uncertainties of innovation make communication over such issues complicated, so that the complexity effectively limits arousal of public debate. As fuel cell technology is not perceived as dangerous nor touches upon questions of ethics like nuclear energy, cloning or genetically modified crops, public is not concerned and thus not going to criticise the development. Hence, fuel cell policies are discussed in a closely confined environment. In a subsystem (or environment) like that mutual influence is much stronger as there exists a shared perception of problems, causes and solutions. Therefore, the distinction between mobilisation and inside initiation could be said to be less clear than the one made in contested subsystems into consolidation and outside initiation respectively. As pointed out before, the creation of the study group could be regarded as a reversed form of guidance: the state is creating a forum for discussion and largely follows its recommendations. In the end, deciding if state or societal actors dominated the agenda-setting process evolves around the following issues: can dominance be defined as the power to select and appoint the individuals that produce policy proposals? Or is exactly this formulation capability the way to exercise influence? The way one answers and weights these questions against each other will determine if state or societal actors are in the driver's seat.

This also underlines that agenda-setting and policy formulation may be more or less integrated stages. Formulation took place inside the study group and the reorganisation into FCCJ happened after finishing the report. Thus, new actors were only integrated after basic policy recommendations were formulated. This also highlights another aspect: although the study group was embedded into the subsystem, it was in charge of identifying obstacles and formulating recommendations. With regard to the decision-making stage it should be noted that neither MITI nor industry lobby groups seem to have drawn up own, rivaling policy proposals. Further, it cannot be stated if there was considerable debate inside the study group while deliberating the proposals for the report. With respect to the composition of this body, the relatively high number of university professors should at least have prevented complete dominance by industry representatives. However, it is hard to determine if discussion was open to new ideas or not. Hence, it can only be stated that formulation either took the form of policy tinkering or program reform.

With regard to decision-making, it again should be highlighted that the legal authority rested with METI. However, similar to the Sunshine Program, decision-making followed the recommendations of a study group that was put in charge of formulation. Absence of rivaling policy proposals demonstrates that decision-making may not even require different, competing proposals, but simply be a question of approval or denial. Therefore, it could be stated that decision-making was limited to the question if and to which degree recommendations were adopted by METI. From this perspective, one aspect is particularly crucial: the policy literature has broadly acknowledged that Members of Parliament, especially in parliamentary systems, tend to be insignificant actors in the policy process and highlighted the role of bureaucrats. However, this example shows that the role of appointed officials may also be fairly limited, e.g. if highly complex and specialised topics must be addressed.

In this environment, constraints must be regarded as low: there was no broad public interest in this topic. Within the inescapable inherent uncertainties of innovation policy, there was no considerable lack of information or understanding of fuel cell technology. The subsystem was not very complex: the study group resembles this to a large extent. Non-industry actors were experts from NEDO, academia and a journalist. There were no members from other agencies, environmental or social NGOs involved. The number of involved individuals and institutions was low and the discussion was mainly structured by technical and scientific experts. Speaking with May, these were “policies without publics”. Therefore, decision-making must be described as a rational search.

Implementation again mirrors the BPEV/HEV case. The target was broad as the complexity of FCEV development and the parallel pursued aim of energy supply systems plus infrastructure build up were (and still are) interlinked. Constraints were low, because of little public concern, economic or environmental immediate necessity of fuel cell technology. Hence, implementation delivered directed subsidisation towards R&D activities. In the case of infrastructure build up, a mixture of subsidisation and directed provision can be identified: although private companies construct and operate hydrogen refueling stations, the costs are entirely covered through the state. This particular form of public-private interaction must be attributed to the specific case: although the objective is quite narrow, a wide variety of possible hydrogen sources exists, but without any certain knowledge about technical feasibility or economic viability. As there is no technical standard, the state leaves the construction and testing to private industry, but provides the needed funds to gain the necessary experience and data to identify viable solutions for future widespread installation of hydrogen supply infrastructure.

The comprehensive approach towards fuel cell technology in general and FCEVs in particular was caused by policy learning from BPEV and HEV development. But was there any new learning from the evaluation process of this policy approach? The only recent change is the stronger emphasis on industry-academia collaboration, which can be found in the latest NEDO projects. However, it appears that this shift is caused by general learning in innovation policy and not limited to fuel cell technology. The redefinition of the role of national universities and the reforms made all aim at stronger cooperation between the academic and industrial sector. Thus, learning on the central national level, embodied by CSTP's call for increasing collaboration, seems to have trickled down to specialised innovation policies. Again, the composition of CSTP and the lack of knowledge about which actors are dominating the internal discussions of this body make it hard to determine if this process should be described as social or instrumental learning. Here, it is only possible to state what is learned and by whom, but not how or why learning occurred.

5 Innovation policy regime

In order to combine the insights of both case studies and to reach some conclusion about Japanese innovation policy, what can be stated about dominant processes and contents addressed by public policies? First, innovation policy is closely related to industrial policy. Innovation policy is largely the domain of METI and its subsidiary agencies, which are closely cooperating with Japanese industries. Other ministries play a substantially lesser role. MEXT is preoccupied with the education system and the national universities. Although performing an important function, namely the education of scientists and a qualified labour force, MEXT and the universities are not dominant in innovation policy. As the investigated cases show, other ministries like MoE or MLIT may also be involved, but they are not able or willing to challenge METI's position. Second, innovation policy seems to follow established patterns of METI's policy approach. The practice of targeting key sectors to ensure future competitiveness is still firmly in place. With regard to the case of alternative vehicles, it should be pointed out that it falls into the crossroads of economic, energy and environmental policies, the former two being firmly under METI's jurisdiction. Hence, other case studies, e.g. from the S&T Basic Plan priority field of life sciences, which is strongly related to the authority of the Ministry of Health, Labour and Welfare (MHLW), might find METI's influence on innovation policies less dominant. Third, despite this continuity, some incremental changes are visible: inter-ministerial cooperation is fostered since administrative reform in 2001 through institutions like CSTP. Further, collaboration between industries and universities is now increasingly facilitated. Nevertheless, these changes are gradual and seem to confirm that regimes prevail over a long period of time and only allow a limited degree of change.

6 Future prospects?

In the end, there remains the question about the future development of the discussed alternative vehicle types. It is only possible to sketch some scenarios and identify certain obstacles which could slow down or hinder diffusion into the market.

An issue seldom discussed with regard to BPEVs, HEVs and PHEVs is the scarcity of lithium, which should be used in LiIon-batteries to power these cars. The main deposits are concentrated in the so-called lithium triangle between Argentina, Bolivia and Chile. Therefore, the often cited notion of energy independence through these vehicles must be doubted. Rather, instead of being dependent on Middle Eastern oil, transport would be dependent on Latin American lithium. Also, expansion of lithium production in these states would cause environmental damage to a unique eco-system, salares (salt deserts), so that it would be highly doubtful to label these vehicles as green or eco-friendly (Meridian International Research 2008: 11-16; 39-48). Further, it should be stressed that many, especially US-American, car producers use the theoretical optimum to project the amount of lithium a unit needs. However, when realistic conditions are applied for projections, the amount is estimated to be two to three times higher (Meridian International Research 2010). Hence, the number of vehicles that could actually be produced with the available lithium quantities is significantly lower than forecasted. Another resource that will be much required for a shift towards electric mobility is copper. Given the already high price of this commodity, mass production of alternative vehicles is likely to further raise demand and price.

With regard to HEVs and PHEVs, the Japanese case shows that the technology is market-ready, but also that subsidies may play a crucial role to influence consumer behaviour towards these products. However, the recent problems of Toyota that seem to include the Prius could have a major negative impact on hybrid technology as a whole, as the Prius is the quasi-embodiment of HEVs. Further, the costs of the product recall could limit the company's funds available to advance development of alternative vehicles. On the whole, further diffusion of

HEVs and PHEVs is likely as most manufacturers now demonstrate increased efforts to develop and commercialise these technologies.

FCEV introduction is a completely different story. Past forecasts concerning the date of commercialisation and the production volume have been overoptimistic, so instead of speculating about those issues, it may be more prudent to name conditions that will allow future mass production. Probably the prime condition for the spread of FCEVs is cost reduction. Several sources - from policy programs to scientific papers - indicate that the price of a FCEV must be brought down to 1% of the current cost (Ishitani/Baba 2008: 66; METI 2008: 22; Sakai et.al. 1999: 768). The timeframe of these publications also indicates that progress in this particular field of FCEV development has been marginal. Also, it is common opinion that through economies of scale, mass production would lead to a price three to five times higher than a standard ICEV (METI 2008: 22). According to METI, its aim is to reach that price range this year and to decrease it further to 1.2 times by the year 2020 (ibid.). A significant problem seems to be the platinum demand of current fuel cells and this issue is addressed in R&D programs in order to overcome this obstacle (NEDO 2008a: 19).

Another issue that is crucial for FCEV introduction is hydrogen infrastructure. Similar to FCEVs, the main issue about infrastructure is not technical feasibility, but cost (Ogden et.al. 1999: 152). Currently, this poses a chicken and egg problem, because without FCEVs entering mass production, no company will be interested in building up supply infrastructure and without hydrogen available to fuel these cars, consumers will be restraint from buying FCEVs. Solving this causality dilemma will probably require state assistance, because states could provide infrastructure for pilot and demonstration projects in order to support technological breakthrough. Therefore, regions that have been chosen for pilot projects are the most likely areas where larger numbers of FCEVs could appear on the streets. Examples for such regions are Los Angeles, Vancouver, Reykjavik and Tokyo, which are all demonstration showcases by national or regional governments: California and British Columbia are both determined to demonstrate their scientific and innovative potential. Iceland wants to utilise its abundant renewable, largely geothermal, energy resources to rid itself from dependence on foreign oil and gas (Vergragt 2004: 23). However, with the massive impact of the recent financial crisis on Iceland, it remains to be seen if the country will use its limited assets to promote hydrogen-based mobility. Further, all these places have in common that they are located in technologically advanced countries. Although they have the necessary know-how, decision-making is likely to be embedded in the already existing infrastructure and connected to vested interests. Therefore, transition to hydrogen-based transportation is likely to happen gradually due to path-dependency. From this perspective, countries that are in the process of economic and technologic catch-up development, e.g. China, India or Brazil, which are less subject to path-dependencies, may be more able to install the necessary infrastructure and make a faster transition to alternative transportation (Nieuwenhuis 2009: 148).

In Japan, future planning of policy towards FCEV development will be influenced by the evaluation of the JHFC, whose infrastructure demonstration study is going to end this year. As the purpose of this study is to identify technically feasible and economically profitable hydrogen sources, future infrastructure support measures could be concentrated on methods that had met those criteria. As the following S&T Basic Plan will be drawn up this year and implemented from 2011, continued priority on energy technologies will also help the innovation and commercialisation process. Given the heightened attention the Hatoyama administration demonstrated towards energy and environmental issues, combined with the already invested funds, time and expertise devoted to fuel cell technologies, continuation or slight alteration of efforts will most likely occur.

Last, but not least, one should keep in mind that all vehicle types are competing against each other and also against increasingly efficient and clean ICEVs. Although hybrid technologies are often thought as stepping stones towards a FCEVs, it also possible that advanced HEVs or PHEVs rival FCEVs as they have a head-start and their need for additional infrastructure is zero (HEV) or limited (PHEV). At the moment it seems impossible to forecast the development in transport technology. Only scenarios can be employed to clarify some very basic relationships between the various vehicle types (Grahn/Williander 2009: 5-10): if battery costs are high, hydrogen and natural gas vehicles will soon gain market shares. If gas storage is costly, HEV and PHEV technology is more competitive. Interestingly, under no scenario, BPEVs are found to not be cost competitive. Further, scenarios show that if progressive technology like carbon capture and storage or concentrated solar power is introduced, this prolongs use of ICEVs, because harmful emissions can be reduced in other sectors than transportation. This again highlights the connection of energy, environmental and transport technologies and policies

A future large-scale shift towards alternative vehicles will be surrounded by many issues that can be named, but not solved: If FCEVs became the new standard mode of transportation, how and from what sources will the necessary hydrogen be coming from? If BPEVs or PHEVs succeed, how will states and societies produce the extra amount of electricity? Will the additional electricity or hydrogen be produced in a sustainable way? Or will they be produced through the use of nuclear energy, gas or oil combustion? If ICEVs prevail, how long before the global oil reserves will be depleted?

All these questions demonstrate that innovation and change in transportation are linked to energy as well as environmental policy. As there are many stumbling blocks, political solutions and assistance in this transformation appear necessary. Although politicians and bureaucrats cannot enforce change, they can influence the direction and provide favourable framework conditions. The latest measure initiated by the Obama administration to implement stricter CAFE-standards for SUVs from 2016 (Spiegel online, 03.04.2010) is just one example of how regulation can advocate technological improvement, energy saving as well as lower environmental degradation. Other political measures that could support alternative vehicles are the pollution-free zones established by the EU, which are administered by municipalities. The complex linkages between technologies, the global environment and related policies demand and require more coordination between state and societal actors, not less. National innovation systems will be confronted with the task to create new products, process and services that are energy efficient, eco-friendly as well as economically competitive.

Conclusion

To sum up the main findings of this study, Japanese policy on alternative vehicles is characterised by comparatively early and sustained support, which extended into more comprehensive promotion measures later on. During this process, the initially limited provision of R&D and subsidisation funds also was scaled up. Therefore, Japanese policy was able to initiate and maintain a certain level of private industry activity in those technologies. However, the real turning point, which sparked the interest and commitment of Japan's automobile manufacturers to develop alternatives vehicles, was the Californian ZEV-Mandate accompanied by yet another increase in oil prices in 1990. Although the policies of the government, especially METI, addressed the future need for these technologies, only the threat of loosing a main export market made the industry change its attitude towards alternative vehicle types. Thus, it could be stated that external pressure functioned as a catalyst which speeded up the development process. It must be pointed out that the former R&D projects and subsidisation practice provided a basis of accumulated experience, from which Japanese car producers could start finding methods to comply with CARB's regulation. Seemingly, external pressure initiated activity, but development could utilise already existing, internally generated knowledge.

Interestingly, the development of HEVs, unintended by the Japanese decision-makers and CARB and only marginally supported, demonstrates that innovation often occurs in unpredictable ways. Further, the support given through subsidisation in Japan and the granted credits in California both exemplify that the respective governments were able to realise and learn that this innovation fell short of achieving the original target, but nevertheless was a step in the right direction.

What does public policy on alternative vehicles tell us about innovation policy? In general, the Japanese national innovation system is characterised by centralised decision-making, but increasingly decentralised performance of R&D. These activities are mainly conducted by private companies, while state and academic actors only play a supporting role. By targeting key industries, Japanese innovation policy seemingly continues its formerly successful approach to foster development of technologies and branches deemed necessary to ensure future competitiveness.

Despite continuity, there is also a significant level of change visible in Japanese innovation policy. The historically rather low level of governmental R&D funds has been completely altered. Since the end of the 1990s, Japanese governmental R&D has skyrocketed, not only in the national context, but also in comparison to European countries or the USA. There has been criticism of this shift, stating that there is little impact of R&D expenditure on economic growth and that other aspects of the national innovation system must be addressed (Shiozawa/Ichikawa 2005: 148f.). Keeping in mind the insights of the interactive innovation model, this is arguably true. However, there is one aspect that must also be considered: R&D never translates into immediate economic growth, results of present investments could be expected within a timeframe of ten to 15 or even 20 years, which can partially be seen in the presented cases of alternative vehicle development. Therefore, merits and flaws of this major shift may not be fully visible yet.

Institutional changes towards centralised decision-making and decentralised management and performance of research activity occurred simultaneously. The altered institutional set-up, which is much in line with OECD recommendations, seeks to combine conflicting tendencies: coherence versus specialisation and decentralisation (or agencification) as well as future-oriented, foresighted planning versus adaptive governance. Achieving all these targets at the same time resembles squaring the circle and should be regarded as an ideal-type which can be pursued, but may not fully realised. This partly signifies a greater problem of establishing international best practice solutions: path-dependency is described as a problem to adopt or emulate the successful model practiced by other states, although innovation systems literature suggests that such institutional transplantation may not result in equal performance. Hence, adopting best practice solutions may not work or even harm national innovation systems.

Returning to the case studies, they highlight two particular features of the Japanese innovation system. On the one hand, state actors, in the past especially METI, are able to induce and sustain private sector R&D. The administrative reform of 2001 still holds METI as a main actor of innovation policy, but the establishment of CSTP signifies more inter-ministerial coordination and efforts to streamline policies in order to overcome "tatewari". However, in both cases, METI was actively promoting technology development early on and was able to keep companies interested in alternative vehicles over a long period of time.

On the other hand, the cases support the view that Japanese private companies are the main, decisive performers of innovative activity. The lately promoted cooperation between industry and academia signifies that the knowledge and expertise of the latter should be incorporated, but nevertheless, universities still are not influential actors in innovation processes. Although there is substantial support by the state in selected key areas, the development of technologies as well as the application into marketable products is dominated by industrial interests. The Japanese automobile producers have a considerable degree of independence towards administrative guidance as the initially weak commitment towards BPEV development and the self-reliant commercialisation of HEVs demonstrate. FCEV development, embedded in general fuel cell technology, even suggests that the direction of guidance has been reversed. The processes at last underline that guidance is not simply a top-down command procedure, but rather based on, often informal, communication channels and provision of incentives. However, the author would like to point out that this also should be placed in the specific context of the case studies: exercising administrative guidance or even control over a mature, internationalised industry like automobile production is nearly impossible. Of course, a national government could use legal authority to enforce its will on companies or whole industries, but the outcome is likely to negatively affect the national economy on a massive scale, so that the political price of regulation-based guidance is probably higher than the use of incentives and persuasion. Hence, under these specific conditions state-directed economic planning must follow a different approach. However, targeting might still work, if the supported industry is relatively novel and not dominated by few giant conglomerates, but consists of a broad variety of SMEs. Therefore, studying other cases from diversely structured sectors might draw a different picture of the Japanese national innovation system.

Turning to the learning ability of the Japanese system, it appears that incremental lesson-drawing occurred several times: it was obviously concluded that these new types of transportation required infrastructural support if they were to succeed. Also, both cases show that initial R&D may be limited to gain basic understanding and to establish if technology can be successfully developed or not. This follows the logic that R&D should induce private sector activity, not replace it.

However, two aspects of learning should be pointed out: first, state interest in alternative vehicles always heightened when external shocks questioned the future of ICEVs. Interest and programs were reduced after both oil crises, when the problem seemed less pressing. Although support was never halted, a high level of attention was only assured after multiple challenges surfaced in 1990. Thus, lessons already learned seemingly could be forgotten, or in other words, a problem has to occur several times before the insight is internalised, which characterises learning as a cumulative process. Second, it could be concluded that industry realised through the external shocks that developing alternatives is in its own best interest. This confirms the importance of the question: who is learning what? When intra-industry learning happened, it was naturally more decisive than promotion efforts by the state. Self-interest is a much stronger stimulus than external demands or incentives.

This case of social learning currently seems to have extended to European, US-American and even Chinese competitors (or partners) of the Japanese automobile industry. In combination with the rivaling technological options of FCEVs, HEVs, PHEVs and ICEVs, it is by no means clear which company or alliance will be successful in this competition regarding the future mode of transportation. Therefore, although they cannot direct development, national innovation systems still can influence this competition by providing favourable framework conditions, incentives or enacting challenging regulations.

Appendix

Fig.1 Japanese support measures for alternative vehicles

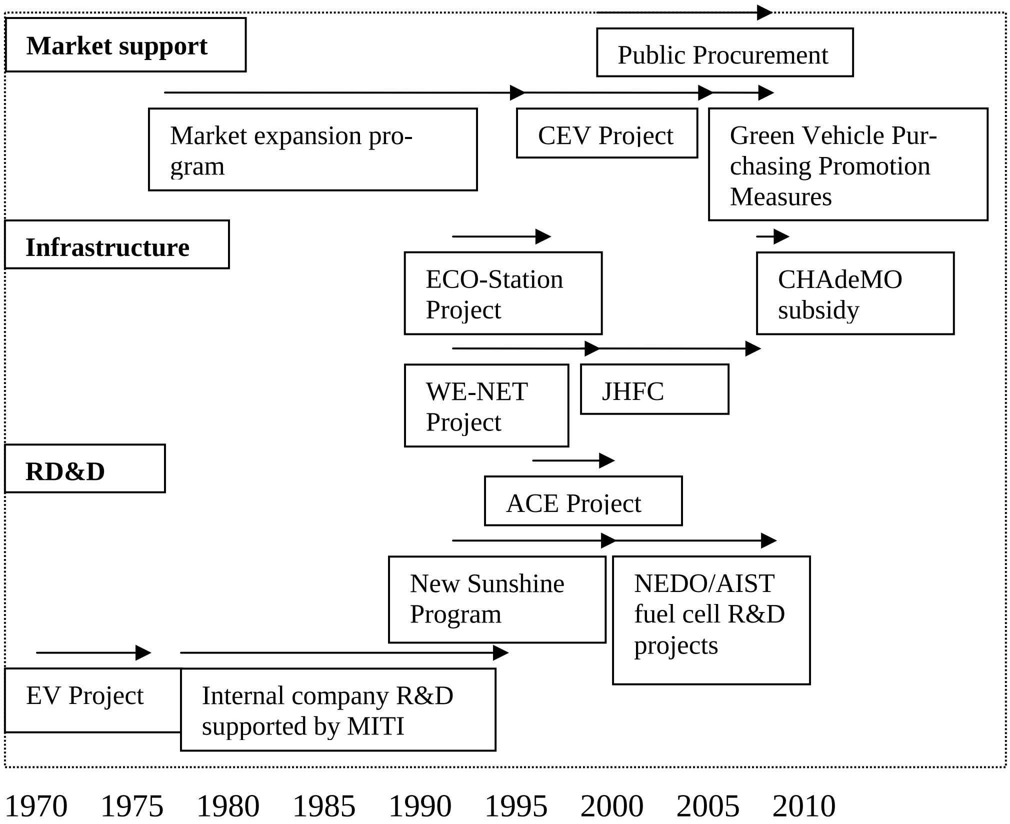
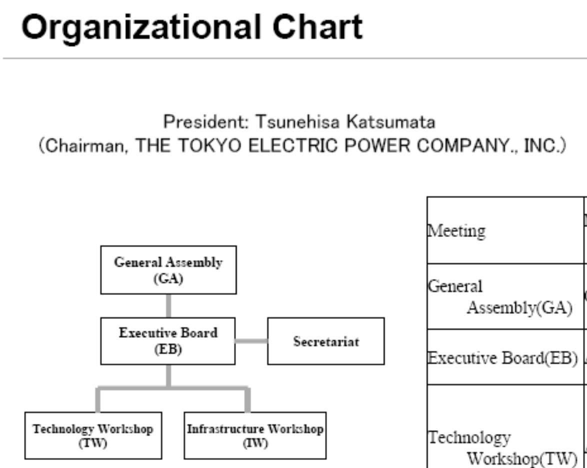


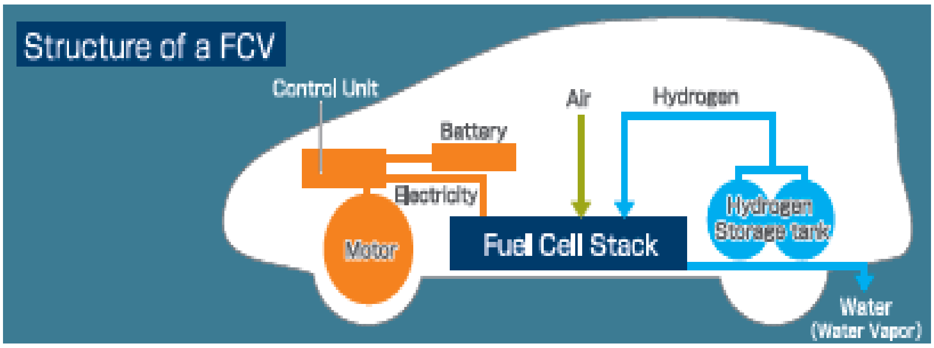
Fig.2 Organisation of CHAdeMO Association



Meeting	Meeting Frequency	Activity
General Assembly(GA)	Once / fiscal year	- Approval of action plan and activity report including fiscal report
Executive Board(EB)	As needed	- Decision of matters related to management and operation of the Association
Technology Workshop(TW)	As needed	- Certification work of quick chargers compatible with CHAdeMO Protocol- Revision of standard specifications- Involvement for international standardization activities through representative body of each country
Infrastructure Workshop(IW)	As needed	- Sharing information regarding installation and maintenance of quick chargers among Members- Reviewing and sharing information regarding development and installation of normal/quick charging infrastructure

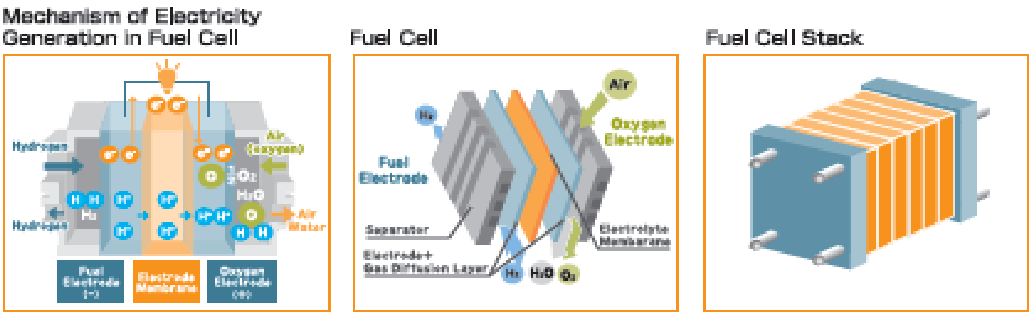
Source: CHAdeMO Association

Fig.3 FCEV structure and components



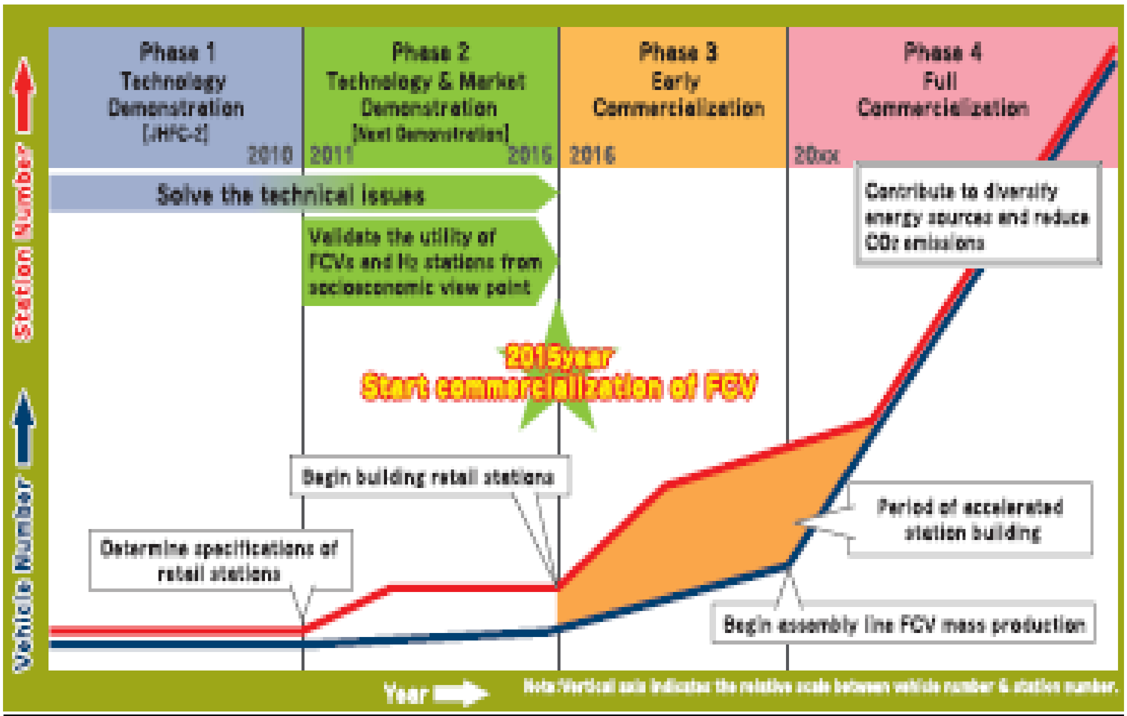
Source: JHFC 2008b: 9

Fig.4 Fuel cell structure and working principle



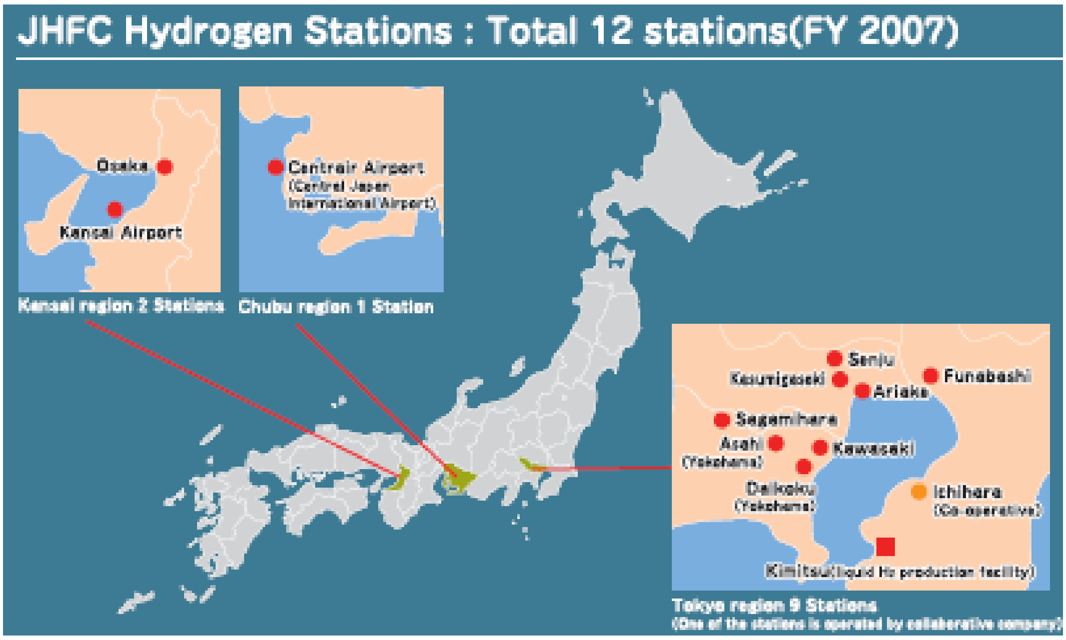
Source: JHFC 2008b: 9

Fig.5 Commercialisation scenario



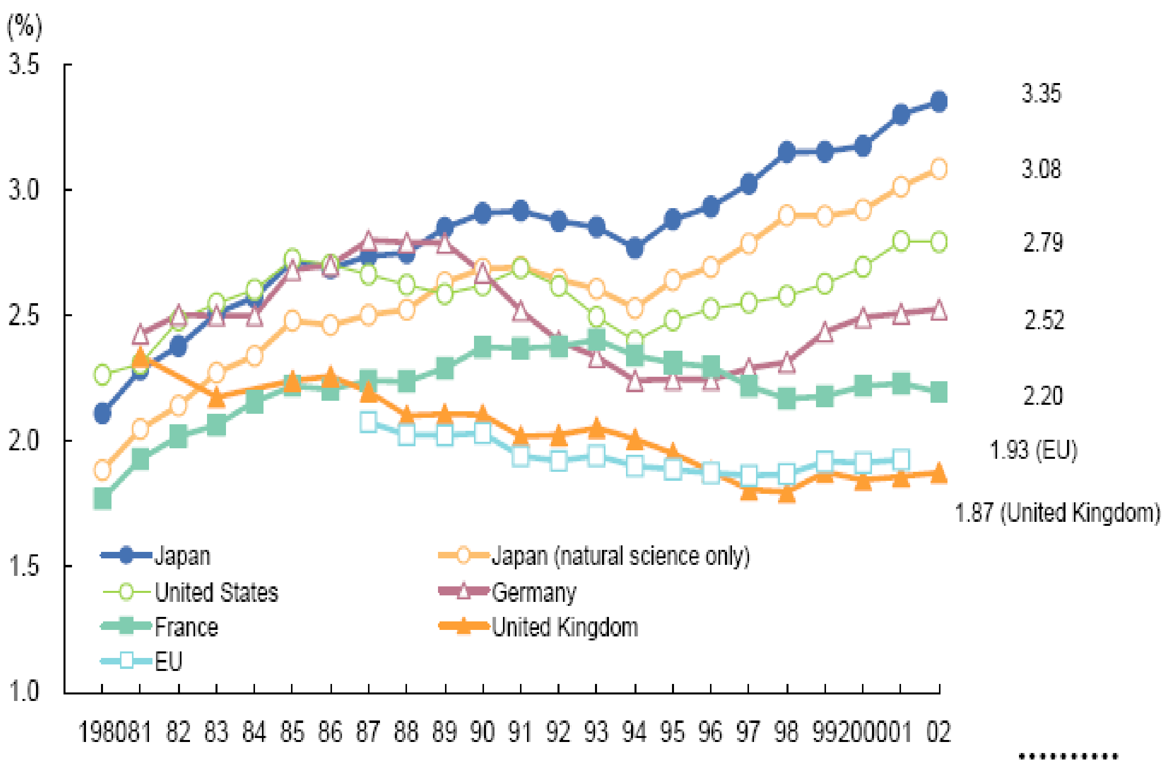
Source: FCCJ 2008

Fig.6 Hydrogen refuelling infrastructure



Source: JHFC 2008b: 5

Fig.7 R&D% of GDP



Source: MEXT 2004: 150

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