Energy Reports 4 (2018) 226–243

Contents lists available at ScienceDirect

Energy Reports

journal homepage: www.elsevier.com/locate/egyr

Identifying business opportunities for green innovations: A quantitative foundation for accelerated micro-fuel cell diffusion in residential buildings

J. von Geibler [a,*], K. Bienge [a], D. Schüwer [a], O. Berthold [b], A. Dauensteiner [c], V. Grinewitschus [d], D. Hoffmann [e], W. Renner [f], Y. Ostermeyer [g]

[a] Wuppertal Institute for Climate Environment and Energy, Doeppersberg 19, 42103 Wuppertal, Germany
[b] GASAG AG, Henriette-Herz-Platz 4, 10178 Berlin, Germany
[c] Vaillant Group, Berghauser Str. 40, 42859 Remscheid, Germany
[d] ebz Business School — University of Applied Sciences, Institut für Energiefragen der Immobilienwirtschaft, Springorumallee 20, 44795 Bochum, Germany
[e] Vivawest Wohnen GmbH, Nordsternplatz 1, 45899 Gelsenkirchen, Germany
[f] Gemeinnützige Wohnungsbaugesellschaft mbH Wuppertal (GWG), Hoeftstraße 35, 42103 Wuppertal, Germany
[g] Chalmers University of Technology, SE-412 96, Gothenburg, Sweden

ARTICLE INFO

Article history:
Received 7 July 2017
Received in revised form 19 November 2017
Accepted 27 December 2017

Keywords:
Fuel cells
Innovation barriers
Low-carbon buildings
Market survey

ABSTRACT

Combined heat and power (CHP) production in buildings is one of the mitigation options available for achieving a considerable decrease in GHG emissions. Micro-CHP (mCHP) fuel cells are capable of cogenerating electricity and heat very efficiently on a decentralised basis. Although they offer clear environmental benefits and have the potential to create a systemic change in energy provision, the diffusion of mCHP fuel cells is rather slow. There are numerous potential drivers for the successful diffusion of fuel cell cogeneration units, but key economic actors are often unaware of them. This paper presents the results of a comprehensive analysis of barriers, drivers and business opportunities surrounding micro-CHP fuel-cell units (up to 5 kWel) in the German building market. Business opportunities have been identified based not only on quantitative data for drivers and barriers, but also on discussions with relevant stakeholders such as housing associations, which are key institutional demand-side actors. These business opportunities include fuel cell contracting as well as the development of a large lighthouse project to demonstrate the climate-neutral, efficient use of fuel cells in the residential building sector. The next step could involve the examination and development of more detailed options and business models. The approach and methods used in the survey may be applied on a larger scale and in other sectors.

1. Introduction

According to the IPCC (2014) report, buildings accounted for 32% of the total global final energy use in 2010. By 2050, the global energy use of buildings is expected to double or triple in some scenarios[1] (IPCC, 2014 p. 711). Improvements to the energy efficiency of buildings are therefore crucial to achieve ambitious climate goals. Combined heat and power (CHP) production in buildings is one of the mitigation options available for achieving a decrease in GHG emissions. Micro-CHP (mCHP) fuel cells are capable of cogenerating electricity and heat very efficiently on a decentralised basis. Although they offer clear environmental benefits and have the potential to create a systemic change in energy provision, the diffusion of mCHP fuel cells is rather slow. There are numerous potential drivers for the successful diffusion of fuel cell cogeneration units, but key economic actors are often unaware of them.

CHP plants in Germany produced a total of 98 TWh of electricity in 2014, which was equivalent to 16.6% of the net electricity produced in Germany that year (Gores et al., 2015). The share of heat from CHP accounted for about 20% of the total heat market (below 300 °C). In total, cogeneration plants in Germany enabled the avoidance of 56 million tons of CO_2 in 2013 compared to the situation with the uncoupled generation of heat and power (Wünsch, 2015). Klotz et al. (2014) have identified a microeconomic CHP potential of 170 TWh_{el} at the business level and a macroeconomic potential of 240 TWhel at the national level in Germany. Together,

* Corresponding author.
E-mail address: justus.geibler@wupperinst.org (J. von Geibler).

1 The report uses several models in each of two scenarios (baseline and mitigation). In both scenarios, the three integrated models POLES AMPERE, GCAM 3.0, TIAM-WORLD 2012.2 are those that exhibit a strong increase in annual global final energy demand in the building sector (IPCC, 2014 p. 710–711).

https://doi.org/10.1016/j.egyr.2017.12.002
2352-4847/

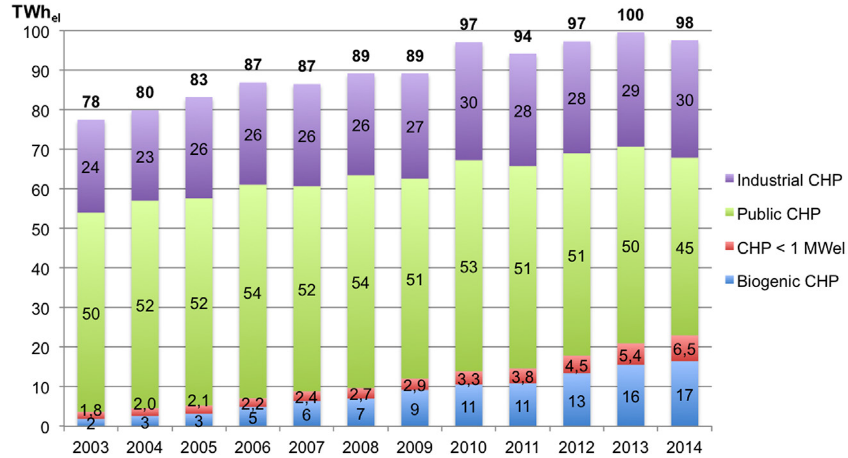

Fig. 1. Development of CHP by sector in Germany between 2003 and 2014.
Source: Own illustration, data by Gores et al. (2015, p. 9).

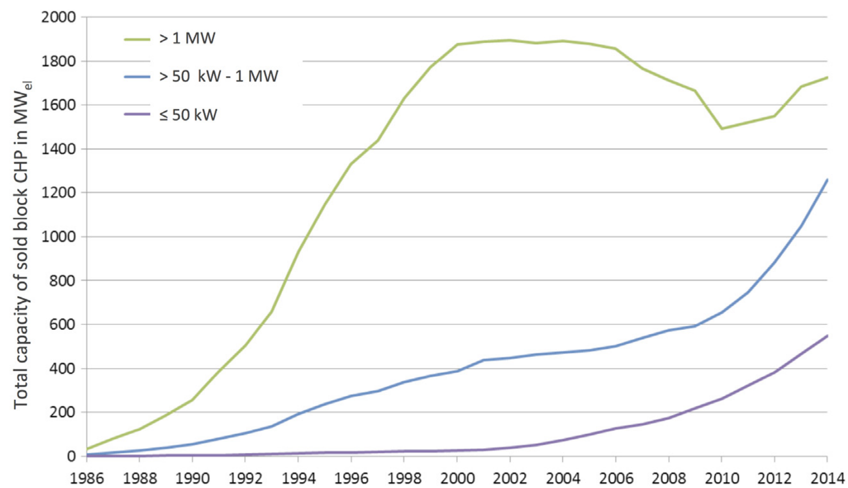

Fig. 2. Development of cumulated fossil block CHP installations in Germany between 1986 and 2014.
Source: Gores et al. (2015), own translation.

the public sector (45 TWh) and industry (30 TWh) produce 77% of Germany's CHP electricity. As Figs. 1 and 2 show, however, biogenic and small-scale CHP plants (<1 MWel) exhibited the strongest growth rates in the period from 2005 to 2014. In industry, on the other hand, CHP increased only slightly and remained more or less constant in the public sector.

At the European level, the energy policy framework for CHP is mainly provided by the Energy Efficiency Directive (EED) 2012/27/EU and the earlier CHP Directive 2004/8/EC. To enable investments to be made in cogeneration plants in a liberalised power market with overcapacity, the Cogeneration Act (Kraft-Wärme-Kopplungs-Gesetz, or KWKG for short) was passed in Germany in March 2002. This Act provides for the financial support of power from CHP involving a feed-in tariff system featuring a surcharge; it also obliges network operators to accept electricity that has been fed into the grid. The Act has been revised several times, most recently in January 2016. In this most recent revision, the German Government abandoned its previous relative development goal of a 25% share of electricity from cogeneration (defined in the KWKG 2009) in favour of an absolute goal of 110 TWh_{el} for the year 2020. In relation to Germany's net electricity production of 589 TWh in 2014, this figure corresponded to less than 19%. In addition, the previous general obligation of network operators to accept and pay for electricity from CHP has been gradually replaced by compulsory self-consumption or, alternatively, direct marketing for plants larger than 50 kW_{el}. The payment to small CHP systems below 50 kW_{el} fell from 5.41 ct per kWh_{el} to 4.0 ct per kWh_{el} in the case of self-consumption and supplying a third party, and increased to 8.0 ct per kWh_{el} in the case of feeding in power to the public network.

In addition to passing the CHP Act, the Federal Ministry for the Environment also started subsidising small CHP plants with an electric capacity of less than 20 kW in April 2012. New CHP plants are eligible for a state grant, which depends on the system's electric power. The basic grant is €1900 for very small CHP plants with an electric power capacity of 1 kW — typically installed in detached houses and two-family homes. The basic grant for additional kilowatts is increased by €300 for plants between 2 and 4 kW_{el}, €100 for plants between 5 and 10 kW_{el}, and €10 for plants between 11 and 20 kW_{el} (see Fig. 3). In other words, larger plants with an electric capacity of less than 20 kW are eligible for a grant of up to €3500. Since the funding directive was revised on 1 January 2015, mini-CHPs benefit from two additional bonus payments: a "Power Efficiency Bonus" is granted to plants with a minimum electric efficiency of more than 31 to 35% and a "Heat Efficiency Bonus" is designated for plants equipped with condensing boiler technology (see Fig. 3). Hence, the maximum funding available is between €3515 for a 1 kW_{el} plant and €6,475 for a 20 kW_{el} plant.