CHAPTER 2

Background on Methodology and Case

Abstract The development of micro Combined Heat and Power (mCHP), a radical innovation in the European heating industry, occurred in response to demands for increased energy efficiency and CO_2 emission reductions. This chapter introduces the mCHP case, which provides an excellent understanding of how innovators address standards. The chapter provides an overview over the study's grounded theory approach, which is based on extensive interviews with innovators and other key actors. The chapter also offers important background information about mCHP and the European heating industry. This traditional industry is characterised by its predominantly small- and medium-sized firms and their focus on long-term development.

Keywords Grounded theory · Case study · micro Combined Heat and Power, mCHP · European heating industry · Green technologies

To address the theoretical gaps identified in Sect. 1.2.4, we studied the development of micro Combined Heat and Power (mCHP) technology in the European heating sector. In this chapter, we provide some background information that is helpful for understanding our findings. Section 2.1 outlines our grounded-theory-based methodological approach. Section 2.2 introduces mCHP technology and the setting in which it was developed.

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2.1 Grounded Theory Methodology

As outlined in Chapter 1, we are interested in a detailed exploration of how innovators manage external requirements (imposed by standards), the dynamics that result from this, and how this affects NPD activities. Specifically, we want to explore how this occurs on the company- and industry levels and how these two levels interact. The lack of literature addressing these questions makes an in-depth exploratory case study, which uses inductive reasoning to derive a grounded theory, the most suitable research design (Eisenhardt, 1989; Glaser & Strauss, 1973; Yin, 2009). This grounded theory approach allows us to conceptualise patterns that we find across the data to generate our theoretical contribution (Glaser & Strauss, 1973). In Sect. 2.1.1, we explain our case selection. Section 2.1.2 shows how we collected our data. Finally, Sect. 2.1.3 summarises our approach to analysing these data.

2.1.1 Case Selection: Theoretical Sampling

Following Eisenhardt (1989) and Yin (2009), we selected our case on theoretical grounds rather than through random sampling. Following on from our research question and the identified gaps in the literature, we defined five criteria that the case would have to meet. (1) It needed to be a case of an innovation for which both existing standards are relevant and new standards are required. (2) This innovation needed to represent a substantial technological leap. This maximised our chances of observing standards having a major impact on the innovation, and the involved actors' approaches to managing these impacts. (3) Our specific interest in NPD activities also means that the innovation in our case needed to be at a stage when companies developed products intended to be sold on a large scale. The initial fundamental research considered by Blind and Gauch (2009) should therefore already have been concluded. (4) Furthermore, NPD activities concerning the innovation should preferably be pursued in parallel by several companies as this would allow us to compare their potentially different approaches to managing the relevant standards. (5) Finally, for practical reasons, data about the case needed to be accessible and the case should be relatively recent to ensure that informants would be able to recall the needed information.

We found a suitable case which meets all five requirements in the development of micro Combined Heat and Power (mCHP) technology.

Several companies in the European heating industry simultaneously developed innovative natural gas powered central heating boilers, which convert excess heat into electricity, making them embedded units in the case (see Yin, 2009). Standards were relevant, both because interfaces with other supporting infrastructures (e.g. the electrical installation in a building and the electricity grid) are needed for the innovation to be of value and also because important safety and efficiency issues make this a technology that is covered by the European Commission's 'New Approach'.[1] When mCHP was developed, generating electricity was an entirely new feature for the industry, meaning that it was a substantial departure from existing technologies. Nevertheless, there already were several existing standards affecting the technology, because the market that it was aimed at and the supporting infrastructures (gas, electricity, water) were already in place. Lastly, the case also satisfies the practical requirements outlined above.

2.1.2 Data Collection

The largest share of our data was collected in interviews. Following two interviews with existing contacts, we used snowball sampling and contacted actors who we identified as relevant in desk research (e.g. additional companies with mCHP products) and when attending an industry conference. This approach resulted in approximately 26 hours of interviews conducted between April 2015 and August 2017 as detailed in Table 2.1. These interviews gave us insights into the perspectives of all groups of actors who were involved in developing mCHP-related products and/or managing standards to facilitate the technology, as well as perspectives from different countries which are key markets for the new technology.

In order to ensure that the main topics of interest were covered in each interview while leaving the interviewees enough leeway to 'tell their stories', we used a semi-structured format. Gioia et al. (2013) highlight the importance of the interview guideline to ensure that this results in useful data for deriving theoretical patterns. This guideline was adjusted

[1] Under the 'New Approach', regulation provides 'essential requirements' for products to be sold on the European market and standards are used to specify these requirements and test methods to assess compliance in detail for specific product groups. Also see our more detailed explanation on this topic and its relevance for the case in Sect. 3.2.1.

Table 2.1 List of interviews in chronological order

Interview No.	*Organisation*	*Interviewee (s)*
1	Netherlands-based manufacturer of heating systems, approx. 6500 employees and €1.7bn revenue	Technical innovation manager, responsible for all mCHP-related NPD and standardisation activities
2	Association of the European Heating Industry (EHI)	Technical affairs director, responsible for all mCHP-related activities at the association[a]
3	Engineering research institute at a German university	Researcher, involved in mCHP-related contract research and participating in mCHP-related standardisation committees
4	Germany-based manufacturer of heating systems, approx. 12,000 employees and €2.25bn revenue	Manager responsible for coordinating the company's standardisation activities, involved in mCHP's technological development in a previous role Manager responsible for the company's participation in associations on a strategic level, previously head of new technology development
5	Germany-based manufacturer of heating systems, business unit of a conglomerate with approx. 390,000 employees and €73bn revenue	Manager in charge of the business unit's external affairs, relationships with political actors and governments, and work in industry associations
6	Japan-based supplier of fuel cells for mCHP systems, business unit of a conglomerate with approx. 258,000 employees and €57bn revenue	Manager responsible for advising Japan-based R&D department about European standards and representing the company in European standardisation
7	Germany-based self-employed engineering consultant specialised in mCHP, consulting industry actors on the technical implementation of requirements arising from regulation/standards and active in mCHP-related standardisation committees	
8	Netherlands-based certification body, conducting assessment of mCHP devices' conformity to legal requirements	Head of several testing laboratories, including the one conducting mCHP-related conformity assessment
9	Small UK-based supplier of Stirling engines for mCHP systems	Engineer, involved in the company's mCHP-related R&D in various roles since 2000

(continued)

Table 2.1 (continued)

Interview No.	*Organisation*	*Interviewee(s)*
10	Germany-based manufacturer of heating systems, approx. 12,000 employees and €2.4bn revenue	Head of technology development for mCHP, involved in mCHP-related R&D at the company since 1997 Project leader for CHP applications, responsible for regulatory approval of mCHP devices in an earlier role, involved in mCHP-related R&D at the company since 2000 Project leader, involved in mCHP-related R&D at the company since 1999
11	Germany-based manufacturer of mCHP systems, approx. 30 employees	Managing director
12	UK-based supplier of fuel cells for mCHP systems, approx. 100 employees	Head engineer overseeing all engineering activities at the company
13	Small Switzerland/Italy-based manufacturer of mCHP systems	Manager responsible for regulatory approval of mCHP devices
14	See Interview 1	See Interview 1

[a]A representative of a manufacturer of heating systems was also present during a short part of this interview and participated in the conversation. This person was then interviewed individually during Interview 5

for each interview to cover all important topics (interviewee's involvement in the case, views on relevant standards, companies' processes for managing the topic, interactions with other stakeholders, results of their activities, etc.). Using these guidelines, we obtained detailed accounts of the interviewees' activities in the case and their views on the events.

Where possible, we recorded the interviews and transcribed them verbatim in the language in which the interview was conducted (English for Interviews 1, 8, 9, 12, and 14; German for all other interviews). In addition, some interviewees provided us with internal company documents. Furthermore, we considered European Union policy documents related to the standards in the case which provided us with additional information on the evolution of standards in relation to the European directives that they were supposed to support. A final source of information was attending an industry conference hosted by the European industry association for co-generation of heat and power (COGEN Europe) in March 2016. At this conference, we gained further insights into the major topics of interest for industry actors and gained background information on how mCHP fits into the wider industry context. The conference also provided us with an opportunity to have informal discussions with important actors in the case.

2.1.3 Data Analysis

In line with our study's inductive reasoning, we based our data analysis on a grounded theory approach (Glaser & Strauss, 1973). We initiated our data analysis in parallel to data collection so that the information from earlier interviews could inform subsequent data collection efforts. In order to come closer to Glaser and Strauss's (1973) ideal of developing grounded theory without preconceived notions of existing theory, two assistants performed most of the open coding (see Alvesson & Sköldberg, 2009; Gioia et al., 2013) under the author's supervision. All coding was performed on transcripts in the languages in which the interviews were conducted (German and English, see Sect. 2.1.2) in order to stay as close as possible to the empirical evidence at this stage.

Simultaneously to coding, we started the further data analysis by 'integrating categories', as suggested by Glaser and Strauss (1973, pp. 108–109). Clear themes that later became the key concepts of our theory emerged from the data at this stage, although we did not follow the strict template provided by Gioa et al. (2013). These theoretically saturated (see Glaser & Strauss, 1973, pp. 111–113) key themes are based on the main discussion topics across our interviews and reflect the elements that our interviewees emphasised. Chapters 3, 4, and 5 are structured along these themes and use extensive quotes from the interviews and—where available—supporting evidence from other sources to ensure that our constructs are deeply rooted in empirical observations.[2]

In parallel to identifying these key concepts, we also looked for relationships between them (see Alvesson & Sköldberg, 2009, pp. 68–69; Glaser & Strauss, 1973, pp. 109–113). As suggested by Glaser and Strauss's (1973) description of the constant comparative method, we did so by alternating between noting down our ideas about such links and verifying in the data whether these ideas were supported by the evidence. This verification was based on whether we could identify a plausible explanation for each relationship in the data, for example by comparing different firms (embedded units) in our case, or by searching for interviewees' explanations of the reasons behind certain activities and events. This process ultimately resulted in the theory that we present in Chapter 6 and makes this theory firmly rooted in the empirical observations from our case.

2.2 Introducing the micro Combined Heat and Power (mCHP) Case

As outlined in Sect. 2.1.1, the development of micro Combined Heat and Power (mCHP) is an excellent case to study the management of standards during the development of a new technology. Combined heat and power (CHP) solutions have been developed for all scales, ranging from domestic family homes to large industrial applications. Our case study traces the development of micro CHP (mCHP) which includes all CHP appliances with up to 5 kW electrical output (EHI, 2014). These appliances would typically be used in single-family houses.

The technology is a major innovation in the European heating sector. In addition to providing hot water and heat for buildings, mCHP boilers also generate electricity. This additional functionality represented a major technological leap for the European heating industry which did

[2] Where we quote interviews that were conducted in German we translated them at this stage, labelling each translated quote as such.

previously not make any electricity-generating products. In order to provide context for our analysis of how products using this technology were developed and standards were managed during this process, we cover background information that is important for a good understanding of the case. We first portray the European heating industry and mCHP's role for it (Sect. 2.2.1). Following this, we give a brief overview over different technological approaches to mCHP and how the relevance of standards differed for them (Sect. 2.2.2).

2.2.1 The European Heating Industry and the Market for mCHP

Heating of buildings is estimated to be responsible for around 40% of the EU's energy consumption and 36% of its CO_2 emissions (European Commission, 2017). Consequently, boiler manufacturers and other actors in the European heating industry have been facing expectations from the market and political actors to make their products more energy efficient and contribute to efforts to combat climate change. In response to these demands, the European heating industry developed several technologies to eventually succeed the established condensing boilers for domestic applications, including heat pumps, solar thermal systems, and mCHP. Which of these technologies is most energy efficient depends, e.g. on heat demand and the local electric power generation mix where an appliance is installed. The technologies therefore address different market segments. A key advantage of mCHP products compared to heat pumps and solar thermal systems is that they can be integrated in existing buildings more easily if designed in such a way that they match existing infrastructure in buildings. This made mCHP a potentially promising technology to attain higher energy efficiency in the replacement market, which one interviewee described as existentially important for the companies in the industry:

> We live off the existing [building] stock and replacement. The relation between newly built buildings and existing buildings in Germany in a year is approximately 1:10. This means that, for every boiler or heating appliance that we sell into a newly built house, we sell ten into existing buildings. (translated from German)

The European heating industry is distinctive in that the established players and market leaders are mostly owned by the founding families or by foundations with a mission to ensure the business's long-term viability. This gives the companies and the entire industry a long-term outlook which also manifested itself in the way standards were managed during the development of mCHP. However, it also means that the industry is relatively conservative and "*not really known for being particularly innovative [and consisting of] rather traditionally shaped enterprises*" (translated from German).

Developing mCHP brought the involved actors into contact with several new key technological fields (see Sect. 2.2.2) and the players involved in these areas, requiring the industry to adopt new approaches to innovation and standardisation and become more open to dealing with actors outside the industry as outlined in Chapters 4 and 5. Within the industry, these developments were driven by a range of actors. In addition to the boiler manufacturers (OEMs) who developed and eventually sold complete mCHP appliances, suppliers of key components; certification bodies; engineering consultants; industry associations; and research institutes all were involved in the process. The OEMs developing mCHP and the component suppliers included established players in the industry and new entrants which were specifically founded as start-ups to develop mCHP appliances and components. Our interviews cover all key players in the case as well as some more peripheral actors (see the characterisations of companies covered by our interviews in Table 2.1).

2.2.2 Technological Solutions for mCHP

Four technological approaches exist to realise the functionality of mCHP appliances: (1) Stirling engines; (2) fuel cells; (3) internal combustion engines and (4) steam expansion engines (EHI, 2014). While internal combustion engines and steam expansion engines have been barely used for mCHP applications, both products based on Stirling engines and on fuel cells have been developed and marketed.

All interviewed OEMs have been developing fuel-cell-based mCHP appliances, although not all of them have brought them to the market yet at the time of writing. Some OEMs have been developing and offering Stirling-based mCHP appliances in addition. The OEMs that never developed the Stirling technology or exited its development cited technological challenges and doubts about whether mCHP appliances using Stirling engines could reach the same levels of efficiency as those using fuel cells as the reasons behind the decision to only pursue fuel cells. On the other hand, the companies that still have been pursuing the Stirling engine in parallel to fuel cells see the two technologies as catering for distinctive market segments:

> I expect there will be different technologies in parallel, and they could serve different markets segments. That has to do with the question how the ratio is between heat demand and power demand. That's one issue. And especially when the heat demand is high compared to the power demand then nowadays already Stirling engine could be a better solution than the fuel cell.

Technologically, the two approaches are fundamentally different: (1) Appliances with a Stirling engine add this engine (and some control electronics) to a conventional condensing boiler. Such a boiler produces more heat than is needed to cover the demand for heating and hot water. The excess heat is then converted to AC electricity by the Stirling engine which is tuned to the frequency of the national electricity grid (50 Hz in Europe), meaning that the produced electricity can be fed directly into the grid. (2) Fuel-cell-based appliances contain a reformer that extracts hydrogen from natural gas. This hydrogen is then used to power a fuel cell which produces both heat and DC electricity. An inverter converts this DC electricity to AC electricity that can be fed into the electricity grid. In addition, fuel cell appliances usually include a conventional gas boiler to cover peak heat demand.

Some aspects of these technologies were already known to the involved companies and have been used in their products for decades. Particularly, the condensing boiler units that provide the heat for Stirling engines to operate were very similar to the ones used in the industry's existing products. However, both Stirling engines and in particular fuel cells were new and very complex technologies for all actors in the heating industry. Furthermore, regardless of the technological approach to mCHP, its implementation required the industry to get involved in entirely new technological aspects, such as access to the electricity grid, technologies for communication with other devices, or grid stability. These fields presented a steep learning curve, in terms of both technology development and standardisation, as Chapters 4 and 5 show.

Most relevant standards and regulatory requirements (see Chapter 3) applied equally to Stirling- and fuel-cell-based mCHP appliances and had similar implications for both technologies' development. The standards for connecting appliances to the national electricity grid are a key exception to this. Some changes to them that occurred while mCHP was being developed posed additional challenges for devices using Stirling engines but had a smaller impact on the development of fuel-cell-based mCHP (see Chapters 3 and Sect. 5.2 for details).

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