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Users as Pioneers: Transformation in the Electricity System, MicroCHP and the Role of the Users

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1. Introduction: MicroCHP and the Transformation of the Electricity System

The electricity system in Germany and Europe is currently undergoing a process of transformation. Market liberalisation led to fusions and mergers among electricity suppliers, but also made companies seek out new business areas. Environmental regulation, like the Kyoto process, is putting external pressure onto the sector. New technologies are emerging, be it renewable energy technologies, combined heat and power (CHP) or "clean coal" technologies. In Germany, the nuclear phase-out and the decommissioning of outdated coal plants will lead to a need for replacement of at least 40.000 MW_{el} generation capacity until 2020 (Umweltbundesamt 2003). The need for replacement is an extremely important driver for transformation, making old and new technologies compete for a role in the future energy supply. The recent experiences with blackouts in the USA, Scandinavia and Italy have disturbed the public and security of supply is on the agenda again.

One possible development path is decentralisation. Distributed power generation in small, decentralised, interconnected units could help to save grid capacity, immunise the system against failures and provide opportunities for renewable energies. It may be one building block for a more sustainable energy future. A broad implementation of distributed generation, however, would mean a thorough structural change and require a surge of innovation. Grid access needs to be regulated and adequate system charges be defined to take into account avoided generation and distribution cost as well as additional costs for regulating energy to balance the feed-in of small intermittent power generators. If the decentralised units are to operate in industry buildings or private homes, new forms of co-operation between energy companies and private operators, new models of operating these systems, and new forms of ownership must be devised. Load regulation may require users to change habits, for example to use energy-intensive applications at another time of the day, or to allow the energy supplier to switch certain applications or generation devices on or off in exchange for price incentives. In short, a complex bundle of innovations is needed. Technical and social changes must interlock to make decentralisation possible.

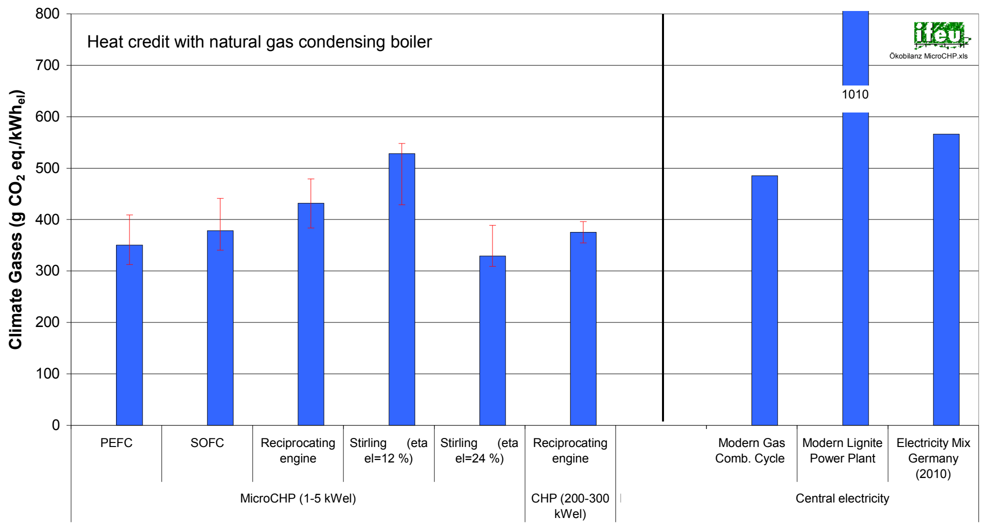
In a current project, the interdisciplinary research group TIPS (Transformation and Innovation in Power Systems, www.tips-project.de) investigates a section of this potential innovation cluster: small combined heat and power plants (MicroCHP) and the conditions for their establishment. Industrial transformation is thus studied in a "micro" perspective: one innovation that could be a contribution to a possible transformation path is investigated intensively. The goal is to identify possible levers and steering mechanisms to shape a process of innovation – and thereby, transformation – in a more sustainable direction.

MicroCHP, as defined in this study, are small cogeneration systems under 15 $kW_{el.}$ They are designed for use in family homes, multi family houses, schools or kindergartens, small commercial enterprises such as hotels, or the like. Various generation technologies are applied: conventional reciprocating engines, Stirling motors, fuel cells or even microturbines. Whereas reciprocating engines are commercially available by a number of manufacturers, Stirling and fuel cell based MicroCHP are still in the development phase.

A large potential is seen for MicroCHP Europe-wide. The British Energy Saving Trust expects 250.000 systems to be installed in Britain until 2010 (Harrison & Redford 2001). The MicroMap study (MicroMap 2002) forecasts between 5 and 12 million MicroCHP systems in 2020.

Life Cycle analyses done in the context of the TIPS project show that MicroCHP promises substantial environmental benefits. Fig. 1 shows the reduction in greenhouse gas emissions that MicroCHP may provide in comparison to other modes of electricity production. Heat output has been credited with a modern natural gas boiler (data and figure courtesy to Dr. Martin Pehnt, Insitut für Energie und Umwelt, Heidelberg).

Fig.1: Greenhouse gas reduction by MicroCHP. Source: Dr. Martin Pehnt, IFEU Heidelberg



The TIPS study investigates the interlocking technical, cultural, institutional, economical and political factors that shape the development of the innovation "MicroCHP". One part of the project is to investigate the role of the end user in shaping and distributing the innovation. Results from this partial study will be presented here.

2. Investigating the Role of the End User

2.1. Why Do End Users Matter?

Technology does not develop autonomously, nor is its course determined by the quest for technological and economical optimisation alone. Rather, technology development is shaped by actions and interactions of various societal actors. These actions and interactions are, in turn, directed by institutional arrangements, by the power structure, and by the actors' goals, values, interests, perceptions and worldviews.

Technology users are an important constituent of this tightly woven network of actors. They influence not only the course of technology and the fate of innovations, they also influence whether the application of some technology leads to more sustainability or not. The exact degree and type of their influence depends, among other things, on the specific technology at stake and on its development phase. As I have argued elsewhere, there are four general dimensions of user influence: technology acceptance, technology handling, technology-induced behavioural change (e.g., the rebound effect), and technology-independent user behaviour – that is, activities that are seemingly unrelated to the specific technology, but may interfere with its functioning, make it obsolete or substitute it (Fischer 2004, forthcoming). In our case, as we are talking about a technology that has not yet been introduced, the main topic of interest is technology acceptance. An end user may decide whether or not to buy and use a new technology. Technology acceptance therefore determines the chances of a new technology to be introduced and to find widespread diffusion. This is true especially when the technology is marketed directly to the end user. When it is sold to an intermediary, for example when a housing company buys heating systems, end user acceptance is less important.

MicroCHP systems are being designed for multi-family houses as well as for individual homes. In the individual home sector it is the end users who will have to decide on whether to apply the new technology. But will they be interested? Which features of the new technology will appeal to them? Which aspects do they consider important? Which economic conditions, institutional frameworks and political instruments are perceived as facilitating or inhibiting the introduction of the new technology?

These questions cannot be answered for all consumers alike. Rogers (1995) has identified different groups of actors in the diffusion process of innovation. Villiger et al. (2002) have adapted this general framework for consumers and for the market diffusion of green products. They distinguish between different consumer groups who take up the product at different times: In the "introduction" phase, it is taken up by a small group of "innovators". This phase is followed by the "early growth" phase where the product is purchased by "early adopters". However, the process only gains momentum when a mass market is reached in the "take-off" phase where uptake increases steeply and the "(early) majority" is ready for the project. In the "maturity" phase, market saturation is reached and the process slows down.

MicroCHP is still in the introduction phase, meaning that our target group are "innovators". However, I prefer the term "pioneers", because "innovators" evokes the association of the entrepreneur and in fact denotes rather the inventor of some novelty than its first user. "Pioneers" seems more suitable to denote users. These pioneers have very specific characteristics. Rogers (1995) describes them as "venturesome", interested in new ideas, as controlling substantial funds which allow them to compensate for potential losses of an investment, and as well educated which enables them to understand the innovation. Due to their originality, though, they may be outsiders. This chapter will try and describe these pioneers in more detail by answering some of the above questions. The following section will describe the methods applied for this purpose.

2.2. Methodology

As MicroCHP is an emerging technology, there is yet no chance to conduct comprehensive market research. Therefore, we built our study on two pillars: first, we tried to infer some conclusions from a literature study on analogous cases, and secondly, we are currently conducting a combined survey and qualitative study on persons who had opted for taking part in a field test of fuel cell based MicroCHP.

The study on analogous cases. As „analogous cases“, we defined technologies for home production of electricity and / or heat which are, in comparison with the established ones[1], innovative and advanced regarding efficiency and environmental effects. The technologies we investigated were, on the heat side, small biomass plants and solarthermal panels. On the electricity side, we focussed on photovoltaics. A literature research, heavily relying on the internet, was done to identify studies that discussed consumer aspects of the introduction of these technologies. The geographical focus was on Germany and Austria. The studies were analysed with regard to the following aspects: socio-demographic characteristics of the technology adopters; attitudes (comprising motives and goals, technology evaluation; and perception of facilitating and inhibiting factors), and, finally, behavioural changes induced by the technology. Hypotheses and questions regarding the transferability of the results to the MicroCHP case were developed. In this chapter, I will focus on the description of the technology adopters in terms of socio-demographic characteristics and attitudes. Induced behavioral changes will not be discussed because there is so far no empirical information on MicroCHP users that could be utilised to compare them to other technology users, test the hypotheses or answer the questions.

The study on field test applicants. The basis of the study is formed by a sample of persons who had opted to take part in a field test of fuel cell based MicroCHP. The number of applicants by far exceeded the number of systems to be tested: of almost 1000 applicants, only 25 could be chosen to take part in the test. The study will comprise interviews with the participants, a survey of half of the 1000 applicants, and focus group discussions with selected applicants.

The survey and the interviews with participants took place in early 2004. There results will be presented by end of July 2004. This chapter focuses on the results of three focus group discussions with applicants which have been completed by the end of 2003. All of the applicants within a certain geographic region were invited to the focus group discussion. The aim was to keep travel distance to the discussion location below 50 km. There were 99 applicants in the region which were contacted by mail. Of these, 94 addresses were still valid. 35 applicants volunteered to take part in a discussion. 28 were finally chosen on the basis of availability at the scheduled time, of which 26 actually showed up. The groups comprised 6-12 participants each and discussed for 2,5 – 3 hours. On the basis of an interview guide, group members were asked about the reasons for their application, about hopes and fears regarding fuel cell MicroCHP, about preferred ownership models, and about the advantages and disadvantages of fuel cell MicroCHP as compared to other electricity or heat technologies. The groups were facilitated by an interviewer who applied various facilitation and activation techniques. During the group session, there was a short “guided tour” to a fuel cell system in action. At the end of the session, interviewees were asked to fill in a short questionnaire with sociodemographic data. Preliminary results will be presented here and compared to the results of the literature study.

[1] Conventional German heating systems are gas or oil-based central heating, gas-based apartment heating, district heating, and, in a few East German cases, individual coal stoves. Electricity is usually taken from the grid.

3. Consumer Needs and Acceptance: Results from the Literature Study

3.1. Overview of the Literature

In general, it was not easy to find scientific studies dealing with consumer aspects of the introduction of the respective technologies. Studies usually focused on technological performance and economic feasibility. All in all, twelve studies dating from 1992 to 2003 could be used. Table 1 gives an overview of the studies considered (sorted by technology). It becomes clear that besides end users, also multipliers, interested persons and non-users have been studied. In this chapter, I will concentrate on information about end users.

Table 1: Literature basis of the study of analogous cases

Study	Technology	Goal	Topics	Sample
Greenpeace 1996	Photovoltaics	Evaluation of the CYRUS campaign (which offered a low cost PV system)	Success of campaign (number of PV systems installed), motivation, user evaluation of state support schemes	1662 persons interested in the campaign
Genennig 1996	Photovoltaics	Evaluation of the national „1000 roofs" support programme	Motivation, satisfaction, user evaluation of the support programme, electricity consumption behaviour	1.445 PV owners in survey, 48 in interviews.
Katzbeck 1997	Photovoltaics	Analysis of electricity consumption behaviour of PV owners	Possession of other energy technologies; attitudes towards electricity consumption, consumption data	32 PV owners
Karsten 1998	Photovoltaics	Survey of motives and experiences of PV owners; development recommendations for support programmes	Motivation, experience, suggestions	123 PV owners: 106 households, 17 firms, associations and public sector departments
Haas et al. 1999	Photovoltaics	Evaluation of the Austrian support programme „Breitenwirkung"	Characteristics of the users: are they „early adopters" as characterized by Rogers (1995)?	60 PV owners, 17 PV merchants, 660 „informed persons"
Reif 2000	Photovoltaics	Project report	Output and consumption data, ratio of output / consumption, degree of self-reliance	23 PV users: 22 households, 1 kindergarten
Hübner & Felser 2001	Solarthermal panels and photovoltaics	Identification of psychological factors conducive to the use of solar energy; advice on how to conduct campaigns and convince people	Motives, barriers, desired characteristics of the technology	Secondary study, no own sample
Polzer 2003	Solar thermal panels and photovoltaics	Assessment of the status of PV and solarthermal systems in a small town	Number and size of systems in the town, motivation, satisfaction, suggestions	147 owners of solar thermal panels, 22 PV owners
Hackstock et al. 1992	Solarthermal panels	Evaluation of the Do-It-Yourself Solarthermal Movement in Austria	Information, motives, user evaluation of the Do-It-Yourself programme	238 panel owners
DENA 2003	Solarthermal panels	Market research	Motivation, attitudes, image of the technology, barriers, user evaluation of support programmes	Users of solar thermal panels no older than two years; sample size is not communicated
Haas et al. 2001	Solarthermal panels, photovoltaics, heat pumps, biomass heaters	Analysis of energy consumption behaviour and energy consumption data in households which use renewable energies	Investment behaviour, consumption behaviour, influence of structural aspects, information, attitudes and motives on energy consumption	101 households owning renewable energy technology, 177 regular households
Rohracher et al. 1997	Biomass heaters	Scientific support for the market penetration of small biomass heaters	Economic, technological and social conditions, motivation, trigger, sources of information, user evaluation of state support schemes	25 biomass heater owners, 116 owners of regular heating systems, 28 multipliers

3.2. Socio-Demographic Characteristics

There is no information about the socio-demographic characteristics of the users in Hübner and Felser (2001) and in Polzer (2003). In the other studies, remarkable convergence of the results can be found. All the respondents were technology *users* and not just owners. That is, the studies do not cover cases where a landlord or a housing company installed innovative energy technology in a house that was not for their personal use. On the other hand, users of innovative energy technology were usually also the owners, with one exception that will be discussed below. They are very often families, live in family homes which they own, and come predominantly from rural areas and small towns. There is an over-representation of the South of Germany, namely Bavaria and Baden-Württemberg. Though there are too little cases to draw a definit conclusion, user groups seem to differ slightly depending on the technology studied. On the one hand, there are the users of solar thermal panels (Hackstock et al. 1992; dena 2003) and biomass (Rohracher et al. 1997). These are predominantly non-academic, with a large share of farmers and skilled manual workers. On the other hand, users of photovoltaics (Genennig 1996; Karsten 1998, Haas et al. 1999; Haas et al. 2001)[2] tend to be high-income academics with a special interest in sociopolitical issues in general and energy issues in particular. An exception to this rule is Reif (2000) where the photovoltaic users are low-income families. This is due to the special design of the project: the 23 houses in question have been built and equipped with PV by a non-profit cooperative who made them available for hire purchase to the families. The families therefore acquired the houses complete with PV systems, which were run by a contractor. In the other cases, in contrast, house owners had to make a particular investment to equip their house with PV.

Which of these results may be transferred to the case of MicroCHP? To answer this question, we need first to understand the results. If we know *why* it was a certain social group that "jumped on the train", we may draw conclusions on whether the same reasons apply to MicroCHP.

A plausible hypothesis is that the possession of a family home is decisive. In contrast to tenants and to flat owners in multi-family houses, family home owners have direct personal control over the house technology that is being installed. In contrast to landlords and housing companies, on the other hand, they have a direct financial interest. Lower energy costs will have an immediate effect on them whereas in a rented house, under German law, they will first of all benefit the tenants and not the landlord. Furthermore, even if the technology should not pay off financially, this does not matter as much in a family home than in real estate purchased for investment purposes. A family home is something else, and something more, than an investment that needs to pay off. It is a culturally defined space for expressing the owner's ideas, values and aesthetic preferences, for fulfilling his or her needs, for being shaped according to the personal lifestyle. Innovative energy technology may be installed if the owner considers it important for some reason, even if it is not profitable.

Home ownership is therefore the core variable that explains the prevalence of families and rural areas: the purchase of a home is usually related to having a family, and home ownership is more prevalent in rural areas. An additional hypothesis is that in villages and small towns, the network of interaction between inhabitants is more tightly woven, so that the word about experiences with new technologies will more easily spread and neighbours and friends will be motivated to try the same. This hypotheses is supported by the fact that a great deal of the study subjects report to have received essential information from neighbours, friends or relatives.

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2 There is no information about education in Greenpeace 1996.

The prevalence of the German South may be explained by the fact that people believe – counterfactually – that only in the South irradiation is sufficient to run a solar system (Hübner & Felser 2001, p.78 ff).

What is interesting is the difference in professional and educational status between the users of different technologies. In the biomass case, most users run the plants with wood from their own land which explains the prevalence of farmers. For the difference between solar thermal applications and photovoltaics, my hypothesis is that solar thermal panels (as well as biomass) are better known, more thoroughly understood and perceived as rather low-tech applications, therefore inviting "Do-It-Yourself". In the study of Hackstock et al. (1992) this aspect is explicit because they evaluated a programme distributing "Do-It-Yourself" kits for solar panels. „Do it yourself" has the double effect of saving investment costs and offering a challenge for people interested in crafting and manual work. Therefore, these technologies may attract users with technical and manual skills to whom the mounting and maintenance of the system has aspects of a hobby. Although there are also "Do-It-Yourself" possibilities for photovoltaics, the latter is less well understood, has a high-tech image, is expensive and, without state support, not economical. It is therefore easily perceived not as a technology for broad application but as a hobbyhorse of technology nerds and environmentalists. Having photovoltaics therefore implies a genuine socio-political statement, means „outing" oneself as environmentalist and pioneer. This may appeal rather to people with „green" political orientation, postmaterialist values, specialised technical interests and / or to individualists willing to take risks. These groups can traditionally be found in the academic high-income strata. Of course, this hypothesis needs careful testing which will be done in the survey to come by assessing the political and value orientation of different technology owners as well as the image of various technologies.

What can we learn for MicroCHP, then? With respect to electrical power, they are designed to fit single or small multi-family houses. For analogous reasons than with the other technologies, we expect that especially family home owners will be interested, and that therefore families and rural areas or small towns will prevail. The prevalence of the South will probably not be replicated because the sunshine argument does not apply. We also expect that professional and educational status of potential MicroCHP users will vary, depending on which technology is applied: reciprocating engine (or motor) CHP, stirling CHP, or fuel cell. MotorCHP is an established technology that seems feasible and economically sound. It will therefore appeal to broader target groups, maybe especially to skilled manual workers and farmers who are experienced in maintenance work and see possibilities for "Do-It-Yourself". Fuel cell MicroCHP, on the other hand, has a high tech image similar to photovoltaics. Self-maintenance is not possible and its workability and reliability is yet unclear. It may therefore appeal rather to people with specialised technical interests or postmaterialist values who would like to make an explicit environmentalist statement – that is, to the academic high-income groups. It is difficult to determine the target group for stirling MicroCHP. On the one hand, it is a rather old technology. On the other, it has been little applied and is not too well-known. It remains an open question which groups of users will be interested in it.

3.3. Attitudes

Three aspects of the users' attitudes have been investigated in the literature: first, the motives, goals and interests that made them decide to apply the technology, secondly, their experience and satisfaction with it, and finally, their perception of support and barriers, especially with respect to state support schemes.

Motives, goals and interests. In all studies, innovative technology users reported mixtures of different motives. Among the most prominent motives were: autonomy, interest in the new technology and a desire to promote it, the wish to help the environment, and economic motives. In some studies, convenience and user friendliness were also mentioned. But because the energy technologies studied do not normally provide more user-friendliness or convenience than conventional ones, these seem rather conditions any technology must fulfill to be accepted than genuine motives to choose innovative ones.

Autonomy was usually not specified by the study authors. It may mean (partial) independence from the grid and transport subjective notions of security of supply, independence from great companies, and the possibility of self-control. Environmentalism encompasses various aspects, most prominently, emission reduction and restraining nuclear energy. Especially interesting is the aspect of promoting a new technology. Subjects see themselves as „pioneers“, they want to give a positive example for others and sensitise the public. However, from the wording of most studies it does not become clear what exactly is perceived as the positive or pioneering aspect that deserves promotion. Do subjects admire engineering skills and technical achievement in the new technology? Is it its novelty? Its efficiency gains? Or rather the expected positive ecological effect? Economic motives usually mean the hope to reduce energy cost. Less often, the technology is perceived as capital investment.

As much as the general set of motives is constant, as much does their relative importance differ among the various studies. Sometimes environmental motives are most prominent, sometimes autonomy, sometimes technical interest. (However, economical motives are never primary). The differences are probably to a great deal due to methodological reasons. The studies word questions differently, present different sets of answers to choose from, pose them in different order and elaborate topics in different detail. For example, there is just one general question on the „environment“ in Rohracher et al. (1997) whereas Haas et al. (1997) mention the environment in several items and highlight specific aspects like "providing alternatives to the nuclear".

What does this mean for MicroCHP? Most of the motives mentioned above may also be valid for MicroCHP. It is a rather new technology, it promises environmental benefits, and there may be an economic incentive once the systems are mature and go into mass production. In contrast to these three motives, I expect that the autonomy motive is not as valid as long as the machines run on gas, gasoline, or other fuels that need to be purchased.

Because of its novelty, MicroCHP involves both high risk and high profile, probably attracting people who define themselves as „pioneers“ (or "innovators", in the terms of Rogers (1995)). There may be a problem with the „pioneering“ motive, however. A MicroCHP plant is not visible from outside the house, like a solar panel or solar cell is. Even when shown, its appearance tells nothing about its functioning – it is nothing but a „grey box“. Therefore, its owners cannot as easily demonstrate their pioneering efforts to the world. Promoting the technology and setting an example therefore requires discussions and explanations. Thus making promotion more difficult, MicroCHP may not be the technology of choice for people who would like to make a visible statement.

For our study, it is also interesting how the various motives are weighted and what they mean in detail: What exactly is attractive about a new technology? What are the expected environmental benefits? What amount of economic benefit do people expect? How do they want to promote it?

Experience and satisfaction. Virtually all participants in all studies are highly satisfied with their systems. Satisfaction is even higher when participants monitor their system themselves, receiving detailed feedback on its performance. Occasional dissatisfaction relates almost exclusively to economic aspects: investment costs were too high or savings were not as substantive as expected. Some PV users had initial problems with the reliability of their systems which diminished over time, though (Karsten 1998).

A prerequisite for satisfaction, of course, is the functioning of the system. Given this, and given the fact that an innovative energy system is something that does not come automatically but is actively sought ought by the users, I assume that satisfaction stems from having successfully realised one's goals and aspirations, and observing the positive effects of this. Therefore, I assume that MicroCHP users will also be satisfied, provided the system works. Satisfaction may be even increased when detailed data about system performance is available.

Support and barriers. An important supportive factor is reliable information. Technology users get information from many different sources: mass media, specialised media, panel or plant producers, energy suppliers, conferences and fairs, environmental groups or plumber firms, the internet, and personal contacts. Many of them are interested in technical or energy topics and have been following the discussion for a while. The variety of possible information sources may, however, also pose problems. It is not always easy to identify relevant information, and to deal with contradictory statements.

Among photovoltaic users, we can observe that many of them made other energy-related investments before. Among them are heat insulation, energy saving appliances and, specifically, solar thermal applications. It seems therefore that other technologies allow participants to gain experience and pave the way for the application of more complex technologies. We can call this the phenomenon of „trigger technologies".

By technology users, barriers were perceived mainly in the administration of support schemes. Programmes were handled too bureaucratically, application procedures too prolonged, sometimes the combination between investment subsidies and feed-in bonuses was not optimised. Although a substantial number of the users would have installed their system even without any support programmes, public support schemes play a significant symbolic role in recognising the new technology as good investment.

To identify barriers, it is helpful to also look at non-users, which was done by Greenpeace (1996), Rohracher et al. (1997), Hübner & Felser (2001), Haas et al. (2001) and dena (2003). It turns out that a substantive barrier is doubt and uncertainty. Doubt refers to the reliability and maturity of the systems, but also to the cost and profitability. With solar systems, there is doubt on whether there will be sufficient sunshine outside Bavaria or Baden-Württemberg. Subjects perceive a high North-South divide in sunshine, though in fact irradiation does not differ much between North and South Germany (Hübner & Felser 2001, p.78 ff). Doubt and insecurity prevail especially when the technology is uncommon so there is no chance to personally make sure it is performing well. This interpretation is backed by the fact that „clusters" of solar energy applications form in certain villages or small towns (Hübner & Felser 2001, p.23): once some systems are installed, they provide a possibility for first-hand information and experience that can reduce doubt.

Other important barriers are of a physical and infrastructural nature. Some potential users just do not have the right roof gradient or direction for solar applications, or lack space for storing wood. And finally, there are aesthetic objections to solar applications.

I assume that for MicroCHP, reliable information will be even more important because the technology is even less known. Trigger technologies will therefore play an important role. Also, infrastructural barriers are important, because the systems take up considerable space and, in case of fuel cell CHP, are dependent on gas supply. Aesthetic considerations will of course not be relevant, which may make the MicroCHP's „invisibility" a good thing, in contrast to the considerations presented above.

3.4. Hypotheses

On the basis of this discussion, I can now formulate some hypotheses concerning the potential target group for MicroCHP.

1. The main target group are families living in their own house in rural areas or small towns. While fuel cell-based MicroCHP may appeal mainly to academic high-income groups, there is potential for MotorCHP among skilled manual workers and small workshop owners.
2. Persons interested in MicroCHP will perceive themselves as „pioneers" with a mission to promote a new technology. The motives behind this are either a keen technical interest, a positive evaluation of innovation in general, or environmental reasons. The technical interest may have a hobby component. Economic motives may also play a part, but are not decisive. The autonomy motive is less prevalent.
3. Being „pioneers", users will have an interest in distributing their ideas, sharing experience and demonstrating the new technology and its workability. These intentions may be counteracted by the fact that MicroCHP is little visible. Users will therefore welcome opportunities to share ideas, thoughts and experience.
4. Provided that the system works satisfactorily, MicroCHP users will be satisfied with their decision and possibly act as multipliers for the idea. Feedback on system performance and possibilities to monitor performance oneself may increase satisfaction.
5. In order to promote MicroCHP, reliable information is crucial to reduce doubt. Potential users will therefore be people who have been dealing with related topics for some time, and probably have gained some experience with „trigger technologies".
6. Infrastructural restrictions play an important role as long as space requirements are not reduced.
7. MicroCHP can be promoted by suitable design of support schemes. A combination between investment subsidies and feed-in tariffs will be welcomed by most users. It is important that programmes are administered flexibly, swiftly and unbureaucratically.

4. Focus Groups: Preliminary Results

Focus group results, especially with respect to sociodemographic data, must be interpreted with caution. On the one hand, the high response rate of 37% indicates that focus group participants are not too untypical for the whole sample of field test applicants. But still, they are probably not entirely representative, but do represent an especially interested and committed subgroup. Given the fact that even the applicants are a positive selection of all potential users and may be characterised as "pioneers", we can assume that focus group participants exhibit these "pioneer" qualities to an even higher degree. Therefore, they do not give us information about the average user, but allow us to describe a special group that paves a new technology the way into the market and is therefore crucially important.

4.1. Socio-Demographic Characteristics

The most striking feature is that all focus group participants were men. In this, they are representative for the sample that was addressed: of the 99 addressees, 91 were men, 4 couples and 4 women. In one group, group members realised and discussed this fact. The discussion brought up possible explanations that will be explored in more detail in part 4.2.

Regarding age group, both mode and median were in the age group of 41-50 years, but there were more participants older than 50 than younger than 40. As expected, all but one were home owners. All lived with a wife, and 20 in families with underage children. Of the 6 participants with no children in their house, 5 were pensioneers. The families were also relatively big: the average number of children per family (excluding the couples without children) was 2,1. Fig. 2 and 3 give an overview of age groups and family sizes.

Fig. 2: Age of participants

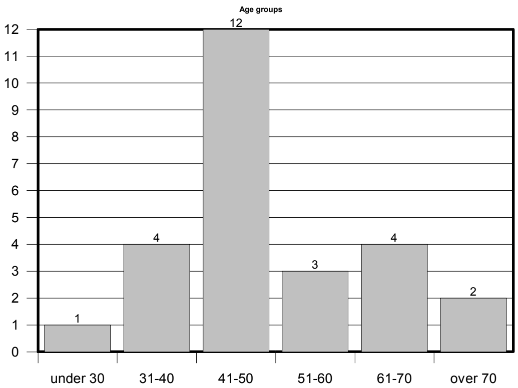
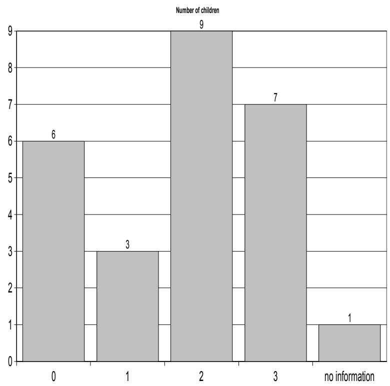


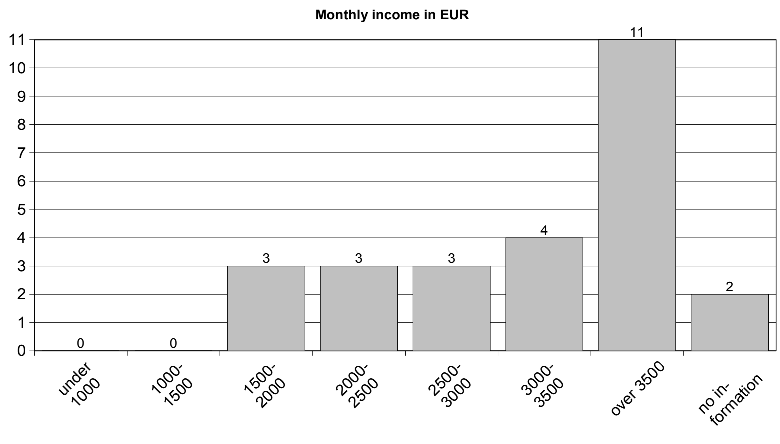
Fig.3: Number of children under 18



We also find that focus group members were highly educated. 81% have a grammar school degree as compared to 20% in the general population. 69% have a university or comparable degree, 20% a technical degree that allows them to train apprentices (*Meister*). With the income, the picture is more mixed. On the one hand, focus group members have high household incomes (see Fig.4), indicating a qualified, high-status career. The results therefore fit into the picture of academic elites. On the other hand, high income does not necessarily mean high disposable funds. Focus gro

Fup members have comparatively big families (sometimes including grown-up children or other relatives) which lowers per capita income. Unfortunately, no exact calculation of per capita income can be given because income was measured in ranges. The result therefore indicates that the most important aspect of income is not the availability of funds for investment, but rather, income functions as an indicator for social status and education.

Fig.4: Monthly household income in EUR of the group members



What is highly interesting is the professions of the group participants. First, there is high technical competence and interest. Of 26 participants, 13 are engineers or technicians. Three more are teachers, all with a science or technology subject. Secondly, the professions mirror an interest in energy and / or the environment. Four of the applicants work in the energy sector, one deals with hydrogen applications, three work in the environmental sector. All in all, there are 19 persons who work either on a technical, energy or environmental topic.

The socio-demographic characteristics of focus group members fit well with Hypothesis 1. We are dealing with a high status, elite group with good education and accordingly good income, living in their own homes with their families. Three quarters of the group members demonstrate an interest in technology, energy and / or the environment already by their choice of education and career. However, the profession only partly indicates a person's interests and competences, therefore I will discuss this subject in more depth in part 4.2. What is striking is the almost exclusive prevalence of men. When I discuss attitudes, I will come back to this fact and consider possible explanations.

4.2. Attitudes

I discuss three aspects of attitudes: first, the motives, goals and interests that made group members apply for the field test, secondly, perceived supporting factors and barriers, thirdly, satisfaction. Because group members were not able to test the fuel cell systems in their homes, satisfaction is mostly based on what they learnt about the systems during the group sessions and the guided tour.

4.2.1. Motives, Goals, and Interests

Motives, goals and interests were surveyed by different techniques. Every group member was asked to explain the motivation for their application. Furthermore, group members performed a guided brainstorming on hopes and fears relating to fuel cell MicroCHP. Every group member was asked to note their ideas on slips of paper, then the ideas were arranged thematically, presented, and discussed in the group. Finally, group members were asked to reach consensus on a hierarchy among different technologies for heat and power generation and give reasons for the order chosen.

When asked about their motives, it first turned out that most participants became interested on some specific occasion. In twelve cases, the heating system was outdated and needed replacement, in three more, the interviewees had purchased or inherited a house and were considering necessary updates. However, there were also interviewees who explicitly stated that there was no special occasion, and that their heating system would continue to work for some time, but they were more generally interested in fuel cell technology.

As expected, we find a very strong interest in technical innovation. 18 interviewees discuss this topic in detail when asked about their motives. Many have been following the development of energy technologies in general, or of fuel cells or hydrogen technology in particular, for a number of years. Among them are not only interviewees with a professional background in engineering or technology, but also "hobby technicians". Technical interest is inseparably interwoven with the interest in the "new" and forward-looking (*zukunftsweisend, Zukunftstechnologie*). Interviewees state to be "open for everything that's new", they want to "jump on the bandwagon of cutting-edge technologies". For this purpose, they are willing to invest some money and incur certain risks. Fuel cell systems are interesting because they are perceived as especially modern in comparison with other generation techniques. Visions articulated in this context dealt with a hydrogen economy, import of solar hydrogen from desert areas, and self-sufficient home systems based on a combination of fuel cells, photovoltaics, and hydrogen storage.

Subjects were not very specific on what exactly makes a technology "forward-looking", though. The notion of the forward-looking in German may have a connotation of the ecologically sustainable, but not necessarily so. Because some interviewees make this link explicit, but others don't, we cannot be sure whether ecological aspects are always implied in the "forward-looking".

Ecological aspects are important, however. Sixteen people spontaneously mention an interest in ecology or "alternative energy", when asked about their motives. Environmental benefits form the biggest share of all hopes articulated in all three groups. Some members state rather broadly that they are looking for something "innovative and ecological" or "ecologically sound". But there are also a number of more specific statements that demonstrate that group members are well informed: they hope to lower CO_2 and pollutant emissions, protect the climate, and give an answer to resource depletion.

Interviewees are no full-fledged environmentalists, though. They don't favour alternative lifestyles and distance themselves from "Greens". Ecological considerations are usually tightly interwoven with the interest in technological innovation – the wording "innovative and ecological" is characteristic. Interest in ecology and innovation melt in the much-used concept of the "forward-looking". Interviewees have an optimistic outlook, assuming that technology will solve the environmental problems. At the same time, new technologies are expected to be more "efficient" and "economical", thus linking environmental and economic benefits. Only in a few cases do people report a more philosophically or politically motivated environmentalism: two are religiously motivated, one is "a determined nuclear opponent", a third one is "grown up with agriculture and feel[s] close to nature".

Group members do not only pay lip service to innovation and the environment. They have already made considerable investments in it. Six have installed solar thermal panels (mostly for hot water) and / or photovoltaics, three more have such systems under construction. A few invested in heat pumps, a wood heater or have equipped their house with heat insulation. As one participant puts it:

It is my aim to rearrange the building in terms of optimum [energy] use. Better heat supply and heat insulation – a combination of solar thermal water heating and a fuel cell would be ideal. Later, this could be combined with photovoltaics, and I'd achieve some form of self-sufficiency.

Self-sufficiency – or autonomy – turns out to be an important idea. Participants stress their desire to be independent from the grid and thus safe from grid failure or blackouts. Autarchy is a dream for many. Autonomy is spontaneously associated with fuel cells even if, at the moment, they run on gas from the grid. When participants become aware of this problem, it is discussed with great interest and balanced against the dependence on fuel oil and the electricity grid that is implied by conventional solutions. The desire for autonomy goes together with a remarkable degree of distrust in anything that cannot be controlled oneself. This becomes very noticeable when participants (in the context of constructing a hierarchy of power supply options) discuss „green power". Green power is unanimously rejected because "I don't know what kind of green power it is", "anyone who believes it is dim-witted", "I fail to see why I should pay more when I don't know where the electricity comes from".

Distrust, however, can be overcome. Participants voice satisfaction that the field test is done by a company that is trustworthy because it is big, well-known and rooted in the region. These qualities make it an acceptable partner.

The desire for personal control becomes also visible when participants argue against contracting, because they want to possess their heating system and "tinker with it". They perceive it as a space for self-actualisation:

„House technology is space for creativity, something you can shape, you can unfold your talents, find solutions. It's not only „It's working, and that's all I'm interested in". No, I want to be ahead, find better solutions than others."

Thus taking pride in the new technology and their competence in handling it, group members are also willing to act as multipliers and inform others. When asked whether they would like to show their fuell cell to others, if they had one, they eagerly agree.

„I look at my solar thermal panel every day. It would be the same with that [fuel cell] system. I'd tell everybody: Hey, come on, look, I show you something."

The teachers among the participants want to pass the information on to their students, and everybody says at the end of the interview that they enjoyed very much exchanging information within the group.

This kind of enthusiasm seems to be specific for the male viewpoint. Group members state that it had been difficult to convince their wives of taking part in the field test. The wives, they argued, had not shared their fascination with the technology or their idealism for the environment, but demonstrated a more pragmatic outlook: How reliable was the new technology? How often would it have to be repaired? Was there a danger to sit in the cold? What tangible benefits would come from it?

The discussion points to the importance of the gender aspect in marketing technology. The women's resistance may stem from two sources: a different interest profile due to a different socialisation, and the responsibility for reproduction work. The socialisation of most women in the generation of the group members did not include raising their interest in technical issues. It is therefore hard for them to share their husbands' enthusiasm. What is more, the wives' reproduction tasks imply that they feel responsible for the family's comfort, and they would be hit more than men by the daily hassles that would come from faults and repairs of the heating system. To market a new technology successfully, it is therefore important to adapt it to the demands of reproduction work.

Finally, there are economic considerations. None of the participants hopes to benefit financially from the field test – they volunteered out of enthusiasm and stress that they want to give the new technology a boost, even if this needs some financial investment. In one group, it is discussed controversially whether economic aspects should be a criterion at all. It is argued that economic cost and benefit is not (and should not be) the central criterion in buying goods. Other aspects like comfort, security, or symbolic reasons were just as important. However, there is general agreement that new solutions need to become economically feasible in the long term. An insatisfactory price-performance relation is tolerated in the development phase, but not for long. Furthermore, economic aspects are thought important for the "ordinary" citizen who does not share the enthusiasm of the group members. Interviewees do not demand high financial returns. Feasibility is enough for them – it must "pay off" after some time. Economic considerations are therefore present, but do not feature too prominently and are thought to be important especially in later phases of technology development when a mass market is tackled.

The motives, goals and interests of focus group members fit hypotheses 2 and 3 with some adjustments. Group members are "pioneers" with a mission to promote the new technology and its environmental benefits. They own "trigger technologies" and are now looking for more. Environmental aspects are important and there is optimism that environmental problems can be technically solved. Economic feasibility is necessary in the long run, but economic motives do not feature prominently. The "pioneers" are eager to spread the word and exchange information and views with each other. Outward visibility is not important for this purpose.

Contrary to hypothesis 2, autonomy is an important motive and fuel cell MicroCHP is measured against it. One possible explanation is that the "self production" of electricity in the fuel cell is very tangible while dependency from the gas grid only becomes clear at second sight. An additional finding is that "windows of opportunity" like heating replacement, can be used to sensitise potential users for new technologies.

4.2.2. Support and Barriers

The first and foremost barrier, specifically in the current state of technological development, is of an infrastructural nature. Most of the applicants, including most of the focus group members, were sorted out because cellars were just too small or low, or doors to narrow to mount the fuel cell system. Correspondingly, focus group members insisted that the systems become smaller.

The question about fears with respect to fuel cell MicroCHP reveals other barriers. First, the immaturity and possible „teething troubles" of the systems are a commonly articulated concern. People fear frequent faults and needs for repair. They are willing to incur a certain degree of risks, but do not want to function as „guninea pigs". Secondly, the uncertainty of costs seems deterring. People cannot assess neither investment costs nor operation and maintenance costs and therefore find it difficult to make a sound calculation and check whether the installation may be economically feasible. A third, albeit not so prominent concern is safety.

It is striking that all the barriers are related to the current, immature state of the technology. This does not mean that there will be no more barriers once fuel cell MicroCHP is ready for mass production. But it is difficult to assess possible future barriers today because they are eclipsed by the current problems.

What are supporting factors that can be weighted against the barriers and help to overcome them? It is crucially important to protect users from risks, may they be of a financial or technical nature. A contracting arrangement may be helpful for this. The contractor runs the plant, bears the financial risk and guarantees heat and power supply for a price fixed by contract. Group members welcome such a contracting system for the development and testing phase. They feel it would protect them well from risks. However, with few exceptions they hesitate to accept contracting in the long run. Once the system is mature, most interviewees prefer to own it themselves. Ownership is an important dimension of the autonomy that is sought.

Information plays a more ambigous role. On the one hand, the fact that interviewees are relatively well informed and have often been dealing with energy topics for a longer time seems to indicate that information supports interest. Interviewees were grateful for the opportunity of exchange with others that was provided by the group discussion, and for the information they received at the tour. They suggested that they be kept informed on a more regular basis and that information about recent developments and successes be published in company newsletters. On the other hand, it was disillusioning to participants when they received detailed information on the actual state and performance of fuel cell MicroCHP, as will be discussed below.

The results back, in general, hypotheses 5 and 6. Suitable infrastructure is necessary, its lack a decisive barrier. Information supports interest – provided, however, that the system is mature enough that the information is not disappointing. Little is there to be said about support schemes, because costs are yet incalculable so it is unclear what type of support programme would be needed. A new aspect is that contracting arrangements can help to overcome insecurity during the development phase.

4.2.3. Satisfaction

During the group discussion, interviewees had the opportunity to see a fuel cell-based MicroCHP in action and get recent information on its state of development. This information resulted in disillusionment among most participants. They had previously assumed that the product would be ready for the market much earlier, and had underestimated technical problems and costs. Some had hoped to be able to buy a fuel cell-based MicroCHP in one or two years. Now they learned that they would not go into mass production before 2008. The information did not result in dissatisfaction with the technology in general, but in disappointment about not being able to purchase it soon.

To avoid this disappointment, it seems important not to raise false expectations. If pioneers for a field test are needed, communication should be addressed only to a small group of possible pioneers and the status of the technology and aims of the field test must be clearly communicated. It is advisable to only address a wider public once the "teething troubles" are overcome.

It is therefore not yet possible to comment on hypothesis 4, because its provision, the trouble-free functioning of the technology, is not yet given.

5. Governing technological change: Some conclusions

Technological change does to a relevant degree depend on pioneer users. So does industrial transformation, insofar as it is driven by technological change. What pioneer users do for the diffusion of an innovative technology is much more than accept or reject it. They are ready to actively promote a technology and raise others' interest - but they are anything but uncritical mouthpieces. Pioneers critically follow the development process, demand to keep informed, make recommendations and communicate successes as well as failures to others. They can be a source of valuable advice to developers. When attempting to govern transformation, it is therefore helpful to know the pioneers and to design suitable programmes to support their pioneering action.

Knowing the pioneers. In the case of MicroCHP, first impressions show that the potential target group for MicroCHP in its early stage is a dedicated group with good education, high social status, enthusiasm for the topic and therefore the willingness to incur a certain degree of risk. They are males with predominantly technical professions or education, and have comparatively large families. They are not the outsider innovators portrayed by Rogers (1995). Rather, they have important characteristics of the "early adopters" that are described by Rogers as arising in the second innovation phase. "Early adopters" are socially well integrated, serve as a role model for others and communicate the new ideas.

Some of the fuel cell pioneers' fascination is specific to the fuel cell (especially the visions of a hydrogen economy), but there are more general motives, like environmental concern, autonomy and fascination with cutting-edge technologies, that make this group a target group also for other technologies. This is illustrated well by the fact that many of them already possess others or have been thinking of purchasing them. The fuel cell pioneers are therefore also possible target groups for other MicroCHP types.

Targeting the pioneers. Governing technological change implies designing political programmes that attract pioneer users and support them in their pioneering activities. First results of this study show that one of the pioneers' core concerns is reliable, trustworthy information. Information should tackle the areas of concern like safety, economic performance, and reliability. Regularity of information and the possibility for feeedback and dialogue are greatly valued. In order to avoid disappointment, information on the state of microCHP development should be veracious and avoid to raise false expectations. Information on sociodemographic data, motives and values of the pioneers, as presented above, may be used to design media, style and content of an information campaign suitable to the target group.

On the other hand, if the goal is broad diffusion of a technology, it is as important to find out who is *not* among the pioneers. That applies especially to the striking gender imbalance. Even if the pioneers users are predominantly male, they live in families and it can be assumed that investment decisions are discussed within the family so that women have an important say in the final decision. If a technology does not appeal to half of the population, its diffusion chances are limited. It is necessary to identify the "blind spots" in the technology and / or its diffusion strategy in order to find out what could make it attractive for women. Possible apects to explore are reliability and convenience.

Another conclusion is that it is important to value the pioneers' contribution, which may be done financially or ideationally. As stated in the studies on "analogous" cases, public support schemes also have an element of ideational recognition. At the very least, recognition means protecting users from risks so that they need not feel as "guinea pigs" of technological development. For such protection, it is helpful to design appropriate contracting or service schemes that remove from users the burden of maintenance.

A broad diffusion of MicroCHP depends strongly on the costs and technological barriers of installation and grid connection and on the financial rewards for feeding electricity into the grid, topics that have not been touched here but will receive more detailed consideration in an upcoming TIPS volume on MicroCHP scheduled for 2005.

As with governance of technological change in general, targeting pioneer users is an enterprise that needs cooperation of various players, including microCHP manufacturers, electricity companies, installers and their organisations, the state, and possibly NGOs. While the improvement of the technology lies in the hands of the manufacturers, electricity companies can aid in its marketing and simplify grid connection. The state and NGOs may provide independent information, the state can give financial incentives and set the political framework for grid connection, grid use and feed-in conditions and tariffs. Installers need special training to be able to install and maintain microCHP and give competent advice to users.

Future research issues. Future research within the TIPS project will describe the pioneer group more representatively and also try to collect information about the "blind spots" by means of a survey of about half of the 1000 applicants. A further step will be to study the interaction between technology and the user in a broader way. To achieve a sustainable energy future, it is not only important in which way a user supports, promotes or rejects potentially sustainable technologies. It also matters in which way he interacts with these technologies, and whether this interaction forms part of a sustainable lifestyle. We have to think not only about technology acceptance, but also technology handling, technology-induced behavioural changes or seemingly unrelated lifestyle issues that may nevertheless make an efficient technology obsolete. To put it boldly, MicroCHP will not help us if users do not accept cuts into their autonomy for load management reasons, if MicroCHP is used to heat ever bigger badly insulated houses, or if it blocks other sustainable technologies (like solar energy). One part of the TIPS project will therefore be to study how people use the technology, and which, if any, attitudinal and behavioural changes are triggered by it.

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