Researching Innovation and Transformation Dynamics in the Electricity System: The Example of Micropower in Germany[1]

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Abstract

The analysis of complex innovation and transformation dynamics in the electricity system requires an interdisciplinary approach. As an example, the diffusion of small-scale units to generate electricity and/or heat (micropower) is assessed, using the technological innovation systems (TIS) framework as suggested by Jacobsson and others. An analysis of the structural dynamics and of the functions is presented. The paper concludes that two separate albeit interlinked TIS for such small-scale generation exist in Germany: one for renewable energies, and one for micro combined heat and power generation (micro cogeneration, or micro-CHP). While the renewable TIS already succeeded in market formation, the micro-CHP TIS is still in a formative phase.

Introduction

The generation and consumption of energy is associated with substantial damages for the environment, the climate and the economy. For a sustainable electricity system to come, significant improvements in energy efficiency and the substitution of fossil energies by less problematic energy carriers such as renewables are required. Innovation, the process of generating novelty, can be assumed an integral part or even a precondition of such transformation. Innovation includes not only technological advances of products and processes, but also changes in the organisational and conceptual dimension of electricity provision (Voß et al. 2003). Accordingly, innovativeness should rather be conceptualized as a socio-technical innovation cluster and not as a technological innovation alone. The paper applies this conceptualisation idea to the case of micropower and asks for the conditions for a successful diffusion of such an innovation cluster.

Micropower is the production of energy on the level of individual buildings or local communities. Micropower comes in various forms and different stages of technological development and market

[1] This paper – in particular the case study for Germany – is largely based on a book chapter comparing micropower diffusion in UK and Germany, co-authored with Jim Watson and Raphael Sauter (Praetorius, Sauter & Watson forthcoming). Funding by the German Ministry for Education and Research (BMBF) within its Socio-Ecological Research (SÖF) framework program is gratefully acknowledged.

introduction. Solar powered photovoltaic (PV) systems produce electricity, solar thermal systems provide hot water and space heating, while micro combined heat and power (micro-CHP) units provide both electricity and heat, usually fuelled by natural gas. Heat pumps use energy stored in the ground for space heating, and micro turbines provide electricity, either powered by wind or water. Micropower is expected to contribute to the transition of the traditionally centralised energy supply system towards a more sustainable energy system. It has the potential to increase overall efficiency, to reduce CO_2 emissions and to contribute to a more reliable energy system and a more competitive energy market. The generation of power close to the point of use in individual homes and the subsequent decentralised structure of supply reduces the need to transport power over long distances and could increase the reliability of power supply. Micropower increases consumers' choice about their energy provision and has the potential to increase competition depending on the mode of deployment (e.g. by the introduction of energy service contracts for micropower technologies). Despite these expected benefits and a considerable potential to contribute to the energy supply, the rate of deployment of micropower has been slow in Germany. Around 1 million units are installed in Germany, with solar thermal hot water systems constituting more than two thirds of all units installed.

The successful diffusion of such innovation depends on many factors. Innovations are accompanied by uncertainty and risk. Information flows and learning deviate from the theoretical optimum of complete transparency. Path dependencies may emerge, which lead to suboptimal innovation results. For understanding the transformation of electricity systems, it is thus necessary to understand the heterogeneity of the underlying innovation processes, the factors that influence them and the way they interact with each other. What is needed is a configuration that works – which is a complex undertaking.

The analysis of such configurations and complex dynamics requires a multidisciplinary but integrated approach. Such an approach has been searched for in the ongoing research project "Transformation and Innovation in Power Systems" (TIPS) for several exemplary innovations.[2] Case studies are being caried out on the three topical empirical areas distributed vs. central generation, emissions trading and behaviour of actors in liberalized markets. In the first area, we are assessing the diffusion process of carbon capture and storage (CCS) as central generation innovation on the one hand, and micro-CHP as distributed generation option on the other. Emissions trading is being analysed with respect to its innovativeness as instrument but also regarding the innovation effects induced in the concerned industry. Behaviour is an issue in all areas, but a specific focus lies on consumer behaviour and barriers to electricity efficiency. An energy system and environmental analysis has been performed for technological innovations (CCS, micro-CHP), complemented by assessments of institutional and market structures, policy structures, and by economic modelling of future investment decisions and impacts on carbon dioxide emissions.

The integration of such a multidisciplinary approach into one research concept is probably as complex as the research topic itself. There are a few attempts for such integration (see Voß & Fischer 2006 for an overview), for example attempts to conceptualise and compile the conditions of long-term change in large technical systems like electricity provision (Kemp 1994; Mayntz & Hughes 1988), or the multi-level and multi-actor concept of socio-technical change as developed for example by Rip & Kemp (1998) and Geels (2002). Other approaches are more directly based on the idea of path dependency and lock-in, but also the idea of a self-sustaining process of cumulative causation (Jacobsson & Bergek 2004) once an innovation is

[2] See www.tips-project.de for further details and outputs of the research team.

successfully implemented in a niche. In this paper, we use the analytical and heuristic framework developed by Jacobsson & Bergek (2004) and Bergek, Hekkert & Jacobsson (2006) in order to understand the dynamics of technological innovation systems (TIS). The TIS approach looks at structural dynamics in the innovation environment, trying to explain them by looking at a set of functions required for the creation and success of a new technological system. We apply this framework to the case of micropower in Germany.

It soon becomes evident that there exists no single TIS for micropower in Germany so far. In fact, the "subsidiary" system for small renewable technologies appears to be much more developed compared to the one for micro-CHP. In the remaining paper, we therefore trace and analyse the evolution of the structural components of the two related TIS in Germany. We examine the fulfilment of TIS functions in order to explain the differences between renewable and non-renewable micropower. The paper is based on recent studies on the German TIS for renewable technologies (Jacobsson, Sanden & Bångens; Jacobsson & Lauber 2006) and an interview-based study of the emerging market for micro-CHP (Pehnt 2006; Praetorius 2006; Praetorius, Sauter & Watson forthcoming) which were analysed and updated, based on interviews, documents and data information.

Analytical Framework

Jacobsson & Bergek (2004) argue that "for the transformation of the energy system to take place, new technological systems with powerful functions need to emerge around a range of new energy technologies". Central to the application of the TIS framework is the definition of a technological system in order to delineate the analysed subject. Jacobsson and Bergek refer to a definition originally developed by Carlsson and Stankiewicz which defines TIS as "network(s) of agents interacting in a specific technology area under a particular institutional infrastructure for the purpose of generating, diffusing, and utilizing technology." (Carlsson & Stankiewicz 1991: 21). This definition does not restrict a TIS to a specific technology such as wind turbines or solar cells, but to a 'specific technology area', such as the scale of technology application, i.e. the installation of micropower technologies at the domestic level.

Two phases of TIS development can be distinguished: the formative phase and the market formation stage. In the formative phase three key processes are relevant: the entry of new firms and other organisations, formation of networks and institutional alignment (Bergek, Hekkert et al. 2006). The entry of new firms is important to provide resources and fill potential gaps in the value chain. The emergence of new firms may also impact on political networks and advocacy coalitions in support of the new 'technology specific area'. These are crucial for the legitimisation process of a new technology and institutional alignment. Existing institutions are built around incumbent technologies and changes are therefore critical for new technologies to be installed. Characteristic features of this phase, which can last for decades, are high uncertainty faced by investors and potentially big impacts of accumulated small changes.

In order to go beyond a rather descriptive level of analysis of technology system structures, Bergek, Hekkert & Jacobsson (2006) suggest the assessment of their performance using a set of functions. Perhaps the most important precondition (and thus function) for a successful TIS is a proper level of legitimacy, which may find its expression as public concern, social acceptance, interest groups and, in the best case, as governmental statements and actions such as policy target. The development and diffusion of "new" knowledge is crucial for a TIS to succeed, with public R&D policies acting as a significant driver

(Jacobsson & Lauber 2006). Effective legitimation and substantial R&D resources are important factors to create a basis and to motivate *external resources* such as investment capital and distribution structures to foster the respective technology ('resource mobilisation'). For example, small developers of technology may be purchased by larger companies with developed distribution structures that are willing to further invest in new innovative technologies. Legitimation and knowledge structures also impact on expectations and thus on the direction of search of *new* potential suppliers of small-scale generation technologies. Another important function is captured under 'entrepreneurial experience' that includes the entry of new actors and the diversification of activities of incumbent players. This leads to the function of market formation measured in terms of market size and its underlying drivers which could be strengthened by government policies. Finally, a new TIS can cause externalities in terms of knowledge flows or the increased political power of technology specific advocacy coalitions (Jacobsson & Lauber 2006). Table 1 summarises these functions and the indicators used to measure the fulfilment of these functions in this paper.

Table 1: Functions and indicators for the analysis of an emerging TIS

Function	Indicator
Legitimation	Attitudes / social acceptance
	Interest groups
	Lobbying
	Consumers
	Governmental statements
Knowledge development / diffusion	R&D activities / expenditures
Resource mobilisation	Capital
	Skills
Expectations and direction of search	Growth estimates
	Regulatory pressure
	Articulation of demand
Entrepreneurial experience	New entrants
	Diversification of activities of incumbents
Market formation	Number, type and size of markets
	Drivers
Externalities	Knowledge flows
	Political power

Source: based on Bergek et al. (2006)

Structural Characteristics of the German Micropower TIS

Until the early 1990s, micropower in Germany consisted of a handful of firms screwing PV and solar water panels on a couple of single house roofs. In terms of implementation numbers, this picture had changed substantially by 2006, even though the share of total energy supply by such small-scale energy systems remains negligible. Nevertheless, Germany is an interesting showcase of a successful market introduction programme for innovative energy technologies – and also of powerful institutional barriers.

Micro electricity generation technologies implemented in Germany in individual households mainly comprise roof-mounted PV systems and micro-CHP, usually in the form of reciprocating engines, fuelled by natural gas. Small Stirling engines could also run on renewable fuels, once they are available in Germany. They are about to enter the market but still have to get over a number of barriers related to accreditation. Micro wind turbines are not much of an issue in Germany, probably because they cannot compete with large wind turbines, installed to form wind parks. With regard to heat generation, innovative technologies primarily include thermal solar installations and ground source heat pumps, and micro cogeneration.

With respect to the general institutional setting and respective alignment processes, two major external changes took place in the last decade: first, the 1998 liberalisation of the German electricity market, and second, much later, the implementation of a regulator, the German Federal Network Agency (Bundesnetzagentur, BNA) in 2005. Despite this late federal regulation effort, financial support systems, grid access procedures and remuneration rules for renewable energy technologies have been in place for a long time. They are mostly standardised, and since the 2000 Renewable Energy Sources Act, small renewables even enjoy priority dispatch in the case of grid bottlenecks.

There are also regulations for micro-CHP: the first (2000) and second (2002) CHP laws oblige grid operators to connect all CHP installations and to buy the electricity provided by these installations at a certain market-oriented price.

A few numbers will help to gain an idea of the significance of the TIS discussed here. In terms of the construction and use of solar cells (modules) and wind turbines, Germany ranks among the leading countries in the world. Wind energy took off with the Feed-in Law in 1990, while PV cells started to follow a decade later, seemingly pushed by the new Renewable Energy Sources Act of 2000. The Renewable Energy Sources Act guarantees operators of renewable electricity generation technologies preferential treatment for their electricity feed-in as well as a fixed, generous feed-in remuneration for a fixed duration of usually 20 years. Similarly, solar thermal panels enjoy generous financial support, with the result of growing numbers of installations; altogether, with 2,960 GWh of heat output in 2005, they even succeed in outperforming PV-based energy generation (BMU 2006). Interestingly, heat pumps are also installed in increasing numbers, despite the fact that there is only little financial support, depending on regional policies and utility programmes. Micro-CHP also shows increasing numbers since liberalisation but with an estimated output of 240 GWh (or 0.04 %) to total electricity generation, it is contributing just a fraction of the generation by renewable technologies so far. The next section will show some reasons behind this unequal development.

Functions and Indicators of the German Micropower TIS

The last section has demonstrated that micropower enjoys increasing attention in Germany and benefits from initial institutional alignments. However, it is far from a breakthrough in terms of market formation. In this section we use the system functions approach to better understand the underlying dynamics and the related blocking and inducement mechanisms.

Legitimation

Both renewable energies but also most of the micro-CHP units available on the market allow to improve energy efficiency, to substitute for environmentally detrimental energies and thus to cut CO_2 emissions as compared to the conventional mix of electricity generation in Germany and usual home heating systems, as the life cycle assessment by Pehnt (2006) shows. In an environment which is increasingly sensitive to climate change risks, these features should find their expression in a corresponding level of societal legitimation for deployment and promotion activities.

Indeed, renewable energy enjoys a high level of legitimacy in Germany: Chernobyl, the climate change debate, and the upcoming scarcity of fuel resources let to a high level of public concern which became articulated in the form of pressure from parliament, interest groups, and lobbying (Jacobsson & Lauber 2006). The German government announced its intention to increase the share of renewable electricity to 12.5% in 2005 and to at least 20% in 2020 (BMU 2006). This forms the basis for market introduction and other financial support programmes. Analogously, renewables enjoy considerable administrative capacities: within its Directorate-General "Climate Protection, Environment and Energy, Renewable Energies, International Cooperation", the Federal Ministry for the Environment employs a whole directorate with 5 divisions and 47 employees (excl. support) to work on renewable energy. Jacobsson & Bergek (2004), Jacobsson, Sanden & Bångens (2004) and Jacobsson & Lauber (2006) give a detailed account of the underlying very successful process of network formation and lobbying for a feed-in remuneration for renewables in Germany since the 1980s.

By comparison, heat pumps have little advocacy, and micro-CHP is mostly treated as the "little brother" of CHP in general, which is an advantage as CHP has a very powerful lobby, but also a disadvantage, as small CHP is not in the focus of this lobby. In fact, a strong advocacy coalition[3] formed around local cogeneration as a consequence of liberalisation and its loss of competitiveness and put pressure on policy. This resulted in the first (2000) and second (2002) CHP law and the obligation for operators to connect all CHP and to purchase their electricity output. Thanks to the fuel cell lobby, small-scale CHP also benefits from these laws, with even higher bonuses granted to them.

Similarly, public acceptance for renewable energy is comparatively high, while there is no information to be found on micro-CHP except for the case of fuel cells. A first analysis of fuel cell pioneers conducted by Fischer (2006) shows that these pioneers are a rather specific group of people so that the results are difficult to generalise. Fuel cells are interesting for well-educated technology fans with a desire for independence, but even these pioneers complain about cost and reliability of the technology.

Legitimation could also arise from other values attributed to energy technologies, such as decentralisation, which is supposedly a "more democratic" form of energy system, see (Pehnt et al. 2006). Other sources could include independence from price fluctuations on the energy market, or from suppliers via "self-generation" of heat and electricity. These (and other) values impact on acceptance levels by household energy consumers. However, decentralisation is not a value per se in Germany - it is rather taken as a side effect of decisions taken to invest in particular technologies. By contrast, independence is a concept that is gaining momentum. In the case of renewable energy, this independence builds on the availability of solar irradiation and ground heat and biomass. In the case of micro-CHP, there is no such independence as long as the technology is gas-fuelled. To sum up, renewable energy technologies appear to be much more reputable amongst households and society in general than micro-CHP.

Development and Diffusion of Formal Knowledge

[3] The advocacy coalitions comprises, among a number of politicians and researchers, of industry and local utility associations like AGFW, B.KWK, VKU, as well as BUND, an environmental NGO, and the trade union ver.di. On the international level, COGEN Europe is a very active advocate.

In Germany, an enormous supply of public resources resulted from the legitimacy level of renewables: first, for technology development, and second, for market introduction via demonstration programmes. More importantly, there has been a long-standing investment support programme plus a financially attractive feed-in remuneration for electricity from renewables. Federal R&D Policy was very successful in initiating the creation and advancement of formal knowledge; its support prompted an increasing number of firms and research institutes to enter the market and to develop design options.

The picture looks somewhat different for the case of micro-CHP. A policy towards micro-CHP does not exist. Although the programmatic orientation of federal policy gives some weight to the expansion of CHP in general, micro-CHP is not explicitly considered part of a future vision of climate-friendly energy provision in Germany. Larger plants for industrial or district heating applications are generally of higher political interest. Sometimes this is explicitly declared on economic grounds; sometimes it can be related to the political influence of municipal CHP plant operators on German federal policy. Market introduction measures (CHP law, tax alleviations, etc.) therefore mainly target CHP in general with some extra provisions for small-scale plants. R&D funding for micro-CHP is overwhelmingly devoted to the development of fuel cell technologies and, to a lesser extent, to virtual power plants. Micro-CHP as such, or technological variations such as reciprocating or Stirling engines or micro turbines, are not a funding area for public R&D support (Cames et al. 2006). In consequence, there is little development and diffusion of knowledge to be observed.

Resource Mobilisation

The effective legitimation frame and substantial RD&D resources had a strong impact on the markets for solar thermal panels and PV. The high levels of support for market introduction and the generous feed-in tariffs for PV attracted investment capital for production sites in Germany, kick-started by two major investors Shell and ASE in 1998 (Jacobsson & Lauber 2006). Renewable energy technologies are an attractive area for young engineers, and the level of capital and skills available is significant. Today, distribution and marketing structures are well developed, with numerous information sites and services, and large amounts continuously invested in new production sites.

In the case of micro-CHP, only two major technology supplier invested successfully in the development of skills, production sites and distribution systems. Senertec is currently the most successful and well-known vendor of micro-CHP units so far, and aims at the production and delivery of 3000 units per year. It set up a sophisticated distribution system, with 30 so-called regional centres all over Germany, and around 280 sales partners with cooperation agreements, as well as framework contracts concluded with energy and Third Party Financing companies. The Dachs is marketed to household customers through lifestyle brochures, a Dachs fan club, and so-called Dachs parties, i.e. information evenings in the house of a Dachs operator for “fans” and potential buyers. Power Plus, the other producer of reciprocating engines, ventured later into the market and has not yet been able to copy the Dachs success with its Ecopower unit. In the future, it hopes to benefit from the established distribution system of Vaillant, one of the large boiler companies and fuel cell developers in Germany, which purchased Power Plus in early 2004. All in all, the micro-CHP segment in general has not been able to mobilise skills and resources to the same extent as the renewable fraction.

Expectations and the Direction of Search

Analogously, the market expectations differ considerably. With an increasing level of public attention and policy support for renewable energy technologies, including generous financial support schemes, uncertainty and economic risks of potential users and producers decreased. Growth estimates for this sector are high and programmatically supported by government policy declarations for a continuous increase of the share of renewables in the future. The Feed-in Law and its successor created enough regulatory pressure to create a secure market for investors. All in all, this is a self-reinforcing dynamic.

By comparison, in the case for micro-CHP, besides the bonus payment regulated by the CHP law, grid connection and feed-in conditions are subject to bilateral negotiations. Feed-in remuneration is volatile (with the power exchange) and by far not as profitable as for renewables. Accordingly, the incentives for new firms to move into solar cell production are high, whereas there is little drive in the market for small scale CHP.

Entrepreneurial Experience

The entrepreneurial experience is largely driven by the above contextual factors. As a result, diversification and variety is fairly large in the case of renewable energy technologies, and the number of firms producing PV cells and solar thermal panels increased continuously over the last two decades (Jacobsson & Lauber 2006). The solar industry is booming, and stock market valuations for the respective technology firms are at a high level. Today, about 50 companies are active in the production of PV and solar thermal modules.

In the case of micro-CHP, few technologies have been offered so far, and the market is dominated by two firms. Senertec has promoted its “Dachs” since 1996 and produced its 15,000th unit in 2006. Power Plus started marketing the “Ecopower” reciprocating machine in 1999 and has implemented some 2000 units since. Foreign Stirling technology developers, like WhisperTech, are also inquiring into the German market but still struggle for technological admission.

In terms of investment strategies and ownership, technology developers like Senertec and Power Plus, along with a number of fuel cell developers have been purchased by larger boiler or micro-CHP technology firms. In the case of Senertec, the British Baxi Group – also a fuel cell developer – is interested in the elaborated German distribution network of Senertec. Just like Senertec itself, the Baxi Group may argue that the more micro-CHP is being disseminated – regardless of technology or firm – the greater its recognition in society. Thus, the chances of selling further units of their own original technology are increased. Power Plus is now part of Vaillant, the traditional boiler companies – a promising cooperation, as micro-CHP plants could be marketed as a “better” boiler that also produces electricity. Such a marketing strategy may simplify the deployment of micro-CHP for various reasons. Firstly, consumers are mostly unaware of CHP and often do not understand it properly. However, they could be informed about micro-CHP plants easily when they need to replace a boiler since boiler manufacturers also offer micro-CHP products. In addition, micro-CHP is economically promising, and much easier to install, when it fully replaces a boiler.

Market Formation (Entry on the Demand Side)

For its successful diffusion, any innovation needs to attract the demand side. The upfront cost of all micropower technologies, however, are unfavourable compared to conventional energy supply systems, i.e. purchasing electricity from the grid and heat from a standard boiler. High up-front investment cost and a long payback time are often unattractive to private house owners. In the case of micro cogeneration, a number of other market failures such as the principal-agent problem add to this fact. The CHP law provides that electricity fed into the grid receives a "usual price" based on the average base load electricity price traded at the European Energy Exchange, plus a bonus payment of 5.11 € cent/kWh fed into the grid. Furthermore, electricity[4] and natural gas[5] tax exemptions are granted. However, this does not cover generation costs which are in the range of 8-12,5 €ct/kWh (Pehnt et al. 2006), which is in line with the observation that micro-CHP has not taken off yet. As a consequence, only a small number of pioneers, motivated by other than purely economic reasons, start off such a market as long as there is no public support scheme beyond the CHP bonus (Fischer 2006).

Indeed, perhaps the most successful driver of market formation is the German feed-in scheme for renewable energies as provided for in the Feed-in Law of 1990, followed by the Renewable Energy Sources Act of 29 March 2000 (with some revisions in 2004). Under this act, electricity from solar PV receives between 40 and 50 € cent/kWh fed into the electricity grid. Other renewables - depending on size, type and other parameter – receive roughly between 6 and 12 € cent/kWh. As a result of these incentives, electricity generation from renewable energies more than doubled between 1999 and 2005 (from 30 to 62 TWh), and the share of renewables in electricity generation increased continuously, reaching 10.2% in 2005. This was mostly accounted for by hydro and wind power, despite the growing number of micropower installations. The cumulative capacity of PV cells, for example, grew from 2 MW in 1990 to more than 1,500 MW in 2005, but PV still accounted only for 0.16% of total electricity generation, or 1,000 GWh, in 2005. Figure 1 summarises the capacity development for PV cells, solar thermal panels and heat pumps since 1990. It shows that thermal technologies gained momentum much earlier than solar PV.

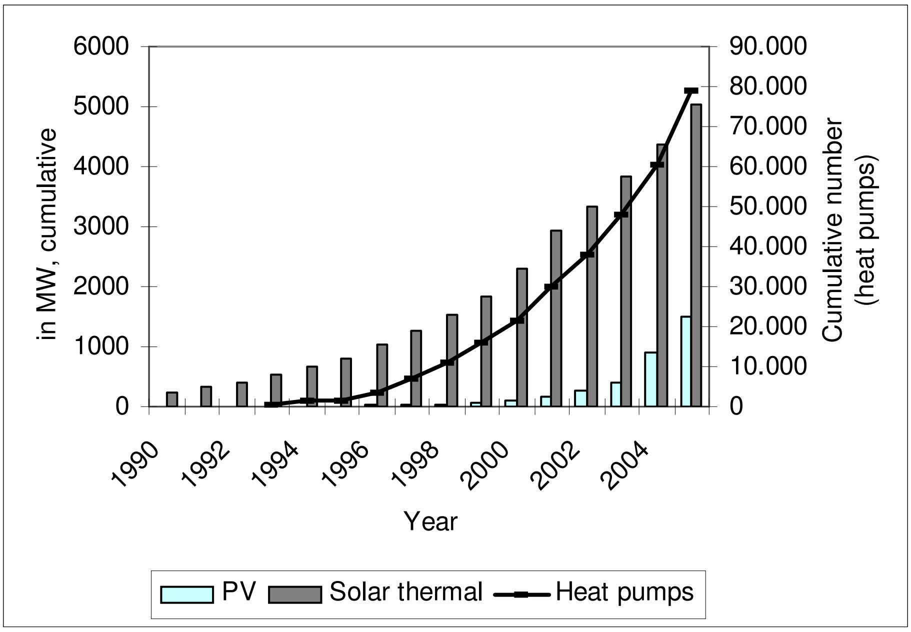

Figure 1: Capacity development of small renewable energy technologies in Germany (cumulative capacities), 1990-2005, Source: BMU (2006).

[4] For plants below 2 MW capacity.

[5] Only for CHP plants with and average energy efficiency above 70%.

Increasing numbers of installations have also been made in the case of micro-CHP: All in all, about 20,000 units have been installed in 2006. In Fig. 2, the installation of new micro-CHP plants (< 15 kW_{el}) in Germany is estimated for the years 1990 to 1998 and 2002 to 2004. It shows that only very few micro-CHP plants were installed during the nineties, whereas, in recent years many more micro-CHP units have been installed. This trend is confirmed by the quantities of electricity fed into the grid under the new CHP law from 1 April 2002 onwards, as reported by the German association of grid operators VDN. From April to December 2002, new CHP plants smaller than 50 kW_{el} fed only some 15 GWh into the public grid, while the quantity increased to 60 GWh in 2003 and 78 GWh in 2004. For 2011, VDN expects this to increase to 250 GWh (VDN 2006). The reason for this slow growth is that the feed-in remuneration for micro-CHP is not as generous as in the case of renewables, so that the market could not take off as much.

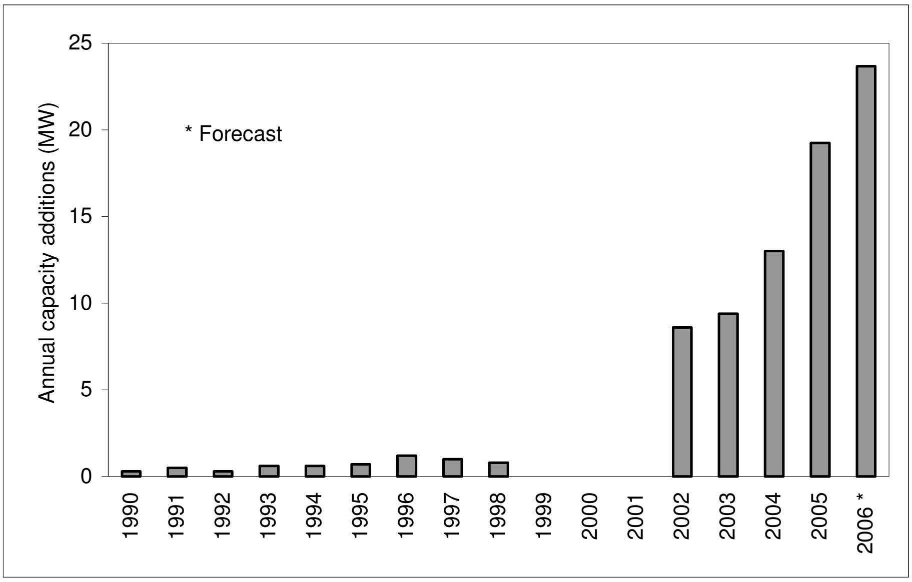

Figure 2: Total annual capacity additions of micro-CHP plants (< 15 kWel) in Germany from 1990 to 1998 and 2002 to 2004, Source: Pehnt & Schneider (2006), updated.

Externalities

Another side effect of the successful networking in the case of renewable technologies was the creation of externalities: Information on technologies and funding is broadly available and reduces uncertainty. Such guidance significantly reduces the cost of search and information, and together with standardised grid access procedure, it allows for uncomplicated investments. Again, micro-CHP is much less standardised and reliable in either search/information or connection cost. One potential positive externality for micro-CHP producers is that each successive installation, whether it uses a fuel cell or another reciprocating engine, might "pave the way" for the next unit.

Discussion of Dynamics, Inducement & Blocking Mechanisms

The aim of this paper was to present an example for an interdisciplinary approach to assessing the diffusion dynamics for an innovative energy technology. We showed that a well functioning TIS has emerged for the case of small (and large) renewable technologies. However, there is no single TIS for micropower, but rather two subsidiary systems for micro renewables and micro-CHP. Germany is characterised by a unique situation with very powerful lobbying and advocacy coalitions with links to both industry and politics supported by a strong scientific community. This setting promoted the idea of a "renewable energy future" within processes like the two Enquete Commissions on Climate Protection. These pressures demonstrated an ability to push and realise a "small" support scheme for PV roofs (1000 roofs programme) and generous feed-in tariffs at a time where electricity from renewables was marginal and nobody really expected such a take-off. As a consequence, positive feedback loops were established and a process of cumulative causation took place.

Drivers for renewable distributed energy technologies include the legislative framework, in particular concerning the regulation and remuneration of electricity feed-in, and the R&D focus on renewables. The existing networks (associations, members of Bundestag, Green Party) work very well and have helped to overcome occasional problems. Potential blocking mechanisms are competing design approaches and economic uncertainty, but development activities are still ongoing, and new developments in the area of PV cells confirm the expected trend of further cost decreases. All in all, distributed renewable technologies have lived up to expectations and have even gone beyond them.

In the case of micro-CHP, blocking mechanisms are more significant. These include a higher degree of economic uncertainty for consumers, the regulation of grid access and remuneration, but also high transaction costs associated with searching for information and administrative efforts. Large electricity supply utilities show little interest in micro-CHP technologies.

Lobbying for large scale CHP on the one hand and on fuel cells on the other have benefited micro-CHP in Germany to some extent. This explains, for example, why the fuel cell lobby managed to integrate a higher remuneration for small-scale CHP into the CHP laws. These changes do not focus on micro-CHP as such, but are rather meant to be an incentive for fuel cells to enter the market. Generally, there is not much interest in micro-CHP within the electricity industry: there is not (yet) a need to consider binding "energy service packages", as customers do not change suppliers anyway, and there is no scarcity of investment capital for large power plants, and grids are owned by the large utility companies themselves. Also, transaction costs for micro-CHP for the electricity industry are expected to be high in comparison to those for large (co)generation units. These structural components do not provide any incentives to push for changes in a complex regulatory system to support small generators.

To summarise, while micro-CHP technologies are partly successful in a small niche market, small (and large) renewable technologies are well ahead in terms of market formation. Institutional alignment activities and R&D policies induced entry of new firms into the TIS resulting in greater variety. Renewable technologies enjoy more acceptance than cogeneration, and also a higher degree of lobbying and networking. An advocacy coalition emerged long ago, while micro-CHP activities within the TIS are still undertaken by individual actors, not networks. Also, partly as a result, funding is more generous for renewables. Finally, the adjustment of the institutional setting is more advanced for renewables than for micro-CHP so far. All in all, the two 'subsidiary' parts of Germany's micropower TIS so far seem to exist side by side but with only few interactions and spill-over effects.

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