Exploring the Unknown Market

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The Anticipated Diffusion of Domestic Micro-Combined Heat and Power (CHP) In the Netherlands

Master Thesis

by

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To my dearest father and mother
Thank for your everlasting love and support

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Thank you those who had helped and inspired me over the last two-year studying in the Netherlands. Thank you those who had fun together in my spare time, you make my student life colorful in Delft.

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Without the filling of the questionnaire by the 22 respondents, it is impossible to carry out this study. Specially thank those respondents I interviewed face-to-face for their kindly willingness to spend 2 to 3 hours on the research interview and providing a great deal of useful information. For those who did not fill in the questionnaire but recommended appropriate respondents to me, I also would like to thank them because I could not reach these professionals without their suggestion.

Finally, as I mentioned before, this thesis is dedicated to my parents who brought me to this world full of happiness and pain and raised me up with their love and support. No matter what happened in the past and is happening in the future, their love and support always stay with me.

Abstract

The Netherlands is one of the countries in Europe with the highly potential penetration of Micro Combined Heat and Power (Micro-CHP) in the market thanks to its significant connection of nature gas network and high penetration of gas central heating system in domestic consumer market. Currently Micro-CHP is still in the stage of field test in the Netherlands and its commercial introduction, however, is imminent. As a disruptive technology, its large-scale adoption will probably bring radical changes to the business model of energy industry and to the traditional model of electricity generation.

To provide reference to future business of the relevant stakeholders in the energy industry, this study aims to predict the diffusion pattern of Micro-CHP and two parameters in the pattern are the focus of the predictions: the time length of market adaptation phase and the potential market size, which are obtained by the analysis of the information gained from a 22-person survey in the form of questionnaire. The questionnaire is designed on the basis of the important variables influencing the diffusion and determined from the literature review and Ortt2005, which is the study on the diffusion patterns of fifty new technologies in history.

The time length of market adaptation phase is calculated mathematically by two regression models established by operating the computer program from Ortt2005 with the data from the questionnaire survey. By quantitatively analyzing the reliability of the two models and the relationship between the mean value of the variables and the time length, it is predicted that 10 to 20 years might be taken for Micro-CHP before the takeoff of its diffusion after its market introduction. The prediction of market potential is executed by qualitative analysis of the estimations from 20 respondents. By comparing and combining this result with the results gained in two projects: MicroMap and Future GOGEN, the final prediction of the potential market in the Netherlands might be 1 to 3.5 million units.

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Chapter One

Introduction

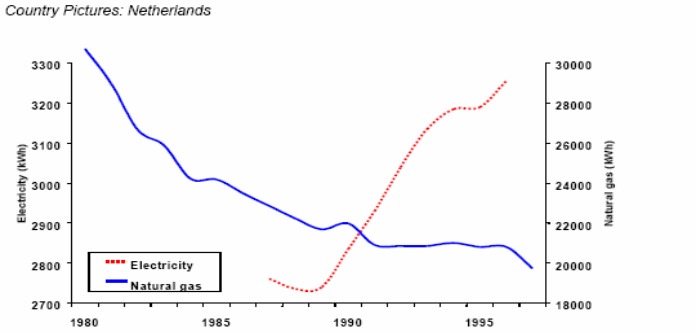
Chapter one Introduction

1.1 Background information

1.1.1 Dutch household Energy consumption in history

The energy consumption in the Dutch household accounts for 18 percent of all the energy consumed in the Netherlands.[1] The energy used in the household takes the form of heat and electricity, the former mainly for space heating, water heating and cooking, and the latter for lighting and electric appliance.[2] The main fuel for energy supply in the Netherlands has already changed from coal to oil before 1970s. In 1959, a natural gas field was discovered in Groningen. In order to take full advantage of this unexpected natural resource, the government invested heavily on the infrastructure of the gas distribution network and set a series of polices to encourage nature gas usage. By the end of 1970s, the gas network penetration to domestic market had already reached 90%. In 1997, 97% households were connected to gas network and the market potential was almost reached because around 2% households without gas connection were in the gas supply area.[3] The high percentage of gas network connection enables the Dutch households to base their considerable heat demand mainly on nature gas. The oil crisis caused the increase of fuel price and the Dutch government became aware of the importance of nature fuel. Many energy conservation measures were taken by the government[4] including the enhancement of the insulation of households and the improvement of the operation of heating system. The household gas (heat) consumption decreased dramatically during the 1980s and the trend continues in 1990s whereas the average household electricity consumption increases steadily after 1990s thanks to the increasing penetration of household electric appliances. The general trend of the average Dutch household natural gas and electricity consumption is showed here:

Figure 1.1 Average household consumption (kWh per annum) of electricity (1987-1996) and natural gas* (1980-1997) (The Netherlands)



Source: Harriet Griffin, Tina Fawcett (2000) *Country Pictures*, Energy and Environment Program, Environmental Change Institute, University of Oxford, UK. Figure 11.2

1.1.2 Energy efficiency improvement and Environment protection

In order to prolong the lifetime of Groningen field, Dutch government launched various programs and projects to improve the energy efficiency with the purpose of reducing the gas consumption. Further energy efficiency standards for new building were constituted to enhance the effective energy utilization. The Condensing Boiler Program was one of these programs launched by the government with favorable subsidy and regulation. This program was executed in two steps: firstly, informing installers and general public by information campaigns; secondly, subsidizing the development of condensing boiler and subsidizing installers and consumers to stimulate the purchase.[5] Until 2000, its market penetration achieved 75% of the Dutch households whereas the condensing boiler just obtained 10% market share in Britain though it was introduced almost at the same time in both countries.[6]

Besides, subjected to the Kyoto Protocol, the Netherlands committed to reduce 8% CO_2 emission below 1990 levels until 2008-2012, which inspires the development of renewable energy, but the percentage of renewable energy in the whole electricity consumption is not very high. The share of national renewable energy production in national consumption accounts for 3.4%[7], which is far below the target for 2020: renewable energy resources account for 10% of the primary energy.

Unlike renewable energy, the Combined and Heat (CHP) or Cogeneration grew enormously and rapidly in the past decades because it not only has higher overall energy efficiency but also releases less CO_2 than the traditional electricity generation only focusing on the increasing electricity efficiency. In 1988 Cogeneration Incentive Program was launched by Dutch government with favorable gas tariff and investment grants. However, due to the nation-wide over-capacity of electricity production after the electricity market liberalization, the government has to slow down the development of CHP by ceasing the investment subsidy.[8]

1.1.3 Definition of some terms

In order to make the thesis readable, some terms need to be defined at the beginning. The definition of Micro-CHP will be discussed further in Chapter two.

Diffusion: the gradual adoption of an innovation in a market segment or in a society.[9]

Market adaptation phase: the phase between the time point of the market introduction of a new product/technology and the time point of its diffusion takeoff.

Potential market size: the maximum adoption of a new product/technology in terms of sales or number of adopters.

Micro-Combined Heat and Power (CHP): appliance producing heat and electricity simultaneously to meet the energy consumption in residential and commercial buildings.

1.2 Problem formulation

The idea of conducting the research is inspired by the Essent Network who is interested in the extent of the influence of Micro-CHP on its existing and future business. After the discussion with the expert from Essent Network and the literature study, three main issues are encountered by Distribution Network Operators (DNOs) in general given Distributed Generation is installed in large-scale:

- Local generation makes the High Voltage electricity grid obsolete
- Local generation reduces the income (revenue) from Low Voltage electricity grid[10] [11]
- Local generation requires extra investment on the low voltage electricity grid.[12]

1.3 Research questions

Whether these issues emerge or the level of the obsoleteness, revenue reduction and investment depend largely on the penetration of Micro-CHP to the Dutch domestic market. The research attention is shifted to the development of Micro-CHP in the Netherlands, which might have significant impact on the future business of DNOs since it probably brings big changes to the grid infrastructure. The main research question is formulated:

What is the anticipated diffusion pattern of Micro-CHP in the Netherlands?

Due to the limited research time, the research is focused on the study of two parameters in the diffusion pattern, which are also interested by Essent Network, thus the question can be embodied as the following sub-questions:

Sub-question

1. What are the variables impacting the market adaptation phase of Micro-CHP?
2. How long will the market adaptation phase last after its market introduction?
3. How big will the potential market size of Micro-CHP be?

The answer for the sub-questions 1 is the basis of the research. The variables are determined by

literature review and variable model of market adaptation phase made by Ortt. The second and third sub-questions are answered by analyzing questionnaire survey which is mainly designed for investigating the variables.

1.4 Research assumption

Before the research is carried out, it is necessary to clarify the assumptions inside, which explicitly shows the base of the study.

- Stable economic and political environments

It is assumed that the economic and political environments in the Netherlands keep stable. The diffusion of Micro-CHP is influenced significantly by the economic situation, for instance, the economic depression and stagnancy hinder the diffusion, either postponing the takeoff of the diffusion or no diffusion at all. The enormous change in political environment also will largely impact the diffusion, e.g. the breakout of war.

- Micro-CHP is regarded as a “black box”

Micro-CHP is equipped with various technologies and it is quite evident that the technology dominating the market in different phases in the diffusion pattern is different because the new technology becomes mature and ready for the market. But in this research, Micro-CHP is only deemed as a concept of new product in general without taking into consideration of the technology adopted.

1.5 Research approach

Due to the fact that Micro-CHP is a new product even without market introduction, it is impossible to get any actual information or data about the customer and the sales. Nevertheless, many studies carried out on the estimation of the diffusion pattern provide the reference for this research. Two research approaches are used:

Literature review

Based on the extensive literature study of the theories of innovation diffusion established since 1960s, a model with the consideration of both the supply and demand sides is formulated and the variables principally influencing the adaptation phase of the diffusion pattern are also determined on the basis of this model.

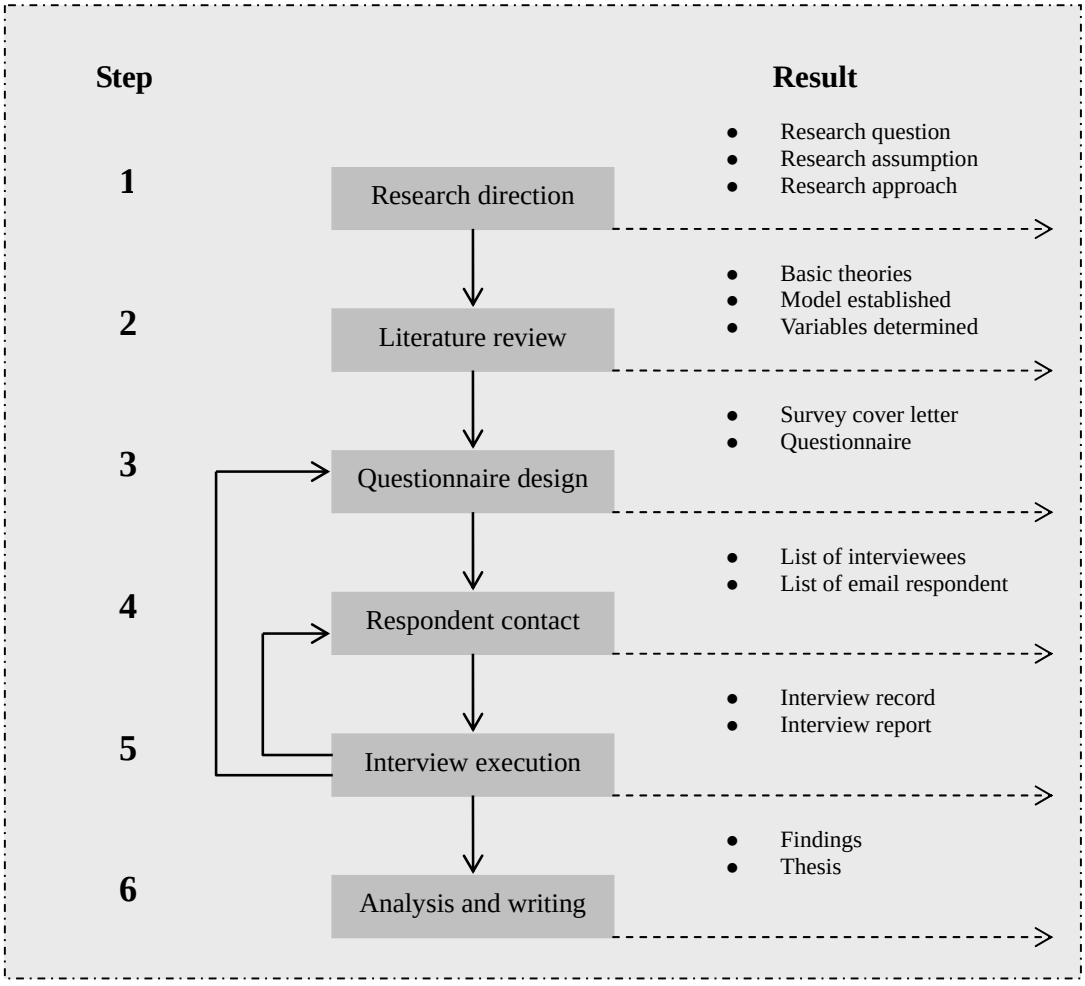
Survey by questionnaire

The questionnaire is designed to collect the data and information from the professionals in the Micro-CHP field. And the questions are based on the variables determined from the literature study and every variable consists of one or several factors displayed as questions in the questionnaire. Both the qualitative and quantitative method will be used for the analysis of the information and data obtained from the survey.

1.6 Phases of the research execution

After the confirmation of the research questions and approaches, the next important phase is the execution of the research. The steps of execution are showed in the flow chart:

Figure 1.2 Executing steps of the research



The execution of these steps is not all in parallel. Especially, step 3, 4 and 5 are performed in alternation since the questionnaire design is based on the established model and the selected

variables, and the selection of respondents is based on the selected organizations involving the development of Micro-CHP. The step 3 interacts with step 5 by getting the comments from respondents and improving the questionnaire, for instance, the expression of the question, but the content will not be changed for the sake of keeping the coherence of answers from respondents. Meanwhile, step 5 also provides the opportunity to contact with other experts by the introduction and recommendation of the respondents. These three steps together complete the data and information collection.

1.7 Reading guide

In order to show the reader the structure of the thesis, the work done in every chapter is described concisely. In chapter two, Micro-CHP is defined on the basis of literature review and the research object focused in this study. Furthermore, two technologies mainly used in Micro-CHP are explained with the purpose of informing the readers the variety and complexity of these technologies.

Chapter three starts with the introduction of the basic innovation diffusion model and theory: S-shaped curve; furthermore, with more and more researchers contributing to its development, the basic model is extended and applied in various domains. Two main contributions are depicted and the differences among these models are also analyzed with the consideration of their restrictions. Based on the diffusion of innovation theory aforementioned, the model used in the research is established and it is the primary outcome of the literature study. On the basis of literature review and the ongoing research of Ortt, the variables important for market adaptation phase are determined by taking into account of the specific new technology: Micro-CHP.

Chapter four mainly describes the methodology used in the survey. After exploring the methodology and process usually executed in survey and according to the characteristics of the research, a five-step survey process is designed and the methods used in every step are expatiated as well. The design of the questionnaire is composed of the design of the questionnaire format and the pre-testing for the questionnaire with the purpose of improving. After discuss how the questionnaire is designed, the methods of executing the questionnaire are introduced and divided into the methods of respondent selection and the interviewing methods. Based on the data and information collected, the analysis will be implemented qualitatively and quantitatively.

Chapter five is dedicated to analysis by calculating, comparing, explaining and summarizing the data and information obtained from the questionnaire. Before the start of the analysis, a preliminary analysis is conducted by coding the respondents and attaching value to the options of questions. With the preparation, the analysis is executed with the combination of calculation and explanation. Both of the quantitatively and qualitatively analytic methods are used to estimate the time length of the market adaptation phase whereas the potential market size is predicted with comparing and combining the result from questionnaire and the results from anther two projects. Finally, the results of the survey are presented and the main research questions are answered.

Chapter six will be ended with the conclusion of the research. The research limitation is also discussed in order to show the reason for the relatively low reliability of the findings in the research. Beside, based on the results of the research, some recommendations are especially presented to Essent Network.

Chapter Two

Micro-CHP

Chapter Two Micro-CHP

2.1 Definition of Micro-CHP

2.1.1 Definition from literature review

The concept of Micro-CHP is described as, on the one hand, the unit running as a heating appliance with the capacity of providing space heating and warm water like a conventional boiler, on the other hand, the unit generating simultaneously electricity as the by-product of its operation. In other words, Micro-CHP operates as a heat demand-led appliance. In addition, Micro-CHP is originally designed as electricity grid-connection mode, which provides Micro-CHP adopters with the feasibility of feeding in the electricity back to the grid when the heat consumption is not balance with the electricity consumption. Nevertheless, stand-alone operation of Micro-CHP is also possible without the connection with electricity grid. Moreover, according to the term "disruptive technology" coined by Clayton M. Christensen[13], Micro-CHP is usually regarded as a disruptive technology since it has the potential to displace the established technology: the central power generation and district heating, rather than improves successively the performance of the market incumbents.

There are many different definition of Micro-CHP (Combined Heat and Power), also called as Micro-cogeneration. The European Cogeneration Directive defines Micro-CHP as a unit with a maximum electricity capacity below 50kW.[14] However, this definition is only meant to set a scope of the Micro-CHP for the state members and they are entitled to define it according to their economical and environmental goals. In order to show the dissimilarity of the definition, a summary is drawn in the table 2.1:

Table 2.1 Micro-CHP definitions encountered in literature review

Project executor	***Definition***
FaberMaunsell Ltd (formerly ECD Energy & Environment)[15]	a system provides both electricity and heating to the dwelling with surplus export of electricity 1-3 kW to the local grid
COGEN[16]	Within the micro-cogeneration category, one can differentiate between domestic cogeneration and non-domestic cogeneration. The first sub-category being 3 kWe or below is effectively designed to suit the needs of a household.

COGEN[17]	Micro-CHP is a mass product appliance for the single family home, though it is also applicable for other applications, such as small hotels, small high street retail outlets, commercial buildings such as small offices and multi-family apartment block. In terms of size, it varies up to 10kWe.
COSPP Markets Policy Finance [18]	Micro-CHP is used to describe domestic-level CHP system, with units of up to 4 kWe, intended for installation in individual home.
EA Technology[19]	Micro-CHP is an individual heat & power producing unit in each home with the thermally led operation.

2.1.1 Definition in the research

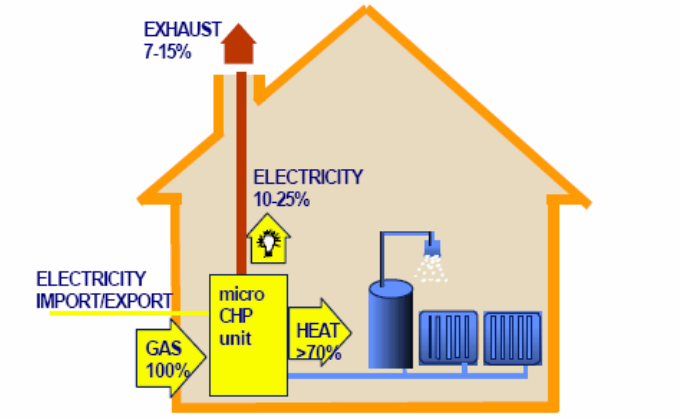
In the Netherlands, the average heat consumption per year in individual home is about 12,500kWh whilst the average electricity consumption per year is around 3000kWe. As described above, the designed capacity of Micro-CHP is based on the heat consumption since it is a heat-demand led system. Due to certain ratio of the heat and electricity production, Micro-CHP with electricity production around 1kW will meet the basic electricity consumption of Dutch home. However, the consumption of electricity and heat in some homes are far more than average. On the basis of the ratio of heat and electricity production and meeting the thermal needs, Micro-CHP with up to 3kW electricity production capacity is able to satisfy the basic electricity consumption of all the Dutch households.

Based on the definition adopted in aforementioned projects and considering the energy consumption and the size of the household in the Netherlands, the term of Micro-CHP in the research could be defined as:

Micro-CHP is an individual-household grid-connected appliance producing thermal energy and electricity simultaneously with a capacity up to 3kWe

Figure 2.1 displays how the Micro-CHP working in the individual household.

Figure 2.1 Micro-CHP installed in household and the energy flow



Source: Micro-Map Mini and Micro-CHP- Market Assessment and Development Plan Summary Report, http://www.cogen.org/Downloadables/Projects/Micromap_Publishable_Report_Summary.pdf,

2.2 Micro-CHP technology

There are several technologies for Micro-CHP and their different ratio of heat to electricity and consequence match with different market sector. The technologies used in Micro-CHP mention in the literature can be summarized as Stirling engine, internal combustion engine, fuel cell and micro-turbine.[202122] However, according to the definition of Micro-CHP aforementioned, the technologies currently under development and suitable for the specific market segment: individual household are Stirling engine and fuel cell.

2.2.1 Stirling engine[23]

Stirling engine was invented by R. Robert Stirling in 1816. In terms of its invention time, it is an old technology; however, since it is applied in a totally new field different from its original application, it can be regarded as a new technology for Micro-CHP.

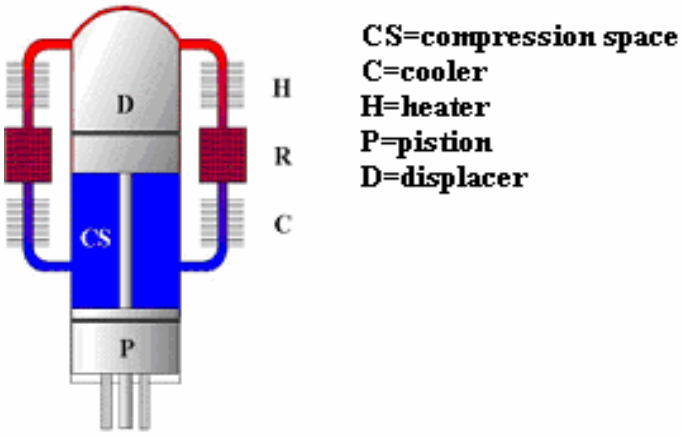
Stirling engine is also called as external combustion engine because the working gas in the sealed cylinder is heated by burning the fuel in the external firebox whereas the internal combustion engine is powered by the direction combustion of the fuel within the cylinder. Stirling engine is mainly composed of cylinder and pistons. The working gas sealed in the cylinder usually is air or other gas such as hydrogen or helium and is heated by the external fuel combustion in the hot side of the cylinder and is cooled by water in the cold side of the cylinder.[24]

The Stirling engine used in Micro-CHP is free-piston Stirling technology since it has less moving parts with the advantage of maintenance-free and less noise compared to classical model of Stirling engine.[25] Figure 2.2 shows its main components and its working theory.

The displacer moves the working gas from the hot to the cold part of the chamber whether expanding or contracting, which further moves the piston up and down. A power piston is directly coupled to an alternator which converts the piston movement into electricity. (Not showed in figure 2.2)

Currently, the domestic Micro-CHP with Stirling engine is the product on the threshold of the market introduction.

Figure 2.2 Components and working theory of free-piston Stirling engine



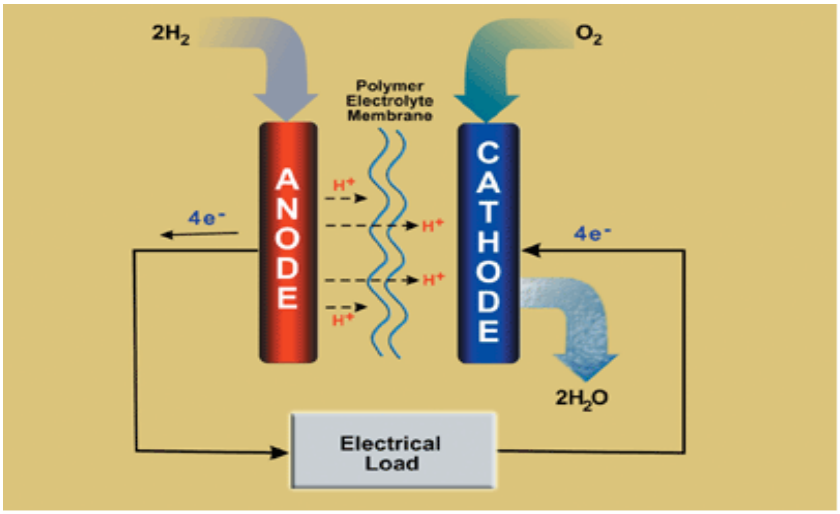
Source: “Investigation of concepts for high power Stirling engines”, University of Karlsruhe: Institute of Reciprocating Engines, http://www-ifkm.mach.uni-karlsruhe.de/Html-e/Project/Stirling/stirling.html

2.2.2 Fuel cell

Compared with Stirling engine, fuel cell is a quite new technology and it works like a battery without the necessity of recharging and produces electricity and heat as long as fuel supplied. A fuel cell consists of anode (negative electrode), cathode (positive electrode) and electrolyte.[26] Normally, hydrogen is fed into anode and oxygen is fed into cathode. The hydrogen is decomposed into positive ion H^+ and electron moving to cathode through an external circuit to create electricity flow whereas the positive ions go through the electrolyte and react with oxygen in the cathode, uniting the electrons and producing water and heat.[27] (Figure 2.3)

Fuel cell is classified primarilyh in terms of the electrolyte used in fuel cell.[28] There are two types of fuel cell under developmentin the Netheralnds: Solid Oxide Fuel cell (SOFC), Proton Exchange Membrane Fuel Cell (PEMFC), which are the potential fuel cell technologies applied on the domestic Micro-CHP.[29] However, fule cell Micro-CHP are still in the laboratory test phase without the recent preparation for market introduction in the Netherlands. Thanks to its high effiency and almost “zero” emission, it is expected to the most promising Micro-CHP technology in 2020.

Figure 2.3 Working theory of fuel cell



Source: Fuel Cell Basics, Queens Fuel Cell Team 2004, Faculty of Applied Science, Queens University, Kingston, Ontario Canada,
http://engsoc.queensu.ca/fuelcell/pages/fuel-cell-faq-why-the-hype_clip_image001.gif

Chapter Three

Literature Review

Chapter Three Literature Review

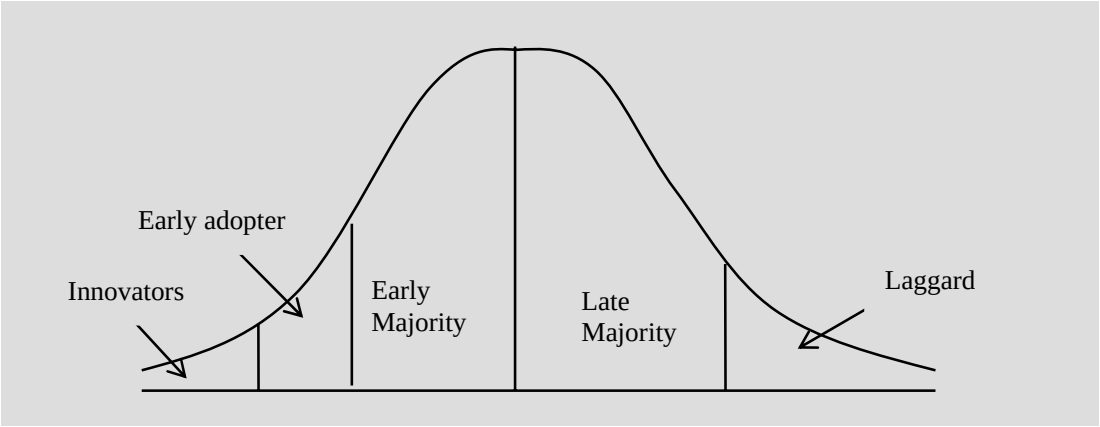
3.1 The development of the innovation diffusion theory

3.1.1 Smooth S-shaped curve and adopter categorization

Basic theory[30]

Diffusion is defined by Roger as "the process by which an innovation is communicated through certain channels over time among the members of a social system"[31]. Four elements are mentioned as the important and primary ones in the diffusion process: innovation, communication channel, time and social system. The rate of adoption is directly connected with the time dimension and is measured by the length of time required for a certain percentage or number of adopters. Based on the past research on adoption of innovation, a bell-shaped curve is plotted on a frequency basis over time (Figure 3.1). Accordingly, the adoption of innovation is drawn as a smooth S-shaped curve (Figure 3.2) based on the cumulative percentage or number of the adopters over time.

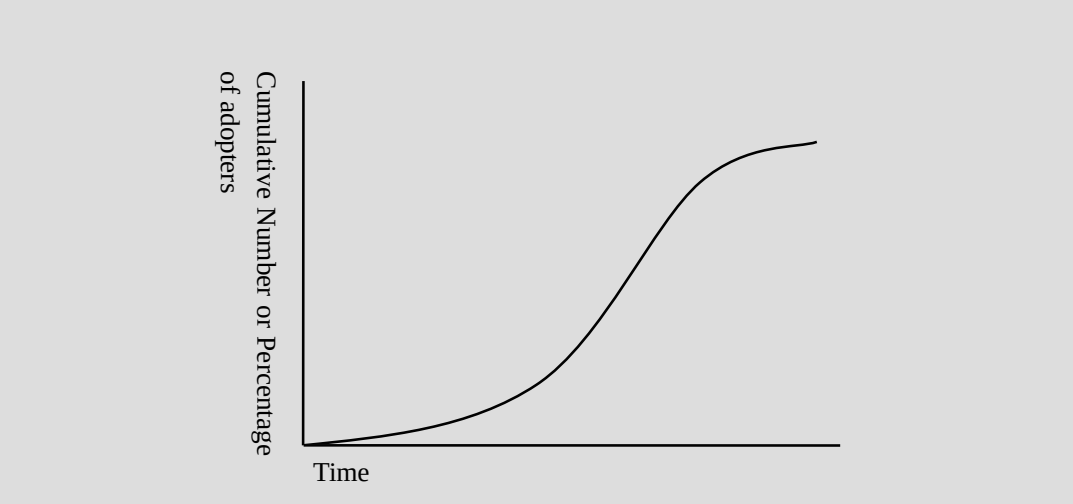
Figure 3.1 Adopter categorization



Source: Roger (1995) Diffusion of Innovation

Furthermore, Roger categorized the adopters into five groups by the criterion: Innovativeness, which refers to "the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a social system". The five adopter categories are innovators, early adopters, early majority, late majority and laggards, which are widely used in the diffusion research of different fields currently.

Figure 3.2 Smooth S-shaped curve



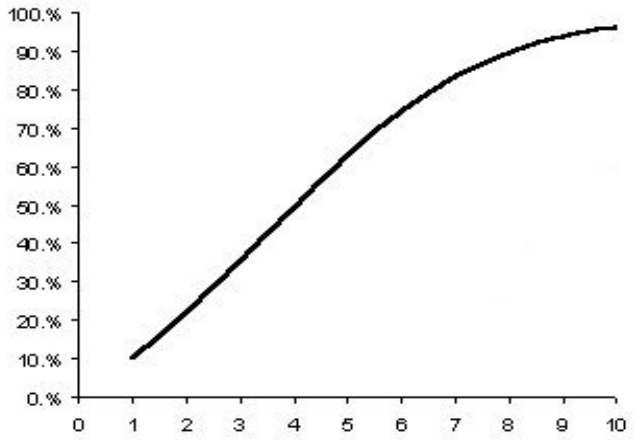
Source: Roger (1995) Diffusion of Innovation

Though the pattern of diffusion is always portrayed as a continuous and smooth S-shaped curve for the successful innovation, Roger also describes in reality, many innovations fail after a few adoptions because the innovations are rejected by the potential mass adopters (the early majority and late majority), which can be showed as the discontinuance or the nosedive of the curve. The considerable difference between early adopters and early and late majority resulting from the different personality and communication behaviors of these adopters requires that dissimilar approaches, such as communication channels or messages, should be employed for different adopter categories in order to diffuse the innovation from one adopter category to another; otherwise, the gap will be formed and widened. Moreover, Roger also mentions that the socioeconomic gap between early adopter and later adopter is widened as the consequence of innovation adoption.

The application and development of the theory[32]

After the S-shaped diffusion pattern was published, many researchers apply the model to their researches and prove the theory further by empirical evidence. One of the developments of the diffusion mode is contributed by Bass, who starts the practical and commercial application of diffusion theory: a growth model for the timing of the initial purchase of new consumer durable products, which is tested empirically by sales data of eleven consumer durables. \

Figure 3.3 Standard Bass curve for the diffusion of innovation



From Figure 3.3, it can be seen that the Bass model looks similar to the S-shaped curve. The discussion of the adoption of diffusion of new ideas or new products by Roger is largely literary, but the Bass theory further discusses diffusion by establishing accurate mathematical model, which could be used in long-range forecast of the sales of new products. Therefore, it can be said that the S-shaped curve of diffusion is proved by the sales data of new products in reality.

The Bass theory is primarily applied to:

- The new generic classes of products rather than new brands or new models of older products
- Durable products

Micro-CHP is not a simple successor of the condensing boiler in the Dutch household and actually it is completely new domestic product in terms of its functions. Moreover, it is not frequently purchased product as clothes, foods and usually has the life time more than years. For this reason, it is proper to base the analysis of the diffusion of Micro-CHP on the S-shaped diffusion pattern.

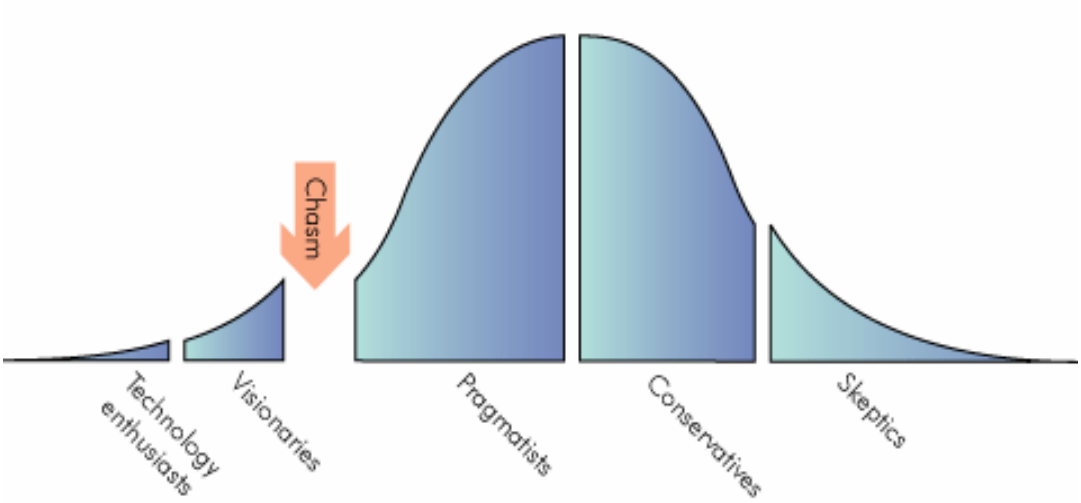
3.1.2 Chasm between the early market and mainstream market.[33]

The presence of the chasm

Geoffrey Moore is one of the researchers who use the five-group adopter categorization in business purchase but he adapts the theory to high-technology products. In his model, the five adopter categories described by Roger are renamed as technology enthusiasts, visionaries, pragmatists, conservatives and skeptics correspondingly (Figure 3.4). In his

analysis, Moore symbolizes the degree of difference between different categories as gaps due to that each category of adopters has its unique characteristics. In order to emphasize and show the large gap between the visionaries and pragmatists (Figure 3.4), Moore groups the technology enthusiasts and visionaries as the Early Market while pragmatist, conservatives and skeptics as the Mainstream Market. His main contribution to the development of innovation diffusion theory is that he propounds that the gap between these two markets is the deepest and widest schism and the most formidable transition in the adoption and diffusion of innovation. Actually, the chasm can be interpreted as the difficulties the new product developers encounter before the sales takeoff.

Figure 3.4 The revised technology adoption life cycle



Source: ***Crossing the Chasm***, Wikipedia, the Free Encyclopedia, visited on June 25, 2005, http://en.wikipedia.org/wiki/Crossing_the_Chasm

The cause of the chasm

The gap exists between every two of the adopter categories, but only the gap between the visionaries and the pragmatists is the most difficult one to be leaped over. Moore lists his explanation for the emergence of the chasm. The cause can be explained in two aspects:

- The visionaries are not the good reference in pragmatists' buying decisions

What the pragmatists care are completely different from that of the visionaries who always find out the potential benefits of the new technology/product and are willing to take higher risks to adopt. In their opinion, these technologies/products are the means to realize their dreams and bring the feeling of being the pioneers whereas the pragmatists care more about

the practical aspects of the new technology/product, e.g. the quality and the reliability of the product, the service and the infrastructure for the product. Due to the different expectation of the two groups, the pragmatists do not regard the visionaries as the credible reference for their purchase decision.

- Lack of pioneers in pragmatists

For pragmatists, the credible reference only could be obtained from their congeners, but the pioneers in the pragmatists market does not exist at that moment. Thus, the emergence of the pioneers from pragmatist becomes the crucial point to cross the chasm.

The different essence of the two gaps

The chasm described in Moore's theory is explained as the obstacle for the successful diffusion of innovation. However, the gap is not only deemed as the reason for the unsuccessful diffusion but also as the consequence of the diffusion, which is represented as the widened socioeconomic gap between early adopters and late adopters in Roger's theory.

3.1.3 Ortt's three-phase diffusion model [34]

Based on the research on breakthrough of communication technologies, Ortt concludes that the diffusion of some of the communication technologies perfectly match the S-shaped curve, whereas the diffusion of several communication technologies introduced after 1970 cannot be described in the smooth S-shaped curve. Especially, the time interval between the first introduction and the start-up of the diffusion is considerable and the state in the phase is unstable and unambiguous, which further indicates the existence of the chasm between the early market and mainstream market described in Moore's research.

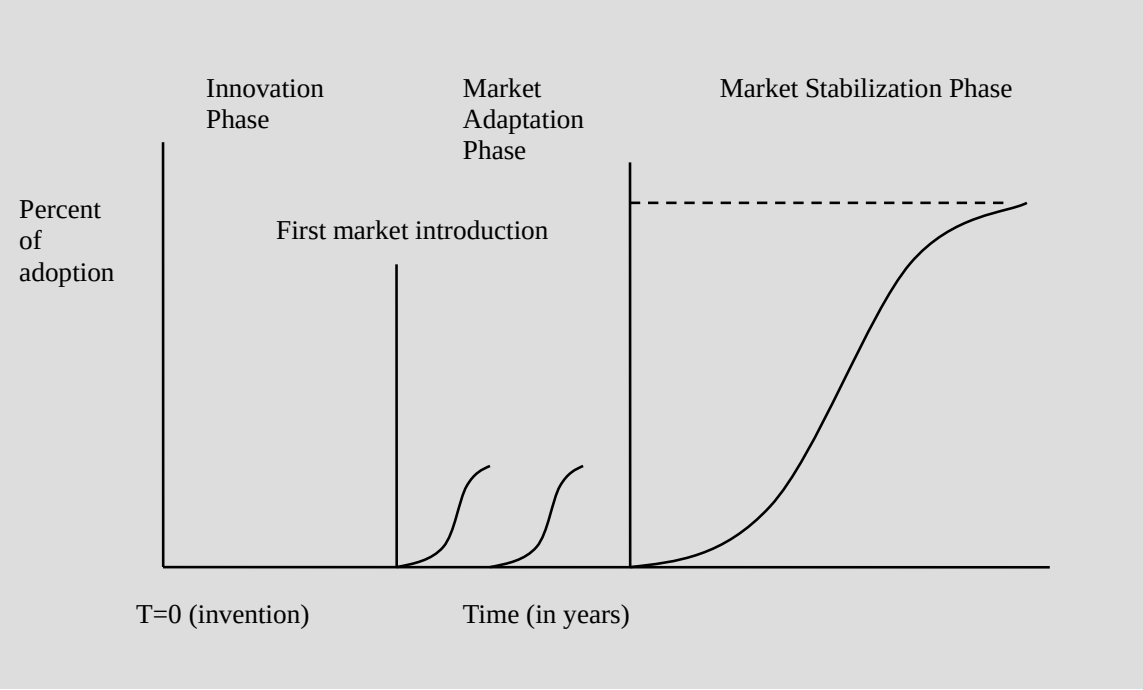
On the basis of the Roger's S-shaped curve, an extended model is developed to capture the pattern of the diffusions of communication technologies. The diffusion model is composed of three phases: Innovation phase, Market adaptation phase and Market stabilization phase which is showed as the smooth S-shaped curve (Figure 3.5).

- Innovation phase: starting from invention of a technology and ending at the first market introduction of the product incorporating the technology.
- Market adaptation phase: the period from the first market introduction up to the sales takeoff of the new product. The diffusion of innovation in this phase is depicted as

some small S-shaped curve because of the unstable markets before the sales takes off in practice.

- Market stabilization phase: beginning from the sales takeoff and ceasing when the product is substituted after the reach of the potential market size.

Figure 3.5 Extension model of S-shaped curve



The market adaptation phase can be interpreted as the trials of crossing the chasm, if the pragmatists market is established successfully, the immediately succedent phase is the market stabilization phase and the time length for the market adaptation phase is short. Otherwise, the diffusion of the innovation might experience the periodic introduction, decline and re-introduction, which is showed as the several small S-shaped curve in this phase.

3.1.4 The difference among the above models

Though the three models illustrate the diffusion pattern of innovation either on the cumulative number of adopters over time or on the adoption frequency over time, they represent the trend of the adoption of innovation similarly. Nevertheless, the extended diffusion model propounded by Ortt is different from the other two models with respect to

research focus and explanation for diffusion driver.

Table 3.1 The difference of the three diffusion models

	Roger & Moore	***Ortt***
Focus	Product	Technology
Explanation	Demand side	Demand and supply side

The differences are showed in Table 3.1 and explained as followings:

Focus

In Roger and Moore's models, the study of the diffusion of innovation focuses on the diffusion of a new product with the explanation of how the product diffuses in the user community over time. Nevertheless, Ortt's extended diffusion model is established on the research on the communication technologies, which have various product types. It could be said that his theory is mainly about the diffusion of technology rather than product.

Explanation

In Roger and Moore's models, the customer, the demand side of the innovation is explained as the main driver for the diffusion of innovation whereas in Ortt's extended diffusion model, both the demand side (customer) and supply side (supplier) are regarded as the drivers for the diffusion. In addition, the main market actors and their roles in different phases are analyzed in details in order to show that the supply side is also crucial for the successful diffusion.

3.2 Determination of the variables

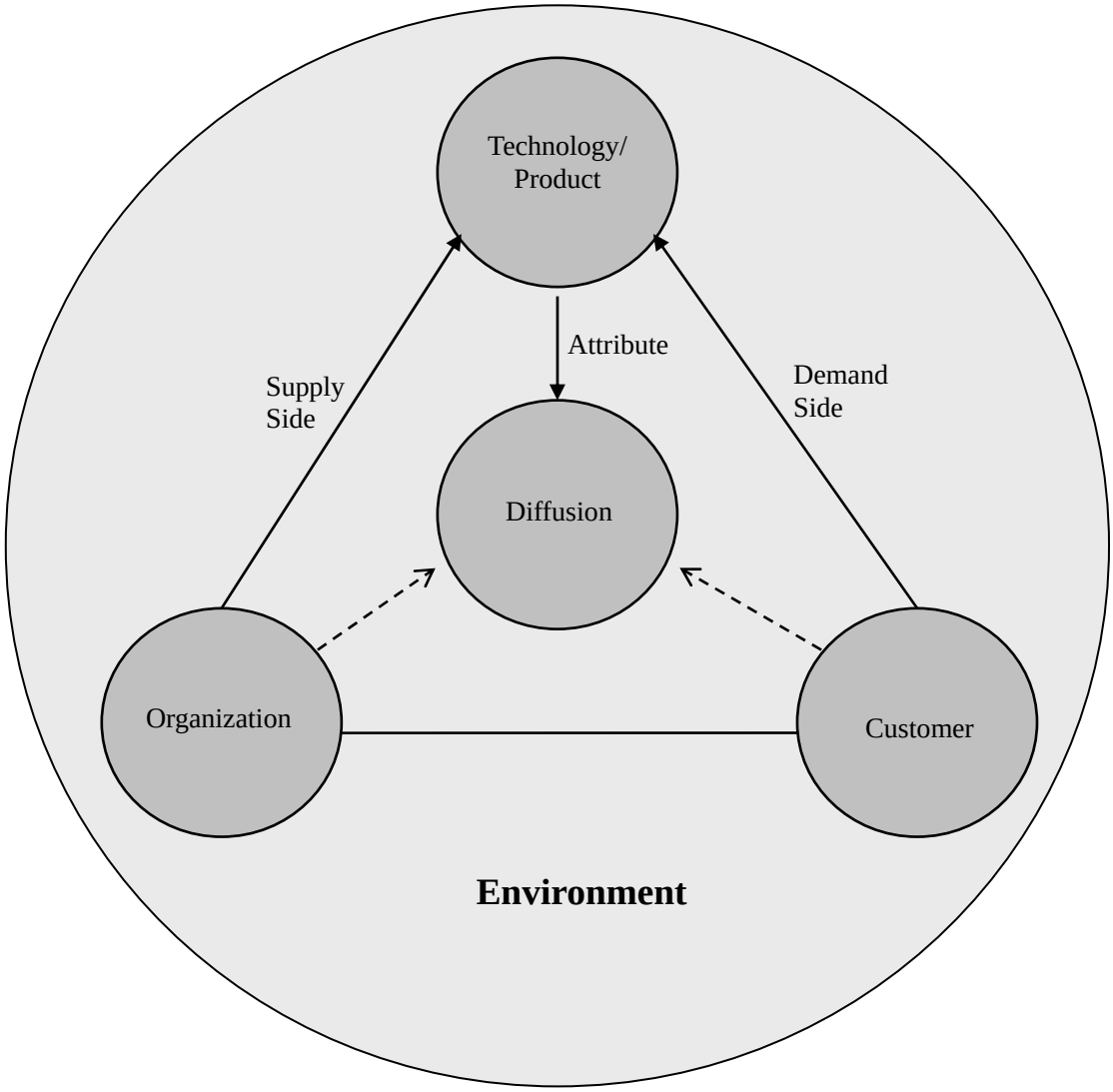
3.2.1 Supply-demand diffusion model

With the development of the diffusion model, the research focus is extended from demand side to supply side related to the market actors and their role in the diffusion of new technology/product. Based on the literature study of the diffusion model, a new model is established with regard to organization/company as supplier, technology itself, the customer and the institutional environment in which they interact with each other. (Figure 3. 6)

This model shows the actors involved in the diffusion of innovation, the relations among them and the roles of the actors in diffusion. In this model, the organization refers to all types of market actors who are involved in the development of new technology/product, for instance, the manufacturer, the installer, the research institute, etc. The customer is the

potential adopters for the new technology/product. The environment includes the government and the society constituting various rules and regulations.

Figure3.6 Supply-demand diffusion model



3.2.2 Ongoing research of variables for the market adaptation phase

Currently, the research focusing on the analysis of the variables influencing the market adaptation phase in the diffusion pattern is being conducted by J. Roland Ortt (referenced as Ortt2005)[35]. In his research, the selection of the variables is based on the empirical data from the diffusion of 50 new technologies (Annex F). Similar to the model described above (Figure 3.6), the variables are derived from organization, technology and consumers respectively. Besides, some variables with regards with the market environment also are determined as important ones in Ortt2005. The categorization of the variables is displayed concisely in the Table 3.2

Table 3.2 The summary of the variables in Ortt2005

	Organization	***Technology***	***Consumer***
Size	Size, assets & Power of organization	Size of technology	Size of demand side
Newness	Organization's experience	Technology/product newness	Demand side newness
Costs	Supply cost		Adoption cost
Willingness	Willingness		Need & wants
Los			

Market environment				
Availability of standards regulation	Cooperation	Protection	Government scale	Los

* Los: Any variables that cannot be classified into any group showed in the table will be listed under Los.

3.2.4 The literature review of the variables

The variables used in the research, which aims to forecast the time length of market adaptation phase of Micro-CHP in the Netherlands, are determined both by the literature review and the variables used in Ortt2005. In order to clearly show the sources of these variables, Table 3.3 summarizes the main results from the literature review. Each variable consists of several factors, which are transferred into the questions in the questionnaire. As for the effect of these variables on the diffusion of Micro-CHP, it is explained in the third column in Table 3.3. These variables influence the development and diffusion in two directions: positive or negative.

- Positive relationship (+): The variable positively affects the benefits of adoption, which accordingly affects the number of adopter over a certain time length. In a word, the variable helps to stimulate the diffusion of Micro-CHP.
- Negative relationship (-): The variable has a negative influence on the diffusion, which might hinder the adoption.

Table 3.3 Variables obtained from the literature review

Variable	*Factor*	*Reference*	*Effect on diffusion of Micro-CHP*
Organization Size (Sizeorg)	Available assets	Agarwal & Bayus (2002), Roger(1995), p379, Ortt2005	(+): The more assets available for the development of Micro-CHP in the organization, the quicker Micro-CHP starts to diffuse.
	Degree of aligning power		(+): The aligning power owned by the organization enables it to align the industry to cooperate with each other and accelerate the diffusion
Organization Newness (Neworg)	Experience of Micro-CHP technology	Ortt2005	(+): If the organization is more experienced in the three aspects, it is helpful to adopt appropriate strategy to stimulate the diffusion and shorten the market adaptation phase.
	Experience of commercializing new technology		
	Experience in the market		
Organization Costs (Costorg)	Degree of change market strategy	Mansfield (1961)[36], Stoneman (1981)[37], Ortt2005	(-): The change of market strategy requires financial support, the costs for the change is the obstacle for the diffusion because organization is usually reluctant to invest on product without ensured profits. The higher the change of market strategy, the more difficult Micro-CHP gets the investment from organization to be developed.
	Required assets for development and introduction		(-): The larger required assets for diffusion, the higher risk the organization takes, which postpone the takeoff of the diffusion.
Organization Willingness (Willorg)	Endurance and willingness of main actor to develop and invest	Cooper & Smith (1997)[38], Ortt2005	(+): The main actors are of importance to the diffusion. If they are willing to invest on the Micro-CHP technology in long term, the technology will get improved, which is beneficial to the diffusion.
Organization	Required cooperation among relevant actors	Ortt2005	(-): The actors involved in the development of Micro-CHP are various. The high required cooperation among them makes the diffusion more difficult to take off.

Environment (Marketenv)	Degree of support from relevant actors		(+): More relevant actors involve in the development of Micro-CHP and support the industry; the shorter the time is taken in the market adaptation phase.
	Availability of existing standards		(+): If the existing standards and regulations are suitable for the operation of Micro-CHP, it is unnecessary to constitute new ones, which obviously make the adoption easier.
	Availability of existing regulations		
	Interest of government on Micro-CHP	Bassala (2001), Ortt2005	(+): Government's interests on Micro-CHP lead the actions of other actors. The higher the interests the government has on Micro-CHP, the quicker the diffusion because of the attention from the government.
	Intervention of government on Micro-CHP		(+)/ (-): Government has a decisive role in the development and the diffusion of Micro-CHP. It can stimulate the diffusion by subsidy or restrict the adoption by strict standards.
Technology Size (Sizetech)	Degree of substitution	Ortt2005	(+): The ability of Micro-CHP to substitute the closest alternative determines the adoption rate, which affects the time length of the market adaptation phase.
	Degree of change required for electricity grid	Tushman &Rosenkopf (1992)[39], Ortt2005	(-): The change required for the electricity grid is an obstacle for the diffusion of Micro-CHP because the network operators are unwilling to invest on the additional change.
Technology Newness (Newtech)	Complexity	Roger (1995), P15-16, Ortt2005	(-): Customers only care whether the new product can meet their requirement and do not care what type of technology used in the product and how complex it is. However, the developers, manufacturers and installers have to spend more money and time on the development before reaching the takeoff of diffusion.
	Reliability and stability	Roger (1995), P15-16, Ortt2005	(+): The higher reliability and stability of Micro-CHP product compared to its alternatives will stimulate its diffusion

	Number of alternatives	Ortt2005	(-): The alternatives are the competitors of Micro-CHP. More alternatives provide more choices for the consumers and the market is more competitive, which hiders the diffusion and reduces the market share of Micro-CHP.
Technology Environment (Protectech)	Technology protection	Mahajan, Muller & Wind (2000), Ortt2005	(+): The strict protection of technology avoids the free copy and the license-purchase provides a healthy market competition mechanism, which reduces the instability of market adaptation phase and helpful for the takeoff of diffusion.
Consumer Size (Sizecons)	Potential market size	Ortt2005	(-): Given the same adoption rate, the bigger the potential market size, the longer time it takes to achieve the saturated market.
	Critical mass supply	Ortt2005	(-): If the minimum number of customer required to make the suppliers of Micro-CHP economically viable is large, it is difficult for them to survive at first, then saying nothing of the takeoff of diffusion.
	Critical mass demand	Goolsbee & Klenc (2002)[40], Roger (1995), p31 Ortt2005	(-): The decision of the potential adopter is influenced by the actions of the people around them. The larger the number of the adopter required to make the product interested by others, the more difficult the diffusion takes off and longer time will be needed before the diffusion takeoff.
Consumer Newness (Newcons)	Newness of customer group	Ortt2005	(-): The emergence of new customer group requires modification or complete change of the market strategy, which, compared to the unchanged customer groups, needs more time to adjust and delays the diffusion.
	Number of new actor entering into energy industry	Ortt2005	(-): The entering of the new actors makes the value chain of the Micro-CHP more complex and the cooperation among them more difficult, which prolong the time of adaptation phase.
Consumer Costs	Degree of change in behavior Degree of learning required	Ortt2005	(-): More changes in consumer's behavior and more learning required from consumer cause the consumer's unwillingness and hesitation to adopt Micro-CHP, which slows down the

(Costcons)			adoption.
Consumer Willingness (Willcons) (Needs & Wants)	User friendliness	Roger (1995), P15-16, Ortt2005	(+): Higher user friendliness enables Micro-CHP to be adopted quickly and shorten the market adaptation phase.
	Preference of potential customer	Ortt2005	(+): The preference of potential customer to Micro-CHP makes the adoption faster because the customer already has good impression of Micro-CHP before their purchase.
	Physical and technical risks	Roger & Stanfield (1968)[41], Ortt2005	(-): The physical and technical risks caused by the operation of Micro-CHP impede its diffusion. Compared with the alternatives, the higher the risks, the slowly Micro-CHP is adopted by consumer.
	Trialability	Roger (1995), P15-16, Ortt2005	(+): Before the purchase, consumer always wants to try new product if it possible. Therefore, the higher the trialability of Micro-CHP, the more easily consumer adopts, which results in the quicker takeoff of diffusion.

Some of these literature reviews are elucidated as followings:

- Technology/product

From the customer's (adopter) perspective, five attributes[42] significantly influence the diffusion of innovation:

1) Relative advantages: it not only can be measured in economical terms but also can be expressed as social prestige, convenience and satisfaction
2) Compatibility: the innovation is compatible with social-cultural values and beliefs, past experiences, and the needs of the potential customers.
3) Complexity: the extent of the difficulties the innovation is understood or used.
4) Trialability: the degree of the ability of an innovation can be trialed by potential customers.
5) Observability: the degree to which the results of an innovation are visible to others

In the selection of the variables for the market adaptation phase, the relative advantages can be embodied as factors: user friendliness and the technology's reliability and stability. The compatibility and observability do not enter into the important factors since Micro-CHP does not relate to them distinctly.

- Organization

As the supply side of the new technology/product, the organizations dominant in the market adaptation phase aforementioned and play the stimulating or impeding role depending on the characteristics of the organizations. For instance, the size of the organization regarded as the predictor of organization innovativeness is discussed by many researchers and it is finally summarized by Roger.[43] In the paper written by Agarwal and Bayus, the size of the organization is also suggested as the one of the factors based on their quantitative analysis of 30 product innovations introduced in USA between 1849 and 1983. "The entry of larger firms with great resources and commitment to build the market may attract other firms to the nascent industry".[44]

- Consumer

As the demand side of the technology/product, the potential customer is the pull force for the diffusion of innovation. Their preferences and their attitudes for the new technology/product significantly influence the rate of the adoption. Besides the subjective factor from the consumer, the sale of product is also restricted by the potential market. One crucial factor in the diffusion of innovation introduced by Roger[45] is critical mass, "which occurs at the point at which enough individuals have adopted the innovation so that the innovation's further rate

of adoption becomes self-sustaining". Especially, critical mass is pivotal for the diffusion of interactive technology, for instance, telephone, cell phone and fax. Nevertheless, critical mass also plays a critical role in the diffusion of non-interactive technology because the individual behavior always depends on and is influenced by the behavior of the people around them.

- Environment

The environment is the external environment, e.g. institutional environment, society, for the organizations, the technology/product and the customers. The environment impacts on the diffusion of technology/product indirectly via its influence on organization, customer or technology itself.

The government is able to facilitate or hinder the development of technology by direct means such as regulation or by indirection means, e.g. the subsidy on demand side or supply side. Bassala[46] emphasizes the decisive role of government in the development of technology in every phase. In the innovation phase, it can subsidize the research and in the market adaptation phase, it is able to restrict or stimulate by constituting legal system (regulation and tax law). In the market stabilization phase, it has the ability to influence the supply and demand of the technology/product.

The protection of technology is another factor in market environment and its role for the diffusion of technology is discussed by Mahajan.[47] The instant camera market in the United States is taken as the example to explain the patent-infringement's influence on the diffusion of technology and the data shows that the instant camera expanded due to Kadak's entry.

3.2.3 Adjusting the composition of variables

Tough the determination of variables is mainly based on the Ortt2005; some changes are made because of the specific application on the new product: Micro-CHP.

The re-composed variable

- Organization:

1. The experience and expertise of orgainzation is more related to the newness of organization, therefore, this factor is transferred from Los to variable "Organization Newness".
2. The degree of the change of market strategy reflects the costs for the organizations which plan to introduce new product to market. The factor is thus grouped into the variable

"Organization Costs".

- Technology:

1. The degree of substitution and the degree of the change required for the next large system are slotted into the variable: "Technology Size" because the development size of the technology depends on the next larger system in which it positions and its potential ability to substitute the existing technology.

2. The reliability and stability depend on the type and the development phase of the technology. Usually the breakthrough technology has less reliability and stability in its early product model and gets improved with the efforts of developers during its development. This factor indicates the technology newness in this point, therefore; it is categorized into "Technology Newness" from "Consumer Willingness".

3. The alternatives for Micro-CHP can be regarded as its competitors. The newer the technology is, the fewer competitors it has. The number of alternatives is categorized into variable "Technology Newness" from Los.

- Consumer

Degree of trialability of Micro-CHP is grouped into variable "Consumer Needs & Wants" since it can be tried whether it meets the needs of consumers before the adoption.

- Environment

Since the organization, technology and customer interact with each other and influence the diffusion within environment, it would be reasonable to integrate environment with organization, technology or customer to produces new variables whereas in Ortt2005 they are separately listed (Table 3.2 and Table 3.3). Because the development of Micro-CHP is largely influenced by the regulation and the cooperation between organizations, the environment in this study mainly refers to the institutional environment and the interactions among different organizations. Therefore, the factors under the groups: Availability of standards and regulations, Cooperation, Government scale and Los are all classified into the variable "Organization Environment". The technology interacting with its environment mainly relates to the protection of technology and usually it is protected by law, thus it is grouped into variable: Technology Environment" (Technology Protection).

The re-composed variables are showed in detail in Table 3.4, which is the basis of the design of questionnaire. (Every factor corresponds with one question, which is showed in Table 3.4 in question number.

Table 3.4 The re-composed variables and its composition

	Organization	***Technology***	***Consumer***
Size	● Available assets Q14c ● Degree of aligning power Q17	● Degree of substitution Q4 ● Degree of change required for electricity grid Q5B	● Potential market size Q7a ● Actual market size Q7b ● Critical mass supply Q19a ● Critical mass demand Q19b
Newness	● Experience of Micro-CHP technology Q13c ● Experience of commercializing new technology Q13d ● Experience in the market Q13e	● Complexity degree Q1b ● Reliability and stability Q2 ● Number of alternatives Q3	● Newness of customer group Q6 ● Number of new actor entering into energy industry Q12
Costs	● Degree of change market strategy Q14a ● Required assets for development and introduction of Micro-CHP Q14b		● Degree of change in behavior Q11a ● Degree of learning required Q11b
Willingness	● Endurance and willingness of main actor to develop and invest Q15		● User friendliness Q3 ● Preference of potential customer Q8 ● Physical and technical risks Q9 ● Trial ability Q10
Environment	● Required cooperation among relevant actors Q16a ● Actual cooperation Q16b ● Degree of support from relevant actors Q16c ● Availability of existing standards Q20 ● Availability of existing regulations Q21 ● Interest of government on Micro-CHP Q22 ● Intervention of government on Micro-CHP Q23	● Technology protection Q18	

Chapter Four

Methodology and Process Of Survey

Chapter Four Methodology and Process of Survey

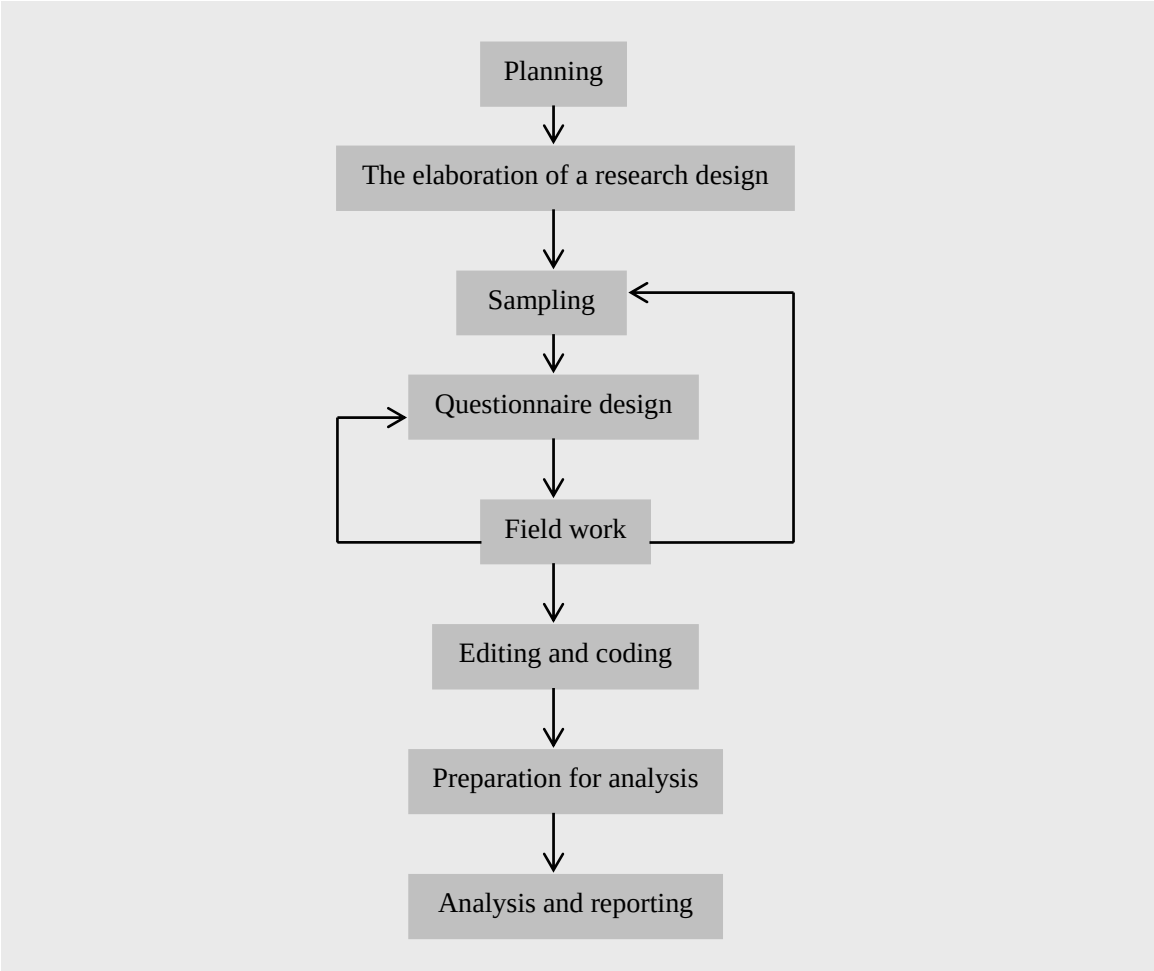
4.1 Methodology and Process of Survey

The methodologies and processes of surveys are diverse thanks to their distinct characteristics and different research purposes. Some of these surveys are designed to collect data from large number of samples and are analyzed quantitatively, whereas others are carried out within a limited number of respondents and the qualitative analysis is primarily implemented. Moreover, some surveys are conducted with an organization either by the in-house staff or by out-sourcing external experts to meet its special needs, which could be analyzed qualitatively or quantitatively depending on the number of the samples.

4.1.1 Eight stages survey process

Warwick and Lininger[48] propose that the survey process can be represented as eight stages, which are the typical process for the survey with large number samples and every stages is interdependent. The process can be summarized in the flow chart (figure 4.1)

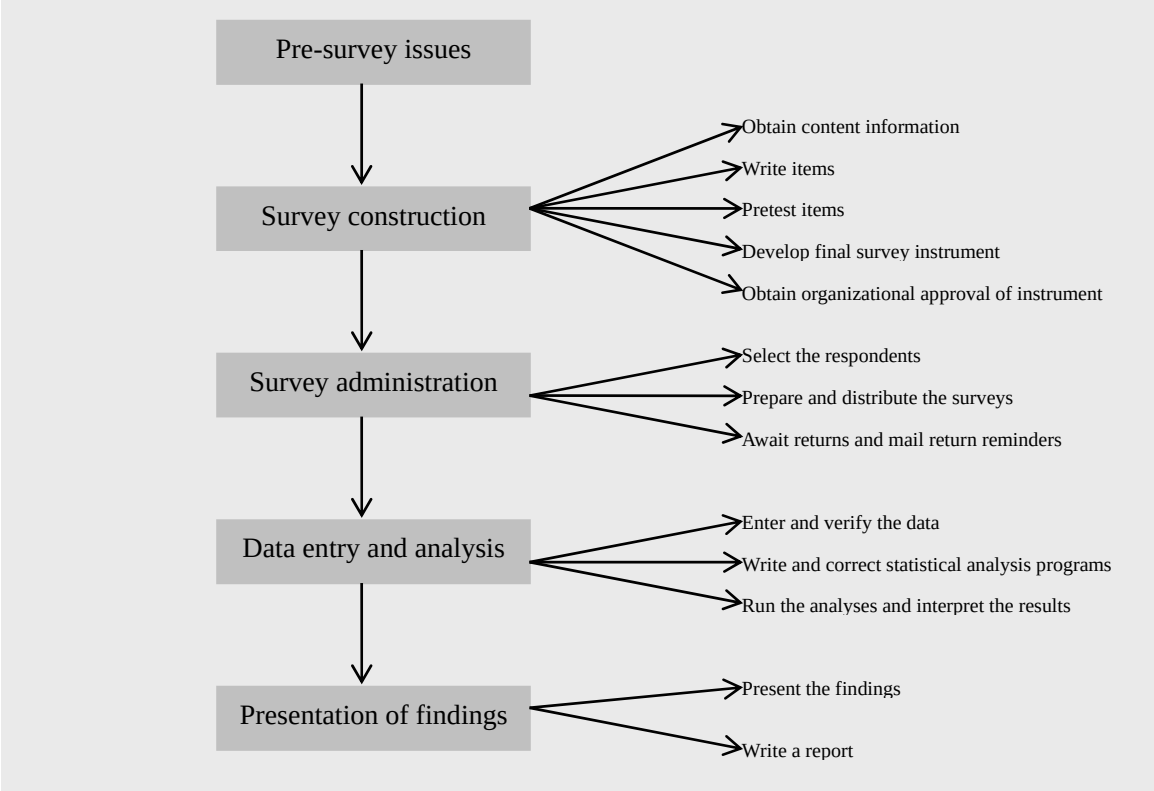
Figure 4.1 The eight stages of survey process



4.1.2 Five phases survey process

In the book edited by Rosenfeld, Edwards and Thomas, one article[49] specially describes the general five phases of the survey process and emphasizes the thirteen steps for the in-house survey of an organization. The five-phases survey is conducted more sequentially compared with the eight-stage survey. Figure 3.2 shows how to implement the survey process:

Figure 4.2 General five-phase survey process



4.1.3 Methodology and process of survey in this research

Characteristics of the research

The two processes of survey aforementioned indicate that there is not any universal process or methodology for survey; therefore, the methodology and process employed in this research have to be designed in accordance with the characteristics and purpose of the research. Unlike the survey conducted in other researches, the survey possesses the following distinctness:

- The limited time for the research (half an year)
- The restricted research object (the potential market size and the time length of the market adaptation phase in the Micro-CHP's diffusion pattern in the Netherlands)
- Combined analysis approach: qualitative and quantitative

Methodology and process of survey

On the basis of the two processes of survey above and according to the characteristics of the study, the methodology and process of survey is designed as a five-step process, nevertheless, the pre-survey task is already finished in Chapter 3: the determination of variables, which is the basis for the questionnaire design.

Step 1: Questionnaire design

- The format of questionnaire
- The pre-testing of questionnaire and revising

Step 2: Survey implementation

- Select respondents and the implementation method
- Distribute questionnaire or interview while improving the questionnaire
- Summarize the information obtained in every questionnaire

Step 3: Preparation for analysis (Editing and coding, chapter 5)

- The coding of the respondents (assigning number to respondent)
- The coding of choices (assigning values to choices of question)
- Group questions into variables (Editing)
- Enter and verify the numbers and values
- Calculating the mean value of every variable

Step 4: Data entry and analysis (Chapter 5)

- Qualitative analysis
- Quantitative analysis

Step 5: Reporting of findings

- Predict and present the result (Chapter 5)
- Conclusion (Chapter 6)

This five-step survey process is established on the two survey methodologies and the characteristics of the study. Since the survey is carried out in the form of questionnaire, the first step is questionnaire design, which is crucial to collect the useful information and data for analysis. The eight-stage survey process is mainly used for survey with large number of sample, in this study the number of the sample (respondents) is relatively small due to limited research time and restricted research objects, therefore, the stage of redesigning the questionnaire and reselecting samples by field work is not suitable for the survey carried out in this study. The questionnaire is only pre-tested before its distribution. Because Micro-CHP is a very new product with respect to the concept of producing electricity and heat simultaneously and is not introduced commercially in market in the Netherlands formally, it is impossible for the layman to answer the questionnaire and so the selection of professional

respondents significantly impact the result of the survey. The questionnaire is mainly implemented by face-to-face interview and noting down the recording after every interview not only helps to collect the information efficiently but also improves the questionnaire with the comments from the interviewee. So the second step is the implementation of survey and includes the three tasks. In the five-step process, the preparation of analysis is designed as one important step because the coding and editing the data and information obtained from the questionnaire is the step before carrying out the analysis. It is different from the eight-stage process and the five-phase process of survey, the former separates the coding and editing from preparation of analysis and the later does not mention the coding and editing at all. However, in this study, the coding the respondent and choice and calculating the value of the variable are the basis for the analysis. Therefore, the preparation of analysis is designed as the third step. The step 4 and 5 are similar to the last two steps in the eight-stage process and five-phase process since those previous steps implemented are for the last two steps: analysis and reporting the results, which are also the most important two steps in the survey.

4.2 Questionnaire design[50]

The questionnaire design is based on the questionnaire used in the Ortt2005, but due to that Micro-CHP is a new technology without any commercial sales in the Netherlands, the questionnaire is redesigned according to the determined variables in Chapter 3 and the research purpose of the study.

4.2.1 Questionnaire format

The description and definition of the research object

In order to give a clear idea of the term CHP (Combined Heat and Power), at the beginning of the questionnaire, the CHP concept is explained with high efficiency compared with the electricity-only traditional power generation and heat-only boiler. Based on the concept, the Micro-CHP system is introduced to the household level due to its potentially large-scale adoption in the Netherlands, in which several favorable conditions provide the possibility.

The Micro-CHP is defined differently for different research purposes, so the definition of Micro-CHP is presented at the beginning in order to confine the research scope.

The purpose of the survey

The purpose of the survey in the questionnaire is meant to show the respondents the aim of conducting the questionnaire and research scope. The questionnaire focuses on the prediction of the potential market size and the time length of the market adaptation phase in the Netherlands. Some terms are also explained in case that the respondents are not familiar with

them.

Instruction for fill-in

Initially, the questionnaire is designed as the self-administered questionnaire sent by mail or email; therefore, the instructions of filling in the questionnaire are crucial to obtain effective data and information from the returned questionnaire. Though the interviewing method is altered to face-to-face interview because of the reduction of the number of samples (respondents) and the instruction can be explained orally during the interview, the part is still kept in case that some respondents are unable to participate the face-to-face interview and willing to answer the questionnaire by mail or email. Several aspects are mentioned in the instruction:

- Choose the best option for every question
- How to do when the respondents do not know the answer
- The confidential of the questionnaire

Professional backgrounds of respondents

It is planned to interview the people from various organizations or companies involving in domain of Micro-CHP. The professional backgrounds of the respondents provide the information to explain from which point of view they answer the questions with the awareness of the basic reason why they answer in that way. Four aspects are inquired:

- The type of the organization or company in which they are employed
- The function/responsibility they have in their organization or company
- The main activities they conduct in the Micro-CHP field
- Their knowledge level of Micro-CHP market and technology

Question type

The preliminary idea of the question design is that the question type should be closed question, which meets the requirements of the interviewing method of sending questionnaire by mail or email to large number of samples: limiting the scope of the answer, providing the option and saving time for the respondents. On the one hand, with the reduction of the number of the sample and the utilization of qualitative analysis method, the interviewing method changes from questionnaire sent by email to face-to-face interview and accordingly, the question type changes from closed question only to the combination of closed and open question because the open question is valuable and essential in exploring the qualitative aspects of a problem[51], on the other hand, this face-to-face interviewing method provides the feasibility of executing the open question which needs more detailed oral explanation.

Finally, three types of question are decided to be used in the questionnaire:

- Closed question

1) Question

All of the closed questions have the same format and are composed of two sub-questions. One is questioned about the degree of the factor mentioned in the question under certain conditions, e.g. compared with the closest alternatives or before a time point. Another is inquired of the importance of the factor influencing the diffusion of the Micro-CHP. Take the complexity of Micro-CHP as example and the question format can be displayed as:

Figure 4.3 The format of closed question

In your opinion, compared with the closest alternative, what is the complexity of Micro-CHP? How significant of the complexity of Micro-CHP affecting its large-scale application?

2) Option of answer

Based the question format, the response options are designed into five scales, which are in balance and some of which are explained with examples. For the degree of the factor, the options are listed in accordance with its influence on the time length of the market adaptation phase and the time length becomes longer from top to down. For the importance of the factor, the option shifts from the scale of **Very important** to the scale of **Very unimportant**. Corresponding to the question format, the responses format are designed as in Figure 4.4

Figure 4.4 The format of response for the closed question

Degree
❑ *Far more simple*
❑ *More simple*
❑ *As simple or complex*
❑ *More complex*
❑ *Far more complex*

Importance
❑ *Very important*
❑ *Important*
❑ *Average*
❑ *Unimportant*
❑ *Very unimportant*

- Open question

As described above, the open question is used to collect valuable information for the qualitative analysis. The adding of open questions into the questionnaire offers the respondents with opportunity to express their opinions of a problem and reflect on the answers they give. No fixed format of open question in the questionnaire.

- Closed-open question

The combination of closed and open question into one question is designed for the purpose of gaining more specific information for qualitative analysis while the data obtained from the closed part of the question can also be analyzed quantitatively. The format of the type of

question is demonstrated as follows:

Figure 4.5 The format of closed-open question

How many potential alternative technologies under development are available to replace Micro-CHP in the electricity grid?

- ❑ *No*
- ❑ *One*
- ❑ *Two*
- ❑ *Three*
- ❑ *Four or more No*

Please list here:

_____

_____

_____

The pre-testing and modification of questionnaire

- The goal of pre-testing

After the completion of questionnaire design, pre-testing is the critical step to improve questionnaire before its distribution. In the survey, most of the questionnaires are filled during the face-to-face interview, so the pre-testing is carried out in the same way. The goal of the pre-testing is to[52]:

1) Know the required time in order to use interview time efficiently
2) Verify the clearness of the sentence and terms for the respondents
3) Obtain comments for questionnaire (the phrasing of questions, the rating scales, the displaying of the information) to modify the questionnaire

Without the pre-testing, the dash of implementing the questionnaire might result in:

1) The shortage of the interview time which influences the response accuracy
2) The false or useless response of question
3) The debasement of the reliability of findings

- Conduction of pre-testing and revision of the questionnaire

Before implementing a formal pre-testing, two professors from Delft University of Technology (TUDelft) were invited to give their comments on the questionnaire draft and the revised questionnaire becomes the first version for the pre-testing. The pre-testing was conducted by means of a face-to-face interview with an assistant professor from TUDelft. During the trial of the questionnaire, several aspects attract the attention due to its large influence on the quality of the questionnaire:

1) The tendency to choose the **No opinion** option: in the questionnaire used in the pre-testing, the rating scale of the importance of the factor was depicted as four scales: **High, Average,**

Low, No opinion. However, it was found out that the interviewee has the tendency to choose the **No opinion** option specially when he really did not know the answer and the question is difficult.

2) Incomprehensible terms: the terms such as **Substitutability, Trial ability**, **Support, Critical mass** and **Critical supply** were not easily understood by the interviewee because either the term has various meaning or the term is rarely used.

Based on the information and comments gained in the pre-testing, the questionnaire is revised accordingly:

1) The scale of importance of the factor is modified to five rating scale by deleting the **No opinion** option: **Very important, Important, Average, Unimportant, Very unimportant.** The five rating scale not only subdivide the scale of the importance to improve the preciseness, but also it is a balanced scale, which makes the format of the responses more concise and the match with the format of the response of the **Degree** question.

2) In addition to the literal modification of the questionnaire, some of the inquiring methods are also adjusted. The meanings of the terms mention above are interpreted before the interviewees ask to clarify them.

The survey package consists of the survey cover letter and questionnaire, which are enclosed in the Annex B and Annex C.

4.3 Methods of questionnaire execution

The next step after the questionnaire design is implementation phase, during which the questionnaire is continuously improved. The respondent selection and interviewing method are the footstones for the implementation phase and determine the validity and reliability of the survey findings.

4.3.1 Selection of respondents

Originally, the survey is planned to be sent to the organizations or companies which are involved and interested in Micro-CHP, but the risk of conduction the survey in this way is no return or few return of questionnaire due to the lack of the direct contact with the respondents. In order to reduce the risk and due to the limited research time, the number of respondent is reduced and the targeted respondent is changed from the organization or company as a whole to the specific person(s) in that organization or company.

For the sake of obtaining comprehensive opinions of the development of Micro-CHP, the questionnaire is prepared to be distributed to the respondents working in the organization or companies which are the important actors in the development of Micro-CHP. The actors are categorized into seven groups: developer, research institute, manufacturers, installer, government, energy company, environment organization.

In order to avoid the useless returned questionnaire, some criteria are established for the selection of the respondent:

- Involvement in the Micro-CHP field formerly or currently
- Possession of the technology and market knowledge of the Micro-CHP
- Representative from every actor group

4.3.2 Interviewing method

General interviewing method

Traditional interviewing methods include face-to-face interview, telephone interview, self-administrated questionnaire delivered by mail or the combination of the above.[53] With the development of the technology and the expanded usage of computer and fax machine, the questionnaire also can be distributed by email or fax.

The interviewing method used this survey

In the survey, most of the contacts with respondents are via email and the survey cover letter is also send by email. A majority of the survey are implemented by face-to-face interviews with the assistant of questionnaire, which provides the basic route to conduct the interview and guarantees the systematic and continuous implementation of the questionnaire. Some respondents choose the other interviewing method due to the issue of location and time: the distribution of questionnaire by email and the return of questionnaire by mail or email or further discussion by phone. Which interviewing method adopted is approved by the respondent before the questionnaire implementation. Therefore, the interviewing method employed in the survey is the combination of:

- Face-to-face interview,
- Telephone interview
- Self-administrated questionnaire delivered by mail
- Self-administrated questionnaire delivered by email,

The interviewing method adopted in the study could be also regarded as a combination of traditional and modern interview methods. Though the face-to-face interview provides the

chance for respondent to explain his choice for the question and provide much information of the Micro-CHP development in Dutch market, the questionnaire provides the basic data collection method, so the data gathered either from interview or from self-administrated questionnaire delivered by mail or email is regarded with same reliability and will be analyzed with same methods.

4.4 Approach of analysis

In order to make full use of the information and data obtained from the questionnaire, qualitative and quantitative method are both employed.

4.4.1 Approach of quantitative analysis

This approach is used for the estimation of the time length of market adaptation phase in the Micro-CHP's diffusion pattern. It is implemented in the following steps:

Coding

By attaching number to the respondent and the values to the options of every question, it makes the succeeding calculation more systematically.

Identifying variables

Based on the categorization of variables in chapter two, the questions are group into 12 variables, every of which is composed of several factors (in the form of questions).

Calculating

Firstly, the mean value of every question is calculated on the basis of answers from all the respondents. In the case of answer missing due to the lack of the particular knowledge or lack of hypothesis for answering, these answers are regarded as invalid and are excluded from the calculation. For instance, if one question is answered by four respondents from six respondents, then the mean is only calculated by dividing the total value with 4 rather than 6. Secondly, the mean value of one variable is obtained by computing the average mean of the questions grouped into this variable.

Comparing and predicting

The mean values of the 12 variable determined typically for Micro-CHP will be compared with the mean values of variables gained from Ortt2005. Each of these variables contributes to the time length by either shortening or lengthening it. Ultimately, the time length of Micro-CHP after its market introduction and before the real takeoff of diffusion will be

predicted.

4.4.2 Approach of qualitative analysis

Two qualitative methods are executed in the analysis.

Percentage[54]

Several issues are questioned in the form of open question and therefore the answers for these questions are unrestricted. By listing all the mentioned items for one issue and get one entire item table, the times of one item mentioned by all the respondents are counted, though some of the items are mentioned by more than one respondent and some respondents suggest more than one item. The times mentioned for every item is divided by the total number of respondents, the percentage of this item mentioned in all the responses is obtained. The higher the percentage, the more important the item is for the issue from the perspectives of all the respondents.[55]

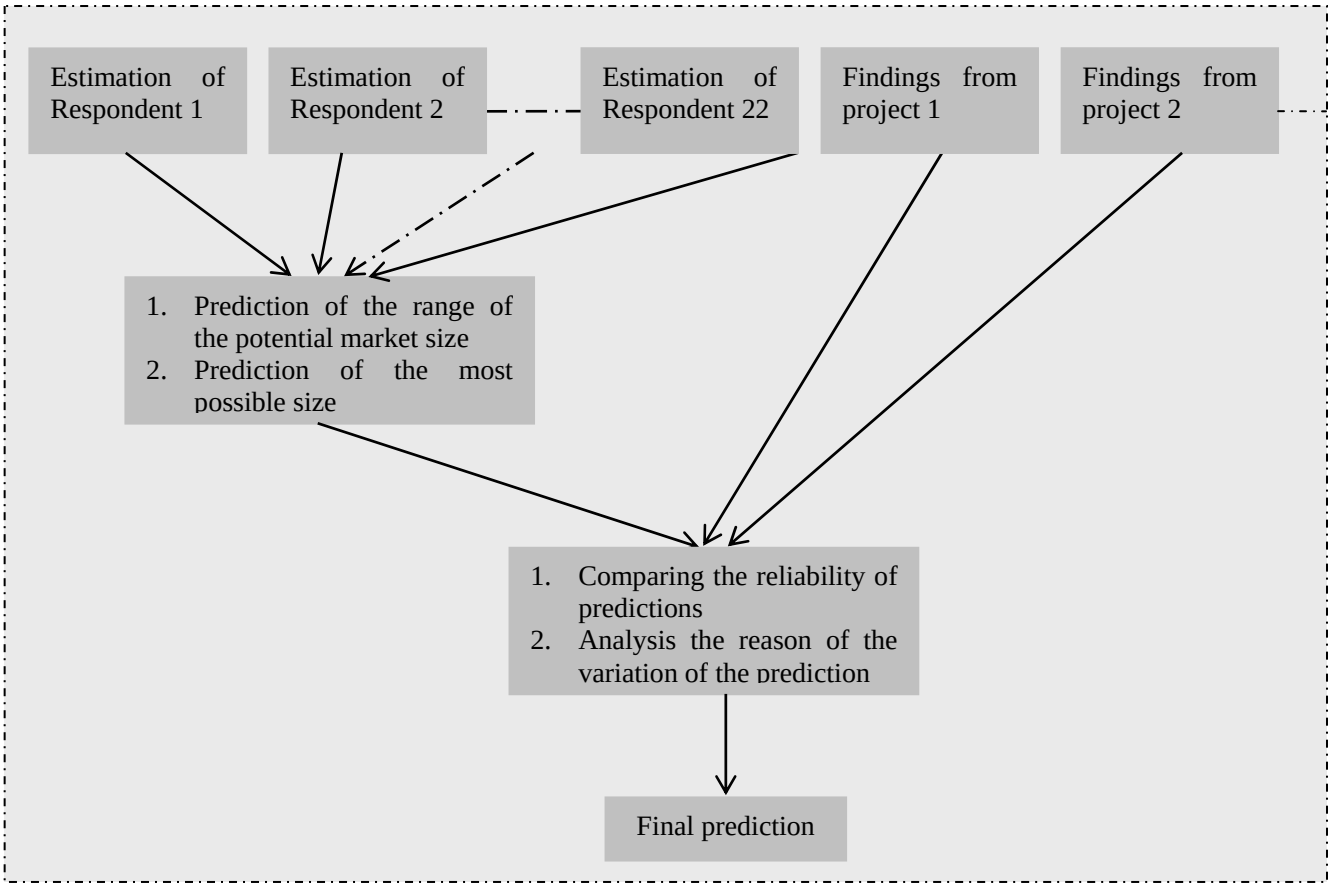
This qualitative method will be used in the analysis in the following issues:

- The type of organization from which the respondents are (Chapter Five)
- The prediction of time length of market adaptation phase (Chapter Five)
- The most important factors influencing the diffusion of Micro-CHP (Annex I)

Estimation by combining literature and questionnaire

The potential market size of Micro-CHP in the Netherlands is inquired in the questionnaire by designing two closed questions which are asked from different angles. Based on the predictions of the respondents from their perspectives, the potential market size could be estimated, however, it only reflects the subjective ideas or opinions of the respondents, which reduces the reliability of the estimation. Many researches are conducted by establishing models, the predictions of which are more accurate but with limitation due to the different hypothetic premises. Taking into account of the two resources, the final prediction of the potential market size will be grounded on the comparison of the estimation obtained from the survey with the prediction attained from these researches. The method is showed in Figure 4.6:

Figure 4.6 Analysis method of potential market size of Micro-CHP



Chapter Five

Survey Analysis

Chapter Five Survey Analysis

5.1 Preliminary analysis

In total, 23 respondents participated in the survey and 23 questionnaires were returned during one and half a month. Sixteen questionnaires were implemented by the means of face-to-face interview and the rest were sent by email and returned back by mail or email. 22 questionnaires were answered almost completely except three respondents failing to answer one question, one respondent failing three questions as well as one failing in 9 questions, but all of these questionnaires are deemed as effective ones. Only one questionnaire is regarded as useless since in the returned questionnaire, half of the questions were not answered.

5.1.1 The quick review of the respondents

The 22 respondents are from seven types of organization and are summarized in the following table.

Table 5.1 Type of organization in which the respondent is employed

Organization Type	*Number of respondent*	*Percentage (%)*
Research institute/University	8	36.4
Energy company	5	22.7
Government	3	13.7
Micro-CHP developer	2	9.1
Micro-CHP production/distribution	2	9.1
Consultancy company	1	4.5
Boiler manufacturer/seller	1	4.5
Total	22	100

As show in the table, majority of the respondents are from Research institute/University and Energy Company. Though Micro-CHP has passed the innovation phase and the commercial introduction is expected soon, the development and improvement of the technology is still crucial for the achievement of large-scale diffusion. However, the respondents from three types of organization: installer, distributor or seller and environment organization, are not reached due to the limited time and difficulty of getting contact information.

5.1.2 Coding and editing

Assigning number to respondents

The number assigned to the respondent is from 1 to 22. In order to make the data entry easy and the subsequent analysis systematic, the respondents interviewed face-to-face are assigned from 1 to 16 in terms of the interview date and time, e.g. number 1 is attached to the first respondent interviewed, number 2 is assigned to the second interviewee, and so on. Successively number 17 to 22 is assigned to the respondents who filled in the questionnaire by self-administration in terms of the date and time of return.

Attaching value to options of question

Every question has five options, each of which is listed in terms of the level of its influence on the time length of market adaptation phase, and the value attached to five options is from 1 to 5 with the meaning of the higher value standing for the longer time length.

As for the importance of the factor indicated in question, the value 1 to 5 is also attached to options from very unimportant to very important. In other words, the degree of importance decreases from 5 to 1.

Calculation of the mean value and median value

The calculation of the mean values of variables is carried out in two steps:

Step 1: Due to that the value is assigned to the options of every question, the value of every factor has to be calculated firstly (Annex C).

Step 2: As showed in Table 3.3, the variables consisting of several factors and the mean value of variable is recalculated according to the values of factors (showed in Annex D).

The value (numbers) attached to the choices for every question merely indicates the order or ranking of choice and the intervals between choices are unequal. The measurement here can be categorized as ordinal scale. The ordinary arithmetic operation is not allowed to perform because it has no meaning.[56] For the data gathered from ordinal scale, the median is suitable to be used to calculate the central tendency of the data set whereas the mean as one type of arithmetic method is proper for the data in internal and ratio scale.[57] In Annex C, the mean value and the median value of every factor (question) are both calculated, and compared the value in the two columns; the difference is very small for the majority except one factor. The close value of the mean and median measure shows that it is acceptable to use the mean value in the following quantitative analysis.

5.2 Analysis and prediction of the time length of market adaptation phase

5.2.1 Quantitative analysis

Regression analysis

After finishing the calculation, the regression analysis is performed by the computer program designed in Ortt2005. The basic principle of regression is to establish the relationship between the twelve variables and the market adaptation phase, which will be presented in the form of mathematic formula, namely, the time length of the market adaptation phase will be calculated mathematically. The output of the implementation of the computer program is showed in Table 5.2.

Table 5.2 Result of regression analysis

Summary Output					
Regression Statistics					
Model		1	2		
R		0.432	0.527		
R Square		0.187	0.278		
Adjusted R Square		0.168	0.244		
Coefficients [a]					
		Unstandardized Coefficients			
Model		B	Std. Erro	t	Sig
1	(Constant)	-3.526	5.183	-0.68	0.500
	Sizeorg	2.723	0.857	3.179	0.003
2	(Constant)	242.982	105.94	2.294	0.027
	Sizeorg	2.242	0.842	2.662	0.011
	Date of invention	-0.126	0.054	-2.329	0.025

a. Dependent Varialbe: market adaptation phase

Based on the coefficients showed in table 5.2, two mathematic models could be formulated to calculate the expected time length of market adaptation phase of Micro-CHP.

- Model 1: Time length = -3.526+ 2.723*Sizeorg
- Model 2: Time length = 242.982+ 2.242* Sizeorg- 0.126*Date of invention[1]

[1] Micro-CHP can be considered as one sub-type of CHP in domestic level and their operations are based on the same principle: the primary fuel, for instance, natural gas or coal produce the second fuel electricity and thermal energy, therefore, the invention of Micro-CHP can be dated back to the invention date of CHP. The basic concept of Combined Heat and Power has been introduced over one hundred years. The first cogeneration patent was got in 1784, which is the new discovery in the application of steam.[1] Until 1882, the first power plant was established, which is also the first cogeneration plant as it produced and distributed both electricity and thermal energy.[1] This power plant is actually the first demonstration of the concept of CHP and can be regarded as the invention date of CHP.

The reliability of the two models

- The analytic variance of the two models

The variance of the regression Model 1 and Model 2 can be explained by the measures in Table 5.2: R Square, Standard Error, Sig (Significance level) and t, all of which also shows the reliability and precision of the regression model.

1) R Square

In order to compare the models with different number of variable, the R Square needs to be adjusted and is calculated.[58] The "Adjusted R Square" under Model 1 is reported as 0.168, which shows that the independent variable "Sizeorg" explains 16.8% of the variation of the dependent variable "Length of adaptation market phase". This is a somewhat poor result which means there are still 83.2% variations in time length is left unexplained. The "Adjusted R Square" showed under Model 2 is 0.244. According to the explanation for Adjusted R Square, Model 2 performs better than Model 1 in predicting the time length.

2) Significance level (Sig.) and t [59]

The standard error is used to explain if the coefficient is reliably different from 0, which means whether the entered variable is truly important in explaining the dependant variable. The smaller the standard error compared to its coefficient, the more precise is the estimation. The "t" is calculated by the standard error dividing its corresponding coefficient and the "Significance level" represents the probabilities based on the associated t statistic. It is standard practice to choose 5% or 10% significance level as the cutoff, which indicates that the coefficient with "Sig." less than 5% or 10% is regarded as truly important in the predicting the dependent variable.

The Significance level of the coefficients in Model 2 are 2.7%, 1.1% and 2.5%, respectively, which are all smaller than 5% level whereas the Significance level of Constant in Model 1 is as big as 50%. It shows that the Model 2 is relatively more reliable or precise than Model 1 in predicting the time length of market adaptation phase of Micro-CHP.

- The variance between literature and regression model

As discussed in Chapter Three, 12 variables are determined as the important variables in the adaptation phase of diffusion of Micro-CHP by literature study and Ortt2005. In both model, however, only the variable "Sizeorg" enters into the formula while "Invention Date" is introduced into Model 2 as important variable. The result of the regression analysis does not seem to match completely with the results of the literature review since other 11 variables are excluded. The large discrepancy between these two results can be explained:

1) This study is based on the research Ortt2005 of 50 technologies, which are from various domains and are not enough to make a general conclusion: the 12 variables significantly impact on the adaptation phase of their diffusions. If technology case is increased to a large number, more variables might enter into the regression model to show their influences on the adaptation phase.

2) Another reason for the variance is that the regression model is established on a relatively small sample size (22 questionnaires), which could not present the relationship between the time length and all the variables.

3) The exclusion of the 11 variables in the regression model does not indicate that they do not have any influence on the time length. The correlation coefficient between every two variables shows the degree of their linear relation. In Annex H, some of the variables have high relations with "Sizeorg" and therefore their influence on the time length is outweighed by "Sizeorg". As a result, these variables do not present themselves in the regression model. The best solution to this problem is to try to increase the sample size of the data set.

From the above analysis, it could be concluded that the relative low reliability of the two models is caused by the lack of large number of sample and the regression model could predict the time length with a certain extent of validity and precision.

The predicted time length by Model 1 and Model 2

- Model 1

The mean value of "Sizeorg" can be obtained from Annex E and the predicted time length is 11.3 years. However, the time length is also calculated based on the value of Sizeorg predicted by every respondent in order to show how these predictions distribute. (Table 5.3)

Table 5.3 Predicted time length from 21 respondents based on Model 1

No. of respondent	1	2	3	4	5	6	7	8	9	10	11
Vaule of Organziation Size	6.5	3	5	5	6	4	5	6	4	6	6
Time length (year)	14.2	4.6	10.1	10.1	12.8	7.4	10.1	12.8	7.4	12.8	12.8
No. of respondent	12	13	14	15	16	17	18	19	20	21	22
Vaule of Organziation Size	8	4	3	7	7	4	7	7	7	0	4
Time length (year)	18.3	7.4	4.6	15.5	15.5	7.4	15.5	15.5	15.5		7.4

Prediction of time length (year)	*Number of respondents*	*Percentage (%)*
4.6	2	9.5
7.4	5	23.8
10.1	3	14.3
12.8	4	19.0
14.2	1	4.8
15.5	5	23.8
18.3	1	4.8
	21	100

33.3%of the respondenst predict time is less than 10 years

66.7% of the respodents predict the time length is between 10 and 20 years

- Model 2

One more independent variable enters into the mathematic formula in model 2 and the time length is calculated as 18.1 years by using mean value of variable "Sizeorg". The distribution of the prediction from respondents is showed in Table 5.4

Table 5.4 Predicted time length from 21 respondents based on Model 2

No. of respondent	1	2	3	4	5	6	7	8	9	10	11
Vaule of Organziation Size	6.5	3	5	5	6	4	5	6	4	6	6
Time length (year)	20.4	12.6	17.1	17.1	19.3	14.8	17.1	19.3	14.8	19.3	19.3
No. of respondent	12	13	14	15	16	17	18	19	20	21	22
Vaule of Organziation Size	8	4	3	7	7	4	7	7	7	0	4
Time length (year)	23.8	14.8	12.6	21.5	21.5	14.8	21.5	21.5	21.5		5.8

Prediction of time length (year)	*Number of respondents*	*Percentage (%)*
5.8	1	4.8
12.6	2	9.5
14.8	4	19.0
17.1	3	14.3
19.3	4	19.0
20.4	1	4.8
21.5	5	23.8
23.8	1	4.8
	21	100

4.8% respondents predict less than 10 years

61.9% of the respondents predict the time is between 10 and 20 years

33.3% of the respondents predict the time is more than 20 years

Based on Model 1 and Model 2, more than 60% respondents predict that the time length of adaptation phase is between 10 to 20 years, in other words, it will take about 10-20 years before the takeoff the diffusion of Micro-CHP. By Model 1, the prediction of the time length less than 10 years is agreed by 33.3% of the respondents while only 4.8% of the respondents (one respondent) have this prediction by Model 2. Moreover, there are 33% of the respondents predict the time length is longer than 20 years based on Model 2. No matter which model is executed, most of the respondents predict that the time length is between 10-20 years.

5.2.2 Qualitative analysis

As explained in 5.1.2, the higher value of the variable, the longer the time length is indicated. Table 5.5 shows the value difference between the mean values of 12 variables calculated based on the research of 50 technologies in Ortt2005 and the mean value of the same variables of Micro-CHP. Comparing the mean values showed in the two columns, some of them for Micro-CHP are bigger than the corresponding ones in Ortt2005 and it is displayed in sign "+" while the rest of them for Micro-CHP are smaller than those in Ortt2005, which is showed by sign "-". Furthermore, the deviation is calculated to explain the accurate difference between them. Here 10% is chosen as the criterion for the comparison, which means that the difference less than10% is considered as the mean value of Micro-CHP similar to the mean value in Ortt2005 and indicates the time length of Micro-CHP is similar to the average time length based on the 50 technologies. The variables with deviation over 10% are highlighted in italics and boldface in Table 5.5.

Table 5.5 Comparison of the mean value from different technologies

	Mean value from Ortt2005	*Mean value of Micro-CHP*	*Value comparison*	*Deviation(%)*
Sizeorg	5.57	5.45	-	2.2
Neworg	***7.62***	***8.59***	**+**	***12.7***
Costorg	6.85	6.27	-	8.5
Willorg	***1.76***	***2.43***	**+**	***38.1***
Marketenv	***23.04***	***19.75***	**-**	***14.3***
Sizetech	***5.94***	***4.33***	**-**	***27.1***
Newtech	9.84	10.76	+	9.3
Protecttech	***4.06***	***2.31***	**-**	***43.1***
Sizecons	10.64	11.57	+	8.7
Newcons	***4.86***	***3.10***	**-**	***36.2***
Costcons	4.94	4.68	-	5.3
Willcons	***10.28***	***12.15***	**+**	***18.1***
Market adaptation phase (year)	**10.68**			

In the seven variables with the deviation more than 10%, four variables have "-" sign while three variables have "+" sign, which indicates that the time length for Micro-CHP market adaptation phase is similar to the average time length of market adaptation phase for 50 technologies in Ortt2005 (10.68 years, Annex G) because the number of variable indicating shorter time length than average time is similar to the number of variable showing longer time. The qualitative analysis proves further the prediction in quantitative analysis that the time length is between 10-20 years.

5.2.3 Final prediction from quantitative and qualitative analysis

In the quantitative analysis, based on Model 1 and Model 2, majority of the respondents predict that the market adaptation phase of the Micro-CHP diffusion in the Netherlands will take 10-20 years. Furthermore, the time lengths calculated by the two models with the mean value of variable "Sizeorg" are also within the range, 11.3 years and 18.1 years respectively. The qualitative analysis shows that the time length is around 10.68 years, which also falls into the 10-20 years range. Based on the two types of analysis, it can be predicted that it might take around 10-20 years before the takeoff of the diffusion of Micro-CHP. Since the development of Micro-CHP is not only the development of a new product, which needs the support from the infrastructure: electricity grid and has large impact on it as well, the present development of Micro-CHP in the Netherlands is that it needs more time to solve lots of problems before its takeoff, such as the regulation of connecting Micro-CHP to electricity grid and the technical issues of feeding electricity back to grid. Therefore, it could be said that the prediction of 10-20 years is quite reasonable if taking into account of the current conditions for Micro-CHP in the Netherlands.

5.3 Analysis and estimation of the potential market size of Micro-CHP

5.3.1 Prediction from survey

When asked about the closest alternative for Micro-CHP in Dutch household, 16 of the 22 respondents' (72.7%) reply is condensing boiler whereas three respondents regard condensing boiler and heat pump both are the closest alternatives for Micro-CHP. Two respondents hold the idea that there is not any closest alternative for Micro-CHP because it is unique equipment to produce electricity and heat simultaneously and condensing boiler only meets the heat needs of the household. From the perspectives of majority of the respondents, Micro-CHP is deemed as the successor for condensing boiler and the prediction is made in terms of the target market- gas fired central heating system. On the other hand, some of the respondents predict the potential market size in the light of the number of the Dutch household. In a word, the respondents estimate the market potential size in two methods:

3) Predicting by estimating the replacing rate of Micro-CHP for condensing boiler in the form of the percentage in the annual sales of condensing boiler
4) Based on the fact that there are 7.million[60] private households in the Netherlands in 2003, predicting the possible household penetration.

Table 5.4 summarizes the prediction from the 20 respondents (two respondents failed)

Table 5.6 The prediction of potential market size from survey

Number of the respondent	*Prediction of the potential market size*	*Time length*	*Reasoning*
1	About 2.5 million units		Half the boiler market*
2	1.1 million units	After 15 years	The annual boiler sales are 300,000 units and 25% of it will be substituted by Micro-CHP.
3	About 3.5 million units		50% of the Dutch households is maximum with the consideration of no influence on grid
4	6.3 million units		Of 7 million households, probably 10% are not installed with central heating system.
5	About 3.5 million units	After 15-20 years	50% of the households will substitute their boiler with Micro-CHP
6	About 1.7 million units	About 10 years	The annual sales of condensing boiler are 0.35 million units, 50% of which will be Micro-CHP, therefore, the cumulative sales are 1.7 million within 10 years.
7	About 2.5 million units		80% of the condensing boiler market*
8	About 3.5 million units		Half of the households
9	About 1 to 2 million units		15-25% of the households
10	About 2 million units		50% the Dutch households are privately-owned which can afford. Taking consideration into the elders who reluctant to try new product and the competitors of Micro-CHP, the potential market size is much smaller.
11	6.3 million units		Of the 7 million households, 90% are connected to gas network, which are all potential consumer of Micro-CHP.
12	About 3 million units		Half the boiler market will be substituted by Micro-CHP and another half will be heat pump.
13	1 million<X<6.5 million		
14	About 3 million		Half the domestic heating market will be Micro-CHP because of the competitors, e.g. heat pump, solar boiler
15	About 3.5 million		Half the 7 million dwellings is maximum size for Micro-CHP.
16	About 5 million		70% of the household (7 million) consuming more than 2200m^3natural gas are the potential size of Micro-CHP.

18	About 1.6 million units	Over 20 years	Half of the condensing boiler market*
19	Less than 1 million	5-10 years	
20	About 1.6 million units	15-20 years	Half of the condensing boiler market*
21	Less than 1 million		

* The prediction of the market potential size is based on the statistics data of space heating in 1998 and 1999[61]. In 1997, 97% household had nature gas-fired space heating system, of which the majority (78%) of the households has a central heating boiler. The penetration of condensing boiler in boiler market is about 75%.

Of the 20 respondents, 14 of them (70%) predict the potential market size of Micro-CHP is about 1 to 3.5 million units eventually. In other words, 1 to 3.5 million households will be the most possible maximum number of household for the installation of Micro-CHP, which is based on the rational purchase behavior of consumer: every household merely buy one unit to meet their needs. It is different from the purchase of some durables, e.g. television and car.

During the survey, several respondents regard the households with nature gas grid connection in the Netherlands as the potential market for Micro-CHP. However, the prediction is not reasonable and some other respondents point out the potential market size is limited in several ways:

- High unit price: due to the higher unit price compared to boiler, the potential customer is limited to those household privately-owned. The rent agencies owning the rental apartments are reluctant to invest on Micro-CHP because their costs are raised without increasing profits. This problem might be solved by the economic scale of Micro-CHP production or establishing cooperation between energy utilities and rent agencies.
- The energy consumption in different house type: Micro-CHP is most suitable for those households with more than average heat demand, which is around 3.5 million.[62] The buildings with good insulation have less heat demand than the average, the heat pump are more suitable for them in terms of energy efficiency.
- Competitors: Heat pump and solar energy equipment: solar boiler and solar photovoltaic (solar PV) are the potential competitors under development. The new-built living district without gas grid connection is considered to be equipped with heat pump or solar PV rather than Micro-CHP due to its less heat demand and the cost reduction by saving the invest on gas grid infrastructure.

5.3.2 Prediction from projects

MicroMap[63] [64]

In the report MicroMap, the forecast of future market potential of Micro-CHP in the European domestic sector under three scenarios, which are based on various energy market and environment policy conditions:

- Scenario 1: Business as usual

This is the minimum effort scenario and the current conditions are kept with legislative and regulatory framework slowly moving forward. No public incentives exist.

- Scenario 2: Medium effort

In this scenario, reasonable efforts are made with regard to legislation, policy and financial incentive.

- Scenario 3: Optimum

Considerable actions are taken to promote Micro-CHP in various ways: financial support from government, public incentives, favorable legislation and regulation for the development of Micro-CHP, etc.

In this report, Micro-CHP is classified as three types of system for the purpose of potential market modeling

- Small Stirling engine: 1kWe, e.g. WhisperTech Stirling engine
- Large Stirling engine: 3kWe, e.g. Sigma Stirling engine
- Small efficient fuel cell: 1kWe

Based on the results of the modeling, the cumulative sales of Micro-CHP in the Netherlands are showed under the three scenarios with various time phases.

Table 5.7 The potential sales of Micro-CHP by scenario for the Netherlands

	No. o f Potential Total Unit Sales (Cumulative)								
	Scenario 1			*Scenario 2*			*Scenario 3*		
Year	2005	2010	2020	2005	2010	2020	2005	2010	2020
Sales in unit	2,132	17,481	340,382	2,136	17,692	352,205	2,202	21,990	626,265

The potential sales of Micro-CHP could rise up to 0.6 million until 2020 under the optimum scenario; however, it has a large deviation from the prediction obtained in the survey.

Future COGEN Project[65]

The purpose of the study is to examine the prospect of cogeneration growth in 28 countries

across Europe under four scenarios: Present Policies, Heightened Environmental Awareness, Deregulated Liberalization and Post Kyoto. The domestic Micro cogeneration (Micro-CHP) only exists under the Post Kyoto scenario, which is the best case with assumption of the full world-wide ratification of Kyoto and economic and energy policies focusing on the decentralized generation. In Post Kyoto scenario, the potential Micro Cogeneration capacity in different year is assessed using SAFIRE[2] model. In order to test and validate the result of SAFIRE model, a calculation is also performed by the Sigma Micro cogeneration model. (Table 5.6)

Table 5.8 The prediction of potential Micro cogeneration capacity in the Netherlands by two models (MWe)

Year	*2005*	*2010*	*2015*	*2020*
SAFIRE	471	2552	5718	6574
Sigma model				6180

The growth of Micro-CHP is forecasted in capacity in the report. In the introduction of Micro-CHP concept in Chapter two, it is defined as the generator with the electricity production capacity up to 3kW, which indicates the potential market size of Micro-CHP until 2020 could reach as high as 6.5 million or 6.1 million (assuming all the Micro-CHP with the capacity 1kWe) and as low as 2 million (assuming all the Micro-CHP with the capacity 3kWe). Due to the different heat demand by different households, the capacity of Micro-CHP required is various; therefore, the potential cumulative sales for Micro-CHP could be estimated as 2 to 6 million units.

5.3.3 The comparison of the two types of prediction and final prediction

Based on the sub-conclusion made in the above projects, the prediction of Micro-CHP potential market size can be summarized firstly in Table 5.7.

Table 5.9 The comparison of the prediction of three researches

Prediction from	*The potential market size (in million)*		*Time phase*
	Smallest	*Largest*	
Survey	1.0	3.5	
MicroMap Project	0.3	0.6	by year 2020
Future COGEN Project	2.0	6.0	by year 2020

Comparison of the three predictions

As showed here, the prediction in the three researches are quite different, which might be

[2] Strategic Assessment Framework for Implementation of Rational Energy, which is a database and computer model that assesses the markets for and impacts of new energy technologies against a background of different economic instruments and policies.

caused by the different modeling methods and assumptions of the scenario. Especially, the predicted number of Micro-CHP in the largest market size is 6 million, which is far different from other predictions. The large deviation could be explained as following: Micro cogeneration in the Future COGEN Project is predicted in terms of capacity whereas the market size is predicted by unit in other studies. The largest potential size of 6 million units is calculated based on the assumption of all the Micro-CHP units sold with capacity 1 kW, but in reality, some of the households require bigger capacity thanks to their energy consumption, so the largest potential size might be much smaller than 6 million units.

In MicroMap and Future COGEN project, the prediction of potential sales unit is limited by the time phase and both of them estimate prospect of Micro-CHP until 2020, which only indicates the possible market size until that time point and could not be explained as potential market size with saturated sales. Therefore, the potential market size should be larger than the predicted size in the two projects given enough development time for Micro-CHP.

Final prediction

The prediction of potential market size from MicroMap and COGEN Future all are limited by the year 2020, which only shows the market size until 2020. However, the potential market size refers to the number of sales of Micro-CHP reaches its saturation without the time limitation. Considering the prediction of 10-20 years taken before the takeoff of the diffusion in section 5.2.3, it is quite reasonable to regard the market size (0.3-0.6 million) until 2020 predicted in MicroMap as the takeoff market size for Micro-CHP and the potential market size could be in the range of 1 to 3.5 million units.

Chapter Six

Conclusion
Recommendation
Research Limitation

Chapter Six Conclusion, Research Limitation &Recommendation

6.1 Conclusion

The purpose of this research is to forecast the diffusion pattern of Micro-CHP in order to provide reference to Essent Network for its future business. And the research is concentrated on the prediction of the market potential size of Micro-CHP in the Netherlands and the number years it will take before its diffusion takeoff; however, it only shows a partial picture of the diffusion pattern.

The research questions raised in the beginning of this report can be answered:

- The variable impacting the market adaptation phase of Micro-CHP

The basis of the overall research is the determination of the variables influencing significantly the adaptation phase of Micro-CHP. Based on the literature study and Ortt2005, 12 variables with regards with the technology per se, organization, customer and market environment are confirmed: Organization Size, Organization Newness, Organization Costs, Organization Willingness, Organization Environment, Technology Size, Technology Newness, Technology Protection, Consumer Size, Consumer Newness, Consumer Costs, and Consumer Willingness. However, not all of these important variables determined from literature study are included in the regression model established on the data from the survey. The variance might be caused by the research limitation or some of the excluded variables really are not important for the market adaptation phase of Micro-CHP.

- Time length of market adaptation phase

The prediction of time length of market adaptation phase is implemented by regression analysis. Two models are formulated with excluding most of the variables determined and examined previously. The relatively low precision results from the two models are caused by the lack of large number of sample rather than research methodology. The qualitative analysis of comparison between the result from Ortt2005 and Micro-CHP proves further the market adaptation phase will take 10-20 years. Based on the quantitative and qualitative analysis, the time length of market adaptation phase finally is predicted around 10-20 years, which also matches the analysis of the current development of Micro-CHP in the Netherlands.

- Market potential

The market size of Micro-CHP is not easy to predict due to too much uncertainty in the development of Micro-CHP. In this research, the final prediction is concluded from the combination of the prediction summarized from 22 respondent's estimation and the prediction from two projects, MicroMap and GOGEN Future, on the Micro-CHP market potential. In both of the projects, the market size is merely predicted until 2020, which might be considered as the takeoff time for the diffusion of Micro-CHP according to the prediction of time length of market adaptation phase aforementioned. As a result of the previous prediction, 1 to 3.5 million households in the Netherlands might be the potential adopters of Micro-CHP, and the largest potential size accounts for half of the entire Dutch household.

6.2 Research limitation

The diffusion of new technology or new product is influenced by many factors. For a typical technology, the main factors are determined according to the type of technology and the area it is developed. In this research, the research object is the diffusion patter of Micro-CHP in the Netherlands. The selection of variables for Micro-CHP is primarily based on the literature review and the research of 50 technologies, which establishes their diffusion patterns on the basis of the world-wide history data of their development. The application of the findings from 50 technologies on Micro-CHP cannot give an accurate prediction. In the two models of the time length of market adaptation phase, the entered variables are much less than the determined variables previously and their reliability are not high enough.

Another research limitation is caused by the small sample size and the data is only collected from 22 questionnaires, which reduce the precision and the reliability of the prediction and is also one of the reason for the low reliability of the two regression models.

Moreover, the research is carried out by investigating the information obtained from the questionnaire survey. Since the respondents are from the organizations with different involvement in the development of Micro-CHP, they answer the questionnaire more or less from the stance of their organization, even some of they answer quite subjectively due to their personal preference. In some sense, the result of this research is based on the analysis of subjective opinions and objective facts.

Last, the respondents should be selected from the actors influencing or influenced by the development of Micro-CHP in order to make the research more credible. Nevertheless, due to the limited time and the difficult access to some respondents, three types of actors fail to

be included in the survey: the installer, the distributor or seller and the environment organization.

6.3 Recommendation to Essent Network

From the point of view Distribution Network Operators (DNOs), Micro-CHP is a disruptive technology for the electricity grid with a number of challenges and few benefits and a significant threat to their existing and future business. Since the revenue of DNOs is obtained from charging users by network tariff, the reduced energy consumption in the household due to the installation of Micro-CHP implies the less usage of the network and results in the revenue loss. With a certain market penetration of Micro-CHP, the electricity feed into the network at a low voltage might have an impact on the stability of the network, which requires the network redesign (the reverse power flow). However, Micro-CHP may also bring some benefits to DNOs by delaying or avoiding the reinforcement of high-voltage network serving the domestic customers. The large-scale installation of Micro-CHP in one living area can establish the virtue power plant to enhance the reliability and stability of the neighboring network.

Micro-CHP is still in the trial development phase and currently there are several field test projects being implemented in the Netherlands, nevertheless the formally commercial market introduction is forthcoming. Based on the prediction of the time length of market adaptation phase and the potential market size of Micro-CHP, Essent Network as one of the Dutch DNOs should take into account the development of Micro-CHP market when it establishes its future business strategy. It can be recommended:

- Within 10 years, it is not necessary for Essent Network to worry about the loss of revenue because the takeoff of the diffusion of Micro-CHP is predicted to happen at least after 10 years and it needs time to achieve its largest market penetration.
- Essent Network has to deal with all the technical and economical issues caused by Micro-CHP due to that the biggest potential customers reaches 3.5 million households in the Netherlands, which is enough to have an significant impact on the electricity network. Therefore, sufficient preparation for the large penetration is very necessary.

Annexes

Annexes

Annex A The list of the Selected Micro-CHP Experts

Name	*Organization Name*	*Departmen Name*	*Group Name*	*Location*	*Interviewing Method*
Dr. Ivo Bouwmans	Delft University of Technology (TUDelft)	Faculty of Technology, Policy & Management	Energy Industry	Delft	Face to face interview
Ir.G.J.J.Beckers	ECN/ENATEC	Clean Fossil Fuels	Stirling Technology	Petten	Face to face interview
Ing. Hans Overdiep	Gasunie	Trade & Supply	Innovation of Gas Application	Groningen	Face to face interview
Ir. Margot van Gastel	COGEN			Driebergen	Face to face interview
Prof. Rolf W.Kunnneke	Delft University of Technology (TUDelft)	Faculty of Technology,t Policy & Management	Economics of Infrastructure	Delft	Face to face interview
Ing. Henri Giesen	Essent Retail Sevives BV			Landgraaf	Face to face interview
Ir.Peter Poolman	SenterNovem	New Energy Technologies		Utrecht	Face to face interview
Philip Leily	Essent Network BV			Zwolle	Face to face interview
Drs.Pierre Bartholomeus	Gasunie	Energy Conversion		Groningen	Face to face interview
Eric Jordans	Essent Retail Sevives BV	Marekting & Product Development		Den Bosch	Face to face interview
Harm Jeeninga (Msc)	Netherlands Energy Research Center (ECN)	Policy Studies	Energy Innovationand Transitions	Amsterdam	Face to face interview
G.J.Ruijg (Msc)	Netherlands Energy Research Center (ECN)	Clean Fossil Fuels	System & Technology Assessment	Petten	Face to face interview
Peter van der Laag (Msc)	Netherlands Energy Research Center (ECN)	Fuel Cell Technology	Fuel Cell System & Hydrogen Production	Petten	Face to face interview
Drs.J.Koen Kok	Netherlands Energy Research Center (ECN)	Interlligent Energy Management	Sustainable Energy in the Building Environment	Petten	Face to face interview
Jolien Snellen	Utrecht University	Natural Science and Innovation Management		Utrecht	Face to face interview
Lucas Bekeering	ENATEC	Managing Director		Lichtenvoorde	Face to face interview
Peter Cornelissen & Gerard van den Berg	Vaillant BV	Product Development		Amsterdam	By email
Michael Colijn				Amsterdam	By email/telephone
Herbert Karjenbrink	Ministry of Economical Affairs (EZ)	Energy Strategy & Consumption	Competition and Energy	Den Haag	By email
Michiel Slotemaker	MicroGen Energy Ltd.	Business Development		UK	By email
Peter Vestergen	Noun Retail BV	Natural Gas		Arham	By email
Frits Otte	Ministry of Economical Affairs (EZ)	Energy Strategy & Consumption	Competition and Energy market	Den Haag	By email

Annex B Questionnaire

Questionnaire on the Variables affecting the market adaptation Phase in the diffusion pattern of Micro-Combined Heat and Power

Description of Micro-CHP

Combined heat and power (CHP) usually refers to the process of generation heat and power simultaneously and it has much higher efficiency compared with electricity-only generation and heat-only boiler, which, therefore, results in its large implementation in various industries, for instance, refinery industry.

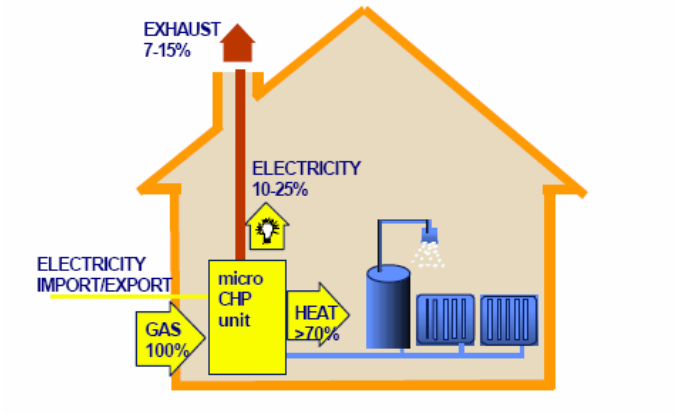
Under the regulation of increasing energy efficiency and reduction of CO_2 emission in many countries, the concept of CHP is also adopted in the heat production of residential and commercial buildings. The concept of Micro-CHP typically focuses on running it as a heating appliance, providing space heating and warm water like a conventional boiler, but unlike the boiler, Micro-CHP generates electricity simultaneously with a very high total efficiency. With the consideration of decreasing the payback time for the investment and increasing the attraction of Micro-CHP for households, the export of the by-product of Micro-CHP: electricity is regarded as an effective method. Most of Micro-CHP units are designed to operate grid-parallel mode, which enables the users not only to continue to receive some electricity from electricity network but also to export electricity to the network.

In the Netherlands, the combination of several factors facilitates the 1kW sized Micro-CHP which is suitable for the individual household:

- Extensive natural gas distribution network
- High percentage of usage of gas-fired boilers to provide thermal needs in individual household
- Tightening climate change commitments
- Suitable energy market conditions

According to the Dutch Micro-CHP working group, of the 6.5 million household in the Netherlands, about 3.5 million household have average or higher heat demand, which also indicates the considerable potential for the Micro-CHP unit in the Netherlands.

The following figure shows the basic concept of Micro-CHP installed in the individual household:



Source: Micro-Map Mini and Micro-CHP- Market Assessment and Development Plan Summary Report, http://www.cogen.org/Downloadables/Projects/Micromap_Publishable_Report_Summary.pdf, visited on March 30, 20005

The purpose of the questionnaire

The aim of this survey is to estimate the length of the market adaptation phase by investigating the factors impacting the diffusion pattern of the Micro-CHP after its first market introduction in the Netherlands. In addition, some factors are also questioned about the significance of their effects in the diffusion pattern of Micro-CHP from the perspective of the experts. This survey will be conducted among 10-15 experts in Micro-CHP field in the Netherlands.

Factors for consideration

- Technology factors
- Market factors
- Actor factors
- Government/regulation factors

Instruction of filling in this questionnaire (Important)

1. For questions without specific instruction, please only tick the best choice you think and special instruction will be given to those questions with more choices.
2. How to tick the choice (choose the square listed before the answer and choose the font color as RED
3. If you do not know the answer, please write down the best one you can think up behind the question and explain the reason in RED.
4. In order to get the idea of the person who answers the questionnaire, the personal background is asked which will be remained confidential and all the answers of the questionnaire will be kept confidential as well.

Professional background

I In which type of organization are you employed? (Multiple choices)

- ❑ Consultancy company
- ❑ Energy company
- ❑ Environmental organization
- ❑ Government
- ❑ Micro-CHP sales and distribution
- ❑ Micro-CHP installation
- ❑ Micro-CHP production
- ❑ Research institute/university
- ❑ _____

II Are you involved in any activities in the field of Micro-CHP? If yes, what are your main activities in this field?

_____

_____

III What is the amount of knowledge of Micro-CHP market/technology you have in comparison to other experts?

Market:
- ❑ Very small
- ❑ Small
- ❑ Medium
- ❑ Large
- ❑ Very large

Technology:
- ❑ Very small
- ❑ Small
- ❑ Medium
- ❑ Large
- ❑ Very large

IV What are your function/ responsibility in your organization?

_____

● Technology factors

1. Complexity of Micro-CHP

1a. What is the closest alternative technology/product available before the introduction of Micro-CHP in the market?

_____

1b. In your opinion, compared with the closest alternative, what is the complexity of Micro-CHP? What is importance of the complexity of Micro-CHP affecting its large-scale application?

Degree
- ❑ Far more simple
- ❑ More simple
- ❑ As simple or complex
- ❑ More complex
- ❑ Far more complex

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

2. Reliability and stability of Micro-CHP

In comparison with the closest alternative technology, what is the degree of the reliability and stability of the performance of Micro-CHP after its market introduction? In your opinion, what is the importance of this factor realizing large-scale application of Micro-CHP?

Degree
- ❑ Very high
- ❑ Somewhat higher
- ❑ Similar
- ❑ Somewhat lower
- ❑ Very low

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

3. User friendliness of Micro-CHP

In comparison to the closest alternative technology, what is the degree of the user friendliness of Micro-CHP after its market introduction? In your opinion, what is the importance of this factor in the large-scale diffusion of Micro-CHP?

Degree
- ❑ Very high
- ❑ Somewhat higher
- ❑ Similar
- ❑ Somewhat lower
- ❑ Very low

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

4. Substitutability of Micro-CHP

What is the degree of Micro-CHP substituting the closest alternative technology/product after its introduction in the market within 15-20 years? How important it will be in the large-scale diffusion of Micro-CHP?

Degree
- ❑ No substitution
- ❑ A few substitutions
- ❑ Half of the market is substituted
- ❑ Almost complete substitution
- ❑ Complete substitution

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

5. Position of Micro-CHP

As a new concept, Micro-CHP enables the household to produce electricity and heat on base of its consumption. The export of electricity from household to grid not only brings financial benefit but also balances the production and consumption of heat and electricity in different time of a day. Therefore, the grid-connected Micro-CHP is the development trend for Micro-CHP and the electricity grid might be the next larger system (e.g. a turbo is applied in the next larger system a motor; a motor is applied in the next larger system car; a car is applied in the next larger system road transport system, road transport is part of general transport system)

5a. How many potential alternative technologies under development are available to replace Micro-CHP in the electricity grid?

- ❑ No
- ❑ One
- ❑ Two
- ❑ Three
- ❑ Four or more No

Please list here:

_____

_____

_____

5b. To what extent of the larger system has to be changed when the Micro-CHP is installed (Say 5-10 year or 15-20 years)? In your opinion, how important of the changes is in electricity grid in order to achieve the large-scale of Micro-CHP?

Degree
- ❑ Remain intact
- ❑ Minor parts rebuilt
- ❑ Half parts rebuilt
- ❑ Major parts rebuilt
- ❑ System rebuilt completely

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

● Market and customer factors

6. ***Newness of Micro-CHP to customer***

The newness of the customer groups that might adopt Micro-CHP and what is the importance of the factor influencing the large-scale diffusion of Micro-CHP?

- ❑ Same customer group (market and customer group already exist)
- ❑ Similar customer group (existing market segment is enlarged or reduced)
- ❑ Renewed customer group (new market segments appear)
- ❑ New customer group (new market emerges)
- ❑ Completely new customer group (entirely new market arises)

Importance

- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant
- ❑ Completely new customer group (entirely new market arises)

7. Market size of Micro-CHP

7a.What is the **potential** size of the market expected at the introduction of Micro-CHP in the Netherlands? (There are 6.5 million household in the Netherlands)

- ❑ Very large (several million or more potential consumers)
- ❑ Large (about one million potential consumers)
- ❑ Medium (thousands to a million potential consumers)
- ❑ Small (hundred to thousands potential consumers)
- ❑ Very small (up to a hundred potential consumers)

7b.What is the estimation of the **actual** market size just after the introduction of Micro-CHP in the Netherlands (e.g. in short term, 5-10 years)?

- ❑ Very large (several million or more consumers)
- ❑ Large (about one million consumers)
- ❑ Medium (thousands to a million consumers)
- ❑ Small (hundred to thousands consumers)
- ❑ Very small (up to a hundred consumers)

8. Preference of the potential customers

Compared with the alternative products, what is the degree of the preference of potential customers after the market introduction of Micro-CHP? In your opinion, how Important of the preference of potential customers will influence the large-scale of Micro-CHP?

Degree
- ❑ Larger preference to Micro-CHP
- ❑ Preference to Micro-CHP
- ❑ Equal preference Micro-CHP/alternatives
- ❑ Preference to alternatives
- ❑ Larger preference to alternatives

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

9. Physical and technical risks

What is the degree of physical and technical risks for potential customers and society after the production, supply and use of Micro-CHP? In your opinion, how significant of the possible risks will influence the large-scale of Micro-CHP?

Degree
- ❑ Large decrease of risk
- ❑ Small decrease of risk
- ❑ No significant change in risk
- ❑ Small increase of risk
- ❑ Large increase of risk

Significance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

10. Triability of Micro-CHP

What is degree in which the Micro-CHP can be trialed by potential customers? In your opinion, what is the importance of the triability of Micro-CHP to reach its large-scale application?

- ❑ Very large (tested and tried very easily before adoption)
- ❑ Large (tested and tried before adoption, payment required)
- ❑ Medium
- ❑ Small (tested and tried after adoption and small-scale implementation)
- ❑ Very small (tested and tried after adoption and large-scale implementation)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

11. Switching cost for customers

11a. What changes of the behaviors (habits and procedures) of customers will happen when Micro-CHP is installed? In your opinion, what is the importance of these changes to achieve the large-scale application of Micro-CHP?

- ❑ Very positive changes (much easier to handle, less risky)
- ❑ Positive changes (easier to handle)
- ❑ No significant change (similar handling)
- ❑ Negative changes (more difficult to handle)
- ❑ Very Negative changes (much more difficult to handle, more risky)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

11b. What is the degree of learning required in the behaviors (habits and procedures) of customers when Micro-CHP is installed? In your opinion, what is the importance of the learning required in achieving the large-scale application of Micro-CHP?

Degree
- ❑ Very small
- ❑ Small
- ❑ Medium
- ❑ Large
- ❑ Very large

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant
- ❑ No opinion

• Actor (organization) factors

12. The newness of the actors

How many new actors enter into the industry after the market introduction of Micro-CHP?

- ❑ Zero, existing actors are engaged in the supplying of Micro-CHP
- ❑ Several new actors
- ❑ Half of the actors
- ❑ Majority of the actors
- ❑ All the actors are new

Please list here: _____

_____

_____

13. Experience and expertise of the actors introducing Micro-CHP

In the Netherlands, the important actors involved in the introducing Micro-CHP can be classified as developer (e.g. SenerTec, Enatec, MicroGen, WhisperGen, and Valliant, Gasunie), sales and

distributor (e.g. Energie Service GelreFlevo Warmtekracht, Essent, Nuon, Eneco), research institute (e.g. ECN, COGEN,), Dutch government, energy company (Essent, Nuon, etc.), and environment organization (Greenpeace).

13a. In your opinion, who are the main actors **BEFORE** and **AFTER** the market introduction of Micro-CHP, respectively, please list here:

_____

_____

From here, please keep in mind that the main actors refer to the MAIN ACTOR BEOFRE THE MARKET INTRODUCTION when answering the questions with respect to the main actors.

13b. Based on the questionnaire answered by other experts, there are five main actors involved in the Micro-CHP field, please rank their importance before the Micro-CHP market introduction according to your opinion from **1** to **5** (the importance decreases from 1 to 5)**:**

Developers: _____
Installer/Service company _____
Research institute _____
Energy company _____
Government _____

13c. Regarding the technical aspects of Micro-CHP, what is the degree of the experience and expertise that main actor(s) own? And from you perspective, how important is the factor affecting the diffusion of Micro-CHP?

- ❑ Very large (actor has absolute unique knowledge)
- ❑ Large (actor among few actors has knowledge)
- ❑ Medium
- ❑ Small (actor has relatively small amount knowledge compared with other actors)
- ❑ Very small (actor has very small amount of knowledge compared with other actors)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

13d. How much experience and expertise with commercializing new technology in general do the main actors possess? And how important is the factor affecting the diffusion of Micro-CHP?

- ❑ Very large (actor has successfully commercialized many technologies before)
- ❑ Large (actor has successfully commercialized several technologies before)
- ❑ Medium
- ❑ Small (actor has successfully commercialized new product, but not breakthrough technology)
- ❑ Very small (actor has no experience and expertise on commercialization)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

13e. How much experience and expertise with the market in which Micro-CHP applied do the main actors possess? What is the importance of this factor impacting the diffusion of Micro-CHP?

- ❑ Very large (actor possesses many products/marketing experience)
- ❑ Large (actor possesses some products/marketing experience)
- ❑ Medium
- ❑ Small (actor possesses experience in related market only)
- ❑ Very small (actor hardly possesses relevant market experience)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

14. Switching cost and available assets of the actors introducing Micro-CHP

14a. To what extent the marketing strategy (distribution, pricing, communication, packaging and etc.) will change when Micro-CHP is introduced in the market? How important is the change affecting the large-scale diffusion of Micro-CHP?

- ❑ Very small (minor changes in marketing approach required)
- ❑ Small (some changes in marketing approach required)
- ❑ Medium
- ❑ Large (major changes in marketing approach required)
- ❑ Very large (completely different marketing approach required)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

14b. How much assets (financial) is required to develop and introduce Micro-CHP in the market?

- ❑ Very small
- ❑ Small
- ❑ Medium
- ❑ Large
- ❑ Very large

14c. How much assets (financial) is available to the main actors when introducing Micro-CHP in the market? How important is the assets available for the large-scale diffusion of Micro-CHP?

- ❑ Very large (very large corporation, alliance of big companies, government)
- ❑ Large (large company, alliance of small companies)
- ❑ Medium
- ❑ Small (small company, large company with major problems)
- ❑ Very small (start-up with hardly any assets, very small company)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

15. Willingness of actors to incur these costs

What is the degree of the endurance and willingness of the main actors to develop and invest in Micro-CHP for long term? How important of the factor affecting Micro-CHP large-scale application?

- ❑ Very large (willing to invest the maximum in long term)
- ❑ Large (willing to invest a lot)
- ❑ Medium
- ❑ Small (investment regarded as one element of a portfolio)
- ❑ Very small (no interest in investment)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

16. Cooperation among actors

16a. What is the **required** degree of the cooperation among actors for the wide-scale diffusion of Micro-CHP? In your opinions, how important is the cooperation in achieving large-scale application of Micro-CHP?

Degree
- ❑ Very small
- ❑ Small
- ❑ Medium
- ❑ Large
- ❑ Very large

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

16b. What is the estimation of the **actual** degree of the cooperation among actors when Micro-CHP is introduced in the market?

- ❑ Very large (centrally coordinated industry)
- ❑ Large (industry with some coordination)
- ❑ Medium (industry with multiple coalitions that are competitive)
- ❑ Small (competitive industry)
- ❑ Very small (very competitive and fragmented actors in industry)

16c. What would be the degree of the support for Micro-CHP from all relevant actors in the industry at the time of introduction in the market? What is the importance of the support degree in achieving the large-scale application of Micro-CHP?

- ❑ Very large (entire industry supports)
- ❑ Large (a large coalition in the industry supports)
- ❑ Medium
- ❑ Small (a small group of actors/company supports)
- ❑ Very small (a actor/company supports)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

17. The aligning power of the actors

What is the degree of the power of the most important actor to align all the relevant actors in the industry? How important of the factor in reaching the large-scale diffusion of Micro-CHP?

- ❑ Very large (the power to completely align the industry)
- ❑ Large (powerful but need negotiation and coalition)
- ❑ Medium
- ❑ Small (need powerful partners to help to align the industry)
- ❑ Very small (no power virtually)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

18. Protection of Micro-CHP technology

To what extent the Micro-CHP technology can be protected? In your opinion, how important is the fact to obtain the large-scale application of Micro-CHP?

- ❑ Very large (very strict patent /complete secrecy/barriers for copying)
- ❑ Large (patent/ some protection provided by law)
- ❑ Medium
- ❑ Small (hardly patentable technology)
- ❑ Very small (easy to copy and hardly protected by any barrier)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

19. Critical mass supply and demand

19a. What is the minimum number of customers required before the production of Micro-CHP becomes economically viable for supplier (critical mass supply)? And, how important is the fact to obtain the large-scale application of Micro-CHP?

Degree
- ❑ Very small (one up to ten)
- ❑ Small (ten up to hundred)
- ❑ Medium (hundred up to thousand)
- ❑ Large (thousand up to million)
- ❑ Very large (a million or more)

Significance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

19b. What is the minimum number of customers required before Micro-CHP becomes interesting for customers (critical mass demand)? According to your opinion, how significant is the fact to obtain the large-scale application of Micro-CHP?

Degree
- ❑ Very small (one up to ten)
- ❑ Small (ten up to hundred)
- ❑ Medium (hundred up to thousand)
- ❑ Large (thousand up to million)
- ❑ Very large (a million or more)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

20. Availability of existing standards

When Micro-CHP is introduced, to what extent the current standards with regard to different aspects of Micro-CHP can be re-used? In your opinion, what is the importance of this factor in achieving the large-scale diffusion of Micro-CHP?

- ❑ Very large (majority of the existing standards can be re-used)
- ❑ Large (some of the existing standards can be re-used)
- ❑ Medium
- ❑ Small (minority of the existing standards can be re-used)
- ❑ Very small (completely new standards need to be set up)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

● Government/regulation factors

21. Availability of existing regulation

What is the degree of availability of the existing regulation that can be re-used when Micro-CHP is introduced? In your opinion, what is the importance of this factor in achieving the large-scale diffusion of Micro-CHP?

- ❑ Very large (majority of the existing regulations can be re-used)
- ❑ Large (some of the existing regulations can be re-used)
- ❑ Medium
- ❑ Small (minority of the existing regulations can be re-used)
- ❑ Very small (completely new regulations need to be set up)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

22. Interest of government in Micro-CHP

In your opinion, what is the degree of interest of Dutch government in the supply and demand of Micro-CHP, and according to you, how important is the interest of government to achieve the large-scale application of Micro-CHP?

Degree
- ❑ Very large interest
- ❑ Large interest
- ❑ Medium interest
- ❑ Small interest
- ❑ Very small interest

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

23. Intervention of government in Micro-CHP

According to your estimation, what is the possible degree of intervention of Dutch government in the supply and demand of Micro-CHP? In your opinion, how important is the intervention of government in reaching large-scale application of Micro-CHP?

- ❑ Very large (government completely control supply and/or demand)
- ❑ Large (government strongly intervenes in supply and/or demand by large subsidies, supplier selection, price setting, obligatory standard/norms)
- ❑ Medium (government intervenes by setting standard quality control and etc.)
- ❑ Small (government intervenes hardly)
- ❑ Very small (government does not intervenes but provides general rules and law)

Importance
- ❑ Very important
- ❑ Important
- ❑ Average
- ❑ Unimportant
- ❑ Very unimportant

24. The most important factor stimulating and impeding the large-scale application of Micro-CHP

24a. In your opinion, what is the most important factors influencing the large-scale diffusion of Micro-CHP, and why? (The factor might be one of those aforementioned or the one you think up)

If you have any **comments** for the questionnaire, please indicate here

Your cooperation is highly appreciated

Annex C Cover letter

Dear Sir/Madam,

I am an international master student studying in the Delft University of Technology (TUDelft) and currently I am doing my master thesis which focuses on the research of the diffusion of Micro-CHP (Combined Heat and Power) that also could be called as Micro-cogeneration or domestic-CHP. This research is both supported by the Essent Network and TUDelft.

The purpose of sending this letter is to give you an idea of my research and introduce myself before you agree to answer the questionnaires. As you knew, in the Netherlands, the Micro-CHP is not commercialized yet and in the stage of field test. Therefore, its development is full of uncertainty and its market is still unclear. By analyzing various factors (four groups: technology factor, market and customer factor, Actor factor and Government/Regulation factor)affecting the development of Micro-CHP in the Netherlands, the length of the market adaptation phase (the time between the market introduction and the start-up of the large-scale diffusion of Micro-CHP) and the market potential will be estimated, which not only provide information to the Micro-CHP manufacturers and other actors involved in the Micro-CHP business to shape their future business strategy, but also help the generation and network companies to understand the market.

In the questionnaires, these factors influencing the diffusion of the Micro-CHP will be presented as 24 questions (some of them consist of several sub-questions) and each of them has 5 choices. I plan to send the questionnaires to 20-25 experts from different organizations and companies in the Netherlands and would like to send the final report of the study to you after I finish.

I will appreciate very much if you could reply me as soon as possible and if you have any suggestion for my research, I would be very glad to know.

Best regards,
Ai Su (charlotte)

Annex D Mean value of factors indicated in questionnaire

No.of Interviewees / Value of questions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total	Mean	Median
Q1b	4	4	4	4	4	4	5	5	5	3	4	4	4	4	4	4	4	4	4	3	4	5	90	4.09	4
Q2	4	5	3	3	3	3	5	3	4	4	4	3	4	4	4	3	4	4	3	3	3	0	76	3.62	4
Q3	3	3	3	3	3	3	4	3	3.5	2	3	3	2.5	3	3	3	4	3	4	2	3	0	64	3.05	3
Q4	3	2	3	3	4	3	2	2	2	2	2	3	3	3	2	3.5	2	3	2	3	0	0	52.5	2.63	3
Q5a	4	4	5	5	2	1	2	4	3	4	1	3	5	3	3	1	2	5	4	3	1	5	70	3.18	4
Q5b	1	1	2	2	1	1	1	2	1	1	1	2	2	2	2	2	5	1	2	2	2	1	37	1.68	2
Q6	1	1	1	1	1	1	1	3	1	1	1	1	3	2	2	2	2	1	0	2	1	1	30	1.43	1
Q7a	1	2	1	1	1	1	1	1	1.5	2	1	1	1	1	1	1	2	1	2	1	3	0	27.5	1.31	1
Q7b	3	3	2	2	2	3	3	3	3	3	3.5	3	3	3.5	3	3	3	2	3	3	3	0	60	2.86	3
Q8	1	3	3	2	2	3	3	2	2	3	4	2	2	3	4	2	4	1	3	2	2	0	53	2.52	2
Q9	4	3	3	3	2	3	3	2	4	3	4	4	2	0	3	3	3	4	3	3	4	5	68	3.24	3
Q10	3	4	5	4	5	5	4	4	2	4	2	5	2	4	2	5	1	5	1	4	2	3	76	3.45	4
Q11a	3	3	3	3	3	3	3	3	3	3	3	4	4	3	4	3	2	2	2	2	3	3	65	2.95	3
Q11b	3	1	1	1	1	1	1	3	1	1	1	2	3	2	3	1	2	2	3	1	3	1	38	1.73	1
Q12	2	2	1	2	2	1	2	1	2	1	1	1	2	2	1	1	3	2	2	2	2	2	37	1.68	2
Q13c	2	2	2	2	2	4	1	2	2	2	2	1.5	1	2	2	1.5	2	4	3	1	2	1	44	2.00	2
Q13d	5	2	4	3	4	4	3	4	3	3	4	3	3	3.5	2	3	4	5	3	2	3	5	75.5	3.43	3
Q13e	4	4	4	2	4	1	2	5	4	3	3	2	3	1.5	4	3	1	4	3	4	4	4	69.5	3.16	3.5
Q14a	3	2	2	3	2	2	3	2	3	2	2	1	2	3	2	2	2	4	3	2	4	4	55	2.50	2
Q14b	4	3	4	4	3	3	4	3	5	5	3.5	4	4	3.5	4	4	3	4	3	4	4	4	83	3.77	4
Q14c	2.5	1	3	3	2	2	3	2	2	2	4	4	2	1.5	3	3	2	5	3	4	0	1	55	2.62	2.5
Q15	2	2	2	2	4	2	4	2	2	2	2	4	3	2.5	4	2	2	1	2	2	0	0	48.5	2.31	2
Q16a	4	5	4	4	4	5	4	3	4	5	4	4	4	4	4	4	4	5	4	3	4	4	90	4.09	4
Q16b	4	2	2	2	3	2	2	3	1.5	3	2.5	4	2	3	3	3	3	4	3	3	3	4	62	2.82	3
Q16c	2.5	2	4	2	4	2	4	4	2	4	4	4	3	3	4	2	2	2	3	2	3	3	65.5	2.98	3
Q17	4	2	2	2	4	2	2	4	2	4	2	4	2	1.5	4	4	2	2	4	3	3	3	62.5	2.84	1.5
Q18	4	1	2	2	0	2	2	2	1	2	2	1	2	3.5	4	1	2	2	4	2	3	4	48.5	2.31	2
Q19a	4	4	5	3	5	5	4	4	4	4	3.5	4	3	4	4	4	4	4	4	5	4	0	85.5	4.07	4
Q19b	3	4	5	1	1	3	4	4	3	4	4	3	3	4	4	4	3	3	3	4	3	0	70	3.33	3
Q20	2	2	2	3	1	1	1	1	1	2	1	1	3	2	2	1	4	2	2	2	3	2	41	1.86	2
Q21	2	5	3	1	2	2	1	4.5	4	1	2	1	2	5	2	4	2	4	1	1	3	2	54.5	2.48	2
Q22	2	3	3	2	4	1	3	4	2	1	3.5	2	4	2	3	2	2	1	2	1	3	2	52.5	2.39	2
Q23	3	3	2	2	3	3	5	3	3	4	3	3	3	4	4	3	4	2	3	3	4	2	69	3.14	3

Annex E Mean value of variables after the group of questions

No.of Interviewees / Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total	Mean
Organziation Size (2)	6.5	3	5	5	6	4	5	6	4	6	6	8	4	3	7	7	4	7	7	7	0	4	114.5	5.45
Organziation Newness (3)	11	8	10	7	10	9	6	11	9	8	9	6.5	7	7	8	7.5	7	13	9	7	9	10	189	8.59
Organziation Costs (2)	7	5	6	7	5	5	7	5	8	7	5.5	5	6	6.5	6	6	5	8	6	6	8	8	138	6.27
Organization Willingness (1)	2	2	2	2	4	2	4	2	2	2	2	4	3	2.5	4	2	2	1	2	2	0	0	48.5	2.43
Organization Environment (7)	19.5	22	20	16	21	16	20	23	17.5	20	20	19	21	23	22	19	21	20	18	15	23	19	434.5	19.75
Technology Size (2)	4	3	5	5	5	4	3	4	3	3	3	5	5	5	4	5.5	7	4	4	5	0	0	86.5	4.33
Technology Newness (3)	12	13	12	12	9	8	12	12	12	11	9	10	13	11	11	8	10	13	11	9	8	0	226	10.76
Technology Envrionment (1)	4	1	2	2	0	2	2	2	1	2	2	1	2	3.5	4	1	2	2	4	2	3	4	48.5	2.31
Customer Size (4)	11	13	13	7	9	12	12	12	11.5	13	12	11	10	12.5	12	12	12	10	12	13	13	0	243	11.57
Customer Newness (2)	3	3	2	3	3	2	3	4	3	2	2	2	5	4	3	3	5	3	0	4	3	3	65	3.10
Customer Costs (2)	6	4	4	4	4	4	4	6	4	4	4	6	7	5	7	4	4	4	5	3	6	4	103	4.68
Customer Willingness (4)	11	13	14	12	12	14	14	11	11.5	12	13	14	8.5	0	12	13	12	13	11	11	11	0	243	12.15

*The number in the parentheses stands for the number of the factors consisting of the variable.

Annex F Fifty cases of technology investigated in Ortt2005

No.	*Technology Name*	*Market Introduction Date*	*Mass production Date*	*Length of market adaptation phase*
1	DVD	1996	1996	0
2	GPS	1964	1979	15
3	Bluetooth	2000	2000	0
4	Wanckel Engine	1964	1964	0
5	Microwave oven	1947	1955	8
6	Transistor	1949	1953	4
7	Astroturf	1965	1966	1
8	Fiber optic Communic	1975	1983	8
9	Jet-engine	1941	1943	2
10	Helicopter	1938	1942	4
11	Memory metal	1968	1972	4
12	Turbo charber	1872	1923	51
13	Aircraft	1908	1914	6
14	Digital camera	1973	1980	7
15	Optical disc	1978	1982	4
16	Mobile telephone	1946	1983	37
17	Internet	1969	1984	15
18	Air conditioning	1902	1915	13
19	Kevlar	1971	1973	2
20	Browser	1991	1994	3
21	CT-scanner	1972	1974	2
22	Nylon	1937	1940	3
23	Bakelite	1907	1911	4
24	Dyneema	1975	1990	15
25	Asperin	1897	1900	3
26	Magnetic recording	1903	1933	30
27	Telegraphy	1840	1844	4
28	Antibiotics	1941	1943	2
29	Fax	1865	1948	83
30	Plasma disply	1971	2000	29
31	SMS	1994	1999	5
32	Ballpoint	1900	1945	45
33	Dynamite	1867	1867	0
34	MRI	1980	1983	3
35	Electon microscope	1939	1939	0
36	Cellphone	1912	1912	0
37	Barcodes	1967	1974	7
38	VCR	1956	1957	1
39	Nuclear energy power plant	1945	1947	2
40	Hearing aid	1955	1957	2
41	ABS	1899	1899	0
42	PVC	1959	1978	19
43	Laser	1931	1938	7
44	Photocopier	1961	1980	19
45	Sonar	1949	1960	11
46	Contraceptive pill	1916	1917	1
47	DNA	1928	1962	34
48	Fingerpriting	1987	1994	7
49	Radar technology	1934	1939	5
50	Television technology	1939	1946	7

Source: Ortt2005

Annex G The mean value of variables for 50 technologies

	Valid case	*Missing case*	*Mean*
Organization Size	49	1	5.5714
Orgainzatin Newness	47	3	7.617
Organization Costs	48	2	6.8542
Organization willingness	50	0	1.76
Organization Market Envrionment	50	0	23.04
Technology Size	50	0	5.94
Technology Newness	50	0	9.84
Technology Market Envrionment	50	0	4.06
Consumer Size	50	0	10.64
Consumer Newness	50	0	4.86
Consumer Costs	50	0	4.94
Consumer willingness	50	0	10.28
Market adaptation phase (year)			**10.68**

Annex H Pearson Correlations between independent variables and dependent variables of Micro-CHP

	Market adapatation phase	*Date invention*	*Sizorg*	*Neworg*	*Costorg*	*Willorg*	*Sizetehc*	*Newtech*	*Protecttech*	*Sizecons*	*Newcons*	*Costcons*	*Willcons*	*Envorg*
Market adaptation phase	1	-0.346	0.388	0.301	0.141	0.044	0.093	-0.040	-0.150	0.058	0.050	-0.078	0.274	0.095
Date invention	-0.346	1	-0.272	-0.250	0.000	0.178	-0.209	0.074	0.155	0.184	-0.065	-0.140	-0.065	-0.120
Sizeorg	0.388	-0.272	1	0.708	0.104	-0.053	0.112	0.051	-0.263	0.029	0.360	-0.010	0.186	0.433
Neworg	0.301	-0.250	0.708	1	0.320	-0.030	0.140	-0.022	-0.247	0.073	0.498	0.174	0.243	0.327
Costorg	0.141	0.000	0.104	0.320	1	0.038	0.285	-0.017	-0.009	0.505	0.261	-0.118	0.240	-0.083
Willorg	0.044	0.178	-0.053	-0.030	0.038	1	-0.148	0.204	0.019	0.030	-0.188	-0.067	0.279	0.074
Sizetech	0.093	-0.209	0.112	0.140	0.285	-0.148	1	-0.051	0.246	0.389	0.344	0.214	0.208	-0.271
Newtech	-0.040	0.074	0.051	-0.022	-0.017	0.204	-0.051	1	0.145	0.049	0.081	0.368	0.462	-0.006
Protechtech	-0.150	0.155	-0.263	-0.247	-0.009	0.019	0.246	0.145	1	-0.116	-0.222	0.054	-0.043	-0.086
Sizecons	0.058	0.184	0.029	0.073	0.505	0.030	0.389	0.049	-0.116	1	0.377	0.171	0.285	-0.156
Newcons	0.050	-0.065	0.360	0.498	0.261	-0.188	0.344	0.081	-0.222	0.377	1	0.315	0.282	0.113
Costcons	-0.078	-0.140	-0.010	0.174	-0.118	-0.067	0.214	0.368	0.054	0.171	0.315	1	0.617	-0.126
Willcons	0.274	-0.065	0.186	0.243	0.240	0.279	0.208	0.462	-0.043	0.285	0.282	0.617	1	0.075
Envorg	0.095	-0.120	0.433	0.327	-0.083	0.074	-0.271	-0.006	-0.086	-0.156	0.113	-0.126	0.075	1

Annex I Addition analysis

Analysis of the factors influencing the diffusion of Micro-CHP

The survey also inquires the important factors for the diffusion of Micro-CHP from the perspectives of the respondents and the result is summarized in Table 5.4.

In total, 22 factors are mentioned by the 22 respondents as the important factors influencing the diffusion of Micro-CHP from their point of view. The factor “cost or price of Micro-CHP unit” can be regarded as the most important one since 18 out of 22 respondents think it determines whether the diffusion will start and the large-scale diffusion will be achieved and the percentage is as high as about 82%.

Besides the most important factor, three factors are deemed as the factor influencing the diffusion of Micro-CHP quite significantly as well:

- The reliability and stability of the technology employed in Micro-CHP,
- The environment advantages brought by the installation of Micro-CHP, e.g. the reduction of CO_2 emission and environment sustainability,
- The economic benefits gained by household thanks to the adoption of Micro-CHP, for instance, the electricity bill saving caused by the electricity production by Micro-CHP.

However, whether Micro-CHP has environment advantages needs further research to prove it. And whether Micro-CHP could bring economic benefits to consumers largely depends on the regulation of grid connection, e.g. the connection tariff, connection procedure, and the price of the electricity feed back to grid.

The important factors in the diffusion of Micro-CHP

Factor / No. Respondent	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Mentiond frequency	Percentage (%)
Price (cost) of unit	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		18	81.8
Technology reliability & stability	✓	✓		✓				✓						✓					✓	✓		✓	8	36.4
Envrionment advantage (co2 emission reduction)			✓			✓					✓				✓				✓	✓		✓	7	31.8
Economic benefits											✓			✓					✓	✓	✓	✓	6	27.3
Regulation of grid connection				✓	✓													✓			✓		4	18.2
The ration of electricity price to nature gas price				✓				✓		✓						✓							4	18.2
Pay back time		✓	✓														✓		✓				4	18.2
Competitive product		✓								✓							✓						3	13.6
Price of electricity fed back			✓		✓							✓											3	13.6
Energy efficiency				✓					✓										✓				3	13.6
Cooperation among relative actors										✓	✓									✓			3	13.6
Comfort degree of unit			✓											✓									2	9.1
Dimension of unit							✓		✓														2	9.1
Installer's involvement	✓																		✓				2	9.1
Lift expectancy									✓				✓										2	9.1
Subsidy from government																✓	✓						2	9.1
Information available to consumer	✓																						1	4.5
Metering					✓																		1	4.5
Consumer preference					✓																		1	4.5
Training for installer													✓										1	4.5
easy installation																		✓					1	4.5
user friendliness																					✓		1	4.5

Reference

Reference

[1] *"Energy Consumption by Economic Sector"*, International Energy Agency (IEA), visited on June 26, 2005
http://earthtrends.wri.org/pdf_library/data_tables/ene5_2003.pdf

[2] Harriet Griffin & Tina Fawcett, "*Country Pictures: the Netherlands"*, Energy and Environment Program, Environmental Change Institute, University of Oxford, UK. 2000, Table 11.4, p66

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