Barbara Praetorius

MICRO COGENERATION: TOWARDS A DECENTRALIZED AND SUSTAINABLE GERMAN ENERGY SYSTEM?

DIW Berlin, 14191 Berlin
Phone: 030-897 89-676, Fax: 030-89789-113, E-mail: bpraetorius@diw.de

Overview

Micro cogeneration – the simultaneous production of heat and power in an individual building based on small energy conversion units such as Stirling and reciprocating engines or fuel cells – is expected to increase energy efficiency on the level of household energy supply. A large-scale introduction of micro CHP may radically change the electricity system and turn consumers into power producers. At the same time, micro CHP could, if supported by favorable economic and policy conditions, represent a considerable market segment, promoting downstream innovations such as "virtual power plants", altered consumer awareness or new household energy management systems. This potential has to be evaluated with respect to its sustainability in both economic and ecological terms. The paper presents selected results of a case study of an interdisciplinary research team (Pehnt et al., 2006).

Methods

The case study considers the status quo and potential of micro cogeneration in Germany. The diverse consequences of a broader introduction of micro CHP for the energy market, the customers, the environment and the economy require an interdisciplinary investigation into the real benefits and barriers of micro CHP. We use various methods, including a life cycle assessment of ecological impacts, a model of its economic performance, and an institutional economics analysis of actors involved in (potentially) implementing micro cogeneration on a larger scale.

Results

In the public perception, high expectations are associated with the introduction of technologies such as fuel cells, while other – more developed – CHP options, such as Stirling and reciprocating engines, are hardly known yet. Correspondingly, perceptions and expectations on the level of government, industry, and science will impact on the level of policy support and incentives granted to micro cogeneration. The paper will discuss the status quo and perspectives behind this observation.

Currently, micro cogeneration represents a rather insignificant contribution to the worldwide power generation portfolio. Taking Germany as an example, we estimate that, by the end of 2004, a stock of about 60 MW micro cogeneration capacity was installed, producing about 0.04 % of overall electricity generation. Thus, though sales numbers are increasing, micro cogeneration is still in a very small niche market and far from being introduced to a broad market. An assessment of available energy scenarios shows that the future contribution of micro cogeneration to the German energy system is expected to remain comparatively small, even in “optimistic” scenarios. The expected decrease in heat demand, for example, will reduce the potential for micro cogeneration applications. On the other hand, micro cogeneration also faces competing – and ecologically attractive – supply options like larger CHP, based, for example, on biomass, solar heat, or electricity import from renewable sources. Altogether, in a sustainability scenario for Germany, micro cogeneration is expected to provide some 3 % of the German electricity demand by 2050.Its potential depends on demand drivers such as population development, building stock and structure, heat demand, and the structure of the heating systems.

With respect to the **ecological performance** of micro cogeneration, we conducted an environmental life cycle analysis (LCA) of micro cogeneration units, particularly of gas-fuelled ones. Compared to separate production, generating electricity and heat in micro cogeneration units leads to primary energy savings and greenhouse gas (**GHG**) benefits. Based on natural gas as a fuel, GHG emissions per kWh electricity and heat produced are typically 20 % (up to 45 %) lower in comparison to condensing boilers and combined cycle power plants. In some cases, for example of technologies with low electrical and total efficiency, however, only little – if any – GHG mitigation can be achieved, compared to separate heat and power production with state-of-the-art technologies. Compared to district heating, micro cogeneration does not offer significant energy and GHG emissions advantages. District heating systems have the disadvantage of high heat-distribution losses; but these are offset by significantly higher electrical efficiencies compared to micro cogeneration. Therefore, we regard micro cogeneration not as a competing, but rather as a *supplementary* technology to district heating, meaning that it should is optimally applied in cases where larger district heating is not viable for infrastructural or economic reasons. In rural areas, for instance, building density is often low, causing long transport distances and thus high investment costs and large distribution losses for district heating networks. On the other hand, natural gas (or heating oil) is readily available making individual heating solutions like micro cogeneration attractive.

The analysis of its **economic** performance shows that micro cogeneration may increasingly become interesting for operators. To date, a number of systems larger than 5 kWel have been successfully commercialized. Smaller systems of about 1 kWel may soon break through, though, since they could fully substitute for boilers in single-family houses. Under current conditions, single-family houses are appearing to become a more promising market than apartment buildings: Micro cogeneration plants are only economically attractive if electricity is to be used or sold on site and not primarily fed into the grid. In the case of apartment buildings, tenants may choose to be supplied by an external energy company and, thus, jeopardize the economic viability of the cogeneration unit. More generally, economic viability of micro cogeneration depends on the attractiveness of competing heat and electricity supply options. In urban areas with high heat densities, district heat may be an economically (and ecologically) more attractive option, whereas in areas with low heat densities micro cogeneration appears more promising. However, the economic attractiveness of micro cogeneration for operators builds largely on **regulatory advantages**, such as tax exemptions, the payment of a CHP bonus for electricity fed into the grid, and avoided concession levies and grid charges for electricity generated on site. If these incentives are excluded, and as long as the external benefits of the improved environmental performance of micro cogeneration are not being taken into account, none of the micro cogeneration technologies assessed here is economically viable in Germany yet. Furthermore, with state-of-the-art micro cogeneration technologies, a trade-off between environmental and economic performance must be acknowledged. In particular, small Stirling engines designed for single-family houses have a rather good economic performance, but a relatively low electrical and total efficiency. Reaching the highest efficiencies possible is crucial for achieving emission reductions at reasonable costs.

The generally favorable economic conditions for the operation of micro cogeneration plants seem not to be sufficient to effectively promote their diffusion as long as the **setting of actors and institutions** is not favorable as well. Market liberalization led to substantial changes in the structure of the German energy industry. The market is now dominated by four vertically integrated electricity companies, which also own major gas companies and shares in all levels of electricity and gas supply. Competition is stagnating and newcomers are rare. The established electricity industry does not focus on small cogeneration units, but rather follows its traditional path of centralized electricity generation. On the other hand, the natural gas industry, insofar as it is not owned and dominated by the electricity industry, is interested in micro cogeneration. Local utilities, too, see some potential in distributed generation. Yet, a prevalent strategy towards fostering the broad-scale introduction of micro cogeneration could not be found among any of the German gas companies. Grid operators use the currently weak regulation of grid access to hinder the emergence of independent power producers. A sufficient procedure for managing conflicts – between, for example, micro cogeneration operators and distribution network operators – has not yet been established. Due to the lack of regulation, negotiations about grid access and tariffs are bilateral, and disagreement often has to be settled by court decisions – an expensive way of regulating conflicts. An additional barrier is the low level of information on the customer side. Technologies other than fuel cells are little known and elicit little enthusiasm. Because of small plant size and operation by non-professional electricity producers, complicated rules and lack of access to information give rise to relatively high transactions costs and reduce the economic attractiveness of micro cogeneration plants. Acceptance of novel marketing and operation strategies that might reduce these information and administrative cost – such as third-party financing – is comparatively low.

Conclusions

Despite a growing number of installations in Germany, micro cogeneration is far from being introduced in a larger scale. It could however form a relevant building block for an energy policy working toward a sustainable transformation of the electricity system. To this end, a number of barriers would need to be overcome, in terms of the ecological and economic performance, as well as of the institutional framework of micro cogeneration plants.

References

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