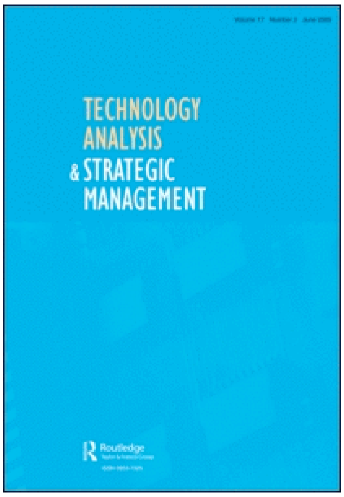


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# Negotiating the local embedding of socio-technical experiments: a case study in fuel cell technology

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# Negotiating the local embedding of socio-technical experiments: a case study in fuel cell technology

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Transitions towards more sustainable socio-technical regimes crucially depend on processes of social learning. This paper focuses on the process of selecting and setting up technology learning experiments at the municipal level. It reports on experiences using a constructive technology assessment (CTA) approach to identify and evaluate potential deployment projects in the area of fuel cell technology in Graz, Austria. The results highlight that dialogue processes between R&D actors, municipal actors and intermediary organisations serve well for the identification of suitable niches for socio-technical experiments. However, for the actual implementation of such experiments the limited room for manoeuvre of municipalities and the importance of the coordination of various governance levels need to be taken into account. In particular, tensions may arise between overarching technology policy goals defined at the national level and problem-based approaches applied at the municipal level based on prevalent local issues and needs.

**Keywords:** technology learning; municipalities; fuel cells; CTA; strategic niche management

## 1. Introduction

It is widely acknowledged that the introduction of new technologies requires social learning processes, especially when this entails changes at a system level, as it is the case with new energy and transport technologies. A number of questions arise around issues such as the deployment of supporting infrastructures, the organisation of value chains, the institutional embedding and regulations concerning these new technologies or the development of new patterns of use.

Relatively little attention has so far been given to the specific contexts and locations of such technology learning processes as well as to the processes of systematically identifying and selecting experiments and pilot projects at the municipal level. Hodson and Marvin (2009) have drawn attention to cities as important actors and mediators in technological transition processes. Some other authors (Van den Bosch, Brezet, and Vergragt 2005, Vergragt and Szejnwald Brown 2007) have highlighted the specific potentials of the municipal level as a setting for early technology

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learning processes. In this paper we investigate these potentials further by presenting results from a case study on the identification and assessment of municipal strategies and experiments in the area of fuel cell technology in Graz, Austria. By reporting and reflecting on a workshop series that was set up to discuss and assess potential contexts of fuel cell applications at the municipal level, we also address issues such as possible roles of the municipality in technology learning processes, tensions between differing rationales at different governance levels and a number of pragmatic issues that need to be taken into account in setting up niches for learning processes at the municipal level.

The structure of the paper is as follows: The following section introduces the concept of constructive technology assessment (CTA), which was used as a reference framework for the process. Section 3 then addresses the specific potentials and challenges of the municipal level as a place for technology learning processes. The actual case study is presented in Section 4. Section 5 then both discusses the results from the workshop series and evaluates the chosen workshop format. Finally the conclusion draws together the most important points of the paper.



## 2. Participatory technology development and assessment

Transitions to more sustainable technology regimes are heavily dependent on processes of social learning. Social learning always plays a role in technological development since social players actively and sometimes unknowingly shape the design of new technologies. Moreover, new social practices around the use of new technologies have to be developed, institutional contexts have to be adjusted – in short, the development and implementation of technologies requires a co-evolution of social and technical elements. With sustainability as a somewhat vague but demanding and often controversial guiding vision, social learning processes become even more important.

A number of concepts and methodologies have been developed to understand and facilitate social learning processes in ongoing technology developments. For our own work on the sustainability of fuel cell technology we have chosen the CTA approach as a methodological framework. Focusing on the potentials of fuel cells in local use contexts at the municipal level, CTA offers valuable insights on social learning processes and the importance of protected spaces for the management of sustainable transitions.

The approach of CTA aims at broadening the decision-making process on technological development and considering impacts already during the development of the technology by bringing together a manageable variety of relevant parties. Designers, users, citizens as well as policy makers should be able to articulate ideas and values quite early and negotiate and renegotiate important aspects throughout the course of the technology development process (Rip, Misa, and Schot 1995; Schot and Rip 1997; Schot 2001). CTA seeks to open the design process at early and/or promising stages in order to learn about possible – negative as well as positive – impacts of the new technology before they become entrenched and possibly negotiate alternative development pathways.

Schot (2001) has specified three general principles that define CTA activities. CTA (1) should advance the capacity to anticipate impacts of future technology (anticipation), (2) it should improve the ability of social actors to consider technology design and social design as one integrated process (reflexivity), and (3) it should enable societal learning. Designers, future users and other relevant social actors should have the opportunity to question their own presumptions and come to new specifications. While first-order learning refers to the ability to articulate user preferences and regulatory requirements and to connect such conclusions to design features, second-order learning means to question existing preferences and requirements in a more fundamental way, to reflect on the roles of various stakeholders and maybe to come up with quite different demands, radical design options or new application contexts (Grin and Van de Graaf 1996).

A specific approach to support technology learning processes within the framework of CTA is strategic niche management (SNM). SNM (see e.g. Hoogma et al. 2002) refers to the creation and nurturing of protected spaces for promising technology to facilitate ongoing interactive learning of the actors participating. A central aim of the development of niches is to learn in realistic use contexts (e.g. market niches, controlled field experiments) about needs, problems and possibilities connected with the technology experimented with, and to help articulate design specifications, user-requirements or side-effects of the innovation. Managing the development of environmental technologies in niches involves organising social learning processes with actors such as producers, technology designers and users in a joint process. Niches have also been studied as local experiments at the municipal level (see Raven et al. 2008), as examples of societal embedding (Kivisaari, Lovio, and Väyrynen 2004) or as 'bounded socio-technical experiments' (e.g. Szejnwald Brown and Vergragt 2008; Szejnwald Brown et al. 2003). However, critical voices also emphasise that niches, such as passive houses, have rarely been set up or managed in a straightforward and planned way (Lovell 2007; Smith 2007).

Given the importance of niches for strategic learning processes about the context of application and use of new technologies such as fuel cells it is rather striking how little attention has so far been paid to the selection of such pilot applications. Not only should such niches be of long-term strategic importance for the transformation of urban infrastructures, but they should also link-up with the needs, competencies and expectations of local actors. This initial phase of identifying and selecting possible options for fuel cell pilot projects was at the centre of a project that will be presented in this paper. Informed by the basic ideas of SNM regarding the selection, preparation and set-up of niche experiments, a workshop series was organised where a variety of stakeholders first identified plausible application areas and then critically discussed requirements for pilot projects in these areas at the municipal level. Before presenting this case study the following section will briefly raise some general issues concerning the municipal level as a place for technology learning processes.



## 3. Technology learning processes at the municipal level

With respect to technology learning processes the municipal level certainly has specific potentials. Van den Bosch, Brezet, and Vergragt (2005) reporting on a case study on system innovation towards a fuel cell transport system in the city of Rotterdam underline a number of characteristics of cities as the location of technology learning processes. These include a high sense of urgency in relation to specific problem situations (such as transport related problems) and a high concentration of stakeholders in government, industry and research. In addition to that they also note the advantages of initial local, small-scale experiments over the top–down global level.

However, it must be taken into account that these learning processes at the municipal level can be approached from two quite different angles, involving different rationales and agendas. At the national level, technology policy goals and strategy development often dominate. From this perspective local experiments serve to contribute to momentum-building in specific technology areas by finding promising niches for technology testing, building up local actor networks, creating initial markets and learning from shared experiences. This corresponds quite closely to what

Karlström and Sandén (2004) have highlighted as the main goals of demonstration projects, namely

- *Learning* in relation to technology performance and the contexts of use
- *Opening up markets*, e.g. by increasing public awareness and identifying institutional barriers and
- *Formation of a network of actors*, which can then evolve into active advocacy coalitions.

This rationale is obviously also well in line with the interests of R&D actors in the technology field in focus, as such experiments provide them with an opportunity for technology probing, product visibility and initial market development.

From the perspective of the municipality, however, the benefit of engaging with technology learning processes will of course be more strongly tied to local interests and needs, such as addressing prevalent problems of the municipality (e.g. local air quality) or strengthening the regional economy by involving regional firms in technology deployment. From this point of view it is not so much an issue of selecting appropriate application areas for a given technology but rather to consider different technical and organisational variants of addressing a particular problem situation.

Nevertheless urban municipalities may in fact also strive for a profile as 'sustainable city' or technology forerunner and therefore become actively involved in the promotion of particular technology areas. Eames et al. (2006) as well as Hodson and Marvin (2009), studying attempts to make London a forerunner of a 'hydrogen economy', find that world cities such as London do actively seek to position themselves as managers of such large-scale transition processes. However, in their attempts to become a central player in the promotion of this technology area, they also find themselves in competition with multinational companies as well as European Union level governance, framing the role of London merely as a kind of 'test-bed' for technology probing.

Thus, while the potentials of municipal technology experiments are multifaceted, so are the rationales and agendas attached to them. Implementing projects thereby also becomes an issue of negotiating differing problem framings (see also Raven et al. 2008) and coordinating different governance levels (see also Kivisaari, Lovio, and Väyrynen 2004). The following case study describes an attempt to actively create a forum for the exchange of the perspectives of different actors, identifying potential technology deployments in the field of fuel cell technology, and for discussing the local embedding of promising options in a municipal context.



## 4. Case study on fuel cell technology at the municipal level

The case study our discussion about opportunities and challenges of municipal technology learning is drawing upon was carried out as part of a practice-oriented research project on the potentials of user and stakeholder involvement in technology development (Ornetzeder et al. 2008). It was funded within a national R&D programme focussing on the development and implementation of 'green' technologies. The case study consisted of some preparative interviews and, as its main part, a workshop series in Graz, Austria, that brought together R&D actors in the area of fuel cell technology with municipal actors and representatives of intermediary organisations. The workshop series thereby aimed to create a reflexive learning environment for discussing the potentials, problems, and possible impacts of fuel cell technology at the municipal level.

In terms of the framings discussed in the previous section, the case study was thus tied to an overarching rationale concerning the promotion of particular technology fields, predefining the technology field to be explored. However, the explicit aim of the project was to contribute to a more reflexive and locally embedded process of technology development and deployment, applying the basic principles of CTA and SNM.

Broadly speaking, fuel cells are seen to be of interest because they are attributed significant potentials regarding the reduction of $CO_2$ emissions and increased energy efficiency levels. The following subsection will briefly provide some further background on the innovation field of fuel cell technology. In a next step we will outline the conceptualisation and implementation of the workshop series and finally present some central results of the workshops.

### 4.1. *The innovation field of fuel cell technology*

Since the late 1950s fuel cells have time and again been the focal point of waves of high expectations, succeeded by phases of disappointment when high striving goals could not be met. Even though most public attention has been attracted to the use of fuel cells as a propulsion technology for vehicles, other major application areas include stationary applications (mostly decentralised energy supply for households, businesses and public facilities as well as off-grid energy supply, e.g. for gauging stations) and portable applications (as a substitute for rechargeable batteries, e.g. in laptops, mobile phones, etc.).

The high expectations with regard to fuel cell technology are to a large extent related to the high ecological potentials associated with it, most notably the potential to reduce greenhouse gas emissions. The overall emissions balance, however, depends not only on emissions at the point of use of fuel cells, but also on the emissions generated during the production of the fuel. While currently (2010) by far the largest part of hydrogen produced world-wide comes from steam reforming of natural gas, the 'ecological vision' regarding fuel cells, consists of using energy from renewable sources to generate the fuel, e.g. producing hydrogen via electrolysis using electricity from wind or solar energy.

Although fuel cell technology has already reached the level of concrete product developments (prototypes, limited-lot production), production costs are generally still too high for broader market introduction.

While it is hard to predict any long-term developments, it seems however likely that within the next years the application of fuel cell technology will be limited to a number of niche applications. These niches can be expected to develop in areas where fuel cell technology may provide a specific advantage over existing or competing solutions. Some possible examples, referred to by R&D actors in fuel cell technology during preparatory interviews for the workshop series included fuel cell vehicles in public transport, hybrid utility vehicles (electric and fuel cell driven for industrial sites, airports, hospitals or city cleaning), emergency power supply (e.g. for hospitals or computer servers) and off-grid gauging and transmitting stations.

A number of the application areas referred to thus relate to municipal utilities such as public transport, hospitals or city cleaning and indeed, a number of municipal pilot projects in the area of fuel cell technology have already been introduced in various cities (e.g. HyFLEET:CUTE, 2006–2009, co-funded by the European Commission and private companies, introducing fuel cell busses in the public transport system).

### 4.2. *Conceptualisation and implementation of workshop series*

The workshop series consisted of three workshops held in the time-span from mid-June to early July 2007 in Graz, a medium-sized city of approximately 250,000 inhabitants in the south of

Austria. The city of Graz was chosen for the workshop series because a significant number of Austrian firms and research institutes with R&D activities in the area of fuel cell technology are located in and around Graz. Also, a hydrogen fuelling and testing station is located there, set up as a demonstration project in 2005. In addition to that, because of the geographical location of Graz, surrounded by hills, particulate matter emissions pose a serious problem and strategies for the improvement of air quality are of particular importance. The city of Graz is also well known for long standing municipal environmental protection activities.

Prior to the workshops, some preparative interviews with experts in the field of fuel cell technology were conducted. They served both to obtain an overview of the innovation field of fuel cell technology and to identify promising fuel cell application areas in a municipal environment. The interviews provided the basis for a background document sent out to participants of the workshop series, introducing the innovation field of fuel cell technology as well as outlining the planned workshop format. Stakeholders invited to the workshop series included fuel cell experts from basic research and industry as well as municipal actors and representatives of intermediary organisations.

The workshop series was devised as a three-step process and made use of the technique of scenario building and assessment as the basis for strategy development. Thereby the discussion of potential fuel cell applications at the municipal level was situated in a broader context concerning the long-term development of the innovation field. The workshop series followed a design successfully applied earlier by Weber et al. (2005):

- *Workshop 1*: Identification of framework conditions influencing the future use of fuel cells, development of basic scenarios concerning future fuel cell use
- *Workshop 2*: Choice of sustainability assessment criteria, qualitative assessment of the strengths and weaknesses of various elements of the scenarios
- *Workshop 3*: Strategy development at the municipal level, discussing possible pilot projects and formulating general requirements for municipal pilot projects

The three workshops were attended by a total of 16 stakeholders, where participation in individual workshops fluctuated between six and ten participants. The larger part of participants consisted of experts in fuel cell technology (R&D actors from basic research and industry), while only relatively few actors from the municipality and intermediary organisations took part. The workshops followed a bottom–up approach, using various interactive techniques, group work and plenary discussions for developing and assessing the scenarios and for strategy analysis. Table 1 summarises relevant details of the implementation process.

### 4.3. *Results of the workshop series*

The workshop series produced a number of interesting results on potentials and priorities for the municipal implementation of fuel cell technology, which will be described in this section.

Already during the first workshop diverging interests and problem framings of different actor groups became quite clear. Participants from research, industry and the municipality alike were most strongly interested in discussing short to medium term applications, notably in the form of potential pilot or demonstration projects. Especially industry actors highlighted the potentials of pilot projects to create higher levels of awareness and acceptance of hydrogen and fuel cell technologies. They underlined the need for providing ‘positive technology experiences’ as well as dealing with security concerns related to hydrogen. One actor also suggested an effect of awareness

Table 1. Overview of implementation process.

| | Central questions | Methods | Participants (affiliation) |
|---|---|---|---|
| Workshop 1: Framework conditions and scenarios | Which types of development pathways concerning the future use of fuel cells are conceivable and plausible? | Brainstorming on framework conditions, development of 'storylines' in small groups (partial cause–effect relationships based on possible framework conditions), grouping of storylines to scenarios by the project team after the workshop | Municipal Department for Energy (1)<br>Private firms involved in fuel cell R&D (5)<br>Research institutes (4) |
| Workshop 2: Sustainability assessment | What are the strengths and weaknesses of various fuel cell application areas according to sustainability criteria? | Plenary discussion and extension of a set of sustainability criteria proposed by the project team; individual assessment fuel cell application areas followed by presentation and discussion in plenary | Private firms involved in fuel cell R&D (2)<br>Research institutes (4) |
| Workshop 3: Strategy development | How can municipal pilot projects in the area of fuel cell technology contribute to the development of sustainable technology applications? Which requirements need to be met? | Plenary discussion, presentations by individual participants on existing pilot- and demonstration projects | Municipal Department for Energy (1)<br>Energy agency of Graz (1)<br>Eco-Energy Network of the Province of Styria (1)<br>Private firms involved in fuel cell R&D (2)<br>Research institutes (4) |

rising through pilot projects on chances for accessing further venture capital. In some individual cases interests in pursuing specific kinds of pilot projects bolstered this general concern for the promotion of fuel cell technology further. Some actors had previously already been developing concrete plans for projects and thus tried to push their stakes in pursuing these particular project plans further.

Nevertheless R&D actors were generally quite keen on a broad discussion of the potentials and risks of fuel cells in general, of advantages and disadvantages of particular applications and of their local embedding in the municipal context. A broad agreement could be reached that the largest sustainability gains would be achieved by an introduction of fuel cell technology to the transport system (fuel cell vehicles, e.g. in public transport, municipal utility vehicles, logistics system for transporting goods to the inner city, on the longer term also private cars). Also backup systems, such as fuel cell use as a load balance for renewable energy sources, were seen to have a significant potential. Most workshop participants rated the use of fuel cells in stationary power supply as not particularly interesting for municipal applications, although some differences of opinion emerged on this point between different R&D actors. It was noted that stationary applications currently do not offer significant advantages over conventional systems, both in economic and environmental terms.

This ranking was by and large supported from the side of the municipality and it was pointed out that more attractive alternatives to fuel cells could be found in the area of stationary energy supply. In terms of possible transport applications attention was called to the need for a differentiated judgement of individual projects, mentioning aspects such as technological alternatives and costs as well as highlighting the issue of political timeliness. Pilot projects touching upon areas of highly controversial political debate would stand low chances of being implemented. This was judged to be the case for attempting to implement an access-control system in Graz, only permitting zero-emissions vehicles, e.g. fuel cell vehicles, to enter the city free of charge.

A related point was brought forward in response to a suggestion to introduce a logistics system for transporting goods to the inner city based on electric and fuel cell driven vehicles. As this would require the involvement of a large number of individual people, in particular the suppliers and merchants of inner-city shops, it would certainly entail a high degree of organisational complexity. It was generally acknowledged that for an initial pilot project organisational complexity should be kept at a lower level.

Finally, the definition of the role of the municipality within a pilot project was also found to require special attention. While R&D actors certainly had some hopes that the municipality may become an important ally for technology deployment projects, it soon became clear that the municipality itself was more inclined to see its role only as provider of a potential 'test-bed' for technology deployment. Lacking the sources for financial investment and being relatively far removed from technology policy developed at the national level, the municipality appeared to be rather reserved towards taking on an active and formative role in the implementation of pilot projects in the field of fuel cells. As it turned out, none of the discussed options for pilot applications met the actual needs and expectations of the municipality (department of energy) at that time. The workshop therefore does not seem to have set off further niche experimentations or pilot projects as it had originally intended. Nevertheless some mention was made of the possibility of acting as an intermediator between different actor groups. All in all it became clear that multiple possible roles exist for a municipality within local deployment projects (e.g. as a technology user, active developer and driver of certain applications, and mediator) and that not all of them can be expected to be fulfilled in individual projects.

Box 1. Summary of central results of workshop series.

*Basic ranking of fuel cell applications for deployment in municipal context:*

1. Applications in transport, such as fuel cell vehicles in public transport, municipal utility vehicles, vehicles used for logistics system for transporting goods to the inner city, on the longer term also private cars
2. Backup systems as a load balance to renewable energy sources or as emergency power supply for hospitals or computer servers
3. Fuel cell use for stationary energy supply

*Requirements for the local embedding of pilot projects:*

- In each individual case, comparing the possible benefit of fuel cell technology to technological alternatives
- Development of integrated concepts with regional and renewable fuel production
- Involvement of regional firms
- Orientation towards the needs of the municipality
- Taking account of political timeliness/awareness for potentially controversial issues
- Limiting organisational complexity
- Defining appropriate role for the municipality based on its interests and potentials. (Possibly making use of extraneous funding sources, e.g. national funding programmes)



Box 1 summarises the results arrived at during the workshop series concerning relevant application areas and requirements for the local embedding of municipal pilot projects.

## 5. Discussion

### 5.1. *Technology learning at the municipal level*

The results from the workshop series clearly provide us with some lessons on practical issues related to the local embedding of pilot projects that need to be considered during the design and implementation phase.

One of these points is the issue of political timeliness. As mentioned in Section 3, Van den Bosch, Brezet, and Vergragt (2005) have highlighted a certain 'sense of urgency', e.g. around transport related problems, as a potentially helpful characteristic of technology learning processes at the municipal level. Nevertheless, our workshop discussions also highlighted that issues standing at the centre of political debate involve the risk of polarisation. So while a pilot project should address current problems and relate to the municipality's policy strategies, a project touching upon controversially debated policies may become 'trapped' in these debates and stand low chances of being implemented. This risk of polarisation will certainly have to be assessed at the level of each individual case – possibly by conducting a careful evaluation of stakeholder positions at the outset.

Another interesting aspect concerns the cautionary stance of the involved stakeholders towards the involvement of a large number of individual actors in initial pilot projects, as a result of the high complexity this may involve. This runs somewhat against the notion that pilot projects can serve to mobilise stakeholders from a variety of backgrounds and instead highlights the considerable coordination efforts this entails, such as the alignment of interests of the various actors involved. Thus, in each individual case an appropriate balance will have to be struck between mobilising a sufficient number and well-selected set of stakeholders and containing the complexity of the actor network, which is thereby constructed.

Also, the actors involved in an initial dialogue process, like the workshop series reported on here, cannot necessarily already be seen as part of an emerging actor coalition. In our case, for example, while R&D actors pushed for the implementation of fuel cell deployment projects, the municipality took on a rather critical position towards the issue. Harborne, Hendry, and Brown (2007) report on similar experiences concerning only conditional support of fuel cell technology by bus manufacturers involved in the implementation of demonstration projects. However, the clarification and discussion of different interests and agendas over the course of a workshop series can serve to reflect on and possibly redefine the framing, the purpose and the actor roles associated with technology deployment projects.

This became particularly clear during our workshop series when the multiplicity of possible roles the municipality may take on – or be expected to take on – with respect to pilot projects was discussed. At the most basic level, the municipality may simply take on the role of an early user of a technology, implementing certain applications in municipal utilities, while additional costs are covered by extraneous sources. However, it could also act as a promoter and funding body and – in addition to that – as a policy maker, e.g. incorporating pilot projects in longer-term strategies as well as passing relevant legislation. Even more detailed questions can be expected to arise in the implementation of concrete pilot projects, such as issues around ownership and intellectual property rights. In the context of climate change mitigation activities these different roles of municipalities have also been addressed as different modes of governing in municipalities, such as self-governing (e.g. own car fleet), governing by authority (regulations), governing by provision (municipal utilities) and governing through enabling (campaigns and promotion) (Bulkeley and Kern 2006).

Eames et al. (2006) and Hodson and Marvin (2009) have already highlighted diverging expectations concerning the role of the city of London in attempted moves towards a 'hydrogen economy'. As mentioned in Section 0, the city's efforts to position itself as an active player in this process contrasted with the perspectives of multinational companies viewing London mainly as a 'test-bed' for technology probing. Nevertheless in our case study the situation appeared to be somewhat reversed. As a result of limited budgets and lacking an explicit technology strategy, the municipality appeared to be rather reserved towards taking on any role going beyond that of a simple 'user' of fuel cell technology. Participation in technology trials was seen as a possible option, but taking on the role as a funding body or even central coordinator and promoter for such a project was not regarded as feasible.

These experiences may partly be specific to the situation in Graz. Furthermore, as the workshop series focussed specifically on fuel cell technology, the role of the municipality was already somewhat narrowed down to an evaluator or co-organiser of possible deployment projects in a pre-defined technology area (see Section 0 for a more detailed discussion). Nevertheless our results suggest that municipalities, especially in small to medium sized cities, may often be lacking the means to provide substantial support and leadership in technology learning processes. As noted in Section 3, municipalities are often strongly dependent on higher levels of governance, such as the financial resources allocated to them, explicit technology strategies at the national level as well as relevant policies and institutional frameworks. Yet, this is not to say that the municipal level cannot provide significant impulses concerning the application, regulation and maturation of emerging technologies. Rather, it highlights the importance of the coordination of various governance levels in the context of technology learning processes. Thus, while specific niches for technology learning processes can be identified and realised at the local level, these efforts may need to be coordinated with overarching technology strategies, legislation and product standards as well as funding programmes at the regional, national and possibly international level.

### 5.2. *Process evaluation – lessons learnt*

The previous subsection has discussed some of our results from the workshop series in relation to general questions concerning technology learning processes at the municipal level. In this subsection, by evaluating the process along the criteria proposed by Schot (2001) for CTA processes, some further conclusions on technology learning processes at the municipal level will be drawn, especially concerning the specific format of workshop series applied in this case study. Since CTA was chosen as a broad reference framework for the workshop series, Schot's criteria of anticipation, reflexivity, and societal learning appear to be quite suitable guidelines along which to evaluate the process.

*Societal learning* occurred at different levels. First of all the workshop series facilitated an exchange of perspectives between municipal actors and technology developers. In particular, several R&D actors pointed out that they learned a lot about the perspective of municipalities, the specific demands and visions the city representatives articulated, the technologies they would prioritise, or the specific restrictions of municipalities (lack of financial resources; self-perception as facilitators or users but not as project funders). Thus, technology designers did not so much take home new user specifications but rather learned about the practicalities and also difficulties of implementing technology projects at the municipal level. To a certain extent this can be seen as an instance of second-order learning where technological options need to be rethought in a rather fundamental way in view of realistic use contexts. This process of learning about other perspectives was also true for city representatives, who usually had not been confronted with technology opportunities or the importance of local deployment projects, also for export oriented companies.

Second, technology designers evidently could profit from the discussions on relevant application fields for fuel cell technology in municipal contexts. A rather broad and well-founded agreement could be achieved about worthwhile fields for further demonstration projects and strategic niche management processes, such as fuel cell applications in public transport, municipal utility vehicles or logistics systems for transporting goods to the inner city. These prioritised fields could integrate a number of perspectives: the problem situation of the municipality, the interest of technology suppliers (e.g. demonstrating specific strengths of the technology, potential for up-scaling markets) and sustainability requirements. Third, the workshops also provided a platform where participants established new contacts and developed plans for further collaboration. While this aspect has not been evaluated systematically, there is at least anecdotal evidence of some joint project proposals and meetings between companies and representatives of the municipality and intermediary organisations resulting from the contacts made in the workshops.

Nevertheless, it must be stressed again that while the time frame and limited resources of a research project were sufficient to start a process of learning and reflection, it has not been successful in kicking off new pilot projects or niche management processes. Some R&D actors participating in the workshop series did express their interest in having a more continuous platform to interact with municipalities and to develop demonstration projects in close cooperation with municipal and other demand side actors. However, it appears quite likely that these ideas will not be implemented at all or the system-oriented view will split up again into isolated technology demonstration projects without further process facilitation.

In terms of *anticipation* the workshops also showed some interesting results. Both technology developers and municipal actors were initially rather reluctant to develop future scenarios for the use of fuel cell technology and instead pressed for a direct discussion of projects that could be realised in the short to medium term. Nevertheless the workshop series was in the end quite successful in kicking-off debate about sustainability aspects of fuel cell technologies and about different socio-technical scenarios and trajectories for future developments of the field. As a result, some well-informed and comprehensive mini-assessments were produced in a quite short period of time. For technology designers it became clear that sustainable innovation is a rather complex process taking a variety of factors into account and that the question whether fuel cell technologies are contributing to a more sustainable energy system heavily depends, e.g. on the assessment of alternative solutions, the relating infrastructure as well as specific local conditions.

In this sense the process also contributed to the *reflexivity of the actors* participating in the workshops and was helpful to embed their short-term interests into broader perspectives.

However, despite the successful anticipation and reflection of fuel cell implementation projects at the municipal level, the absence of practical implementation following up these discussions seems to be due to inherent tensions between the municipal and national problem framing, as pointed out in the introduction. While the municipality was interested in solving practical environmental or transport-related problems irrespective of the specific means to be employed, the CTA process, emerging from a national technology policy problem frame, had a strong technology bias, which appears to be inherent in any CTA-type process. These contradictory positions could not be productively overcome in the workshop process. Exploring the societal context and local embedding of a particular technology within a participatory process does indeed open up the innovation process to a broader set of stakeholders. At the same time, however, it also limits the problem horizon to the specific technology under focus, isolating it from technological or organizational alternatives. Moreover, especially in the case of a rather generic technology like fuel cells, a variety of different application areas may exist, which relate to quite different groups of demand side actors, implementation contexts and alternative solutions. Thus, while the workshop did create a forum for the exchange of perspectives of different actors, the technology bias could not be sufficiently overcome.

This became apparent in a number of respects. First of all, the workshop series suffered from a relatively low participation rate of municipal actors. This may partly be attributed to the preparation phase of the workshop series, where higher efforts were put into mapping the technology and its applications than in mapping and articulating demand. Second, the emphasis on the mapping of the innovation field in the preparation of the workshop series also had implications for the focus of the workshop that turned out to be more attuned to the interests of technology developers than to the problems and needs of the municipality. Third, pre-defining the technology to be discussed to some extent also pre-defined the possible roles of different workshop participants. Thus, while R&D actors could try to use the workshop series for promoting 'their' technology, the role of municipal actors in the discussions was too often restricted to that of a commentator and potential recipient of fuel cell deployment projects.

These experiences draw attention to the intricate problem of achieving a balanced framing when bringing together different interests and agendas into a joint discussion forum. As Raven et al. (2008) have noted: 'The types and methods that are mobilized, the questions asked (by whom), the timing of their mobilization, and the alignment of social interests and the concomitant resources that they draw on highlight the politicized extent of participatory methods that are often viewed as depoliticized and neutral' (p. 467).

Reversing the process and taking the problem situation of the municipality as a starting point for technology learning processes would certainly also be a promising approach and resolve some of the problems encountered in this case study. However, it is likely to open up new questions concerning the coordination with national technology policy goals or simultaneous access to a variety of different technology fields. It would not resolve the dilemma of bringing together the different agendas but also competences of local actors, national technology policy as well as researchers and industry actors. What remains is a basic 'dilemma of alignment': Regardless of the starting point that is chosen – either a technology field or a local problem situation – the problem framing this entails is likely to constrain the mobilisation and contribution of actors from 'the other side'.

However, future projects with similar objectives may strive to work more symmetrically in terms of mapping the interests and perspectives of municipal actors in the preparation phase of a dialogue process and leaving more space for alternative technologies or social arrangements. If the starting point is to work from a particular technology field, greater efforts need to be put into matching technology potentials with existing problem situations and identifying interested demand side actors within municipalities before the actual meetings are organised (see also Kivisaari, Lovio, and Väyrynen 2004). From a broader perspective, long-term partnerships between municipalities and intermediary organisations that provide more continuity in exploring suitable 'green' technologies may constitute an interesting possibility to be explored.



## 6. Conclusion

Technological innovation certainly plays an important role on the way towards a more sustainable society. In order to make this happen, it was often argued, a new paradigm to manage technology development is needed, a more reflexive approach based on broad and to some extent open learning processes and practical experimentation.

In this paper, we have focused on some preconditions to systematically set up technology learning strategies at the municipal level. We have argued that despite the huge potential of cities for creating locally defined technology niches and stimulating social learning processes in real-world experiments, relatively little attention has so far been given to the process of setting up and locally embedding such niches and to the opportunities and specific problems this entails.

In accordance with similar findings the experiences in our case highlight that the preparation of technology learning processes at the municipal level needs to take into account the limited room for manoeuvre of municipalities as well as the importance of the coordination of various governance levels. Municipalities, even if they see themselves as technology forerunner, are limited in terms of funding as well as relevant policies and institutional frameworks. Furthermore, when dealing with technology learning at the municipal level, it is important to be aware of the multiplicity of roles a municipality may take on in a technology learning process; as early user of a technology, as a promoter and funding body, as a policy maker considering longer-term strategies as well as passing relevant legislation, or eventually a combination of these different roles. However, to co-operate with municipalities in pilot projects or similar niche experiments in any case involves the risk to become part of a political debate with an uncertain outcome. Also, while municipal technology learning projects can serve to mobilise stakeholders and thus shape new actor coalitions in the respective innovation field, the effort of coordinating a possibly large number of actors also needs to be taken into account.

The internal evaluation of the process indicates that the applied workshop design was capable to encourage the anticipative, reflexive and societal learning capacities of the actors involved. The workshops facilitated substantial exchange of perspectives, especially between the municipality and technology developers, and provided a platform to establish new contacts and develop plans for further collaboration.

However, some structural shortcomings also constrained the process of technology learning and the wider impact of the workshop series. Two main problems emerged, namely the problem of achieving long-term continuity of such an intervention process and the problem of the technology bias that is easily inherent in CTA-type processes. In the context of municipal technology learning, the latter problem is closely related to conflicting approaches that may be taken on the subject – either starting from a particular technology area and attempting to contribute to technology learning and momentum building around the technology in focus – a problem perspective which is often adopted by national R&D programmes – or working from the needs and problem situations of the municipality and exploring different technological and organisational solutions. This results in a 'dilemma of alignment' – with the actors and agendas prevalent in this initial framing easily dominating the other side, which is merely considered as the 'context' of the process.

In spite of all these challenges the municipal level clearly offers a huge potential for technology learning processes. For many reasons (e.g. relevant infrastructure, concentration of stakeholders, clearly defined boundaries, etc.) municipalities could be seen as 'natural' niches for exploring new technologies in realistic use contexts on a limited scale. At the same time municipalities can profit from environmental and economic benefits from experimenting with 'green' technologies. Future research in this field could deepen our understanding of the necessary conditions at the outset of technology learning experiments at the municipal level, the multiplicity of roles and competences of municipalities, the possibly unavoidable political character of technology in this context, and the way technology learning is embedded and linked to other governance levels.

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