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The challenges and success factors of commercializing cleaner technologies

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ABSTRACT

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Cleaner technologies include products, services, technologies, processes and systems that in use create less environmental hazard than the existing alternatives. Rapidly growing cleantech sector possesses an essential competitive advantage in the future. However, no profound research has been conducted on the characteristics of cleaner technologies and their effect on the commercialization process. This thesis aims at synthesizing scattered information and creating a basis for accelerating cleaner technology commercialization in Finnish context. Two research questions are defined:

1. What are the key challenges and success factors in the commercialization of cleaner technologies based on the existing literature?
2. What kind of lessons can be learned from the Finnish success stories of cleantech commercialization?

The research was conducted as a literature review and supported with three case interviews. The results suggest that literature-based challenges are mostly related to, for example, difficulty in gathering customer information, unrealistic customer expectations, lack of resources, networks and proper success indicators, legislation, and unstructured strategy planning stemming from company culture. Handling the barriers require, above all, open communication from all stakeholders, management commitment and accurate goal setting, government-driven funding and incentives, and cooperation with educational facilities. Finnish success cases emphasize especially customer attention: listening to customers and receiving feedback from them during the whole commercialization process to correct the errors early and save resources, visionary in fulfilling customer needs, ability to question company's own business performance, not being afraid of making mistakes but learning from them, and continuously observing and evaluating the commercialization process.

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Puhtaat teknologiat käsittävät tuotteita, palveluita, teknologioita, prosesseja ja järjestelmiä, jotka tuottavat käytettäessä vähemmän ympäristöhaittaa kuin olemassaolevat vaihtoehdot. Nopeasti kasvava cleantech-sektori tulee muodostamaan tärkeän kilpailuedun lähteen tulevaisuudessa. Kuitenkaan kattavaa tutkimusta erityisesti puhtaiden teknologioiden erityispiirteistä ja niiden vaikutuksesta kaupallistamisprosessiin ei ole tehty. Tämän diplomityön tarkoituksena on koota hajanaista tietoa ja luoda pohja puhtaan teknologian kaupallistamisen vauhdittamiselle Suomen näkökulmasta. Työlle on määritelty kaksi tutkimuskysymystä:

1. Mitkä ovat puhtaan teknologian kaupallistamisen haasteet ja menestystekijät?
2. Mitä suomalaisen cleantechin menestystarinoista voidaan oppia?

Tutkimus suoritettiin kirjallisuuskatsauksena, jonka tueksi tehtiin kolme case-haastattelua. Tulokset osoittavat, että kirjallisuudesta kumpuavat haasteet liittyvät esimerkiksi asiakastiedon keräämisen vaikeuteen, epärealistisiin asiakasodotuksiin, resurssien, verkostojen ja sopivien menestysmittareiden puutteeseen, lainsäädäntöön sekä yrityskulttuuriin perustuvaan epäjärjestelmälliseen strategiasuunnitteluun. Haasteisiin vastaaminen edellyttää avointa kommunikointia kaikilta sidosryhmiltä, johdon sitoutumista ja täsmällistä tavoitteiden asettamista, yhteiskunnallista rahoitusta ja kannusteita sekä yhteistyötä tutkimus- ja koulutuslaitosten kanssa. Suomen menestystarinat korostavat etenkin asiakasyhteistyötä: asiakkaiden kuuntelua ja palautteen saamista koko kaupallistamisprosessin aikana virheiden korjaamiseksi ja resurssien säästämiseksi, visionäärisyyttä asiakastarpeiden täyttämisessä, kykyä kyseenalaistaa yrityksen koko liiketoimintamalli ja olla pelkäämättä liikaa virheiden tekemistä sekä jatkuvaa kaupallistamisprosessin seuraamista ja arviointia.

PREFACE

I would like to thank professor Anne Jalkala who ultimately gave me the opportunity to become a part of the collegium in the Department of Industrial Management and to end my studies by familiarizing myself with an interesting research topic. The whole university time in Lappeenranta has taught me a lot of new things and widened further my perspective of the world that awaits ahead, again. In addition, thank you to all of those people who have contributed to this journey one way or another.

"It's only a race against yourself."

Table of Contents

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AI	artificial intelligence
B2B	business to business
cleantech	clean(er) technologies
EGS	environmental goods and services
EIT	electrical impedance tomography
EOP	end-of-pipe technologies
EPPs	environmentally preferable products
EST	environmentally sound technologies
FECC	Finnish Environmental Cluster for China
IT	information technology
LCA	life cycle assessment
NETS	Nordic Environmental Technology Solutions
PR	public relations
R&D	research and development
Sitra	the Finnish Innovation Fund
SMEs	small and medium-sized enterprises
TEKES	Finnish Funding Agency of Technology and Innovation

1 INTRODUCTION

This chapter is divided into four sub chapters that provide the background to the research along with research questions. Limitations and research methods are also considered.

1.1 Background of the research

Due to an increasing awareness of environmental problems caused by human activities (Fijał 2007, p. 914) environmental business has recently developed to one of the fastest growing sectors in the world. New technologies are developed in order to reduce emissions and make the energy use more efficient. (Saarnia and Hassinen 2008.) The growth rates in several markets have reached an annual figure of 10 % after millennium. Although in Finland the business is fairly new and the figure lies between 1-3 % respectively, an upward trend can be seen. (Mäkinen and Perttu 2008, p. 17.)

Cleaner (or clean) technologies or cleantech can be shortly defined as sophisticated products, technologies, services, processes and systems that are likely to create more environmental preservation in the long run than their alternatives (cf. Koltuniewicz and Drioli 2008, p. 9-10; Kemp, Olsthoorn, Oosterhuis and Verbruggen 1992, p. 616). Environmental know-how in this context is regarded as a reduction of the disadvantages of environmental effects and as relative energy and material efficiency based on life cycle assessment (LCA). As a whole, environmental business can be defined as commercializing cleaner technologies in a way that environmental know-how builds an essential competitive asset for business. (Sitra 2007, p. 5.)

The environmental impact of cleaner technologies is expected to increase and companies are encouraged to pay more attention to their environmental performance and sustainability (Guziana 2011, p. 827). Therefore, the investments in technology development are considered more crucial than before. In Finland the portion of public research and development (R&D) investments directed to cleaner technologies is remarkably high, over a third of all the investments, and as an employer the sector is also substantial: approximately 50 000 people have a job in the cleaner technology sector in Finland (Cleantech Finland 2012a). Commercializing cleaner technologies in general is a stepping stone for growth, creating new jobs and promoting environmental protection and, thus, offers a huge opportunity for Finnish cleantech companies.

However, the adoption of cleaner technology in markets does not seem to be rapid enough due to economic, institutional and social barriers (del Río González 2005, p. 20-21). This leads to the need to fully understand the factors affecting the commercialization process of cleaner technology. Technology commercialization is a widely discussed topic and specifically the diffusion of cleaner technologies according to Montalvo and Kemp (2008, p. S1) has been considered an important booster for economic growth in the 21st century. However, no profound and straight-lined research has been conducted specifically on the characteristics of cleaner technologies and their effect on the commercialization process. Neither have the factors affecting cleaner technology commercialization been categorized systematically in different phases of the commercialization cycle. Therefore, the cleaner technology commercialization process calls for further research.

1.2 Research questions and limitations

This thesis aims at synthesizing the scattered information on special characteristics of cleaner technologies and their commercialization and creating a fruitful offset for further empirical research regarding the acceleration of cleaner technology commercialization especially in Finland. This is done by ironing out how the commercialization of cleaner technology can succeed and what kind of hindrances can affect the process. These factors will be studied in certain phases of the identified cleaner technology commercialization cycle. Based on the background of the research, the research questions are defined as follows:

1. What are the key challenges and success factors in the commercialization of cleaner technologies based on the existing literature?

2. What kind of lessons can be learned from the Finnish success stories of cleantech commercialization?

Commercialization is a multifaceted and long-term process and, thus, needs to be specified and limited to a certain research context. In this thesis the focus is mainly on Finnish firms' level although universal and generalized theory will be pursued to understand the general technology commercialization process. Although cleaner technologies include also, for example, services and processes, the research examines mainly the commercialization of technology which is transferred into a product and, further, launched to the market because also the related literature is mainly focused on the technology aspect. The product type itself depends on the nature of the actual technology (Kemp and Volpi 2008, p. S15) but in this thesis the focus is overall on all kind of cleaner technologies and not on specific technology subcategories because especially general information on the topic is lacking.

This thesis is closely related to TEKES (Finnish Funding Agency of Technology and Innovation) funded project 'Cleantech Solutions - Co-creating Environmental Solutions with Lead Customers' (2011-2013) which strives to find new ways to increase industrial companies' competitiveness by identifying and developing novel processes and tools to facilitate the co-creation, assessment and rapid commercialization of cleantech solutions. The project is led by Lappeenranta University of Technology in collaboration with the University of Oulu, and one of the project's main work packages focuses on studying how the commercialization cycle of cleantech solutions can be accelerated in collaboration with lead customers. The other two work packages concentrate on creating knowledge on innovating cleantech solutions with lead customers, and assessing the environmental performance and customer value added by cleantech solutions. This thesis will form a literature-based grounding around the topic and contribute to drawing up a survey targeted at several Finnish cleantech companies.

1.3 Research method

The nature of this research is qualitative as a history-based literature review is utilized to build an understanding of theoretical concepts and terminology related to technology commercialization and cleaner technology industry (e.g. Rowley and Slack 2004, p. 32). Utilizing qualitative research is justified when no systematically wide information is available on the specific research theme yet. Literature review as a qualitative research method explores already conducted research (secondary data) and gathers their results in order to form a grounding for new research results. (Salminen 2011, p. 4; Chiesa and Frattini 2011, p. S7-S8.) According to Baumeister and Leary (1997, p. 312) literature review is a beneficial method for developing existing theory but also creating new theory and evaluating it, identifying problems, and providing an opportunity to illustrate historical development and research on a particular topic. Thus, this method is particularly appropriate for this research. The nature of literature review can be further divided into either descriptive, systematic or meta-analysis (Salminen 2011, p. 6) as presented in Figure 1.

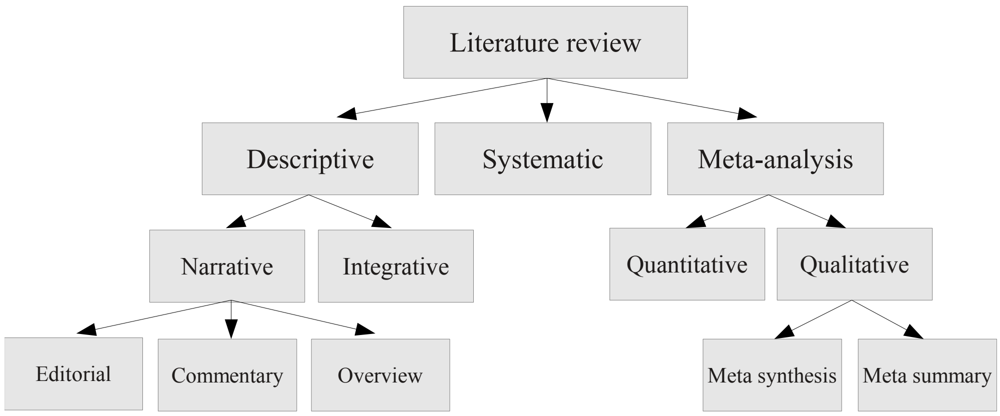

Figure 1. The typology of literature review (based on Salminen 2011, p. 6-9; Torraco 2005, p. 103)

A descriptive analysis is based on an overall review which is not limited to strict methodological rules. Research questions can be more loose than in systematic review or meta-analysis but the researched phenomenon and its characteristics can be accordingly classified. A descriptive literature review is further divided into narrative and integrative by nature (Salminen 2011, p. 6) from which the latter is mostly applied in this thesis because the objective of the research is to provide as multi-faceted information as possible on the research theme. In addition, integrative review helps in retrieving and examining the most appropriate literature but also analysing, evaluating and synthesizing it critically (Torraco 2005, p. 356-357). Narrative description is described as a wider process which aims at summarizing conducted research but does not typically make critical statements (Green, Johnson and Adams 2006, p. 103).

Although a descriptive analysis is mainly used in this thesis, also some features of systematic review can be detected as these methods share some similarities. One dimension of systematic review involves revealing potential research gaps around the topic and addressing further research need. Another dimension is evidence-based decision making which means that the research is conducted in order to gather information for supporting profitable decision making in companies. (Salminen 2011, p. 19; Walsh and Downe 2005, p. 204-205.) This further includes finding the success factors for improving company performance which also supports using literature review method in this research as a fundamental starting point because the aim is at providing useful insight to Finnish cleantech companies in order for them to perform better in the commercialization. Meta-analysis, in turn, although having both qualitative and quantitative dimensions, concentrates on providing numerical and statistical data results in order to improve the credibility of the research. Using meta-analysis requires choosing the most high standard material but at the same time the literature may be controversial because similar studies are difficult to find to make valid comparisons. (Green et al. 2006, p. 105.)

Due to the fact that the current literature does not provide sufficient and detailed information on Finnish companies' cleaner technology commercialization, three phone interviews (see Appendix 1) are made to gain understanding, practical insight and experience on the commercialization. The interviewees are selected as representatives of their organizations (see Rowley 2012, p. 260). Two of the interviews are conducted with Outotec's and Numcore's cooperation representatives and one interview is conducted with a representative of ZenRobotics. As Qu and Dumay (2011, p. 238) discuss, although an interview may not be the primary source of data, it is often used as a preliminary research method before a wider survey is conducted and, thus, forms an appropriate approach to this research.

1.4 Structure of the research

This thesis follows the same structure as any systematic or descriptive review: 1) defining research questions, 2) collecting relevant literature, 3) setting evaluation criteria, and 4) analysing and synthesizing results (Stechemesser and Guenther 2012, p. 18-19). A more detailed structure and contents of the research are illustrated in the following table (Table 1) and described afterwards.

Table 1. The structure of the thesis

CHAPTER	**OUTPUT**
Chapter 1: Introduction	Introducing the background of commercializing cleaner technologies, research need, limitations, questions and research methods.
Chapter 2: Cleantech markets	Describing the current state of cleantech industry and company structure in Finland.
Chapter 3: Technology commercialization	Defining technology commercialization, describing the commercialization process and ways to measure it.
Chapter 4: Commercializing cleaner technologies	Gathering and presenting the special characteristics of cleantech and forming a commercialization model for cleaner technologies, introducing successful commercialization stories from Finnish cleantech sector, as well as synthesizing and categorizing the success factors and challenges of cleaner technology commercialization based on

	literature and case interviews.
Chapter 5: Conclusions	Summarizing the answers to research questions, presenting theoretical and managerial implications.
Chapter 6: Future research	Presenting limitations of the research and research gaps for future research, providing insight for further empirical survey.

The thesis begun with a brief *introduction* to the cleantech overview including the description of the research need, research questions, limitations and methods of the study. In *chapter 2* a more detailed view of the current structure and growth potential of the Finnish cleantech companies is presented. This chapter gives important insight as it defines and forms the ultimate background for cleaner technology commercialization. *Chapter 3* provides information on general technology commercialization and its characteristics by introducing a pattern of how the technology commercialization process typically is illustrated in the literature to proceed. It is relevant to identify and understand the basic process before a model for cleaner technology commercialization can be formed and because the barriers and success factors of cleaner technology commercialization will be scrutinized in its different phases. *Chapter 4* aims at making a synthesis between (Finnish) cleantech sector and technology commercialization. This is done by presenting a conceptual model for cleaner technology commercialization, and collecting and categorizing not only the cleaner technology characteristics but also the success factors and challenges that can be faced in cleaner technology commercialization. Two examples of successful commercialization stories from Finnish cleantech companies will be presented as a basis for the classifications. In *chapter 5*, the research findings are summed up and discussed both from theoretical and managerial perspective. Finally, *chapter 6* presents aspects for further research as well as limitations to the current study.

2 CLEANTECH MARKETS

In this chapter the focus is on defining the cleaner technology markets from Finland's perspective and on clarifying the relevant concepts related to the topic. An overview of the cleantech sectors and their growth potential are presented by introducing the most essential Finnish cleantech companies in three categories based on the company size. In addition, the potential of Finnish cleantech companies to answer the global demand is also briefly discussed.

2.1 Concept of cleaner technologies

Definitions used in describing environmental technology vary depending on the context, authors and organizations in which or by whom they are used (Glavič and Lukman 2007, p. 1875). According to Guziana (2011, p. 829), *environmental technologies* cover all technologies that produce less damage to the environment than the existing ones and/or the ones that treat and prevent environmental damage. Some examples of the related terms include: environmental goods and services (EGS), environmentally sound technologies (EST), environmental solutions, green technology, environmentally preferable products (EPPs), clean technology and low carbon technology. Leading industrial firms in many sectors have been transforming their value propositions into "packages" instead of marketing single products or services (e.g. Sawhney 2006, p. 366). Sawhney (2006, p. 366) describes these packages, *solutions*, as integrated combinations of products and services that are needed to solve customer's problem. They are designed to provide customized experiences for specific customer segments which requires that customer problems are thoroughly analysed before an appropriate solution can be shaped.

Generally, environmental solutions are considered to entail either *cleaner technology or end-of-pipe technology* (EOP). Shortly, the first aims at reducing the production of pollution beforehand while the latter focuses on collecting and treating pollution (Markusson 2011, p. 294). Del Río González (2005, p. 22) clarifies further that end-of-pipe technologies are mostly used in displacing environmental hazards while cleaner technologies, which require changes in production processes, are aimed at reducing waste and pollution during the whole life cycle and eliminating the problems from the start. Therefore, cleaner technologies are regarded as a true potential for the future encompassing all knowledge-based technologies, products, services, processes and systems that in use create less environmental damage than their alternatives (cf. Kemp et al. 1992, p. 616; Stone 2007, p. 4; Glavind, Damtoft and Röttig 2001, p. 4). The benefits that are gained include, for example, process optimization, more efficient use of raw materials and renewable energy sources, improved environmental measurement and minimized environmental impact, water supply management and air and soil protection, and increased financial benefits and profitability in the form of minimized waste management costs, recycling or reusing of waste. (Hooper and Jenkins 1995, p. 34-35; del Río González 2005, p. 25-26; Montalvo and Kemp 2008, p. S1; Zhang, Yang and Bi 2011, p. 1-2; Zeng, Meng, Yin, Tam and Sun 2010, p. 975; Staniskis and Stasiskiene 2003; Stone 2007, p. 4.)

Despite the refined criteria, drawing a line between what is cleantech and what is not may sometimes prove difficult (Cleantech Finland 2012a). Cleaner technology has been criticized being a rather relative concept in comparison to end-of-pipe technologies that entail tangible devices (e.g. filters). Montalvo and Kemp (2008, p. S2) point out that cleaner technology is a subcategory to a wider concept of technology and can be seen to consist of all technologies that help reducing pollution and waste. This suggests that the concept of cleaner technology would also include end-of-pipe technologies, waste management techniques and also green products which involve technology configurations. Therefore, the notion is relative as it is critical to have a point of comparison when considering the cleanliness of technology, as was presented earlier (Coenen and Avdeitchikova 2011).

However, in this thesis specifically the term ‘cleaner technologies’ (shortly: cleantech) in environmental sector is mostly used because the term has risen from many research when describing new, environmentally cleaner alternatives for existing technologies. In addition, the term ‘cleaner technology’ itself encompasses importantly the concept of a solution which means that in cleantech sector not only does technology provide an answer to various problems but also the products they are incorporated with. Also services used in delivering the technology play an important role in the process.

2.2 The current structure of Finnish cleantech sector

Finland is on the leading edge of environmental know-how and problem solving due to good environmental legislation, well developed infrastructure, a high level of environmental awareness and a good quality of technology and innovations. According to Cleantech Finland’s statistics, the Finnish cleantech turnover rose to approximately 20,1 billion euros in 2011. Between 2010 and 2011 the annual growth rate reached the level of 10,6 % and for the year 2012 the estimated figure is 8,9 %. Despite a moderate decrease, on a global level the annual growth estimate is still lower than that, only 7 %. Finnish cleantech business represents 1 % of the global cleantech market and, thus, in volume the sector in Finland is considerably high in comparison to the national economy’s global share. (Cleantech Finland 2012a.)

Cleantech is not a separate industry but cuts through several industrial sectors from food to energy and, thus, forms a driver for the whole business society (Coenen and Avdeitchikova 2011). Different classifications on cleantech sectors can be made but, for example, Stone (2007, p. 6) and Lauffer and Robbins (2007, p. 14) represent a four-dimensional grid which highlights energy, transportation, materials and water as the main groups under which several subgroups fall. These groups are illustrated in table 2.

Table 2. The main categories of cleaner technologies (based on Stone 2007, p. 6; Lauffer and Robbins 2007, p. 14)

Energy	Transportation
Bio fuels Energy efficiency Fuel cells Microturbines Solar, wave and wind power	Batteries Alternative-fueled vehicles Electro propulsion Hybrid-electric vehicles Hydrogen refuelling stations Vehicle components Solar-powered vehicles Logistics
Materials / Buildings	**Water**
Biobased and nanobased materials Green buildings Green chemistry Biodegradable products Recycled materials Polymers	Biological water filtration Decentralized filtration systems Ultraviolet purification Wetlands restoration Water conservation

According to Sitra's report (2007, p. 10), the most essential fields of cleantech within environmental sector are water and waste management, recycling, environmental measuring, air, soil and water protection, and construction and transportation which are scattered in the 4-grid. From these categories Finnish cleantech companies operate the most successfully, for instance, in waste management, water management, energy efficiency and overall industrial processes. However, the downside of Finnish cleantech sector lies in a fragmented market picture of environmental business: from over 2000 Finnish cleantech companies in various sectors approximately 90 % are small companies with less than 20 employees. (Saine 2012, p. 10.) In relation to this, major internationally oriented companies are scarce but the 10 leading cleantech companies according to the extent of environmental business are responsible for 95 % of the annual turnover (Heikkilä 2012, p. 16-18; Mäkinen and Perttu 2008, p. 19; Hassinen, Hietaniemi and Lutfi 2007, p. 12).

2.2.1 Major Finnish cleantech companies

The geographic location of Finland has provided a fruitful opportunity to utilize years of cold climate experience and high technological know-how in order to support sustainable economic growth and take a head start in many sectors of clean energy (Green Net Finland 2008, p. 25, 36). A few years ago, Mäkinen and Perttu (2008, p. 37) discussed that Finnish cleantech markets were lacking strong and large engine companies willing to act closely with customers, for example, as a value network leader. These kind of companies would concept new solutions and simultaneously commercialize Finnish know-how that could create international market demand. Since then, the situation has improved as several Finnish cleantech companies have succeeded in gaining growth (Green Net Finland 2008, p. 25, 36) but commercialization support is still strongly needed.

TEKES project, to which this research is related, collaborates with three Finnish cleantech suppliers including Outotec, Kemira and Metso that are among the flagships in Finnish cleantech sector in their own fields of speciality. However, according to Heikkilä (2012, p. 16-18) currently Wärtsilä holds the number one position among the biggest Finnish cleantech companies measured by environmental performance as presented comprehensively in the following table (Table 3).

Table 3. Top 10 Finnish cleantech companies by their environmental performance (Heikkilä 2012, p. 16-18)

Company	**Business area**	**Size (employees)***	**Turnover (million €)***
Wärtsilä	complete lifecycle power solutions for the marine and energy markets (e.g. power plants)	3500 (in Finland)	4 209 (2011)
Metso	technology and services in the process industries of mining, construction, pulp and paper, power, oil and gas	30000	6 646 (2011)
Kemira	water management applications	5000	2207 (2011)
ABB	electric power and automation technology	7000 (in Finland)	2300 (in Finland, 2011)
YIT	technical building systems, construction and industry services	26000	4 400 (2011)
Vapo	biofuels, bioheat	1200	705 (2011)
Cargotec	future oriented cargo	10500	207 (2011)

	handling solutions		
Outotec	minerals and metals processing: non-ferrous and ferrous solutions, environmental solutions and services	3900	122 (2011)
Rautaruukki	energy efficient solutions for building, infrastructure and engineering, mineral products	11800	2800 (2011)
Kuusakoski (Group)	recycling services	3200	980 (in Finland, 2011)

* Figures are based on companies' web pages and TalousSanomat (www.taloussanomat.fi/yritykset/)

The largest Finnish cleantech companies demonstrate the versatility of different business areas and support Saine's (2012, p. 10) view of the most essential industries in Finnish cleantech structure. As can be seen from the previous table, Finland is still strongly characterized by traditional business sectors that involve forest and metal but the rise of versatile energy and electronics industry is closing. This, further, builds an enormous expertise base for managing several cleantech sectors. (Green Net Finland 2008, p. 36.) Especially in this large firm category, for example, bioenergy forms an important renewable energy source. Saarnia and Hassinen (2008, p. 22) state that the potential contribution of bioenergy to global policies is considered extremely high and several technologies in the sector have been developed in the recent years. All in all, Finland's competitive advantage lies in versatile know-how as integrated solutions typically require intertwined expertise from several sectors including, for example, energy, water and waste (Saarnia and Hassinen 2008, p. 1).

2.2.2 Small and medium-sized Finnish cleantech firms

Small companies, which are, currently somewhat lagging behind the growth markets, still hold the future potential in developing substantial cleaner technologies. Momentarily the most promising Finnish applications are especially related to energy savings and the biggest potential lies, for example, in Beneq, Chempolis and ZenRobotics. (Hassinen et al. 2007, p. 12; Heikkilä 2012, p. 16-18.) These and other growth seeking companies, their business areas and the most relevant key figures are presented in table 4. However, the table is not exhaustive as new startups continuously emerge which supports further the unbalanced industry view.

Table 4. The most promising small Finnish cleantech companies (in alphabetical order) (Heikkilä 2012, p. 16)

Company	**Business area**	**Size (employees)***	**Turnover (€)***	**Founding year***
Akkuser	recycling of batteries	10	1118 000 (2012)	2006
Asema Electronics	electricity savings in consumer sector	13	141000 (2011)	2008
Beneq	thin films coatings, solar energy	85	10034 000 (2010)	2005
BT Woods	wood handling chemicals for construction	4	18000 (2011)	2010
Chempolis	technologies for biorefining of residual biomasses, biofuels	24	1013 000 (2010)	1995
Ekolite	recycling materials	-	11 000 (2011)	2009
Enercomp	pump and fan systems	-	21 000 (2011)	2007
Enersize	industrial energy saving	-	-321000 (2010)	2010
Enevo	optimizing waste management	-	2000 (2012)	2010
GreenStream Network	management of industrial emissions	-	4134000 (2011)	2001
Marimatic	systems for waste management	22	6599 000 (2011)	1983
Mervento	wind turbines	38	5222 000 (2011)	2008
MetGen	industrial chemicals	6 (2010)	120000 (2011)	2006
MHG Systems	accelerating industrial performance	10	67000 (2010)	2005
Neapo	modular construction	15	5198000 (2011)	2007
Netcycler	recycling	7 (2010)	14000 (2011)	2008

Numcore (Outotec acquisition in March 2012)	management of industrial liquids	13	597000 (2011)	2008
Pegasor	particle detectors	-	1294000 (2011)	2008
Savo Solar	solar energy	13	109000 (2011)	2010
There	energy savings in consumer sector	25	24000 (2010)	2009
Ultranat	recycling of ash	2	25000 (2011)	2009
ZenRobotics	recycling of waste	27	207000 (2011)	2007

* Figures are based on companies' web pages and TalousSanomat (www.taloussanomat.fi/yritykset/)

As illustrated in the previous table, the know-how of Finnish cleantech companies is even more versatile in small-size category than with the larger companies and the amount of currently promising companies is notable. Taking into consideration the size imbalance of cleantech companies in Finland, it is not surprising that the majority of the most potential ones are categorized as micro companies having less than 10 employees and the turnover or the total of balance sheet at maximum of 2 millions (European Commission 2012). Startups generally fall into this category as they are rather young, still developing their first technology and may not yet be making such a great profit. However, for example, Chempolis and Marimatic represent companies that have existed for some time now but still await larger business growth opportunities in markets.

To point out few of the business areas that rise from the table, several solutions for waste management and recycling have been in the focus of small Finnish cleantech firms to increase the energy potential. Saarnia and Hassinen (2008, p. 22) discuss that the drivers for paying more attention to waste-to-energy solutions include increasing energy demand followed by increased energy prices, closing of landfills and turning towards recycling, local energy control and stricter emission control. On the other hand, for example Savo Solar concentrates on solar energy which is considered the most natural global energy source. Although the price of equipment needed for the energy production is high, the operation itself causes considerably fewer expenses in comparison to fossil fuel sources. Solar energy that is used, for example, in building construction and water heating is expected to affect greatly the supply of energy in the future. Wind-power systems also rise to one of the focus areas in generating electricity (Saarnia and Hassinen 2008, p. 21). The report of Green Net Finland (2008, p. 4) highlights that Finland is indeed among the largest suppliers of wind turbine components world-wide.

When considering medium-sized Finnish companies such as Ensto, which is focused on energy efficiency, and The Switch, which specializes in permanent magnet generators, it is obvious that with turnovers of several million euros they are an important backbone in Finnish cleantech (Heikkilä 2012, p. 16-18). Along with these two, the most potential companies in medium-size class in Finland are presented in the following table (Table 5).

Table 5. The most promising medium-sized Finnish cleantech companies (in alphabetical order) (Heikkilä 2012, p. 17)

Company	**Business area**	**Size (employees)***	**Turnover (million €)***
BMH Technology	handling of biomass fuels to industrial and municipal power plants	101	54,1 (2011)
Ensto	energy efficiency, charging electric cars	464	93,8 (2011)
Halton	ventilation systems	1200 (2011)	140,6 (2010)
Lamor	prevention of oil leaks	32	54,5 (2011)
Moventas	wind turbine gears	462	69,6 (2011)
MW Power	bio-based heat and power plants	58	55,6 (2011)
Oilon	burners, heat pumps, solar heat collectors	132	28,7 (2011)
ST1 Biofuels	renewable energy	-	15,1 (2011)
The Switch	full-power converter packages, permanent magnet generators	226	93,8 (2011)
Vacon	frequency variables, energy saving	1470	380,9 (2011)
Vaisala	weather observing solutions	1382	273,6 (2011)
Winwind	wind turbines	295 (in Finland)	50,5 (2010)

* Figures are based on companies' web pages and TalousSanomat (www.taloussanomat.fi/yritykset/)

The companies presented in the previous table form the engine of economic growth in Finland although not all of them stand out with a huge amount of employees. According to estimates, there should be 10-20 more of these middle-sized companies in Finland (Heikkilä 2012, p. 16-18; Mäkinen and Perttu 2008; Hassinen et al. 2007, p. 12). This suggests further that smaller companies should be helped to gain rapid growth in order to reach international markets and the medium-size class. For example, Lamor and Moventas represent newer companies (founded in 2006) that have rapidly achieved a substantial scale of turnover and demonstrate the existing growth possibilities.

Heikkilä (2012, p. 16-18) points out that one of the main challenges especially for startups in Finland is finding investors as new business always involves uncertainty and high risk. Investment company Cleantech Invest reckons in Heikkilä's (2012, p. 16-18) article that Finland is currently not making enough investments in cleantech although it is building the cornerstone for the Finnish economy. According to Cleantech Invest, opportunities should be sought before the market entry becomes too difficult. However, without commercialization the utilization of new technologies stays inadequate which is why more focus should be put on bringing them successfully to international markets.

2.3 Global demand and cleantech markets from Finnish perspective

The growing demand for cleaner renewable energy is comparable to the growing concern of global climate change, foreign oil and the increasing price of it, which results in seeking new technologies both at supplier and customer side. This, further has an effect on labor intensive orientation as handling new technologies requires more work force. Jobs arise in all economic levels from different phases of product development and from businesses that supply, for example, raw material, equipment and services to energy companies. (Lauffer and Robbins 2007, p. 15.)

In environmental sector the domestic markets for cleaner technologies are too narrow and do not offer the needed market potential for Finnish companies. Thus, new growth should be sought internationally as discussed earlier (Mäkinen and Perttu 2008, p. 17; Hassinen et al. 2007, p. 12). Environmental export is to a larger extent project-based which is why country-specific research results on cleaner technology cannot be entirely generalized for every sector of the industry. Saarnia and Hassinen (2008, p. 3, 22) state that although cleantech market is expanding world-wide in most sectors, the potential market should be chosen on the basis of the specific cleaner technology or business segment. As an example, sludge treatment is mostly demanded in eastern and middle Europe and wave energy solutions, which have only recently reached the true potential for commercial utilization, are appreciated in ocean shore countries. All in all, instead of the term ‘export’, Mäkinen and Perttu (2008, p. 35) actually prefer talking about internationalization of cleantech business as it describes better the multifaceted nature in targeting new markets.

Currently the most important market areas for Finland include, above all, China which offers opportunities especially for air and water monitoring solutions but also Germany, Russia and India are strengthening their market positions (Saarnia and Hassinen 2008, p. 3; Cleantech Finland 2012a). China and Germany have strongly held the top 2 positions for the past three years but, according to initial estimates, Russia will increase its attractiveness and catch up them by 2015. The potential of Russia lies in the growing need to follow the governmental energy saving objectives by strengthening the energy efficiency especially in water and waste management, air protection, and clean processes, products and materials. (Cleantech Finland 2012b, p. 4, 8; Rautio 2012.) Germany’s role in cleantech sector is substantial as it aims at increasing its reliance on renewable energy sources including solar and wind to replace the nuclear generation. The cleaner technology industry is estimated to more than double by 2025 and it is expected that the rapid growth in cleantech will also stimulate other, more traditional, economy sectors. (Nicola 2012.) Cleaner technology cooperation with India is also considered to intensify. Currently, India is provided with expertise in the fields of energy efficiency, renewable energy and water treatment. Finnish companies, such as Kemira, Ensto and Chempolis, have begun to expand their performance in India by contributing to one billion euro investment in India and offering products, services and technologies that minimize the negative impacts on environment. With the highest transmission and distribution losses in the world, India offers a remarkable business potential also for Finnish SMEs that are seeking partnerships in India. (Bora 2012.)

Overall, Mäkinen and Perttu (2008, p. 4) suggest that Finland needs partnerships with transitional economies rather than promoting traditional export in order to maximize the benefits. This kind of partnership would provide experience that is needed to build networks, develop managerial know-how and strengthen the opportunity to operate successfully in international markets. The report of Green Net Finland (2008, p. 5) proposes that efforts should be put on user-drivenness as customers continuously demand for more complete solutions and expect suppliers to fulfil their needs and solve problems by improving their business processes. This signifies that in order to create additional value for customers, suppliers need to understand their customers' business environment and become a partner with the customer. This kind of customer-centricness inevitably also requires cooperation between other companies and actors in the industry. (Hassinen et al. 2007, p. 13.)

Generally, help from both public and private sectors are needed to promote industry growth and several programmes and projects have recently been launched in order to do that. One of the examples to support Finland's partnerships with other economies has been a programme called 'Finnish Environmental Cluster for China (FECC)' that has focused on the commercialization and internationalization of Finnish environmental business to support growth in rapidly expanding Chinese markets (Mäkinen and Perttu 2008, p. 6; Rantajärvi 2012, p. 18-19). As a result especially companies in waste management industry, which is considered to have a lot of export potential in the future, have gained customers from China. As another example, 'Nordic Environmental Technology Solutions (NETS)' was a project between environmentally advanced Nordic countries primarily aimed at developing a platform for commercializing key business sectors, increasing the global competitiveness of

Nordic cleantech SMEs and increasing the visibility of Nordic cleantech solutions through networking. In this project China and Russia were proposed as potential targets for expansion although many small companies did not consider entering these markets as a top priority mainly due to the lack of assistance from established networks. (Saarnia and Hassinen 2008, p. 3.)

2.4 Summary

Despite a somewhat blurring definition, cleaner technologies represent a huge potential to tackle environmental problems as they expand across several industries. Currently only a few leading giant companies dominate the Finnish cleantech industry being responsible for 95 % of the total turnover. (Heikkilä 2012, p. 16-18; Mäkinen and Perttu 2008, p. 19; Hassinen et al. 2007, p. 12, Stone 2007, p. 6; Lauffer and Robbins 2007, p. 14.) Finland possesses diverse expertise and experience on cleantech but the main problem lies in a huge amount of startups that have not been able to meet the expectations and find a boost to gain growth. It goes without saying that startups face the biggest challenges when they enter the cleantech sector as underdogs without pre-existing networks and resources.

The purpose of the second main chapter of the thesis was to introduce the background and current structure of cleaner technology industry in Finland. The bottlenecks pointed out are especially related to startups and 'stuck-in-the-growth' companies struggling to compete against larger companies that are holding a strong position in the sector. The competence of the whole Finnish cleantech industry culminates in the ability to take advantage of the potential of new cleaner technologies and cooperation with other actors in the sector as international growth may not be managed without building first a stable position in domestic markets. Overall, developing a promising piece of technology is not enough as it requires carefully managed commercialization planning which is a prerequisite for success. Thus, the process may form a bottleneck for the whole company performance (e.g. Heikkilä 2012, p. 16-18) if not executed systematically.

3 TECHNOLOGY COMMERCIALIZATION

Technology in general is a multi-faceted concept than can be understood in many ways. Ziamou (2002, p. 365) follows Jolly (1997, p. xii-xvii) in the definition of a new technology stating that it is a new capability that can be used in different products. According to Rogers (2003, p. 13) technology in general has two components that complete each other and that need to take into consideration in the commercialization: 1) *hardware* which refers to a tool by which the physical object is embodied, and 2) *software* which consists of the information needed for the physical tool. These aspects are to be considered in relation to the commercialization planning that will be discussed in more detail in the following chapter.

3.1 Technology commercialization process

"Companies that excel at commercialization have learned to treat the process as a top priority..." (Nevens 1990, p. 24)

In Wonglimpiyarat's research (2009, p. 227) *technology commercialization* is shortly comprehended as the competence to use technologies in products and launch them fast and productively to different markets. Technology commercialization can be seen as a detailed sequence of steps during which an initial idea or concept is converted from laboratory conditions into a product or process that will gain market acceptance and be adopted. Commercialization is the key to ensure that the technology meets both performance, reliability and the economic requirements. (Balachandra, Nathan and Reddy 2010, p. 1843-1844.)

The fundamental logic behind commercialization process is the same with products and technologies: understanding, creating and communicating customer value (Simula, Lehtimäki, Salo and Malinen 2010, p. 16). The process is also the same in small and larger companies but the methods vary depending on, for example, the access to resources. Pries and Guild (2011, p. 319) along with Gans and Stern (2003,

p. 334) state that there are basically two alternatives in commercializing new technologies: 1) through product markets which means developing products or services that contain new technology, or 2) through markets for technology which means selling or licensing rights to use the technology as a basis for new products or services in other companies. The first is about transferring products and/or services, while the latter mainly requires information and intellectual property transfer, and thus, is limited out of this thesis. Based on the study of Pries and Guild (2011, p. 319-322), a clear majority of startups operate through technology product markets in which financial returns are gained straight, for example, from services, products and applications that are sold.

Several slightly or drastically different commercialization process models exist of which each emphasizes a certain perspective (cf. McCoy, Thabet and Badinelli 2009, p. 105-106; Rogers 2003, p. 137-161; Goldsmith 1999; Prebble, de Waal and de Groot 2008, p. 311-313; Balachandra et al. 2010, p. 1843-1844; Rasmussen 2007, p. 68). Common to all of these models is their linear nature. In this thesis several research have been utilized and combined in order to define different phases of technology commercialization. Therefore, the process is divided into the following sequential phases (see Figure 2): *1) idea generation, 2) technology development, 3) seeking market opportunities, 4) market launch and promotion, and 5) sustaining commercialization.*

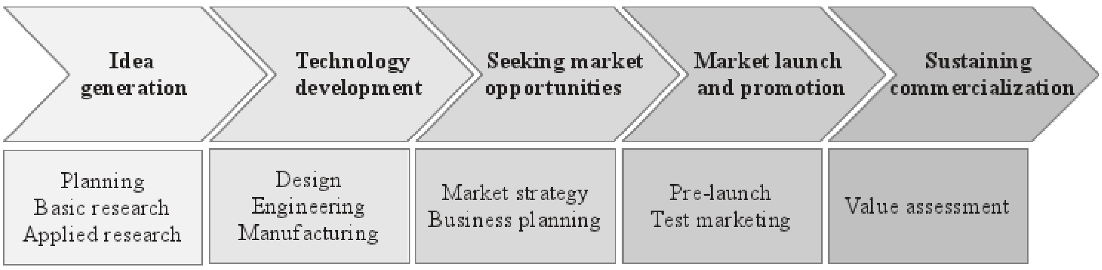

Figure 2. Preliminary conceptual framework for technology commercialization based on literature review (e.g. Balachandra et al. 2010, p. 1843-1844)

Traditionally the commercialization process is seen to be very technology-oriented as the development phase precedes seeking market opportunities for the technology. In this traditional model the technology is seen to be commercialized after it has been launched to the markets. The phases will be introduced briefly in the following chapters.

3.1.1 Idea generation

Traditionally commercialization begins with an idea development process (Prebble et al. 2008, p. 311). For example, McCoy et al. (2009, p. 106) and Rogers (2003, p. 137) emphasize that both the problem and need have to be recognized before determining how technology can provide an answer to it. This is the basis for stimulating technology design and creation. Jolly (1997, p. 3-6) describes the first phase with a word ‘imagining’ which, according to Balachandra et al. (2010, p. 1844), refers to a new device that is created in people’s minds.

Idea generation most often requires basic and applied research to back up the realism of ideas (Rogers 2003, p. 139). Technology exploration is supported by formulating new hypotheses from the basis of initial research. In addition, market insight or research is needed to identify the actual needs (Jolly 1997, p. 4). Theoretical research helps in understanding the theories behind the idea generation (Balachandra et al. 2010, p. 1844). In this phase validating the potential of the composed technology is recommended as well as justifying the whole commercialization with it (Jolly 1997, p. 306; Siegel, Hansén and Pellas 1995, p. 20).

3.1.2 Technology development

Rogers (2003, p. 146) defines technology development as a process in which the generated idea converts into a form that serves the potential adopters and customers in their needs. In this phase the initial decision on commercialization needs to be done in order to allocate resources. Eldred and McGrath (1997, p. 42, 44) emphasize that technology development has its own characteristics compared with product development. Still, although products are separated from technologies in the meaning of commercialization, technology needs to be adapted to the product in which it will be used (Corkindale 2010, p. 42). Thus, the technology process can be seen as a process during which technology successfully becomes a part of a new product. Balachandra et al. (2010, p. 1844) describe this phase utilizing applied research to back the study of technical feasibility. Realistic assessment of the technology utility is needed including determining key applications, variations and modifications of the technology, in addition to connecting real market needs with the technology attributes (Siegel et al. 1995, p. 20-21). Even promising technologies do not automatically convert into a success but they need to be thoroughly developed until they have reached commercialization potential. Therefore, new technologies need to be evaluated carefully. (Eldred and McGrath 1997, p. 41.)

3.1.3 Seeking market opportunities

"Finance and technology meet at the crossroads of technology readiness." (Clausing and Holmes 2010, p. 52)

After conclusive development the technology will be assessed for final manufacturing (Balachandra et al. 2010, p. 1844). Jolly (1997, p. 8-11) embraces a combination approach of market discovery (pull) which requires identifying opportunities and niches and market creation (push) which aims at creating demand and reducing resistance. However, the challenge is to identify market opportunities and cash flows that are to be expected in the future (Bond and Houston 2003, p. 121).

Chesbrough (2003, p. 63-64) states that a business model is a beneficial framework for linking technical decisions to economic outcomes and create a working device out of the technology (Balachandra et al. 2010, p. 1844-1845). Depending on the technology characteristics there are three ways for firms to create and capture value from their new technology as a business model: 1) creating a company to manufacture products and services based on the technology, 2) transferring all the rights to the technology to other firms (technology sale), or 3) retaining ownership to the technology and transferring limited rights to existing companies to use it (licensing) (Pries and Guild 2011, p. 152-153). However, technology is not useful until it has been commercialized and, thus, a business model for commercializing new technology needs to be planned and carried out. The elements of the business model can be defined as: 1) articulating the value proposition of the product or service that uses the new technology, 2) identifying the market segment for the technology, 3) defining the firm's value chain for creating and distributing the offering successfully to the market, 4) specifying the revenue generating mechanisms, the cost structure and profit margins for the organisation, 5) describing the firm's position in the value network, and 6) specifying the competitive strategy in order to gain and maintain advantage over competitors. (Chesbrough 2003, p. 63-64.)

Kumar and Jain (2003, p. 115) have studied that the five most relevant factors affecting the final decision of commercializing new technology include: 1) status of technology, 2) source of technology, 3) market potential for end product, 4) company's business philosophy, and 5) financial status of the industrial firm. Hellman and van den Hoed (2007, p. 313) state that decision on which technologies to patent and which to develop further for production are in either way costly and target market needs to be thoroughly specified in order to save resources and avoid the failure of entering wrong markets (Corkindale 2010, p. 42).

Companies that utilize the competence to commercialize technology are willing to change their whole business model for strategic advantage (Nevens 1990, p. 22). Probert, Farrukh, Gregory and Robinson (1999, p. 15-16) point out that some companies are so technology-dominated that their technology strategy equals to their whole business strategy. The planning can be based on either reactive approach, in which the technology is seen as a tactical resource, proactive approach, in which looking for technology opportunities stirs strategic planning, or 'bonsai' approach, which means that technology is the most important driver of the company strategy.

3.1.4 Market launch and promotion activities

Manufacturing is followed by a stage in which the new technology is transformed into a commercially viable device (Balachandra et al. 2010, p. 1844-1845). Rogers (2003, p. 152) defines the 'commercialization' being reached in this phase after technology has gone through manufacturing, packaging, marketing and distribution for sale altogether. After the manufacturing technologies are shaped into packages to be diffused and adopted among users over time (see also Montalvo and Kemp 2008, p. S2). A slight difference between using the term 'diffusion' and 'adoption' is that the first handles mostly passive acceptance of a new technology by individuals and groups, while the latter concentrates on launching it actively to markets (McCoy et al. 2009, p. 104-105) including, for example, marketing efforts. The process, thus, involves both planned and unplanned, spontaneous, spreading of new technologies (Rogers 2003, p. 5-6).

In this phase information transfer is an absolute especially when technologies are complex, expensive and involve uncertainty (Kemp and Volpi 2008, p. S15). Information is shared through specific channels and accurate targeting of commercialization is considered in order to find the most suitable markets and identify the leading companies in the industry to utilize the technology (Rogers 2003, p. 5-6; Siegel et al. 1995, p. 21). Jolly (1997, p. 4, 10-12) also emphasizes the need for mobilizing assets for technology delivery. These assets are versatile and consist of, for example, financial assets, managerial and technical personnel, technical know-how, market concept and access, and manufacturing capacity.

3.1.5 Sustaining commercialization

Marketing activities lead to a stage in which business needs further development and commercialization sustainability. The technology is rarely ever totally ready when launched for the first time and will typically be improved during its life cycle (Kemp and Volpi 2008, p. S16-S17). From customer perspective this could be seen as a confirmation phase during which adopters either continue using the technology after adopting it or alternatively reject it (Balachandra et al. 2010, p. 1844-1845). Rogers (2003, p. 157) refers to 'consequences' that are the occurred changes faced by an individual or a social system due to the use of new technology.

Jolly (1997, p. 284, 306) discusses that every piece of technology is at some point of its life cycle to be substituted with better ones. However, it is notable that the ultimate value and advantages of technology in some cases realize only after the actual purchase and long-term use of the technology (Aarikka-Stenroos and Sandberg 2007, p. 5). Thus, the value of commercialized technology should be prolonged in order to maintain its dominant position as long as possible. Jolly (1997, p. 283, 373) presents three ways to do this. Firstly, conditions for a longer technology life span is to *entrench* the product / process in which the technology is incorporated. In practice this would mean changing the features of the technology or creating new ones, improving applications, sustaining the interest of market segments and creating user dependence. Another option is to *expand* the use of the technology by introducing it to new market segments or applications. Third alternative is to *dominate* the technology leadership in a way that long-term profits are secured for its inventors. However, still no technology can survive forever and trying to preserve it too long can be hazardous. (Jolly 1997, p. 284, 290, 303.)

3.2 Measures for commercialization

Rogers (2003, p. 161) points out that as considerable efforts and investments have been made to reach the final phase of commercialization, it would be of great importance to also follow the results. Thus, the advantage of measuring lies in the fact that improving performance may prove to be difficult if the development is not being tracked. The key objective is to observe the performance, provide information on well-managed phases of commercialization but also identify the most critical areas that are in the need of improvement and reinforce the profitability by correcting the bottlenecks. Measuring in general helps in understanding every aspect of the company performance and business management and this way focusing on providing better customer value. (Simula et al. 2010, p. 98-99.)

Firm-level success is traditionally based on economic indicators, for example, market shares and profitability, but as Palmberg (2006, p. 1253) points out, firms can carry out several projects that are assessed with different success measures. That is, the success of commercialization as a concept is blurring because the term ‘success’ can contain several meanings and the various alternatives for measuring success need to be considered from each company’s own perspective (Simula et al. 2010, p. 98-99).

Simula et al. (2010, p. 97-98, 103-104) divide the measures of successful commercialization into economic, technical and market-based measures. *Economic measures* are especially crucial in monitoring the most important objectives of a company. However, sales and profitability figures need to be adapted to the environment of the company as well as its objectives, and typically they observe events that have already occurred. In addition, numerical results created by the measures need to be understood in order to maximise the benefits of measuring. *Technical measures* are important mostly from the perspective of product or technology development because they assess how the company has succeeded in its activities. However, these measures do not actually reveal if the product or technology has achieved support in the markets. *Market-based measures* are typically customer-related factors that provide key figures from marketing perspective. Examples of measures of each group are presented in the following table (Table 6) from the technology point of view.

Table 6. Examples of technology commercialization measures (Simula et al. 2010, p. 104-106)

Economic measures	**Technical measures**	**Market-based measures**
• profits in relation to sales and investments • the share of the specific technology from total sales or profits	• maintenance costs • delivery time and capability • the amount of detected errors • the realized costs of the technology	• market share and sales • the amount of new customers achieved by the technology • assessment of perceived customer value • media attention and

• the realization of cost and price objectives • the gained market share in a certain time • payback time • sales volumes	• down-time of the production • the level of competitive advantage created by the technology • the realized quality level • time-to-market	improved brand awareness • the effect of the technology on customers and competitors • the reach of the best lead customers • the level of substituting existing technologies

The measures can also be divided by their duration. Simula et al. (2010, p. 99-100) discuss that examples of short-term measures include development costs of a product, timetable of launch and time-to-market which refers to the time from initial idea generation and development to launch and the actual commercialization state in which a market position has been gained (Balachandra 2010, p. 1843; Hivner, Hopkins and Hopkins 2003, p. 81). Long-term measures include, for example, customer acceptance on the product, economic measures such as profits in relation to investments and overall profitability.

3.3 Summary

In technology commercialization most often the hardware aspect is emphasized over software. The process can be seen very technology-driven and linear starting from idea generation, going through designing development, finding markets, executing launch and ending up with sustaining commercialization. In a dynamically changing environment technologies quickly become obsolete and substituted with more advanced ones and, thus, various ways of maintaining their value need to be considered (e.g. Jolly 1997, p. 284, 306), especially when the benefits in many cases may become visible only after long-term use (Aarikka-Stenroos and Sandberg 2007, p. 5). Prolonging commercialization could be done by, for example, adding or improving technology features, expanding the market segments or dominating technology leadership (Jolly 1997, p. 283). The indicators of technology commercialization are versatile but measuring the success has not been discussed broadly in the literature although it is the most relevant factor in the commercialization process.

The purpose of the third main chapter of the thesis was to introduce the theoretical starting point of technology commercialization and highlight the traditional process structure because it will form the framework for identifying the commercialization process of cleaner technologies. The special characteristics of cleaner technologies, which are to be introduced in the following main chapter, ultimately shape the process because more than solely technologies are concerned. However, the fundamental idea behind the commercialization is similar which makes it interesting to compare the results with the theory. A relevant aspect is also the chronological approach to handling the factors that affect the commercialization process, not to forget practical success measurement in relation to theoretical measures, as all of this may provide useful tips to Finnish cleantech companies aiming at successful commercialization from early on.

4 COMMERCIALIZATION OF CLEANER TECHNOLOGIES

Following Hellman and van den Hoed‘s study (2007, p. 305), the presumption is that the commercialization process of cleaner technologies has several similarities with the commercialization of other technologies. However, cleaner technologies have certain characteristics which tend to differ them from other technologies and which need to be taken into consideration in the commercialization process. From the basis of these characteristics the commercialization process of cleaner technologies will be evaluated through Finnish success stories, and commercialization-related barriers and success factors will be presented.

4.1 Special characteristics of cleaner technologies

So far, it has not been structurally researched what kind of special features cleaner technologies actually possess in comparison to other technologies and how these characteristics affect the commercialization process. Thus, at this point these specific characteristics need to be gathered from different studies and different sectors of cleantech in order to form a general view of the common factors. From the basis of several research some aspects of clean technology industry can be identified. These are categorized in four groups in the following table (Table 7).

Table 7. Categorized cleantech characteristics (based on research by del Río González 2005, p. 28; Hellman and van den Hoed 2007, p. 306-308; Lauffer and Robbins 2007, p. 15; Hassinen et al. 2007, p. 12; Coenen and Avdeitchikova 2011)

Network	**Economic**	**Technology**	**Supplier**
• B2B collaboration • collaboration between user and supplier as a source of	• capital intensity • investment orientation • relevance of raw materials	• high-technology dynamism • incremental technological development	• imbalance of company sizes (economies of scale vs niche markets) • heterogeneous

innovation • need of wide network externalities	and energy in cost structure • stretching through several industries • market-drivenness	• technology and system complexity • the need of complementary technologies	company strategies • imbalance between supply and demand • increasing importance of environmental protection • entrepreneurial orientation
need of regulatory support, emerging industry, immaturity, uncertainty and risks, number of incumbents, project cycle			

According to Coenen and Avdeitchikova (2011) and Geels (2004, p. 913), cleaner technologies as an industry are shadowed with tremendous uncertainty regarding new technology direction, markets, user cases and regulatory issues. In addition, fast movement plays a crucial role. For example, changing regulations have an effect on technologies, new and highly advanced technology can cause changes in the organization structure, productions and employees, and market uncertainty occurs in the form of unlikely return of investments. (del Río González 2005, p. 27; Berkhout, Hartmann and Trott 2010, p. 479; Chiesa and Frattini 2011, p. 438.) Moors, Mulder and Vergragt (2005, p. 663-665) add that new and unproven technological development carries a lot of risk as it may result in losses in case the technology does not fulfil the expectations. Thus, for example, smaller companies tend to hold back and only respond to the changes occurred instead of pro-actively embracing them (Man, Lau and Chan 2002, p. 128-129). Certain cleantech industry segments rely heavily on favorable public policy and cleaner technologies involve a number of incumbents (Stone 2007, p. 4) which, according to Coenen and Avdeitchikova (2011), signifies lack of internalization of environmental costs for incumbent technologies which, further, "leads to a mismatch between the firm and society level utility of a clean technology". This is considered the main difference between cleaner technology and other technology commercialization and highlights how the prevailing social and economic systems affect especially entrepreneurial-oriented small cleantech companies and their adaptability to the industry conditions.

As cleaner technologies encompass knowledge-based products, services and processes, the sector is generally characterized by a high level of information technology (IT) and market-drivenness (Stone 2007, p. 4; Hu and McLoughlin 2012, p. 325). As was mentioned earlier, cleaner technologies stretch across several different technologies, sciences and also services (Coenen and Avdeitchikova 2011). Therefore, from the sustainability point of view, the cleantech sector provides substantially huge economic opportunities to more rapid growth markets in comparison to other technology sectors and also provides an enormous cultural economy of emerging sectors in the long-term (Stone 2007, p. 4; Caprotti 2012, p. 379 and 382; Cleantech Finland 2012a). In addition, as Caprotti (2012, p. 380) discusses, due to this versatility cleaner technologies are considered clearly the most potential answer to the consequences of climate crisis.

Although 'cleaner technology' by its definition includes products, technologies as well as services, the technological orientation has been dominant. Respectively, services have not been profoundly discussed although they are among the most promising targets for building new environmental business (Rantajärvi 2012, p. 18-19). Indeed, in environmental sector the importance of services has strengthened as companies base their performance and strategies primarily on collaborative and service-based actions (Hassinen et al. 2007, p. 34; Hemert, Nijkam and Masurel 2012). Typically 'services' as a company capability involve developing service business, offering life-cycle services and this way attaining growth in the market share and profitability of customers. Also customers have increasingly begun to show interest in integrated solutions that would be customized case by case. Berkhout et al. (2010, p. 476) have presented a very descriptive model on the relationship of technology, products and services (see Figure 3) which illustrates well the trinity of cleaner technologies although it originally bundles products and services together. Based on Berkhout et al. (2010, p. 476), a more adapted model can be presented.

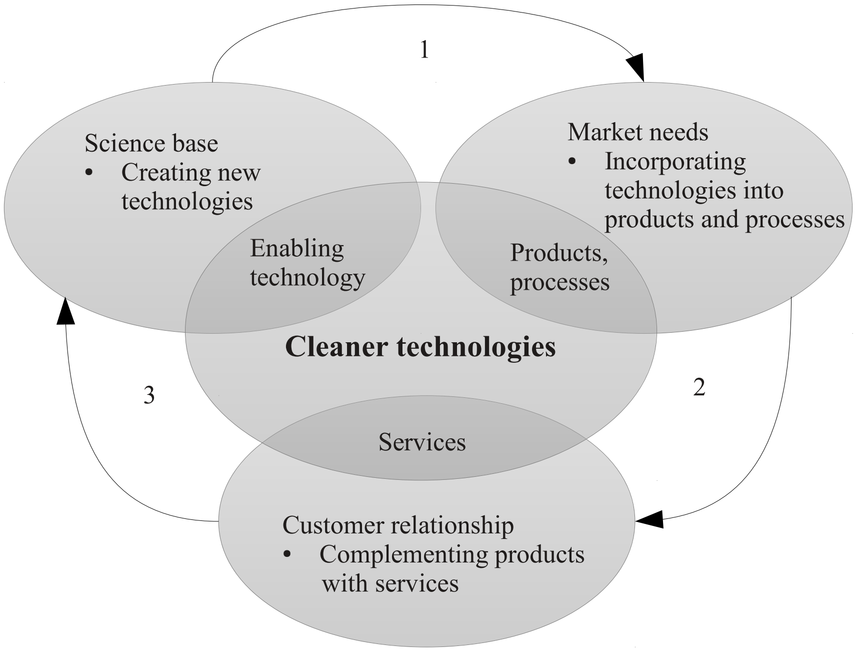

Figure 3. The relationship between technology, products and services (adapted from Berkhout et al. 2010, p. 476)

The leading companies have understood customer co-creation and intensive communication being a prerequisite for success (Gustafsson, Kristensson and Witell 2012, p. 311). A more intimate relationship with customers can be created by offering services (Alam and Perry 2002, p. 518) and, thus, cleaner technology suppliers have adopted an approach of working closely with customers as it enables understanding better their business and in this way create innovative, effective, productive and environmentally high-quality solutions according to customers' needs. Similar to solution business (Storbacka 2011, p. 699-701), the business planning of cleaner technologies requires stricter customer involvement. In addition, the whole commercialization process should include customer sensing and co-creation of value right from the beginning until its final phase. The research of Hu and McLoughlin (2012, p. 325-326) supports Storbacka's (2011, p. 699-701) insight on that companies can have great potential to create markets for services by co-working with customers. However, the level of involvement varies along the market development process.

4.2 Success stories of Finnish cleantech commercialization

Successful cleaner technology commercialization stories in Finland could provide a role model for both startups but also for more experienced companies in the cleaner technology industry. As discussed before, for small cleantech companies the commercialization process is relatively more challenging and often cooperation with larger firms acts as the only booster for growth. An opportunity for Finnish companies' collaboration within cleaner technologies resides in the trend that technological solutions are coming closer together (Sitra 2007, p. 14-15). Thus, two different cleaner technology commercialization cases will be presented in order to explore their success path and point out the most crucial factors in the process. The first one examines a young individually performing startup and the other one scrutinizes a startup that has opened doors to cooperation. The information is for the most part based on interviews with the company representatives and will be utilized in forming a framework for cleaner technology commercialization process.

4.2.1 ZenRobotics

ZenRobotics is a Finnish high-tech company which was founded in 2007. The company specializes in recycling technology and advanced artificial intelligence (AI) robotics that is considered the most advanced technology used in the recycling business (see Table 4). Their main product, ZenRobotics Recycler, is a device capable of utilizing machine learning to pick and sort raw materials, such as metal, stone and wood, from waste to be sold further as scrap (Anderson 2012). ZenRobotics Recycler provides a tool especially for companies that handle construction waste but as additional features increase, the customer base will be expanded to involve the whole waste business in the world (Rehn 2012). The recycler is not purpose-specific which allows the software to be upgraded for carrying out new tasks (Anderson 2012).

The representative of ZenRobotics, Marketing and Commercialization Manager

Rainer Rehn, believes that business has to be market-driven, not technology-driven, which means that the commercialization should start with carefully listening to the customer and his problems. Customer attention forms the core of the commercialization. Rehn (2012) discusses that observing and writing down the observed customer needs in everyday life is the first step that can take several years. Afterwards it is to be determined whether a solution for the problem already exists or not. The process may not even require actual inventing, only observing. One of the first challenges in the commercialization hides, however, in choosing the most important needs and determining their monetary value: how much is the customer willing to pay for satisfying his needs. Without this validation, the product will not be developed. Above all the product has to be simple enough to attract customers:

> *"If more than five sales arguments need to be presented in order to catch customer attention, something is wrong." (Rehn 2012)*

Rehn (2012) considers traditional marketing research old-fashioned. Instead, a technology company has to have their own visions which form the basis for success: things have to be seen also on the behalf of the customer without the need to ask how their business could be improved. Customers may not always recognize their needs and, therefore, they rarely come up with a solution themselves and even more rarely do they create prototypes because it is considered time-consuming and not manageable in practice.

The verification during the commercialization process is crucial as the process is relatively long-term by nature. Customer feedback in every phase helps in correcting the product into a right direction, prevents making unnecessary mistakes and makes the process more efficient when resources and efforts are not misplaced. In cleaner technology industry, as in all high-tech industries, changes occur fast and moves have to be made quickly:

> *"Interaction with the outer world needs to be cherished instead of locking oneself into a development chamber." (Rehn 2012)*

Rehn (2012) considers that a company which receives the most feedback from customers is also the most likely to succeed and reach the goal first. Customer interaction may not be continuous, as technology visionaries are able to see and express customer feedback. However, the most relevant information ultimately comes from the end-user, the decision maker and the buyer of the technology. All in all, maintaining the customer dialogue during the whole commercialization process facilitates correcting the errors early and developing the product according to market desires. Reacting quickly to changing conditions in the industry can be challenging as it is difficult to draw the line between healthy agility and unhealthy wiggle. Therefore, experience is required.

After the product has been further developed, test marketing determines if it meets the requirements. Test marketing should be carried out as any marketing but rather earlier than later, as it typically reveals the weaknesses that need to be corrected. The development is, thus, continuous because the world and industry themselves develop dynamically. According to Rehn (2012) making mistakes is often feared too much and strong negative feedback is actually a beneficial way to ensure that everything goes into the right direction. However, also test marketing has its limits as there has to be enough resources to correct the errors and learn from them. Rehn (2012) sees the process simple but suspects that in larger companies this simplicity often drowns under everything else. As cleaner technologies are a rather novel branch of industry, there are no existing models or guidelines to follow and cross-overs from other industries have to be applied to cleaner technologies. In comparison to old-fashioned industries, such as end-of-pipe technologies, benchmarking poses a challenge because not even all cleaner technology sectors follow the same criteria for purchase. (Rehn 2012.)

The core of the commercialization lies in scaling sales: making it as global as possible and as quickly as possible. However, domestic markets need to be first gained in order to demonstrate the quality of the technological product and be able to attract customer overseas. For startups additional capital is required from investors to manage the globalisation and guarantee the overall performance when there are no references to demonstrate the experience. According to Rehn (2012) in market economy the commercialization can be truly measured only by the occurred sales, the capital achieved. Continuously rising key figures are to be reached and the commercialization process has to be questioned. One must be ready to question even the whole business model and start all over again with different tactics because sticking with small revenues does not serve the purpose in the long run. During the process, before the actual result and sales can occur, objectives need to be set to decreasing costs and increasing the profit margin. (Rehn 2012.)

In September 2012 it was announced that ZenRobotics raised 13 million euros for expanding international presence (Anderson 2012), which supports Rehn's (2012) view of the importance of going global and doing it fast. An international equity investor, Invus, provided evergreen capital to lead the investment and it is estimated that this partnership will offer huge future opportunities for ZenRobotics. Intensive R&D has result in deals worth one million euros with Belgian and Netherlands-based recycling-oriented companies. (Anderson 2012.) However, although success is remarkable, Rehn (2012) currently considers the biggest business challenge lurking in finding experienced cleantech sales force. International sales and environmental know-how does not have long roots in Finland, as the industry is new. In Middle Europe the situation is clearly more fruitful as the history in cleaner technology industry goes farther back. Environmental sector will undoubtedly strengthen its visibility and competent people are to be needed.

4.2.2 Numcore (Outotec)

Outotec has been one of the bellwethers in cleantech (see Table 3). In spring 2012 Outotec made a corporate acquisition out of Numcore, a young cleantech startup (see Table 4), which develops and markets 3D-imaging measurement technology. Currently, the process is still ongoing but provides important insight on the importance of cooperation between different sized cleaner technology companies in the commercialization process.

Jari Moilanen (2012), Automation Director at Outotec, highlights that the cleantech commercialization process in B2B markets is based on a mutual understanding of the customer needs and ways to meet them. As cleaner technologies, again, are a rather young industry both for the developers and the customer base, the actual "clean" part of the technology needs more understanding as it may involve different elements of customer value in relation to other technologies. The concepts and the value that is achieved with cleaner technologies need to be exactly defined and discussed together with the customer. In addition, the end product requires reasonable development and execution as well as a sales channel which is supported with a local network in the market area. Sales personnel need to be well trained and the delivery to the customer has to be guaranteed. The commercialization process is long-term and involves customer experiences along with reference value. Thus, the difference between other and cleaner technologies would also encompass the creation of environmental value (see Table 7).

The commercialization process of Numcore's technology started a few years back when the technology was presented in university laboratory as a spin-off. Ari Suhonen, former Sales Manager at Numcore and present Electrical Impedance Tomography (EIT) Technology Manager at Outotec, sees that everything starts with a good idea that can stem anywhere, for example, from customers, universities or informal discussions. The most essential element of commercialization, according to Moilanen (2012), actually lies in the conceptualization phase which involves listening to customers, understanding their business and identifying the drivers in order to determine customers' latent needs which they may not be aware of. The perceived customer value and costs need to be in balance and the product has to meet customer expectations and solve the defined problem. Several critical choices in this phase need to be made including a throughout estimation on where the idea could be utilized and how the customer segments for the concept could be reached. Eventually the idea will be prepared for actual execution to answer the needs. (Suhonen 2012;

Moilanen 2012.)

In Numcore's case the technology was initially developed with public funding. Gradually, the point was reached, in which first workable prototypes and applications were created for testing. (Suhonen 2012; Moilanen 2012.) According to Suhonen (2012) especially in mineral processes new ideas are often dealt with suspicions. The validation of the developed product is carried out by launching the product to the first customer for further refinement. Preparing the product for the markets is in general extremely difficult. There has to be strong willingness to continuous development and patience in analysing the results. Setting accurate milestones helps in dividing this time-consuming phase into manageable periods. (Moilanen 2012; Suhonen 2012.) However, when a partner is assured on the benefits, the next step in the partnership is a lot easier as it involves becoming familiar with each other and building a deep personal relationship. (Suhonen 2012.) Suhonen (2012) considers a radical action being a threat to take the product to a competitor if the potential customer is not totally convinced. If there is a change for developing a breakthrough technology, the potential customer may not want to take the risk of not taking part in creating competitive advantage. Suhonen (2012) also reminds that only after the customers seem willing to pay for the end-product, the actual commercialization can begin. The numerical price is thereafter only a sort of formality although an important one.

In Numcore's case, after wakening wider customer attraction, for a young startup an important decision was faced and made: instead of continuing expensive development of the technology by itself it was decided to be left to someone that was more capable of handling the process and already had an established resource base and distribution system in the eyes of the customers. (Moilanen 2012; Nordgren 2012; Mörk 2012.) Numcore's own resources would not have been adequate in the competition against experienced giant cleantech companies. Considering cleantech as a solution-like business, Numcore only had developed one part of a solution. A shared technological vision with Outotec made it possible to construct elements around the focal technology and create a whole solution. (Moilanen 2012; Suhonen 2012.) For Outotec Numcore’s high-tech instruments meant strengthening the forerunner position as a significant technology provider and provide competitive advantage especially in flotation and thickening solutions (Outotec Oyj lehdistötiedote 2012; Seppälä 2012).

If a relatively small cleantech startup was to manage by itself, substantially important contacts should be formed to support the performance. The visibility of the startup should be fiercely boosted in the right channels and forums, depending on the technology, application and industry, to spread information and raise awareness. Adequate marketing efforts are crucial and the marketing message needs to be clear and simple especially when a totally new technology is involved. (Suhonen 2012.) Suhonen (2012) considers, for example different fairs inefficient as they are numerous, on a technical level the visibility is insufficient, they are expensive and, above all, the visitors typically do not represent the actual decision making unit of a potential customer company. However, the customer interface has to be reached and deep connection be made, for example, by making private customer appointments. Support is offered to startups but according to Suhonen (2012), the marketing competence that is based on experience is not on top in this field as many marketing managers may have been promoted on the basis of personal relationships and not necessarily on the actual knowledge and competence.

One additional aspect in considering the initial take-off of the commercialization is that Numcore would not have achieved its current position without the funding from Finnvera Venture Capital and TEKES Young Innovative Companies programme which made the start of technology development possible in the first place. No other funding sources were available for a totally new idea except for TEKES which also made Numcore to question the conventional ways of doing business and to carefully consider it from the perspective of customer value. With the help of funding Numcore was able to refine and productise technology-based solutions for different areas of process industry that conduct reference projects for international actors. In addition, the finance and sales of the company were supported. Obviously, the rise of Numcore was enabled partly due to the company structure, clear actor roles and expertise: the company was managed as it would be a larger company. (Nordgren 2012; Mörk 2012.)

The performance of Numcore has continued under the same business name after the acquisition (Nordgren 2012; Mörk 2012). However, the ongoing integration process will result in fading Numcore by the end of the year 2012 after which technologies will be integrated into a product palette and efforts are put on expanding the performance globally and increasing the volumes. This, further, requires training field experts. When Numcore still was an independent company, the volumes were much smaller which made it easier to manage the business. Overall, Outotec's acquisition meant taking a step back: making summaries, reconsidering the product development process, improvements and productising as well as testing on a wider scale and looking for partners, for example, to complete the manufacturing. (Suhonen 2012.) Currently, it is being tested if the conceptualization phase of commercialization could be differentiated to a separate organization with specialized and skilled people. The direction is also to differentiate the technical part and the service part which includes selling only services. This concept forms a critical stage in the continuing of the commercialization and if this kind of concept succeeds and gets adopted by the customers, a totally new business model would be created. (Moilanen 2012.) During the short 5-year history of Numcore the time was lacking to develop services but as Moilanen (2012) suggests, their role may strengthen substantially in the future.

According to Moilanen (2012), the success of commercialization can be measured in various ways. Suhonen (2012) highlights the need to utilize users' experience and comments to evaluate the success. The overall process needs to be continuously observed and evaluated and measures are required to indicate in which stage the commercialization is in a certain point and how it proceeds because, as was discussed earlier, the performance of distribution channels is vital. The distribution of the solution to the customers has to work according the guidelines that have been set and people that are involved in the process have to be well-trained in order to carry out it properly. However, ultimately the commercialization process is measured in economic terms afterwards, firstly, by the amount of customer projects or deliveries that have been achieved. The feedback from customers is considered extremely crucial as they either decide to adopt the cleaner technology or to reject it. As the commercialization continues further, the ultimate effects on turnover will be the most relevant measurement of the commercialization success. (Moilanen 2012.) Suhonen (2012) agrees with Moilanen (2012) and Rehn (2012) on the fact that commercialization never ends, which also highlights the need of accurate measures.

4.3 Synthesis of challenges and success factors in different phases of cleaner technology commercialization

Commercialization forms a critical stage in technological process (Chiesa and Frattini 2011, p. 437) as can be seen from the previous company cases. Simula et al. (2010, p. 13) have stated that the very basic grounding for success requires clearly defined understanding on what factors actually affect the commercialization process. However, the topic has not been able to attract enough attention to be managed properly within firms throughout the industry (Chiesa and Frattini 2011, p. 437), and the problems and their interconnection related to commercialization process lack more thorough empirical research (Pellikka and Virtanen 2004, p. 1-2). In this review the main focus regarding cleaner technology commercialization challenges is on identifying the overall firm-level barriers, partly based on the previous success stories from Finland and partly from the related scientific research. Notable is that many cleantech characteristics that were illustrated in table 7 actually simultaneously act as a grounding for potential threats. Depending on the nature of the barriers, a few advice can be presented to be better prepared to overcome them (Moors et al. 2005, p. 664).

As, for example, Coenen and Avdeitchikova (2011) have concluded, the models of technology commercialization are typically linear and apply technology-driven approach. However, people and their excellence are a fundamental key to successful commercialization because they are the ones who conduct research, identify markets, make investment choices, build networks and create successful businesses and, ultimately, form the fundamental competitive advantage in different stakeholder roles during the whole commercialization process (Rotman, Gibara, Lazaridis, Lum, Risley and Samarasekera 2006, p. 5). Taking into consideration the special characteristics of cleaner technologies, the conducted interviews (Rehn 2012; Moilanen 2012; Suhonen 2012) and the general process of technology commercialization, a conceptual and non-linear framework for commercializing cleaner technologies can be introduced (see Figure 4).

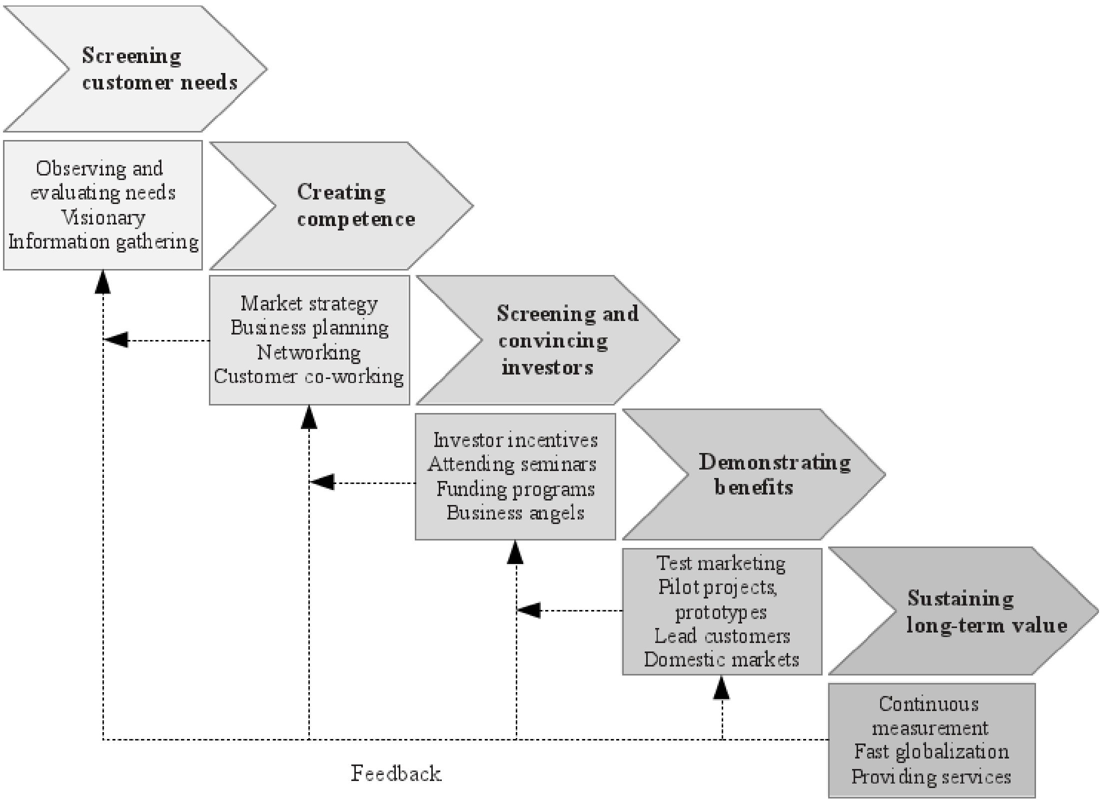

Figure 4. Extended process framework for cleaner technology commercialization (based on Rehn 2012, Moilanen 2012 and Suhonen 2012)

As can be seen from Figure 4, the theoretical model for commercialization process of cleaner technologies follows the basic norms of any technology commercialization cycle but with an emphasis on customer perspective. The most significant aspect is the feedback loop in every phase of the commercialization which proposes a non-linear approach (Rehn 2012). However, further theory testing and refinement calls for additional empirical research. Nonetheless, as the cycle of commercialization is chronological shifting from one phase to another, although it can always return to the previous phases, from company perspective it is useful to look at the success factors and barriers in relation to the different stages of commercialization.

4.3.1 Screening customer needs

"Appreciating and understanding the potential of new technology and uncovering what the market will and will not embrace are a key challenge." (Berkhout et al. 2010, p. 479)

Bond and Houston (2003, p. 125) remind that starting to create a new technology is not a value itself but the unique value is measured in the eyes of the customers. It needs to be understood in what way a novel technology is useful and how it brings advantages and solves their problems (see Chapter 4.2). Ensuring that cleaner technologies match simultaneously the needs and capacities of the potential markets and the requirements for sustainable economic growth is crucial (Verspeek 2001, p. 63).

The success lies in gathering and profoundly understanding customer needs, both latent and expressed, and finding the best possible technological means to answer them (Rehn 2012; Moilanen 2012; Suhonen 2012). That means differentiating and positioning cleaner technology accordingly (Slater and Mohr 2006, p. 30; Harrison and Waluszewski 2008, p. 116; Corkindale 2010, p. 43). Mu and Di Benedetto (2011, p. 340-341) follow this perception by bringing up the need of seeking information on markets also to enable digging out the latent needs, market changes and trends and forming a proactive approach towards them. Succeeding in pursuing market opportunities, making commitment of resources and taking actively risks calls for entrepreneurial attitude from cleantech companies (Coenen and Avdeitchikova 2011). Initiatives need to be made, network partners need to be sought and relationships need to be managed and improved with both existing customers and other actors (Mu and Di Benedetto 2011, p. 341; Rehn 2012; Suhonen 2012; Moilanen 2012). Johnson and Suskewicz (2009, p. 53-54) discuss that successful commercialization is mostly due to an innovative business model that builds up an offering to meet customer's problem at a profit. This insight is also supported by Rehn (2012) and Suhonen (2012). Especially in the case of complex, cleaner technologies, models should be carefully aligned according to customer needs (Prebble et al. 2008, p. 313).

The profitability ultimately depends on the size and nature of potential markets. It can be challenging to find the right markets for cleaner technologies because in emerging industry markets may not yet exist and/or customers' needs are not identified due to difficulty in gathering customer information (U.S. Congress, Office of Technology Assessment, 1995, p. 51; Corkindale 2010, p. 43; Pries and Guild 2011, p. 321; Rehn 2012). Montalvo (2008, p. S1-S3) suggests that environmentally friendly consumers are usually in the position to support cleaner alternatives but if the companies are not convinced about customers' willingness to actually pay more for them, the investments in cleaner technologies may not be made (Suhonen 2012). In the case of cleaner technologies the competition with existing end-of-pipe technologies or alternatively with other new technologies may mitigate the market of cleaner technologies. The markets need to be in alignment with company strengths which means that, for example, smaller cleantech companies and startups tend to concentrate on smaller niche markets rather than large markets dominated by larger cleantech companies. (Montalvo 2008, p. S1-S3.)

4.3.2 Creating cleaner technology competence

The ultimate core of cleaner technology competence rises from the company itself. Thus, company characteristics stir the commercialization. The most typical confrontation is drawn between SMEs and large companies (del Río González 2005, p. 25) especially in cleaner technology industry which is characterized by a huge amount of small startup companies. Typically they struggle the most with lacking resources while companies that are integrated into bigger foreign companies obviously do not face such a barrier because an access to all resources needed is available (see Carayannopoulos 2005, p. 219-232). In addition, bigger companies are more prepared with the necessary facilities for embracing cleaner technology production (del Río González 2005, p. 25, 32-33; Frondel, Horbach and Rennings 2007, p. 579). The lack of resources results in difficulty to make specific plans which leads in cost overruns when the commercialization process does not progress according to initial objectives and estimates that are difficult to be precisely calculated due to project cycle of cleantech industry (Hassinen et al. 2007, p. 12). This may also result in losing controllability over the commercialization process (Kajanus, Heinonen, Eskelinen and Pellikka 2012, p. 6-9; More 1983, p. 110). However, in many cases it may be a too challenging task for a small company to acquire the required resources (Fildes 1990, p. 65-67, 69) as was presented in the case of Numcore (see Chapter 4.2).

Small firms are often managed by their owners who have personal ways of doing things (Pal, Sethi, Nath and Swami 2008, p. 1265). According to Coenen and Avdeitchikova (2011) more and more companies in environmental sector are established by entrepreneurs. This entrepreneurial nature may drive an individual decision making and business management (Kajanus et al. 2012, p. 6-9) which may not take full advantage of customer involvement which was emphasized in Finnish companies' success. The skills are also typically shared nearly unchanged among employees from generation to generation (Pal et al. 2008, p. 1265). The downside lies in the tacit knowledge which easily results to intuitive actions and negligence of clear and formal documentation on business cases which prevents learning from the past experience (cf. Clarke 2012, p. 14-15; Kajanus et al. 2012, p. 6-9; Pellikka and Lauronen 2007, p. 97). This further, affects the way these companies respond to opportunities and threats that continuously stem from the business environment

(Kajanus et al. 2012, p. 4). For example, in Saarnia and Hassinen's (2008, p. 3) research many small cleantech companies hesitated on entering unfamiliar markets because of the fear of tremendous cultural differences.

Of course, there are exceptions of these holding-back companies from which the case of Finnish ZenRobotics (see Chapter 4.2.1) was a good example. In comparison to the prevailing insight on smaller cleaner technology companies being underdogs and faced by relatively more several hindrances in their performance, Coenen and Avdeitchikova (2011) suggest that these entrepreneurial companies actually are more capable of recognizing business opportunities arising from market failures, adapting to the environmental changes and taking advantage of them. Hierarchical structures in larger companies may hinder this respond. However, this perspective does not currently seem to represent the mainstream literature.

Although SMEs typically have a more informal and flexible lead of management, for the same reason they also often possess insufficient managerial and industrial business expertise regarding technology management which also affects the ignorance of cleaner technology advantages and markets. Without proper intelligent no future predictions about trends in environmental sector can be made in order to develop a suitable technology to answer them. (Kajanus et al. 2012, p. 6-9; Hooper and Jenkins 1995, p. 34-35; del Río González 2005, p. 24-25.) All in all, no company can survive without a well-organized management of commercialization process and its activities (Pellikka and Virtanen 2004, p. 4-5). Clarke (2012, p. 18) states that people who are not making the final decision typically have the best knowledge and experience to make them and vice versa. In addition, SMEs may not always be in a position to understand and be informed about the benefits of cleaner technology alternatives and, further, make decisions on shifting towards them (Hooper and Jenkins 1995, p. 34-35.) Thus, a certain dependency on bigger companies and other actors prevails (Verheul 1999, p. 214) which suggests that a cleaner technology pressure stemming from the business environment is relevant (e.g. Pal et al. 2008, p. 1265).

Del Río González (2005, p. 24) adds that in many cases the management lacks overall commitment with environmental issues. Also Outotec representative Moilanen (2012) considers that in cleaner technology industry the markets and customers may be the same, but the actual target of commercialization may be different. Cleaner technology values may not go through the whole organization and typically the management is the most receptive group regarding cleaner technology message. Other than cleaner technologies may be accepted at a lower level by technical gatekeepers of the facility. (Moilanen 2012.) However, in companies that have budget restrictions the management prefers to concentrate on daily operational practices which means rather short-term decision making and business strategy planning for cleaner technologies. Also the environmental scanning for potential new technologies and market opportunities are considered only few years ahead, although environmental effects typically realize long-term, on a time scale of 25-50 years. (Verheul 1999, p. 214; Moors et al. 2005, p. 665.) Aarikka-Stenroos and Sandberg (2007, p. 4; 2011, p. 6) point out that the timing of starting commercialization process can form a barrier due to different perceptions within companies of what is meant by short- and long-term decisions (see also Pries and Guild 2011). The decisions on timing the market entry for technologies may be totally wrong if markets are unknown, nor can niches be found easily without proper insight on markets. According to Dermer (1992, p. 413), competitive success is about finding opportunity windows before others.

Additionally, a conservative corporate culture and standard routines tend to generate change resistance as employees are not willing to learn new ways of handling technologies (Moors et al. 2005, p. 665). Del Río González (2005, p. 22) discusses this being related to technological 'lock-in' which makes firms follow familiar routines when they face uncertainty in decision making. Incumbent technologies are being so dominant that they can prevent cleaner technology companies from seeing the potential in new technologies and result in innovating something that is already known (del Río González 2005, p. 22; Foxon and Pearson 2008, p. S150). However, technological change is vital for further development of new technologies, products and services.

Technological solutions carry a variety of challenges starting from the unsuccessful identification of their optimal functionalities (Pellikka and Virtanen 2004, p. 4; Ziamou 2002, p. 365) as is also suggested by Suhonen (2012) who considers that the development phase of cleaner technology can include many versatile hindrances. For example, cleaner technologies are typically characterized by risky complexity which is greater than in the case of end-of-pipe technologies (del Río González 2005, p. 25). In Carayannopoulos's research (2005, p. 231) it was considered that the end-solution can be even too complicated to an already complicated environment. That is, the risk of causing more problems than solving them can be too high. When talking about continuously developing technology, also the concern of technological obsolescence prevails as was suggested earlier by Jolly (1997, p. 284, 306).

On the other hand, new technology may not be compatible with the existing systems and infrastructure (Moors et al. 2005, p. 664). More (1983, p. 112) discusses that success with one technology in a company does not automatically guarantee success with another technology due to their different characteristics. Every new technology needs to be analysed case-specifically. Also, even when the question is about the same technology by two companies, the situation calls for different approaches. (More 1983, p. 112-113.) Thus, not even the success stories presented in Chapter 4.2 can be applied straight to all Finnish companies. As environmental systems are substantial and technically complex investments, they also require specific skills to be managed accordingly. Therefore, the lack of technical expertise within the firm inevitably results in obstacles. Operating, installing and changing the characteristics of a new technology could result in the need of acquiring training programs for employees or even hiring new people which would again increase the budget too much for some firms. On the other hand, drastic changes may lead in a decreasing need to have employees as their users at all. (Hilson 2000, p. 123-125; del Río González 2005, p. 25, 27-28.)

Another dimension in technology characteristics affecting the commercialization is the *stage* of its development (Moors et al. 2005, p. 664). First of all, insufficient incubation of the technology affects bringing out its true potential for commercialization (Jolly 1997, p. 2). Secondly, in the case that scientific knowledge may yet be developed, not all technical problems are ready to be solved which leads to a technological research barrier. Also, as complex technologies are involved, creating straight-lined strategies for resolving these issues is difficult. Therefore, making incremental improvements rather than developing totally new technologies is more common. (Moors et al. 2005, p. 664.) Additionally, Dermer (1992, p. 412) lists overconfidence regarding technology and its competitive advantage being one hindrance because the constant need of development is neglected.

But how could the company and technology-related risks presented in the previous table be turned into a success? Probably the most dominant motivation for a company to move towards cleaner technologies is to keep up with regulations as it helps in avoiding risks, protecting revenues and preserving company image but also in generating ideas for creating new business. However, certain companies are genuinely worried about the environment and wish to carry their share of ecological responsibility and company image which typically stems from the company history. (Dangelico and Pujari 2010, p. 474; Frondel et al. 2007, p. 578.) As suggested previously by Coenen and Avdeitchikova (2011) cleantech startups may actually possess an advantage when the embrace of cleaner technologies is carried along from the initial establishment of the company and not being integrated to the performance afterwards.

Del Río González (2005, p. 25) advises companies to create a proactive environmental strategy and set accurate goals for it. A written environmental policy and organizational structure along with corporate and individual responsibilities need to be defined: without careful planning and documentation objectives are easily obscured. Setting milestones and strategies was mentioned by Suhonen (2012) as a beneficial way of managing a long-term process (see Chapter 4.2.2). Also Galbraith, DeNoble and Ehrlich (2012, p. 216-223) recommend passing milestones as it helps in predicting the speed of revenues. Pellikka and Lauronen (2007, p. 97) add that a documented plan helps in estimating the amount and timing of resources that are needed in the commercialization process. Preferable is to rely on a self-constructed model or a purchased model that is specifically designed for the company in question. Merely transferring a successful plan from another company cannot be fulfilled without problems.

As the lacking awareness of cleaner technology benefits and other related aspects is one of the most fundamental hindrances in the commercialization, the companies need sufficient information in every phase of the production process (Frondel et al. 2007, p. 579). Therefore, commercialization can be seen to have a starting point in increasing the general and multifaceted awareness of environmental issues and the potential of cleaner technologies to solve them. In addition, technological knowledge needs to be enhanced. One option to receive information is environmental management practices (Frondel et al. 2007, p. 579) which could include success-like stories from the sector. Saarenketo, Puumalainen, Kuivalainen and Kyläheiko (2004, p. 367-368) highlight the need of continuous and proactive search of information in companies, for example, about changing market conditions, customers and competitors. Several sources of information are available in today’s information society starting from Internet and continuing on to more experiential and reliable network knowledge. Electronic databases can act as a supportive tool in rapid dissemination of information which is in general cost-effective and produces no remarkable disturbance to the business management itself. On the contrary, the efforts dedicated to raising awareness of cleaner technologies may result in multiplied benefit outcome. (Hooper and Jenkins 1995, p. 34-35.)

Both private and public institutions including research institutes, local business developers and educational facilities (e.g. universities) help in educating and training skilled employees for understanding and carrying out the commercialization process (Kajanus et al. 2012, p. 10). Verspeek (2001, p. 63, 68) discusses that without human resource handling, education and training to improve capabilities, the technology itself will not meet its purpose. Research institutes also conduct research on cleaner technologies and act as an information sender by transferring the current knowledge into the technology industry. Respectively, they gain access to the knowledge from the companies which enables necessary knowledge sharing for further design and development of cleaner technologies (Inganäs, Harder and Marxt 2007, p. 4603). Kajanus et al. (2012, p. 10) discuss that managers' responsibility is to handle resource-related issues by building networks and creating interaction with these research and educational institutes and other partners in order to maintain marketing activities and support internationalization. Therefore, managers need to pull the strings for both firm-internal and inter-organizational activities.

Along with Moilanen (2012), Suhonen (2012) and Rehn (2012), also Cooper (2000, p. 56) emphasizes customer involvement by reminding that customer voice must be heard throughout the development process, for example, through focus groups, customer panels and working with lead users. Customers should be pro-actively involved in working with developers who carry the heaviest responsibility in determining commercialization success (McCoy et al. 2009, p. 125; Cooper 2000, p. 56). Also Hu and McLoughlin (2012, p. 325) recommend taking customers into the commercialization process from early on because co-working to develop ideas for complex technologies, products, processes and services forms the premises for superior company performance. It will also help in increasing the reliability of the outcome and decrease the time allocated on development. Both the development of technology incorporated into products and services makes it imperative to figure out and anticipate customer needs better than competitors do.

Based on Hu and McLoughlin's (2012, p. 326) research, service-focused technology companies prefer the strongest customer involvement in the early phase of idea generation, in the improvement of existing services and in identifying new uses for an already existing services. Gustafsson et al. (2012, p. 314) add that technology providing companies should focus their attention on communicating with customers in the development process to guarantee the match between the technological outcome and customer needs, as was also emphasized by Rehn (2012) (see Chapter 4.2.2). There is evidence on customers speeding up the development process as they can provide essential information.

Moors et al. (2005, p. 663-664) also suggest building an actual knowledge infrastructure within a company because in order to manage external relationships, firm-internal knowledge sharing needs to have a strong basis first. Creating inter-firm knowledge networks enable a better exchange of information and know-how related to clean technologies. To extract the tacit knowledge from people's heads a shared outlook and mutuality of values must be built by discussing technological issues explicitly. The role of technology and its competitive advantage should be questioned (Rehn 2012) and possible product failures researched by several managers. Therefore, the possibility for discussion and asking questions needs to be promoted throughout the company. (Dermer 1992, p. 412-413.) Firm-internal strategy aims at better combining the expertise of all separate units by bringing them under the same objective of creating commercially viable technology. Robust relations are a prerequisite so that everyone in the firm-internal network can be convinced of the common objective. In addition, the stimulation of funding must be targeted at corporate level instead of business unit level to ensure a firm-wide cohesion. (Moors et al. 2005, p. 663-664.)

Based on research certain kind of technology characteristics can be more appropriable and less risky than others and, therefore, more likely to be commercialized. For example, Chen, Chang and Hung (2011, p. 526-528) have presented four technology attributes which can improve market potential and ultimately the technology commercialization probability: innovativeness, genericness, simplicity and compatibility. *Innovative* nature of technology aims at attracting creative adopters and providing learning curve advantages (Chen et al. 2011, p. 527). *Genericness* refers to the overall benefits of technology that can be widened across many sectors. *Simplicity* is related to an easy and simple use of the technology. Customers seek technologies that can make their performance more efficient which is why the adoption may be postponed or totally rejected due to the difficulty of understanding the use of technology (Chen et al. 2011, p. 527; Rogers 2003, p. 15-16; Anokhin, Wincent and Frishammar 2011, p. 1067). A higher level of technology *compatibility*, in turn, decreases the uncertainty of potential adopters and provides a better fit between technology and existing values, experiences and adopters' needs. Rogers (2003, p. 15-16) adds one more dimension which is considered important in evaluating the success of a technology, *observability,* which reveals the extent of advantage visibility. Overall, the higher the degree of the attributes, the faster the cleaner technology will be adopted. However, commercialization is dependent on many simultaneous attributes that need to work together (Rogers 2003, p. 15-16). The probability of success rises when technologies are used widely and when several technologies are used in one product.

4.3.3 Scanning and creating relationships with investors

One big barrier in cleaner technology commercialization is related to high investment costs and long payback times on the investment that were described as an essential characteristic of cleantech industry (del Río González 2005, p. 27, 32-33). Cleaner technologies call for greater amount of initial capital than normal technologies which is difficult to gain back by solely putting more efforts on sales (Moors et al. 2005, p. 663-664; Carayannopoulos 2005, p. 231-232). The profits occur during a longer period of time, if at all, whereas costs are formed during an essentially shorter period of time. This can remarkably hinder companies from making R&D efforts in cleaner technologies unless environmental performance is truly in the core of their business (Hooper and Jenkins 1995, p. 34-35; Hilson 2000, p. 123-124). In addition, the more radical the cleaner technology is by nature, the larger are also the initial capital costs. Zeng et al. (2010, p 976) seem to promote this mainstream economic theory by stating that unless firms have attractive incentives for pollution reduction, they will only contribute to it in a threat of compulsion, although a certain amount of investment is always required to fulfil the legislative qualifications.

Especially cleantech startups are shadowed with additional uncertainty and risks in the eyes of potential investors because their performance and value proposition are unknown to a wider audience. The lack of information and demonstration on company's capabilities easily leads to the situation where the company is neglected unless it for sure can deliver its promises and be able to stay in business long-term. The situation naturally reflects investors' willingness to invest in these kind of companies (Pellikka and Virtanen 2004, p. 4). Undoubtedly, limited networks and contacts with external stakeholders, again, hinder building the reputation (Carayannopoulos 2005, p. 231).

Lauffer and Robbins (2007, p. 27-28) summarize capital being the most essential and simultaneously the most difficult resource to acquire. Therefore, in cleaner technology commercialization receiving funding is vital (del Río González 2005, p. 25-26; Lauffer and Robbins 2007, p. 27-28) as was discussed especially in the success story of Numcore which was supported with TEKES funding. Overall, funding in early state of commercialization can have a significant effect on cleantech companies' performance as it affects technology providers' ability to further develop generated technologies and boost the performance. According to Lauffer and Robbins (2007, p. 27-28) the first source of funding cleantech companies includes government-allowed grants which requires assisting companies to compile successful grant proposals and understanding the overall process including grant award management. Governments provide financial sponsorship in R&D of technology commercialization but simultaneously it is necessary not to support all market-ready technologies if profits are not guaranteed (Caerteling, Halman and Dorée 2008, p. 144). This will also balance the technological conditions.

Governments are seen as a strong stakeholder group and as an opportunity to ultimately lead firms into a greener direction not only by shaping financial incentives for cleantech companies but also by setting effective environmental regulations and penalties (cf. Chen et al. 2011, p. 526; Balachandra et al. 2010, p. 1848; del Río González 2005, p. 22; Hooper and Jenkins 1995, p. 34-35; Johnson and Suskewicz

2009, p. 55-56). Still, however, the nature of regulation might in some point even favor end-of-pipe solutions because the regulations concentrate on already occurred waste stream. Regulations regarding the processes that actually generate the waste and take a step towards cleaner technologies are not as thorough. (Moors et al. 2005, p. 664.) Thus, in some context environmental policies can act as a driver for commercialization but in other circumstances actually form barriers due to standards that affect, for example, market competition and the nature of property rights (Montalvo 2008, p. S8; Caerteling et al. 2008, p. 143-145).

Besides governmental funding Lauffer and Robbins (2007, p. 27-28) mention two steps in acquiring capital: firstly, the companies need preparation for raising investment capital and/or obtaining customers, and secondly, companies need to build connection with capital sources. This means that investments can be received both from individual and institutional sources including investors, angel groups, and venture capital firms. Investors and especially venture capitalists enable receiving the financial resources and managerial competences needed for a successful commercialization. (Inganäs et al. 2007, p. 461-462; Balachandra et al. 2010, p. 1847-1848; Lauffer and Robbins 2007, p. 27-28.) Private investors, so called 'business angels', have been discussed to be a substantial possibility as these investors are able to bring their experience and insight on marketing and internationalization as well as networks from previous relationships into the starting business. It is also possible to help companies to take care of and support the development of entrepreneurial teams with a different background of expertise. (U.S. Congress, Office of Technology Assessment 1995, p. 76; Kajanus et al. 2012, p. 10.) However, as Verspeek (2001, p. 67) points out, despite the awareness of environmental opportunities environmental investments from financial facets remain small which suggests that more incentive, for example, in the form of taxes is needed to motivate making investments in the growth of cleantech companies. (Heikkilä 2012, p. 16-18.) In addition, as was discussed in Chapter 4.2, especially startups need to pro-actively boost their visibility in different forums in order to catch investor attention.

Venture-fundable cleantech companies with high growth potential need to be assisted with equity funding through carefully managed programs to attract funding providers. For example, since 2008 TEKES in Finland has offered young innovative companies, including Numcore and ZenRobotics, a new opportunity of financing which is considered a promising step to a right direction (Mäkinen and Perttu 2008, p. 26). Lauffer and Robbins (2007, p.28) discuss a systematic creation of programs that include both supporting companies to pitch investors and also forming a network of investment contacts. Also, for example, business assistance programs, the aim of which is to provide especially small firms with assistance from technology incubators, can be a beneficial support (U.S. Congress, Office of Technology Assessment 1995, p. 78). Lauffer and Robbins (2007, p. 29) suggest entrepreneurial seminars and programs that could provide the necessary facilities for sharing educational content and networking. The most special attention would be targeted at cleantech startups that would be apprised of important aspects, such as industry trends, legislation and funding possibilities. Seminars and programs are especially beneficial for marketing and generating partnerships throughout wide regions (Lauffer and Robbins 2007, p. 29). Public relations (PR) and open communication act as a crucial determinant of commercialization as cleantech brand always needs to look for funding for the business to gain awareness and grow (Krietsch 2012, p. 36). The focus of communication should be directed towards building credibility, loyalty, commitment and overall awareness.

Hemert et al. (2012) bring up a perspective that policy makers, including governments, may not have been able to see the true meaning of networks for SMEs. Vital would be to form certain strategies and policy instruments such as receiving funding for cooperation or carefully selecting the companies which can get involved in the legislation negotiation of environmental issues. By this choice proactive companies may be favored to act as a role model for cautiously performing companies. (Verheul 1999, p. 218.) Yakowitz (1997, p. 175-177) lists several activities that governments can perform to support cleaner technology in addition to allowing grants. These include providing valid results of success stories, arranging demonstration projects, appealing to financial institutions to favor cleaner technologies in investment decisions, developing certification system on cleaner technology products, services and processes, acting as a technical assistant to firms and helping in developing managerial accounting systems for cleaner production. Finally, government could act as a role model by buying only cleaner products. In addition, Moors et al. (2005, p. 663-666) emphasize the need to harmonize the environmental legislation regarding clean technologies on an international level to allow fair and equal competition in different countries.

4.3.4 Demonstrating the benefits of cleaner technologies

"The key is to find out the key influencers and work out a strategy for co-opting them in the delivery of technology and the creation of demand" (Jolly 1997)

Developing a potential cleaner technology and defining a suitable market for it still calls for further means to prove technology superiority. If the benefits of cleaner technologies cannot be demonstrated properly and no important people have been achieved to support the technology from the beginning, selling new technology both internally and externally becomes difficult (Jolly 1997, p. 2; Bond and Houston 2003, p. 124). Marketing is a cornerstone for commercialization as it can provide a large amount of useful information for ensuring successful acceptance of new products and technologies (Berkhout et al. 2010, p. 479) which is why marketing planning and measures are recommended to be started in the early beginning of the commercialization (Pellikka and Virtanen 2004, p. 3-4, 8; Rehn 2012). Failure in reaching, gathering and exploiting the market and customer information can prolong the commercialization process substantially (Kajanus et al. 2012, p. 6-9) but also affect marketing activities and their allocation in addition to right timing for the marketing actions. Comprehensive marketing actions naturally require economic expertise, wide business know-how and the ability to rapidly take advantage of new market opportunities. (Pellikka and Virtanen 2004, p. 8; Kajanus et al. 2012, p. 7-10.) Thus, SMEs and startups are again faced with an even greater challenge.

The study of Chen et al. (2011, p. 529) suggests that there is willingness among customers to pay more for cleaner technologies. However, as Moors et al. (2005, p. 663) and Nill (2008, p. S65) point out, capital-intensive technology needs long-time demonstration for determining diffusion potential before the true potential of commercialization can be proved. Cleaner technologies are often first of their kind, unique, and tremendous efforts are required to raise the awareness on it which is why demonstration and promotion in processes they are to be used is required (see Aarikka-Stenroos ja Sandberg 2007, p. 5-7). Especially in the case of sceptics, who represent the latest adopters in the diffusion model, selling the technology requires relatively more convincing (Jolly 1997, p. 2).

Testing and demonstration, such as making prototypes, models and pilot plant facilities, are valuable alternatives for building customer confidence (Balachandra et al. 2010, p. 1844-1845; U.S. Congress, Office of Technology Assessment 1995, p. 65). The ultimate goal of demonstrating cleaner technologies is communicating the customer value which is vital both to explain the technology and to persuade potential customers on an individual level but at the same time avoid generating unrealistic expectations (Hellman and van den Hoed 2007, p. 308). Verspeek (2001, p. 62) proposes using demonstration programmes to highlight technical feasibility and benefits of the cleaner technologies and also utilize techniques for benchmarking other companies. However, the challenge of how to actually communicate with customers is also faced (Ziamou 2002, p. 365-366). For example, SMEs tend to focus intensively on technical details and product development rather than putting efforts on communication (Kajanus et al. 2012, p. 8). Also Suhonen (2012) discusses that engineers need to step down to the customer level and be able to speak the same language with them.

More (1983, p. 115) and Hu and McLoughlin (2012, p. 326) present that commercialization resources should be directed to early adopters and efforts put on convincing them. Siegel et al. (1995, p. 20-21) discuss initiating commercial actions by working with specific people and companies (industrial opinion leaders) in order to determine technical and economic feasibility and provide a straighter path to commercialization. Corkindale (2010, p. 45) adds that new technologies should be first adopted by the naturally enthusiastic but not necessarily commercially wise customers. Technology enthusiasts are the ones who are the most eager to rapidly adopt the technology while sceptics represent the other end not wanting to meet any risk in the adoption process. To them, technology has to be tested thoroughly. In addition, as suggested by Rehn (2012), efforts should be put on building a strong position in the domestic markets as the achieved success acts a demonstration for potential foreign customers. This could be further aided with a potential cooperation with other domestic cleantech companies as was demonstrated in Numcore's and Outotec's partnership.

Utilizing lead-users ensures the sustainability of development of a user network (Harrison and Waluszewski 2008, p. 128). Also Aarikka-Stenroos and Sandberg (2012, p. 199) emphasize the role of individual authorities in the commercialization success. Certain key persons who are influential to the company's decision-making process are able to provide positive publicity, advice, user demonstrations and overall proof on the benefits of new technology and stimulate customers who may not be too interested in cleaner technologies (Verheul 1999, p. 214). When opinion leaders gain the position in which they are able to educate new users and demonstrate the benefits of a new technology, it can accelerate remarkably successful market entry. Further, a study by Aarikka-Stenroos and Sandberg (2012, p. 203) shows that if two different kind of opinion leaders were able to convince a customer over the beneficial aspects of an innovation, it was considered a lot more credible. However, this perspective presupposes that needs of the customers are clearly defined and stay unchanged (Harrison and Waluszewski 2008, p. 116).

4.3.5 Assessing and sustaining commercialization value

Although clean technologies are supposed to bring many benefits for adopting firms, some of the effects are realized only after purchasing or long-term use (Moors et al.

2005, p. 665) which calls for proper indicators to demonstrate the changes that have occurred. However, picking the most suitable measures for tracking commercialization is not an easy task either. The challenges also lurk in implementing the chosen measures: the lack of resources and requisite systems as well as adapting the measures into the corporate culture can prove a hindrance. Using the measures correctly company-wide is an issue that requires internal training. The evaluation of new technologies may often be based on old criteria that has been used in the evaluation of previous technologies which may bring the new technology incorrectly into an unfavorable light (see e.g. Pellikka and Virtanen 2004, p. 5). In the worst case scenario the cleaner technology will eventually be neglected as an alternative due to this misconception. This factor is, thus, also closely related to having insufficient information and skills to update the evaluation accordingly (del Río González 2005, p. 27). Additionally, small companies have to struggle with data collection and data handling due to scarce resources (Simula et al. 2010, p. 97-99).

The need for measuring performance continuously during the commercialization cycle is partly influenced by value co-creation but also by the fact that stakeholders are accountable to each other (Philbin 2008, p. 18). The starting point for measurement lies in the initial phase of commercialization when the company sets objectives for cleaner technologies in order to evaluate the final outcome on the basis of the objectives. In addition, for example, in the testing phase statistical figures are needed to support the benefit demonstration. However, the most crucial measuring occurs after the commercialization because most benefits realize only after customer purchase and longer-time use of the technology.

As an emerging market cleantech is highly competitive which means that first-to-market approach is needed to guarantee early mind-share with investors and customers. From the commercialization point of view this means putting the strongest emphasis on cutting time-to-market. By Simula et al. (2010, p. 103) this was considered one potential technical measure of commercialization. Palmberg (2006, p. 1259-1260) has studied commercialization durations from time-to-market perspective and found out that totally new or technologically less familiar products tend to burden longer mean durations in comparison to having only slight changes. In addition, the complexity of a product seems to prolong the durations further. The same goes with company sizes and it is justifiable to say that in this sense larger companies do not possess an advantage over SMEs.

To follow Simula et al.'s (2010, p. 104-106) advice on utilizing simultaneously both economic, technical and market-based measures, in cleaner technology commercialization market-based measures are clearly versatile when considering the commercialization cycle that was previously defined. For example, the awareness of cleaner technology and its benefits was seen as a crucial starting point of the commercialization (Suhonen 2012; Rehn 2012) process which suggests paying attention to media attention, value creation and the effect which cleaner technologies have on both customers and competitors. In addition, the commercialization can be assessed by the reach of new and also the best lead customers who are the prerequisite and booster of wider adoption, but also beneficial is the information about how cleaner technology has been replacing existing end-of-pipe solutions.

As customer involvement regarding cleaner technology commercialization is required, not taking their insight and feedback into consideration as one measure of success would be regrettable (e.g. Suhonen 2012; Rehn 2012; Moilanen 2012), especially when cleaner technologies involve incremental development also after the launch. Cleaner technologies being quite a substantial and even an uncertain investment for a customer, they may even pro-actively demand additional capabilities of them afterwards in addition to cleantech companies' own efforts on improving their technology (Hu and McLoughlin 2012, p. 325). However, as Suhonen (2012) and Rehn (2012) discuss, the ultimate evaluation of commercialization success is based on economic measures to which all other measures, including customer feedback, substantially affect.

Sustaining successful commercialization depends much on how well or poorly competitors can imitate the source of success. This requires legitimizing cleaner technologies. (U.S. Congress, Office of Technology Assessment 1995, p. 22-23.) Nerkar and Shane (2007, p. 1158) add that first-mover technologies are less likely to be imitated which results in a stronger position to form ground for new technology domain and further its rate of diffusion and market potential. Patents protect the returns gained from successful commercialization but the success itself may not be guaranteed before trying. Patents are closely related to pioneering which increases owners' incentives to invest time and money in new technologies because being a pioneer supports the probability of commercialization.

However, patent policy can even act as an incentive regarding creating new cleaner technologies as companies can gain exclusive rights to them (U.S. Congress, Office of Technology Assessment 1995, p. 62). In addition, patents help in spreading information on the industry development and forming tacit knowledge into explicit knowledge. Another way of legitimizing is to use marketing stories which can reduce various uncertainties and risks that shadow the cleantech market. Open knowledge sharing in the form of stories helps in avoiding misunderstandings. The third option for the cleantech companies is to establish a database calculator, for example on company web pages, for counting the times the company's certain technologies have been cited in research publications. As well as bringing legitimacy, it will also form a comparison platform in relation to competitors. (Hu and McLoughlin 2012, p. 328.)

The most relevant factor in prolonging the commercialization value according to Rehn (2012), Moilanen (2012) and Suhonen (2012) lies in value co-creation with customer which is present in every phase of the process. Especially Rehn (2012) considers that commercialization can be sustained by expanding rapidly to several markets world-wide which supports the literature-based view of Jolly (1997, p. 284, 290, 303) (see Chapter 3.1.5). In addition, the empirical study emphasizes the importance of continuous development which can be seen as entrenching the technological functionalities and improving applications (see Jolly 1997, p. 284, 290, 303). Services that were highlighted in the study are in this sense vital to create long-term user dependence and maintain customer relationships and this way also sustain commercialization process which, according to Rehn (2012) and Suhonen (2012), actually never ends.

4.4 Summary

The fourth chapter of this thesis forms the basis of synthesizing all cleaner technology commercialization related aspects discussed earlier and provides the ultimate source for answering the research questions. The aim of the chapter was to bring together Finnish cleantech prospects, the nature of cleaner technologies and the technology commercialization process in order to present a slightly modified approach to the commercialization process in comparison to normal technologies. General challenges and success factors gathered from the academic literature combined with two success stories from Finnish cleantech field aim at forming a chronological step-to-step guide for Finnish cleantech firms to consider in their commercialization planning.

The interview results suggest that the commercialization process of cleaner technologies follows a non-linear, cyclic-based model which can be seen as the main difference in comparison to linear technology commercialization models presented in the literature. In addition, interaction with the customer and receiving feedback in every phase of the commercialization process was considered extremely crucial in order to stay on the right track and enable successful outcome (Rehn 2012; Moilanen 2012; Suhonen 2012). Success measures were also typically related to the amount of gained customer projects and deliveries, but especially on the ability to demonstrate the (theoretical) benefits of cleaner technologies to the customer. This kind of verification leads to the ultimate measure that is evaluated from the economic point of view: how much money the customer has brought to the supplier. The interviews also suggest that making mistakes is often feared too much and strong negative feedback is actually extremely beneficial.

5 CONCLUSIONS

The purpose of this thesis was to identify the special characteristics of cleaner technologies in order to present their commercialization process and to categorize commercialization related barriers and success factors with the help of Finnish success stories. The research questions were defined as follows:

> *1. What are the key challenges and success factors in the commercialization of cleaner technologies based on the existing literature?*
> *2. What kind of lessons can be learned from the Finnish success stories of cleantech commercialization?*

The research was conducted as a literature review and complemented with three case interviews. As a result several challenges and success factors regarding cleaner technology commercialization were gathered. These results are presented in table 8.

Table 8. Summary of the challenges and success factors of commercializing cleaner technologies (based on literature (black) and interviews (red))

Screening customer needs	**Creating cleaner technology competence**	**Scanning and creating relationships with investors**	**Demonstrating the benefits of cleaner technologies**	**Assessing and sustaining commercialization value**
- Difficulty to gather customer information - Difficulty to identify and evaluate the needs - No existing models to benchmark (novel business) - Lack of visionary + Mutual understanding on cleantech concept + Proactive and initiative environmental strategy + Setting accurate goals + Information gathering on cleantech sector + Long-term needs screening + Cost efficient information dissemination + Risk taking	- Unsuccessful identification of optimal technology functionalities - No insight on future trends - Technological obsolescence - Technological research barrier - Limited R&D efforts + Research institutes and educational facilities providing training and technology research + Fierce building of networks and creating interaction + Customer co-working + Building knowledge infrastructure + Questioning business + Favorable technology features	- High investment costs and long payback times - No existing references (especially startups) - Limited networks - Government regulations + Governmental grants and application support + Attracting and motivating private business angels + Investor incentives + Carefully managed funding programs + Entrepreneurial seminars and programs + Government-driven demonstration projects	- Difficulty in demonstrating benefits that realize in the future - Time-consuming - Difficulty in finding lead customers - Lack of skilled people - Unrealistic expectations - Heterogeneity of customers + Prototypes + Pilot plants + Sponsoring events + Utilizing existing stakeholder contacts + Customer incentives + Comprehensive marketing and promotion activities + Individual authorities + Building strong domestic markets	- The lack of proper indicators - The lack of resources and requisite systems to adapt the measures - Old evaluation criteria for technology - Insufficient information and skills to update evaluation + Adding services to tie customers long-term +Value co-creation + Continuous measurement + Utilizing economic, technical and market-based measures + Legitimizing (e.g. patents)
- Lack of information and resources - Unstructured strategy planning - Distorted image of the company and customers - Company's entrepreneurial culture - Dependency on bigger companies and the environment - Technological lock-in - Lack of technical expertise - Overconfidence in technological superiority		+ Pro-active attitude + Strong (negative) customer feedback to ensure the right direction + Management commitment + Open communication between all stakeholders + Setting accurate milestones and evaluating them		

The colour-highlighted factors in the previous table stem especially from the conducted interviews and other factors mainly from literature although some overlapping may also occur. Following this division, the results of the research are divided into theoretical implications which aim at summarizing the answer to the first research question and into managerial implications which focus on providing some managerial guidelines for Finnish cleantech firms. These are discussed briefly next.

5.1 Theoretical implications

Literature provides several hindrances and success-like factors that affect the commercialization process of (cleaner) technologies. These factors have typically being categorized, for example, to company, technology and legislation related groups. However, in this thesis the focus lies more on the process perspective and, thus, the challenges and success factors have been connected to different phases of the commercialization process in order to help companies to evaluate in which phase they consider to be in their performance and what matters in this certain phase need to be taken into consideration.

Notable is that many of the factors presented in Table 8 can be connected to several phases and that they are often directly or indirectly related to endogenous company characteristics. This supports the view that the company culture ultimately creates a fruitful ground for successful commercialization and explains why companies' entrepreneurial nature has been a relevant part of the cleaner technology commercialization discussion. Thus, the affect of company characteristics is also the most substantial in the beginning of the commercialization. The company atmosphere in general has to be open, innovative and visionary and the company structure needs to be flexible in order to create as fruitful offset for seeking success as possible.

On the other hand, especially legislation and investment related issues are exogenous factors which are most often stirred by governmental actions and not directly influenced by cleantech companies' own efforts. These exogenous issues are typically faced in the middle of the commercialization process (see Table 8) when external funding for further technology development is required. Networks and references are in this phase crucial and, although the company can make huge efforts to gain visibility, still the success depends on the business environment. The confrontation of endogenous and exogenous factors determines the overall success potential.

5.2 Managerial implications

As was discussed earlier, success cases from two Finnish cleantech companies emphasize the fact that customer attention has to stir the commercialization. The process starts with a careful screening of customer needs and visionary in fulfilling them. Visionary is an essential part of previously discussed company characteristics which enables the needed pro-activeness in the commercialization and the whole business. The cases support the insight that a lot depends on endogenous firm characteristics and that the commercialization process actually starts on some level long before the actual idea is generated.

During the commercialization process a constant dialogue with the customers and feedback from them is needed to guarantee success. This way also resources, which are typically scarce anyway, can be saved and allocated properly to other vital functions that may involve more risk taking. All in all, the word 'challenge' should be carefully used as it usually refers to factors that are always present in the process and never really solved. This perspective is supported by the advice of not being too afraid of making mistakes and receiving negative feedback as the learning outcome from it may turn out exceptionally beneficial. It is vital to observe the commercialization process continuously and make sure that milestones are passed according to initial planning. Critical assessment and questioning of the whole business model of the company is also recommended: the company has to be able to re-evaluate its business and in some cases even abandon the prevailing thinking and start the planning again from scratch. However, as the cleantech industry is versatile, no universal models and comprehensive guidelines exist widely yet. In addition, they could not be adopted without company-specific modifications.

Based on the empirical research, success is evaluated by the amount of gained customer projects and deliveries but ultimately commercialization is about gaining the best possible economic outcome which is measured, simply, by the profit made. As the bottleneck in the commercialization process lurks in the benefit verification, the greatest efforts should be targeted at demonstrating the benefits of cleaner technologies to customers and all other relevant stakeholders (e.g. investors). Striving to find the most experienced and competent employees ensures a fruitful basis for utilizing versatile knowledge in marketing and forming networks that are needed throughout the commercialization process. It is also to be understood that commercialization is never finished and company objectives should be scaled up as the process continues.

6 FUTURE RESEARCH

A literature review is considered a beneficial method for gathering information on cleaner technology commercialization and finding out research gaps that have not yet caught adequate attention. However, it became clear that the research questions of the thesis cannot be answered comprehensively merely with a literature review since understanding cleaner technology commercialization requires a more profound, empirical, clarification of commercialization related success factors in order to provide actual managerial guidelines for companies to follow.

Limitations of this research are also related to a relatively small amount of case interviews which did not take into account the type of the cleaner technology although the commercialization process can vary depending on it. Examining the literature-based traps in which companies can easily fall in the commercialization, however, helps in forming and bringing out specific questions that could be utilized in a wider empirical survey for cleantech companies in Finland. In this sense, the conducted three interviews (see Appendix 1) build a beneficial ground for specifying questions further to include, for example, a deeper discussion on how cleaner technology characteristics actually affect the commercialization process as the presented process model for cleaner technology commercialization (see Figure 4) requires further testing from a wider sample of case companies. An interesting aspect would also be dividing the case companies on the basis of their historical background because differences in the process can occur if a company is initially born to be cleantech-oriented (new startups) or if a company has adopted cleantech-based performance during its existence.

Overall, literature regarding cleaner technologies, commercialization and lead-users is wide and continuously attracting more interest. However, so far only little have lead-user and reference aspects been discussed in relation to cleaner technologies although case interviews suggest that demonstrating cleaner technology benefits is challenging and that co-working with customers has a substantial relevance in accelerating the commercialization process. Gaining the first reference customer may be a key and, thus, it should be researched what are the actual attributes needed to acquire the first reference and make it successful, and what kind of channels could be used to promote cleaner technology commercialization.

Additionally, although ‘cleaner technology’ by its definition includes products, technologies as well as services, the technological orientation has been dominant while services have not been profoundly discussed. As one of the interviews suggested, totally new business models could be created by focusing on producing purely cleantech related services but only if the customers are able to consider it adequately important. Thus, a service-based perspective could provide an interesting area of future research.

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APPENDICES

Appendix 1: Interview questions

Three interviews were grounded with, but not limited to, eight questions presented below as additional questions were posed on the basis of the interviewees' answers. Also a few company related questions were posed and are presented below.

1. Describe briefly the nature of cleaner technologies (technologies, products, services) that have been commercialized in your company.
2. How do you define (technology) commercialization?
3. What kind of special characteristics do you see in cleaner technologies in comparison to other technologies?
4. What is the commercialization process of cleaner technologies like? What phases does it go through: where does it start and where does it end?
5. What kind of challenges can be seen in different phases of cleaner technology commercialization process?
6. What kind of factors can contribute positively to the cleaner technology commercialization process in its different phases?
7. How is the success of cleaner technology commercialization measured?
8. What is the role of services in the commercialization of cleaner technologies?

ZenRobotics
1. Who are your customers?
2. What is currently the biggest challenge in your business?

Numcore / Outotec
1. How did the cooperation contribute to the success of commercialization?
2. How did the cooperation start? Would success been possible without Outotec?
3. In what phase was the technology commercialization process when Outotec acquired Numcore?