Background Material: Case Study ‘Fuel Cell City’

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1 Case Study Background

The case study is based on the ongoing project ‘Open Innovation’ funded by the Austrian Federal Ministry of Transport, Innovation and Technology within its programme ‘Factory of Tomorrow’. The aim of the project is to develop user-centred perspectives for two selected environmental technologies (fuel cells and wood-plastic composites), by means of an exemplary implementation and subsequent improvement of two methods especially designed for user- or stakeholder-involvement in technological innovation, namely 'Constructive Technology Assessment' and the 'Lead-User approach'.

The case study presented within the CIPAST workshop covers the conceptualisation and implementation of the participatory process in the area of fuel cell technology. From January to March some preparative interviews with experts in the field of fuel cell technology were conducted. The actual workshops and discussion groups are scheduled for the time span mid June – early July. On the basis of the expert interviews it was decided that this participatory process will be oriented towards the development and subsequent assessment of scenarios for the future use of hydrogen and fuel cells at the municipal level. The city of Graz will serve as a focal point for this scenario process. A variety of stakeholders from research institutions, private firms, public administration and politics have been identified and were invited to the workshops.

2 The Innovation Field of Fuel Cell Technology

The basic principle of a fuel cell consists of transforming the chemical reaction energy of a fuel (e.g. hydrogen) and an oxidant (e.g. oxygen) into electrical energy. The process taking place in a fuel cell can thus be thought of as the inverse of electrolysis: Whereas in water electrolysis electrical energy is supplied in order to separate water molecules into hydrogen and oxygen, a hydrogen fuel cell produces electrical energy when hydrogen and oxygen react and form H_2O molecules.

Hydrogen is the most commonly used fuel, although alternative fuels such as methanol are also applied in special types of fuel cells. However, hydrogen should not be thought of as an energy *source* but rather as an energy *carrier*. It is not directly available - rather, hydrogen has to be produced, typically by extracting it from fossil energy sources (steam reforming of natural gas or coal gasification) or by electrolysis.

There are various types of fuel cells that can be distinguished on the basis of their operating temperature and the fuel that is used. The application areas for fuel cells are usually divided into three main fields:

- *Mobile applications* (‘fuel cell vehicles’)
- *Stationary applications* (mostly decentralized energy supply for households, businesses and public facilities as well as off-grid energy supply, e.g. for gauging stations)
- *Portable applications* (as a substitute for rechargeable batteries, e.g. in laptops, mp3-players, mobile phones, etc.)

2.1 High expectations and ecological potentials

Since the late 1950ies fuel cells have time and time again been the focal point of *waves of high expectations*, succeeded by phases of disappointment when high striving goals could not be met. Of all application areas the field of fuel cell vehicles was most strongly characterised by such cycles of hype and disappointment and several announcements concerning imminent market breakthroughs had to be postponed or taken back. Today experts have become more cautious and are usually quite reluctant to make any prognoses concerning the timeline for the introduction of fuel cells to the mass market.

The high expectations with regard to fuel cell technology are to a large extent related to the high *ecological potentials* associated with it. Firstly, fuel cells at least in theory operate at a much higher level of energy efficiency than the conventional combustion engine. Secondly, fuel cells locally contribute to a significant reduction of greenhouse gas emissions: The only waste product generated from the use of hydrogen fuel cells is water or steam; in the case of methanol fuel cells also small amounts of CO_2 are emitted.

However, a comprehensive assessment of the environmental sustainability of fuel cells must also take into account emissions generated in the production of the fuel that is employed. Currently by far the largest part of hydrogen produced world-wide comes from steam reforming of natural gas. The 'grand ecological vision' regarding fuel cells, however, consists of using energy from renewable sources to produce hydrogen via electrolysis. Hydrogen thereby becomes a form of energy storage, which can provide an essential bridge between the production and consumption of renewable energy, when the times and places where renewable energy sources can be exploited do not meet demand curves. Due to the high costs this combination of fuel cell technology with renewable energy technologies entails, it is currently only a realistic option for niche applications, such as off-grid power supply (see section on future potential applications below.)

Another strand of research and development is also exploring various possibilities for using biogas for fuel production, as an alternative renewable source (e.g. sewage gas or biogas produced from biogenous household wastes).

Environmental risks associated with a more widespread use of fuel cells concern a reinforcement of the energy regime based on fossil fuels, if hydrogen production continues to rely on steam reforming of natural gas. Also, a growing demand for hydrogen could create a boost for nuclear power, an energy source whose environmental soundness is itself highly disputed. Both off-peak electricity production and lost heat in nuclear reactors could be exploited for hydrogen production, either via electrolysis or in thermo-chemical processes.

2.2 Status quo: Existing niche applications and open questions

Existing niche applications can almost exclusively be found in areas where costs only play a minor role: Space technology, military applications, energy supply for yachts and travel vans as well as publicly funded pilot projects - e.g. fuel cell vehicles in local public transport or small-scale combined heat and power appliances for households or businesses. (See also appendix.)

This already points to one of the *major problems* inhibiting large scale market introduction. Although fuel cell technology has already reached the level of concrete product developments (prototyping), production costs are generally still too high for market introduction. Most experts agree that these high costs cannot yet be sufficiently levelled by economies of scale and further R&D efforts are needed in order to reach a competitive cost level. Apart from that, improvements still need to be made with respect to the durability and the energy efficiency of fuel cell stacks.

Beyond the actual fuel cell technology a number of questions arise that concern the production, distribution and storage of fuels. In particular, the supply of hydrogen poses a number of problems that still need to be solved (economic and ecological modes of hydrogen production, technical improvement of hydrogen storage, build-up of hydrogen-distribution infrastructure).

Firms aiming to establish themselves in the area of fuel cell technology also need to decide where to position themselves along the supply chain. This is an intricate question, as such supply chains in the area of fuel cell technology are only starting to emerge (Hendry et al., 2004). Furthermore virtually all application areas are still lacking dominant technical design variants. For firms, and in particular for SMEs, it can therefore entail a high risk to focus on one specific technical design option.

2.3 Future potential applications

When thinking about *possible future development pathways* for fuel cell technologies it has to be kept in mind that in practically all areas of application fuel cells are in competition both with established conventional and with other alternative energy technologies. While it is hard to predict any long-term developments, it seems likely that within the next years the application of fuel cell technology will be limited to further niche applications. Apart from the niches referred to above, there are a number of other potential applications, where fuel cell technology may provide a specific advantage over competing solutions:

- *Emergency power supply*, e.g. for hospitals or computer servers:
  The limited durability of fuel cell stacks is less of a problem (only occasional use of backup system) and the possibility of remote control and maintenance provides an extra benefit compared to the conventional diesel aggregate.
- *Off-grid gauging and transmitting stations*:
  In off grid applications the price level fuel cells have to compete with is higher than in regular electricity supply. Also, synergies with other decentralised energy technologies may be exploited (e.g. load balance for photovoltaics systems).
- *Battery-independent energy supply for automobiles*:
  Apart from the use of fuel cells as propulsion unit they may also be used for battery-independent on-board electricity supply for automobiles (e.g. for refrigerated trucks).
- *Fuel cell vehicles in public transport*:
  For use in local public transport the problem of establishing a hydrogen infrastructure is less salient. A single supply station will generally suffice to operate a local bus fleet. Also, the avoidance of local emissions can provide a sufficient incentive for local authorities to accept the higher costs fuel cell vehicles entail. (See also examples in Annex.)
- *Hybrid utility vehicles (electric/ fuel-cell driven):*
  Compared to purely electrical utility vehicles combined electric / fuel cell driven hybrids have an extended range and are able to cover peak-loads (e.g. for motor start) without an oversized battery. Examples of use include industrial sites, airports, hospitals or city cleaning. (See also examples in Annex.)

3 Contested Futures: Which Issues are at Stake in the Prospective Use of Fuel Cells and Hydrogen?

3.1 Visions of the hydrogen economy

A number of existing studies delineate scenarios for the potential future use of hydrogen and fuel cell technology.[1] Concerning possible future forms of a ‚hydrogen economy' a variety of images exist,

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[1] This overview including the list of framework conditions in section 3.2 relies strongly on McDowall, W. und Eames, M. (2004) '*Forecasts, Scenarios, Visions, Backcasts and Roadmaps to the Hydrogen Economy: A Review of the Hydrogen Futures Literature for UK-SHEC*', UKSHEC Social Science Working Paper No. 8, Policy Studies Institute, London. www.psi.org.uk/ukshec/pdf/8_Hydrogen%20Futures%20Review.pdf

differing in particular with respect to the underlying fuel-supply infrastructure (centralised vs. decentralised supply) and with respect to specific modes of fuel production:

- *Centralised vs. decentralised supply:*
  A decentralised supply of hydrogen could consist of small-scale electrolysis and/or small scale steam reforming of natural case as well as the use of biogas. In particular, it would be possible to make use of local energy sources (renewable energy installations and biomass), though this is not necessarily the case in a decentralised hydrogen production infrastructure (e.g. small scale electrolysis making use of centrally produced and distributed electricity). Centralised infrastructures could incorporate large scale electrolysis and steam reforming as well as coal gasification, nuclear hydrogen production and biogas use. Pipelines or trucks would provide the means for distribution.

- *Fossil, nuclear or renewable sources*
  The relative importance of the range of options of fuel production also allows for variable scenarios. Even within the area of renewable sources there are several possibilities (via electrolysis using electricity from renewable energy sources or biogas use).

These potential forms of an extended use of hydrogen and fuel cells not only need to be viewed as potential static endpoints of future developments. Rather, different transition pathways may be formulated that go through different development stages, e.g. from decentralised to centralised infrastructures or from fossil fuels to renewable energy sources. However, also the possibility of a lock-in with respect to a specific technical set-up needs to be taken into account (path dependency).

Furthermore the question to which extent an extensive use of hydrogen and fuel cells can contribute to a reduction in greenhouse gas emissions is still contested. Many studies assume that on the short and middle term (possibly also in the long run) fossil fuels will provide the major source for hydrogen production. The use of carbon sequestration and storage is increasingly cited as a means for reconciling such a regime with the goal of low emission-standards. However, this technique itself is both technologically immature (i.e. probably not available in the near future) and highly controversial from an ecological point of view. Similarly, the potential use of nuclear energy, which is sometimes viewed as an appropriate alternative source for hydrogen production, is likely to spark severe debates.

For the above named reasons it may well be that an increased use of hydrogen and fuel cells will only contribute to the reduction of greenhouse gas emissions on the long term (from between 2030 and 2050 onwards). In fact the use of hydrogen may even contribute to a temporary increase in emissions on the short and middle term. Indeed, some proponents of a sustainable transport and energy system are very sceptical about the potential contribution of fuel cells and would prefer to see resources channeled on renewable energy technologies (solar, wind, biomass, etc.), energy efficiency measures, biofuels and new mobility concepts (technical as well as organisational measures).

3.2 Framework conditions

Several framework conditions are seen to be relevant for the emergence of particular future development pathways in the area of fuel cell technology. The following factors are frequently cited:

- The speed of *technological change* (breakthroughs)
- The strength of *environmental values* and (the perception of) *climate change impacts*
- *Energy prices* (conventional energy sources) and uncertainties concerning the *security of supply* with fossil fuels

- The relative importance of different *policy instruments and forms of governance* (market oriented vs. national and international regulation, international coordination vs. strong regional autonomy)
- *Economic growth*
- *Public perception* of fuel cell technology, including technologies related to fuel production.

However, the framework conditions influencing the development of fuel cell technology differ considerably for different fields of application and in additional application-specific framework conditions need to be taken into account. While developments in the area of portable electronics equipment are likely to be mainly market-driven, the introduction of fuel cell vehicles also depends heavily on political framework conditions, such as ‚zero-emissions-regulation' (Hendry et al. 2004). For stationary applications various factors in the development of energy systems (oil price, security of supply, liberalisation, environmental consciousness, etc.) are likely to play a role.

In all application areas, future developments still heavily depend on further basic research. Thus, research funding schemes also constitute an important factor that will influence future development pathways. As far as concrete product developments are concerned, administrative issues such as operating licences and certifications (e.g. for fuel cell heating appliances) need to be taken into account.

3.3 The municipal level

With regard to the potential future use of fuel cells and hydrogen there are some issues that may be of particular importance to the municipal level (some of them specific to the city of Graz):

- *Local air quality*:

  Apart from making a contribution to a reduction of greenhouse gas emissions, the municipalities of cities are very much concerned with local air quality. The use of fuel cells thus may be attractive, as it contributes to a reduction of *local* emissions, regardless of the way hydrogen is produced. In particular fuel cell applications could contribute to a reduction of the emission of 'particulate matter' - fine particles that are inhaled and can cause a number of health problems (e.g. allergies, asthma, lung cancer) Due to the geographical location of the city of Graz (surrounded by hills), the issue of particulate matter is of special importance there. However, there are of course a number of alternative measures that can address this problem. For example, half of the local bus-fleet in public transport is already operated on biodiesel produced from recycled vegetable oil (previously used for cooking).

  See www.graz.at/cms/beitrag/10022288/356901/ (German only)

- *Profiling as a sustainable city and as a high-tech site*

  More generally, municipalities may be interested in profiling as a 'sustainable city' or a high-tech site. In Graz a programme under the heading 'Ökostadt' (Ecocity) includes a variety of environmental initiatives that aims to improve the sustainability of the 'societal metabolism' of the city.

  See www.graz.at/cms/ziel/245817/DE/ (German only)

- *Contributing to the regional value chain*

  At the local and regional level, the implementation of sustainable technologies may be enhanced by involving regional firms, thereby strengthening the regional economy. Although Austria is not one of the leading countries in the area of fuel cell R&D, there is a notable number of research institutes and companies in and around Graz working in the area of hydrogen and fuel cell technology. (See section 5 below.)

- *Dependence on larger-scale developments*

  Although municipalities may provide significant impulses in the use of emerging technologies, they are of course strongly dependent on larger-scale developments at the national and international level. The tension between the importance of niche applications (e.g. municipal pilot projects) and the constraints set by macro-level developments in emerging technological fields such as fuel cell technology, may be an issue of discussion in a scenario process at the municipal level.

- *Hydrogen Fuelling Station*

  In 2005 the hydrogen fuelling station 'HyCentA' (including hydrogen-research and-testing facilities) was set up in Graz, funded by two Austrian federal ministries, regional funding bodies (province of Styria) as well as corporate partners. However, it is currently only being used for research activities as there are no hydrogen-based application projects in operation in or around Graz. There is a high interest on the part of HyCentA to see this fuelling station integrated in such pilot projects but their efforts to get any such projects implemented (e.g. fuel cell busses in Graz) so far have not succeeded.

  See www.hycenta.tugraz.at/index_e.php

4 The Scenario Method

As mentioned before, the case study 'Fuel Cell City' involves the implementation of a participatory scenario process at the municipal level of the city of Graz. This section is intended to give a brief introduction to the scenario method.

For a more comprehensive treatment please refer to pp. 163-174 in

Eliott, J., Heesterbeek, S., Lukensmeyer, C.J., and Slocum, N. (2005) Participatory Methods Toolkit: A Practitioner's Manual

(Online version available at www.viwta.be/files/30890_ToolkitENGdef.pdf)

4.1 General introduction to the scenario method

When future developments in a particular field are highly uncertain due to the complexity of the driving forces involved (e.g. emerging technologies), *scenarios* help to provide orientation points by describing a variety of *potential future development pathways*, thereby highlighting the involved risks and potentials at various levels (social, economic, environmental, political, cultural). In many cases scenarios are developed and assessed in a participatory process that integrates a variety of stakeholders. (E.g. Experts from a variety of fields, the 'lay' public).

Prior to the actual implementation of a participatory scenario process some *preparative work* is required:

- *Research on the background of the issue at stake* (e.g. economic and technical details, stakeholders and their opinions, etc.)
- *Framing of the issue and deciding on the scope*
- *Selection and invitation / recruiting of stakeholders*
- *Preparing a background document sent out to participants beforehand*

The actual *implementation* of a participatory scenario development process will typically include the following broad steps:

- *Identification of relevant framework conditions / driving forces*
- *Using possible patterns of framework conditions for constructing scenarios as narrative descriptions of potential development pathways* (In a first step formulating basic scenario frames, in a second step fleshing them out.)

- *Analysing the implications* (E.g. assessing the scenarios according to sustainability criteria, strategy development based on the scenarios.)

However, there are a number of varying approaches that may be employed in the detailed implementation of a scenario building exercise. The following list is intended to highlight some of the options that should be considered in the concrete design of the process:

- *Amount of prior specification*:
  Scenarios may be developed 'from scratch' within the scenario workshop. Alternatively, some basic frames may be proposed that may be adapted an subsequently fleshed out.
- *Type of scenarios: normative vs. exploratory*
  The aim may be to construct specifically desirable and/or undesirable scenarios and then to explore ways to support / avoid these development pathways (normative scenarios). Alternatively the goal may be to leave normative judgements aside in the initial scenario development phase and to focus on plausible developments (exploratory scenarios). In a second step these scenarios may be normatively assessed.
- *Approach to scenario assessment*:
  The assessment of scenarios may freely explore the implications of individual scenarios or it may be based on an explicit set of assessment criteria. The emphasis may be on comparing the different scenarios or on the identification of more/less desirable versions of individual scenarios (or a combination of both).
- *Specification of assessment criteria*:
  If explicit assessment criteria are used, they may be pre-selected by the organisers or jointly developed as part of the participatory procedure. As a middle course, a range of criteria may be proposed that can be adapted and / or narrowed down within the process.
  Also, one may apply either a qualitative or a quantitative assessment. (In the case of quantitative assessment the criteria will often have to be 'translated' into quantitative indicators. Furthermore the amount or types of available data will have to be taken into account.)
- *Approach to strategy development*:
  When developing strategies based on the scenarios, the emphasis may be on mapping out policies that support particular development pathways ('backcasting'). Alternatively the goal may be to search for 'robust strategies' that are suitable (low-risk) for a range of possible developments. In some cases a combination of both approaches may be employed. As an aid to continuative strategy development one may try to identify indicators that help to monitor developments (pointing out which scenarios are increasing in probability).
- *Further option: Use of wild cards*:
  After the scenarios have been developed one may wish to explore the impact of selected 'wild cards' on each of the scenarios – low probability but high impact events such as natural disasters or economic or political crises.

Depending on the specific design of the scenario process the number and length of meetings of the scenario team will of course vary.

4.2 Framing of the case study 'Fuel Cell City'

In the case study at hand preparative expert interviews were conducted and complemented by internet and literature research. Defining the appropriate scope of the scenario exercise 'Fuel Cell City' certainly provides a certain challenge. A too narrow focus, framing the issue as a choice between a given set of technological alternatives in a set of application areas will give inadequate consideration the complexities of technological change and to the political, economic and environmental issues involved. Indeed, the question may not be, where conventional technologies could be replaced by fuel cell applications at the municipal level. Conversely, framing the issue as 'the future of mobility and energy consumption' will probably be too broad to produce tangible results.

Furthermore, framing the scenario process will also include deciding on an adequate time horizon (e.g. devising scenarios for 2020 or for 2050). Finally, one may either take a global perspective in scenario development (initially not focussing on the municipal level) and in a second step explore the specific characteristics and implications at the municipal level. Alternatively one may directly aim to develop scenarios specific to the municipal level.

5 List of Actors and Stakeholders

The following list is intended to provide a first overview of (potential) regional stakeholders for the case study 'Fuel Cell City'. The workshop discussion will be open to options for modifying or extending this selection.

Project Team:

The project 'Open Innovation' on which the case study 'Fuel Cell City' is based is conducted jointly by the following two research institutes:

- *Inter-University Research Centre for Technology, Work and Culture* (IFZ)
  An interdisciplinary research institute dealing with issues of socially and environmentally sound technology design. (Initiators and organisers of the scenario process on fuel cell technology.)
  www.ifz.tugraz.at/index_en.php/article/articleview/46/1/1

- *The Institute of Technology Assessment of the Austrian Academy of Sciences* (ITA)
  An interdisciplinary research institute for the analysis of technological change focusing on societal conditions, shaping options and impacts. (Providing an evaluation of the scenario process.)
  www.oeaw.ac.at/ita/welcome.htm

Project partner (expertise in fuel cell technology):

- *FOTEC*: Forschungs- und Technologietransfer GmbH; Subsidiary research institute of the University of Applied Sciences, Wiener Neustadt www.fotec.at/pages/indexEN.html

Funding programme:

- Programme '*Factory of Tomorrow*' (Austrian Federal Ministry of Transport, Innovation and Technology), focussing on the development of environmental technologies
  www.fabrikderzukunft.at/english.htm

R&D Actors in the Area of Fuel Cell Technology / Energy and Mobility:

Basic research on fuel cell technology:

- *Institute of Chemical Technologies and Analytics*, Vienna University of Technology
  www.cta.tuwien.ac.at

- *Christian-Doppler- Laboratory for Fuel Cell Systems with Liquid Electrolytes*, Graz University of Technology www.fuelcells.tugraz.at

Research and demonstration:

- *Hydrogen Centre Austria* (HyCentA): Hydrogen Fuelling and Testing station in Graz (affiliated with the Graz University of Technology) www.hycenta.tugraz.at/index_e.php

Other research institutes:

- *Institute for Energy Research*, Joanneum Research, Graz: Development of energy systems in the area of renewable energy technologies (technical and managerial) www.joanneum.at/index.php?id=98&L=1
- *Austrian Mobility Research*: Research, consulting, training, and project implementation in the field of sustainable mobility management www.fgm.at/index1.phtml?sprache=en

Companies with R&D activities in the area of fuel cells and/or hydrogen in or near Graz:

- *ALPPS Fuel Cell Systems*: Company specialising on the development of high-temperature fuel cell systems (not yet on the market, financed through R&D subsidies and their second branch in the area of thermal systems) www.alpps.at (German only)
- *Graf Carello*: Company producing electric vehicles, R&D efforts in the area of fuel cell vehicles www.graf-carello.com www2.wkstmk.at/wko.at/stwi/stwi_archiv/stwi38_2006/industrie38_2006.pdf (in German)
- *Magna Steyr*: International company in the area of engineering and manufacturing of automobiles and automobile components. R&D efforts in the area of hydrogen propulsion systems www.magnasteyr.com/cps/rde/xchg/SID-3F57F7E5-67BCC8BD/magna_steyr_internet/hs.xsl/263_306.php?rdeLocaleAttr=en
- *AVL*: International company in the development of powertrain systems with internal combustion engines. R&D efforts in the area of fuel cell technology. www.avl.com/wo/webobsession.servlet.go/encoded/YXBwPWJjbXMmcGFnZT12aWV3Jm5vZGVpZD00MDAwNTc2Njg_3D.html

Other Austrian companies with significant R&D activities in the area of fuel cell technology:

- *Fronius International*, Wels (Austria): International company in the area of battery charging systems, welding technology and solar electronics. Component developers for fuel cell systems (power electronics). Planning to a install a combined solar-fuel cell energy system on their production plant in the fall of 2007. (Using excess solar energy for hydrogen production via electrolysis; hydrogen used for hybrid battery-fuel cell powered utility vehicles on industrial site.) www.fronius.com
- *Profactor,* Steyr (Austria): Interdisciplinary applied research institute, working among other things in the area of biogas processing for fuel cell applications. www.profactor.at/index.php?id=18&L=1

Local and Regional Stakeholders:

- *Municipality of Graz* (various departments): www.graz.at/EN, more information on German site: www.graz.at
  - *Umweltamt* (Environmental department), Energiereferat (subdepartment for energy), *Referat für Luftreinhaltung und Chemie* (subdepartment for prevention of air pollution and chemistry) www.graz.at/cms/beitrag/10017576/267086/ (German only)
  - *Abteilung für Verkehrsplanung* (Department for transport planning) www.graz.at/cms/beitrag/10021940/311432/ (German only)
  - Initiative '*Ökostadt Graz*' (Eco-City Graz) www.graz.at/cms/ziel/245817/DE/ (German only)
- *Municipal government* / city counsillor on environmental matters
- Local political *party representatives* (environmental spokespersons)

- *Energy Agency Graz*: Development and dissemination of new energy concepts (energy efficiency and renewables) at the municipal level
  www.grazer-ea.at (German only)
- *Landesenergieverein Steiermark* (Energy Association of the Province of Styria): Organising regional energy projects (energy efficiency and renewables) as well as creating public awareness and providing education and information on energy issues.
  www.lev.at (German only)
- *Netzwerk Öko-Energie Steiermark* (NOEST, Eco-Energy Network of the Province of Styria): Networking organisation of the province of Styria in the area of renewable energy innovation. Funding and dissemination of energy-related projects. Subsidiary to the Landesenergieverein.
  www.noest.or.at/englisch/
- *Grazer Stadtwerke AG*: Municipal utilities company of the city of Graz
  www.gstw.at/home/unternehmen/index_en1.php
  subsidiary companies:
  - *Energie Graz* (Energy supply) www.energie-graz.at (German only)
  - *Grazer Verkehrsbetriebe* (Public Transport) www.gvb.at (German only)
  - *Abfall Entsorgungs- und Verwertungs GmbH* (Waste disposal and recycling) www.aevg.at (German only)

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Annex: Existing Municipal Pilot Projects in the Area of Fuel Cell Technology

Within the last years a number of pilot projects in the area of fuel cell technology have already been implemented at the municipal level in various towns and several more are currently being planned. The aim of a scenario process certainly goes beyond the assessment of a range of possible pilot projects. However, part of the scenario building exercise may be devoted to discuss the significance of potential short- to middle-term niche applications in the context of possible long-term developments. Furthermore the following examples are intended to give an overview of the existing potentials of fuel cell use at the municipal level.

HyFLEET:CUTE: Fuel cell busses in local public transport

The introduction of hydrogen powered bus fleets in local public transport (operating either with fuel cells or a hydrogen combustion engine) is often seen as one of the most promising entry points for hydrogen and fuel cell technology. Already since the 1980s there have been some pilot projects in this area. In big cities already the local reduction of emissions may be a sufficient reason for accepting the higher costs this entails. At the moment ten cities around the world[2] have launched a total of 47 hydrogen powered busses (33 of them with fuel cell propulsion) within the project HyFLEET:CUTE, funded by the European Commission.

For further information see:

http://www.global-hydrogen-bus-platform.com/

Fuel cell utility vehicles in public facilities in Herning, Holstebro and Skejby (Denmark)

In February 2006 a number of hybrid battery / fuel cell powered utility vehicles were introduced in various public facilities in Danish cities. In Herning such a vehicle is being used as a city cleaner and for park maintenance activities. Other vehicles are employed in hospitals for towing laundry and food carts and on a waste treatment site supporting maintenance work. Hydrogen is centrally produced via electrolysis, making use of renewable energy technologies. Compared to purely electrical utility vehicles these hybrids reduce the frequency of recharging / refuelling and provide higher traction power. Similar trucks have already been put to use at airports for towing luggage (e.g. Vancouver, Canada).

For further information see:

http://www.earthtoys.com/emagazine.php?issue_number=06.08.01&article=h2truck

Fuel cell based energy supply in the hospital Grünstadt (Germany)

Also stationary fuel cell applications have been the subject of municipal pilot projects. In particular, the use of fuel cells for the energy supply in hospitals has already been tested at a number of sites. One example is the hospital of Grünstadt (Germany). During a three-year pilot project (2003-2006) the bulk of the energy demand was covered by a fuel cell based block heat and power plant. However, the fuel cell stack not only provided heat and power. Also the steam can be used in hospitals, e.g. for sterilising surgical instruments. Apart from that the fuel cell installation serves as an emergency power supply in case of a failure of the electricity grid. There are further examples of the municipal use of stationary fuel cell applications in residential buildings, office buildings and computer centres.

For further information see:

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[2] Amsterdam, Barcelona, Berlin, Hamburg, London, Luxemburg, Madrid, Peking, Perth und Reykjavik

www.cfc-solutions.com/en/down/down/**hospital**-flyer_E.pdf

www.eere.energy.gov/de/pdfs/cs_verizon.pdf

www.klimaschutz-rhein-neckar.de/seiten/bp4c.htm (in German)

Heat and power from sewage gas: The fuel cell installation in the wastewater treatment plant Stuttgart (Germany)

In the summer of 2007 a fuel cell installation commissioned by the city of Stuttgart (Germany) for the municipal wastewater treatment plant is scheduled to go into service. The high energy efficiency as well as the use of sewage gas as a fuel is intended to contribute to an efficient and ecologically sound generation of power and heat for the wastewater treatment plant. A similar system has already been installed at the wastewater treatment plant in Ahlen (Germany). Seeing wastewater treatment plants are among the largest municipal consumers of electricity, such applications are attributed a high ecological and economic potential.

Trials are also being made to use biogas generated from household wastes in fuel cell applications. The waste treatment plant in Leonberg (Germany) has installed such a fuel cell device. In London the possibility of generating hydrogen from biogenous household wastes to be used in fuel cell busses is being investigated.

For further information see:

www.london.gov.uk/view_press_release.jsp?releaseid=9427

http://www.nypa.gov/services/fuel%20cells.htm (use of sewage gas in projects similar to the ones referred to above)

In German:

www.stuttgart-stadtentwaesserung.de/Downloads/Presse/PRESSEINFORMATION_HotModule.pdf

http://www.bio-pro.de/de/region/stern/magazin/02235/index.html

Demonstrating the combined use of wind energy and hydrogen on Prince Edward Island (Canada)

In 2006 the government of the Canadian province Prince Edward Island decided to implement a comprehensive demonstration project, aiming at the combined use of wind energy and hydrogen / fuel cells. In the first instance a hydrogen production station, a hydrogen storage depot, a hydrogen fuelled generator and a wind-hydrogen integrated control system are to be installed. Apart from the direct use of wind energy, the hydrogen produced at peak times will help to provide backup energy for a number of regional facilities. In a second step a hydrogen refuelling station should be set up which will serve to fuel a number of hydrogen-powered busses in regional transport as well as fuel cell powered utility vehicles.

For further information see:

http://www.gov.pe.ca/envengfor/index.php3?number=1007450&lang=E