Олимпиада НИУ ВШЭ для студентов и выпускников – 2018 г.

Демонстрационный вариант и методические рекомендации

по направлению «Менеджмент»

Профиль: «Управление в сфере науки, технологий и инноваций / Governance of Science, Technology and Innovation» **КОД - 146**

You have 180 min to complete this task.
Read the article and analyze it critically in English. Answer the questions below.

Questions:

1) What are the main drivers and obstacles for technology diffusion? Please, discuss this perception.
2) How to classify and systemize stakeholders' agendas for technology diffusion? Please, propose a structured approach and explain.
3) How can policy makers take stakeholder agendas into account for policy making and technology diffusion? Please, provide a creative approach and discuss the related challenges.

Identification of Stakeholders' Hidden Agendas for Technology Diffusion

Technology diffusion

Technology diffusion has long been discussed in academic literature. The main focus of the discussion and concept was aimed at the management of technology and its subsequent diffusion in the market, respectively in applications. More recently the discussion was extended to diffusion of technology from the science, technology and innovation (STI) policy perspective. The STI policy perspective is especially important in light of the grand challenges to which clean energy belongs. During the last decade governments have initiated and supported substantial efforts to redesign the current national energy policies and priorities, switching the focus to renewable energies in several application fields. However, increasingly these efforts are questioned and challenged by numerous stakeholders for different reasons.

The main obvious and most frequently cited motivation for raising concerns about green energy is the issue of cost, which is used to question the impact and effect of related research efforts. It can be observed that in many countries policy makers are confronted with the quest to justify the substantial investment already made, but even more they are confronted with comparisons of the investment required to change the energy mix favouring green energy over traditional fossil sources and the respective returns from this change. Often policy makers are stuck in a dilemma, which is to enforce the change in the energy mix by various instruments, but also limiting the burden on the energy consumer which in itself is challenging. For changing the energy mix, renewable energies are thought by politicians as being advantageous in many shapes. It is assumed that the technologies are already readily available or at least are available for application in the near future. However the question about whether or not these new technologies will be accepted and applied in the market is not answered, e.g. the current or near term technology availability itself is no guarantee that technologies will diffuse in the market application.

For a reasonably long amount of time technology and innovation diffusion have been the subject of public debate. Namely during the last decade policy makers have especially become more and more aware of the challenges of diffusing innovation in application on a broader scale which leads to the changing attitudes of politicians from considering only the development and generation of technologies and innovation to a more systemic view that includes generation and adaption, e.g. diffusion. At first sight this does not incorporate much change. However for STI policy and policy makers this imposes the challenge of designing and implementing measures that include the diffusion phase.

Although radical changes imposed by new technologies are often the consequence of new entries into competition, external shocks or crises, the outstanding performance of new technologies, market changes and/or industry competition (van den Hoed 2007), there still is no standard form of technology diffusion (Rao, Kishore 2010). In addition, there is a constraint for policy intervention at this stage in the technology and innovation life cycle: in liberal market economies, direct public intervention on the market is not allowed, e.g., the direct support of technology and innovation diffusion is only reasonable in the case of market failures. The difficulty however lies in the definition of market failure.

In a broader sense, innovations are potential replacements of already existing solutions. Thus it is a matter of competiveness of the innovation and its ability to outperform existing solutions and replace them, hence there already is an existing market. With increasing numbers of innovation users, more people, e.g. customers, become aware of the solution and start forming opinions based on the experiences of others (Zapata, Nieuwenhui 2010). In principle this is a reasonable assumption, but it still neglects the fact that competition is not necessarily limited to the actual technology or innovation, but instead replacement competition includes the broader environment in which a new technology can be used and operate (Meissner et al 2013). Therefore technology assessments in the traditional way need to be extended to include the respective opportunity cost for investments that have already been made, so the assessment mostly centred on the technology's characteristics is complemented by an even stronger economic dimension.

At the policy level changes were initiated in technology regimes and they usually come with stakeholder involvement in the early phases of a new technology's diffusion into application. It is common knowledge that this requires the substantial involvement of stakeholders, but there are also potential threats affiliated with this. Brown (2004) argues that stakeholders' involvement requires policymakers' skills in bargaining, negotiating and cooperating with stakeholders. Also he finds that such early stakeholder involvement supports the building of absorptive capacities by stakeholders. Furthermore stakeholder involvement also provides a platform to reach a consensus not only between policymakers and stakeholders, but also between stakeholders by exchanging different understandings and eventually validating a common understanding (Brown 2003). Accordingly policy needs to find alternative routes to influence the market and direct it towards the replacement of existing solutions (Meissner 2014).

Geroski (2000) argues that information and communication channels are suitable instruments for policy makers to influence the markets by involving stakeholders in the initial political agenda. Typically the involvement of stakeholders in such politically initiated and driven communication and information-related undertakings is accompanied by direct measures such as subsidies, which might emerge (Geroski 2000). Policy makers have a range of opportunities to influence the diffusion of technologies, namely the information about a technology and subsidies in different forms (Geroski 2000). The communicative role of policymakers includes targeted and dedicated information for a broader audience, the willingness to perform and act as lead users as well as facilitating the communication between different stakeholders who are affiliated with the technology in question. Such communication activities often aim at building consensus among stakeholders about the characteristics and features of technologies and also at informing the potential user community about the technologies, thus trying to influence the perception of technologies and the attitudes towards them. This is mainly the case for disruptive innovation, which is typically a distinctive feature of premium products in markets that are often saturated with a reasonable share of mass produced products. Moreover especially capital-intensive industries are confronted with additional pressure on companies to assure timely return on of investment. Accordingly the uncertainty of the eventual acceptance and return on the innovation increases with a higher degree of disruptiveness of the innovation. Disruptive innovations that are included in an existing product have even more impact than the sole replacement of technologies/solutions, because they require the revision and adjustment of the manufacturing and assembly process as well as the respective changes and adaptations in the supply chain. Thus besides the initial innovation, which can come in different shapes, additional innovations, often process innovations, are required, which are shown to be essential for eventual acceptance and diffusion.

Public support is frequently granted in different forms, be it either during the actual development and testing of technologies or at the stage of market penetration, e.g., application diffusion (Proskuryakova et al 2015a, b). In principle subsidies are intended to set incentives for users (user subsidies), to accelerate technology development (push subsidies) and to stimulate competition between suppliers (competition subsidies) as well as to support interface harmonization and the standardization of technologies (technical norms subsidies).

The change of a complex system of actors requires changes of multiple elements of the system (van Bree 2010; Schibany 2014; Simachev et al 2014). Basically these changes naturally open opportunities for all actors participating in the system, however the challenge remains to overcome the different perceptions of the opportunities that the actors have. These perceptions are individual, thus the actors in the system will define their strategies and act according to their own interest, which does not necessarily reflect other actors' strategic intentions. To overcome conflicting interests and enable technology and innovation diffusion, political skills such as bargaining, negotiating and collaborating can be helpful in aligning the stakeholders' interests (Brown 2003). Hence a profound understanding of the stakeholders' interests becomes an essential precondition. Over the last decade, stakeholder analysis has evolved as a broadly recognized and applied instrument for finding consensus between stakeholders, i.e. the elements of a system (Friedman, Miles 2006; Jepsen, Eskerod 2009).

Another typical characteristic of disruptive technologies is their applicability to a limited and narrow range of pioneering customers whose experiences with the initial application are commonly valuable and useful for further development, which in some cases leads to a broad mass application eventually. The broad introduction of disruptive innovations frequently requires a transition of the established industry, including significant changes in the socio-technical regime of the industry (van Bree et al 2010, Collantes 2007). Still mass applications needs to be seen in the context of the application, e.g. mass application does not automatically imply mass manufacturing for consumer devices but also relates to unique and dedicated applications for only a limited number of potential customers (Zapata, Nieuwenhui 2010; Kutsenko, Meissner 2013; Vishnevskiy et al 2014, Vishnevskiy et al 2015). Also, predicting the potential diffusion of technologies requires an analysis of the whole picture, which naturally includes the technology in question but also the impact of the technology on other subsystems and on the actors involved in the actual technology and subsystems (Keles et al 2008). Subsystems are understood as the systems that surround a technology and are essential for the technology's operation and use.

Van Bree et al (2010) propose a 4 element model for analyzing the technology diffusion in the automobile industry. First there is a transformation stage during which niche technologies are in principle operational but still require additional development for mass application, second the industry is confronted with a sudden change in the industry environment which forces the industry actors to seriously consider changes in the existing technology regimes. However, considering changes does not imply automatic replacement of existing technologies rather this means intensive competition between emerging niche technologies up to the point until one technology becomes dominant. Third, the substitution of technology takes place and fourth the established set up of the industry is shaken and some actors are replaced. The replacement of actors might include the replacement of OEMs as well as significant changes in the supplier landscape.

Disruptive innovation - fuel cells in the automotive industry

The automobile industry is considered one application field for mobile fuel cells with significant market potential. It has become a common practice in the industry to introduce breakthrough innovations to premium products first, thus making them accessible to a comparably small share of customers in the early stages of the innovation life cycle (Zapata; Nieuwenhui 2010). Fuel cells have been in discussion as a substitute for combustion engines for a long time. However, the discussion was mostly around the replacement of internal combustion engines with different, alternative engines including fuel cells and most frequently hydrogen powered engines. Accordingly there was a reasonable number of assessments of fuel cells for different applications, including mobile and stationary applications (Hart 2000; Pehnt 2003; Baretto, et al 2003; Afgan et al 1998; Afgan, Carvalho 2004; Kwak et al 2004; Hopwood et al 2004; Midilli et al 2005; Midilli et al 2005a). It has been recognized that energy sources such as hydrogen are required that do not cause societal impacts (Afgan et al 1998; McGowan 1990; Hui 1997; Dincer, Rosen 1998, 2005, 2008;

Hammond 2004). Schwoon (2008) finds that emissions from internal combustion engines have decreased substantially per engine recently but these reductions per engine have been offset by the increase in car travel and heavy and light duty vehicles.

Radical changes such as fuel cells in the automobile industry are taking a long time to diffuse for several reasons (Collantes 2007). In the special case of fuel cells, it is evident that the technology per se has been available for quite a long time, but that there was no incentive for the industry to replace existing solutions, e.g. technologies. This is at least partially due to the modest demand for the technology. This appears all the more surprising because the technology itself has been under discussion in the public domain for a long time and efforts have been made to establish the technology several times. Still, expectations towards the technology have been very high and could not be met, either in technological terms or in terms of performance of the final product used by the customers (Collantes 2007). Moreover customers have been used to vehicles powered by internal combustion engines for decades, which has resulted in routines that the customers developed for operating them. Changing routines is widely accepted as one of the most challenging and difficult undertakings of technological diffusion.

The diffusion of fuel cell vehicles is dependent on a variety of factors beyond the actual technology, e.g. fuel cell, and the respective product, e.g. fuel cell vehicle, which influence each other eventually forming a system around the actual technology (Rodriguez, Paredes 2015). Among these factors is the fuel cell itself, which requires a manufacturing and maintenance infrastructure but also the fuel supply infrastructure which differs significantly from the existing fuel supply infrastructure (Keles et al 2008; Turto 2008). The fuel supply infrastructure requires the development and/or adaptation of norms and standards that take account of the special characteristics of the fuel itself, and its production, transport and storage. The challenge is that the different elements of the system are offered and maintained by different actors who follow their own very specific and dedicated agendas. Because each element of the overall system requires substantial investment and the acceptance of customers remains uncertain, companies feel tempted to wait until the whole system is in place but avoiding to take the first initial step which is commonly referred to as the chicken-egg problem (Schwoon 2008). Taking the first step implies taking on additional risk due to the uncertainty of whether and when other elements of the system will follow.

Currently fuel cells remain expensive substitutes of internal combustion engines however it is assumed that with an increase of the scale of production, the cost will decrease resulting in economies of scale which are driven by learning effects and the sheer number of units manufactured using the initial equipment in the first place. Also the necessary manufacturing equipment will improve with the increasing number of units produced, as will the logistical efforts related to the supply chain (Schwoon 2008). Considering the supply chain, it is shown that there are a rather high number of component suppliers with comparable small numbers of units produced, which is still rather atypical for the industry value chain. However the assumption is that also in the supply chain competition will force suppliers who are currently active in the field to merge in order to achieve economies of scale and eventually lower the unit cost. Learning effects and economies of scale can be expected to contribute strongly to decreasing the cost especially in the automotive industry because of the naturally eveloved industry structure, which is characterized by strong OEMs and a tier system of suppliers. System suppliers at the same time provide their solutions to more than one OEM, which enhances the learning effects of these companies. Furthermore tier 1 suppliers purchase components from a variety of tier 2 suppliers and further down the value chain which results in positive network effects (Schwoon 2008).

Especially in the automotive supplier industries, margins are rather low which turns out to be a factor favouring marginal innovations and incremental improvements over radical disruptive innovations, which require substantial investment and carry significant risks and uncertainty of amortization (van den Hoed 2007). The latter is even more prominent and important for component suppliers who often face difficulties financing innovation with a long pay off time period. In this regard it can be assumed that the automotive industry and the especially supplier industry have little interest in promoting radical technological changes. It follows that for such changes to happen, the appearance of new entries, the emergence of external shocks, unexpected performance improvements of technology, sudden changes in the markets and market environments or a shift in the industry competition are required (van den Hoed 2007; van Bree 2010).

Customers often consider the automotive industry as a highly innovation-intensive industry. This perception however is only partially true. Due to the complexity, margins and risks, the industry tends more towards marginal innovations instead of radical breakthroughs (van den Hoed 2007). This refers not only to the initial technology, e.g., the fuel cell in this case, and the related final product specific interfaces of the technology but also to assembly lines and the broader logistical solutions in this context. In this respect another reasonable barrier for disruptive innovation in the field of car engines is the high capital intensive nature of the industry (Zapata, Nieuwenhui 2010). This is for production only, however over the full product life cycle it becomes ever more complex and capital intensive. Mainly due to the high capital intensity of the car industry, the amortization of investments is also a crucial dimension to consider in decision making, e.g., the assessment of an alternative technology is not limited to the new technology’s features but also involves a financial assessment of the investments that have been made for the existing technologies, including capital cost for the equipment needed to embed technology in applications, hence products. Capital costs include expenditures for equipment and opportunity cost, as well as the investment in skills and in the labor force, which are essential to operate an equipment industry (Zapata, Nieuwenhui 2010). Although it is predicted that the cost advantage of internal combustion engines will diminish with larger volumes of fuel cells manufactured due to learning effects and economies of scale (Schwoon 2008), the broad diffusion of fuel cells also depends on transitions in the overall energy system, e.g., the availability of respective fuels and a fuel transport system among others (Turto 2006).

The environmental and the societal dimension of energy supply are closely interconnected (Dincer 2008). The environmental impact of energy generation is largely determined by the choice and use of the energy source, by the transmission of energy and by the effects which occur with the use of the energy that has been generated, in other words, the flow of generation, transmission and application. Society is typically unaware of the flow of energy as described; in general, the population’s understanding of energy is that it’s available as needed. The challenges from energy supply involve a broad range of environmental challenges, namely air pollution, water pollution, solid waste, pollutants and ecosystem degradation, and these problems extend over ever-wider areas (Dincer 2008). Because these types of pollution occur rather slowly, the population has difficulties in recognizing them and assessing their real impact. It seems a common social problem that the consequences of respective actions are not present in citizens’ minds. Rather this is true in the case of unusual events like accidents disruptions in the energy flow when the population shows increasing awareness of the environmental aspect of the energy flow.

Stakeholders’ hidden agendas analysis

Detecting and understanding stakeholders’ interests and strategies requires the systematic analysis of the surrounding factors, e.g. social, technological, economic, environmental and political factors (STEEP). The STEEP analysis has become a widespread analytical concept that is used for analyzing the determinants of current and expected potential technology and innovation diffusion. It is recommended that the general characteristics of each of the five major dimensions be elaborated upon first and that the stakeholders' attitudes towards these characteristics be derived in a second step. The initial characteristics of each dimension are enriched by more general assumptions for the potential drivers which determine the characteristics currently and the resulting possible impact. This is then the basis for the specific stakeholder characteristics.

Social perspective

From the social perspective, it shows that the public attitude towards hydrogen is considered to be one of the key factors towards the transition to fuel cell-powered cars. In the public perception, the availability, accessibility as well as aesthetics and convenience are the predominant features. The main issues are still the actual availability of fuel cell equipped vehicles together with the local availability and national coverage of fuel stations for long distance travel. Besides the fuel network, the maintenance infrastructure and the associated repair frequencies and costs are important in the public's perception, which drives the attitude toward the vehicles. Moreover the initial purchase cost is one of the determinants of the selection of a vehicle but it is still expected that fuel cell powered electrical vehicles (FCEV's) will be significantly more expensive than conventional vehicles and re-fuelling will be limited to a low number of locations. Aesthetics and convenience of vehicles are major determinants for public acceptance of the technology used for mobility of society, although the public attitude towards hydrogen is considered one of the key factors towards the transition to fuel cell powered cars. Thus FCEVs can be presented with a new image by combining sleek design and technology, which may be used to create a new fashion.

Given the recent development in which the automotive industry is converging more strongly with communications, electronics, and photography in the sense of integration and inter-operability, products with information, communication, multi-media systems and social networking technologies with large touch screens will also attract a number of users. Also the mass media are an important channel to promote FCEVs. Media attitudes are equally important, especially mass media, which has a strong impact on public opinions. It has been frequently observed that media tends to report more on accidents and failures of technologies instead of success stories. Here the impact of different media channels on consumer attitudes and behaviour could be given special attention. Furthermore society should be convinced about the safety, security, and reliability of FCEVs, without any negative impacts on public and individual health.

Technological perspective

These factors focus on rates of technological progress, pace of diffusion of innovations, problems and risks associated with technology such as security and health problems. Among the most frequently cited challenges is the reliability of fuel, especially centralized or decentralized fuel production and the respective infrastructure for fuel distribution and the appropriateness of the existing infrastructure for upgrading to the respective fuel distribution. Also the overall energy balance sheet of fuel production for FCEVs causes concerns among stakeholders.

Availability of equipment, namely hardware, is an issue that comes up and requires technological progress. This relates to fuel stations and the appropriate network development, as well as to matters regarding the storage of spare parts related to fuel cell powered cars, namely the transport and actual storage of spare parts (single parts, components or systems) and the maintenance and repair infrastructure, e.g., physical investments in repair equipment and the training of operating staff.

Recent technological progress has the potential to impact the diffusion of technology. Mostly these advances are related to infrastructure development. It is expected that new ways of extracting hydrogen and mobile hydrogen refilling stations can be used to provide further access to hydrogen in remote or congested areas, or when a likely power cut starts effecting supply. The use of lightweight carbon fibre composite tanks for the high pressure bulk transportation of hydrogen, for mobile hydrogen fuelling station applications, and for portable self-contained hydrogen fuelling units is becoming widespread and transportable compressed hydrogen units can be custom-designed to meet customer needs, including transport trailers, mobile fuellers, and portable filling stations.

Economic perspective

Levels and distribution of economic growth, industrial structures, competition and competitiveness, markets and financial issues are significant drivers of technology diffusion. From the demand perspective, the price of the end vehicle together with performance characteristics, such as the range, hydrogen consumption and overall life cycle costs are especially important. Life cycle costs also involve insurance premiums that vehicle owners have to pay and which are currently uncertain. Also it should be noted that the consumer attitudes in terms of different user segments and the size of each group vary. Initial investments in the infrastructure and remaining technological challenges are not likely to pay off earlier than the late 2020s, still business cases should include the first mover commercial advantage. It seems plausible to assume that the first and immediate clients for FCEV will be commercial fleets which also support the leverage of learning effects and cost reductions.

The nearest-term application is for fuel cells seem to be lift trucks (forklifts). Several industrial truck companies have announced commercial fuel cell products that can replace battery-powered forklifts. These have been extensively tested and are available for commercial purchase today to be used in production plants, logistics and airports. A possible “electron economy” may replace the “hydrogen economy”. In an electron economy, most energy would be distributed with the highest efficiency by electricity and the shortest route in existing infrastructure could be taken. The efficiency of an electron economy is not affected by any wasteful conversions from physical to chemical and from chemical to physical energy. With an electron economy, attention could be quickly turned to energy storage technologies and an upgrade to smart grids.

Environmental perspective

The obvious environmental impact is one of the key arguments for supporting or contesting the transition process to hydrogen fuel cell cars. The positive environmental impacts mainly result from zero emissions from the technology and the use of widely available natural gas and existing distribution pipelines to create hydrogen for on-site fuelling. Eventually FCEVs will contribute significantly to improved air quality and a reduction in noise pollution from traffic compared with conventional vehicles powered by conventional engines. Breakthroughs in electric power storage occurred within a decade involving storage, fuel cells and new chemicals and materials including nanotechnology applications have the potential to even increase the environmental impact of FCEVs. Also highly volatile corn prices driven by a bad harvest could hurt corn ethanol producers, which are suffering from a saturated market for ethanol. This may allow hydrogen to take off faster than expected as an alternative energy source.

Political perspective

Political factors involve dominant political viewpoints or parties, political (in)stability, regulatory roles and actions of governments, political action and lobbying by non-state actors. The diversification of the energy supply through hydrogen would help to reduce reliance on fossil fuels for transport which are imported products in many countries and increases energy security in energy importing countries. Furthermore the local production of hydrogen can also provide more of the process inputs to be produced locally by reducing the dependency on external energy markets. This leads to the creation of political incentives in order to promote the diffusion and acceptance of FCEVs, for example national pricing systems for hydrogen and tax exemptions planned for hydrogen vehicles. Supporting the diffusion of FCEVs governments are likely to introduce large scale public procurement programmes, government-backed zero-interest mortgage plans for hydrogen cars and massive movement of public transport vehicles and large fleets to FCEVs.

Conclusion

All relevant dimensions taken together show a clear picture of the existing and potential for, as well as the articulated and hidden arguments against a technology, e.g., the FCEV. Some arguments appear obvious but there remain major obstacles which are not considered in the public debate and presumably are not included in strategic planning and thinking of the actors. It also appears important to note that stakeholders have different influences on the respective decision making and the power to drive the mindsets of decision makers. Accordingly the arguments raised by stakeholder groups potentially prove influential to decision makers when it comes to introduction of technologies and measures supporting technology diffusion (table1). It’s been observed that so far in case of fuel cell technologies many of these arguments were not or only partially reflected in the technology and innovation strategy development although they appear almost equally important for a targeted and effective communication of the technologies to customers.

Table 1: stakeholder arguments - summary

Stakeholder	Influence	Power	Argumentation strategies
Social			
• Traditional car owner	↗	↗	• Misses typical car features • Reluctant towards noiseless drive
• Young generation	↑	→	• Wish to differentiate from traditional drivers • Limited experience with infrastructure
• Car owner association	↑	↑	• Adverse attitudes, mainly dominated by traditional driver • Point on noise, danger of fuel supply, need to train traditional driver to adjust
Technological			
• Producers of solid oxide fuel cell (SOFC), phosphoric acid fuel cell (PAFC), Molten carbonate fuel cell • (MCFC)	→	↗	• Similar application fields for fuel cells or at least potentially similar fields • Might point to dangers and environmental issues of membranes used in proton exchange memebran fuel cells (PEM)
• Infrastructure supplier	↑	↑	• Decentralized infrastructure needs to be built – investment cost • Existing infrastructure reshaped for fuel transport – opportunity cost
• Fuel producer (gasoline)	↗	↑	• Consequences of fall in demand for gasoline – refinery closures, job losses, impact on petrochemical industry
Economic			
• Technology follower	↗	↗	• Technological leadership concentrated in Asia

			(Japan, South Korea), Europeans lagging, oppose with lobby work
• Petrochemical industry	↑	↑	• Job losses due to either refinery closure or high investment in new equipment
• Repair and maintenance industry	↗	↗	• Significant investment in equipment • No competences in new technologies, reluctant to accept dual system
Environmental			
• Laws, legal regulations	↑	↑	• Especially important for environment, health and safety issues
• Environmental groups	↗	↗	• Long-term hydrogen impact not known
• Health, safety groups	↑	↑	• Unknown reliability of new standards and technologies, potential negative impact on safety and health of workers in all domains
Political			
• Municipalities	↑	↑	• Responsible for infrastructural decisions
• Regional	↑	↑	• Financial incentives for municipalities, regional standards, complementarities of standards between regions
• Federal	↗	↗	• Initiator and promoter role but less implementation power

Legend: influence, power: → - low; ↑ - strong; ↗ - medium

In summary it can be concluded that the FCEV is an option for transportation, but it presumably has a short life cycle if stakeholders beyond transport are not considered. Furthermore it seems that FCEV is fulfilling a bridging role from the hydrogen century ahead towards the electron century, which is expected to come in the future. Given the accelerating speed of science and technology development, some are already raising concerns about investments in the hydrogen century as it is believed that the transportation of the future will be decided by the next standard, e.g., hydrogen vs. pure electron. Also there is an indication that stakeholders, namely users' attitudes, might potentially change if investment in standards and users education are going together. Standard setting at the current stage may appear to be a safeguard for decades of technology survival and is precondition for justifying the respective substantial investments.

Currently transport-related roadmaps show weaknesses in considering the agendas of all actual and potential stakeholders. Market roadmaps commonly assume only a modest change in customers' behaviors and focus strongly on competing products and technologies but less on the actual attitudes of users and social agendas and values, etc., which means that mostly the 'hidden' stakeholders, who become obvious if one analyses the systemic impact of FCEVs, are neglected. Still as experiences show, the pace of technology and innovation diffusion, are at least partially determined by the early involvement of all stakeholders. Involvement does not necessarily mean the active inclusion of the stakeholders for adoption of technologies. Rather it is more important to learn the actual agendas and is is most important to elaborate on the hidden agendas of stakeholders, which allows for the identification of existing and potential obstacles for the broad application and diffusion of a technology. From a purely technical point of view, the main challenges of FCs related to the engine, recovery, storage and transfer of hydrogen can be considered solved in principle. Obviously the main hurdle that remains is the integration into the overall system, e.g., the

FCEV and acceptance by the market. The integration of the FCEV includes the technical and also the manufacturing integration of the FC itself but as well as the FCEV, which requires a new logistics system, hence a renewal of the supply chain in the first instance. This also goes along with renewal of the maintenance and recycling infrastructure which are separate dedicated ecosystems. Also market acceptance from customer perspective requires certification procedures imposed by governmental bodies in the first instance and the trust of customers in the second instance.

Regulations and certifications are especially important in the automobile industry. Moreover, even if OEMs have obtained all certificates, what the media is reporting is very important. The experience of Asian OEMs aiming to enter the European car markets gives a substantial indication of the power of media in the diffusion of new products even though by that time the products were reasonably similar. However, in this case, Asian OEMs had to struggle with market entry and penetration for a while. In this respect, it can be argued that media strongly influences public attitudes towards technologies and therefore towards products. Therefore, the media’s role as stakeholder in the diffusion of FCEVs is more important than was previously assumed. Also in this respect, social media, namely internet-based, has its own influence. One might argue that internet media mainly is used for information collection and experience exchanges. The latter naturally becomes crucial for the formation of opinions by customers especially with respect to vehicles.

In the short term stakeholders may raise skepticism, in which the municipalities already claim and will probably continue to claim that they cannot guarantee the safe operation of hydrogen supply infrastructure, which is largely due to a lack in the certification and qualification infrastructure. The petrochemical industry expertly argues that FCs are reasonable to use for vehicles, but also raises concerns about the refining and downstream industry which might suffer as a result of decreasing demand for gasoline, which is a common refining product and this might place pressure on the refining industry due to the emerging need to upgrade existing facilities and equipment. This need for renewal is based on the nature of commonly applied refining processes as a result of which fuel is produced as one product among others. However, changing the refining processes in favor of less or no fuel (gasoline) production requires different equipment.

Until recently a maintenance infrastructure for vehicles (garages, workshops) is in place, which was dedicated to combustion engines with all the necessary technical and personal equipment available. Changing to FCEVs, however, requires an almost full scale conversion of the existing maintenance infrastructure towards a combined combustion engine and FC maintenance equipment. This requires considerable financial investment in technical equipment and also in the training of maintenance professionals in the short term. Presumably the owners of the existing infrastructure would be reluctant and skeptical about such significant investments as long as substantial demand remained unpredictable.

There are also mid-term threats for the FC, namely the inherent danger that society maybe sceptical about the safety, security, and reliability of such a highly flammable and explosive fuel as hydrogen in cars. Furthermore the rapid diffusion of hybrids and the progress in battery technologies may delay the commercial implementation of FCEVs, e.g., a possible “electron economy” may replace the “hydrogen economy”. With the electron economy, attention could be quickly turned to the energy storage technologies and an upgrade to smart grids. The current enthusiasm for electrical vehicles can also be traced back to governments’ announcements, however one might speculate that after a couple of serious accidents, the governments may withdraw their support for these (i.e. the case of Fukushima discouraged some governments from the use of nuclear power plants).

In conclusion, the stakeholder analysis is a widespread approach used for technology and innovation diffusion strategy building. A broad range of social, technological, economic, environmental, political and value issues show a considerable impact on the diffusion of technologies as shown in the sample case of FCs.

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