

**An Entrepreneurial Perspective on Early Product Innovation Processes:
The case of SME in the Swiss Energy Sector**

DISSERTATION

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The President:

Prof. Dr. Thomas Bieger

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List of Abbreviations

BFE / FOEN	Swiss Federal Office of Energy
BIPV	Building-Integrated Photovoltaics
CEO	Chief Executive Officer
CIO	Chief Innovation Officer
CSP	Concentrated Solar Power
CTO	Chief Technology Officer
FFE	Fuzzy Front End
FTE	Full-Time Equivalent
KMU	Kleine und mittlere Unternehmen
MBO	Management Buyout
MW	Megawatt
PV	Photovoltaics
R&D	Research & Development
RE/EE	Renewable Energy / Energy Efficiency
SME	Small and Medium Sized Enterprises

Zusammenfassung

Unter westlichen Unternehmen ist allgemein anerkannt, dass langfristiger Erfolg nur durch eine konstant hohe Innovationsleistung zu erreichen ist. Konnten in der Vergangenheit jedoch Produktinnovationen aufgrund eines guten Technologie- und Marktverständnisses strategisch geplant und erfolgreich im Wettbewerb positioniert werden, so führen regulatorische, technologische und marktliche Unsicherheiten dazu, dass solche planungsorientierten Ansätze an Wert verlieren. Der Schweizer Energiesektor ist ein Beispiel für eine solche Industrie, in welcher ehemals dominierende Unternehmen aufgrund fehlender Planungssicherheit kaum mehr innovative Produkte auf den Markt bringen. Hingegen tauchen kleinere und mittlere Unternehmen (KMU) vermehrt mit Innovationen am Markt auf. Dies zeigt, dass einzelne Unternehmen einen Weg gefunden haben, auch im Angesicht hoher Unsicherheiten erfolgreich Innovationsprozesse zu initiieren. Dieses Handeln im Angesicht der Unsicherheit, welches von Schumpeter mit dem Konzept des *innovativen Unternehmers* in die Literatur eingebracht wurde, wird in dieser Arbeit unter dem Blickwinkel des modernen Innovationsmanagements neu beleuchtet.

Um das Themengebiet an der Schnittstelle von Innovationsmanagement und Unternehmertum zu erfassen, werden neue Entwicklungen aus beiden Bereichen zu einem theoretischen Bezugssystem kombiniert. Dabei wird einerseits auf die Erfolgsfaktorenforschung zum *Fuzzy Front End* (FFE) und andererseits auf die konzeptionelle und experimentelle *Effectuation*-Literatur zurückgegriffen.

Aufgrund der dünnen theoretischen Grundlage wird ein exploratives Forschungsdesign mit Fallstudien konkreter Produktentwicklungen aus dem Schweizer Energiesektor angewandt. Dabei werden grundlegende Mechanismen isoliert, welche im FFE zur Anwendung kommen. Es kann gezeigt werden, dass KMU im FFE auf eine Kombination von strategischer Planung und kreativer Kontrolle zurückgreifen. Die konkrete Ausgestaltung wird dabei entscheidend vom Ausmass und der Art der wahrgenommenen Unsicherheiten beeinflusst. Die Verbreitung der Ansätze im Schweizer Energiesektor wird zudem durch eine breite Umfrage unter KMU belegt.

Die Erkenntnisse der Studie erlauben eine neue Sichtweise auf die Frühphase des Innovationsprozesses und ein besseres Verständnis der spezifischen Verhältnisse bei KMU. In der bestehenden Literatur wird deren Handlungsweise oft als Ausdruck fehlender Rationalität interpretiert oder mit visionärem Weitblick verbrämt. Die vorliegende Arbeit stellt diesen Befund in Frage und zeigt rationale Prozesse auf, welche Ausdruck des Strebens sind, die eigene Umwelt kreativ zu beeinflussen.

Management Summary

It is generally acknowledged among Western firms that long-term success can only be achieved through a constantly high innovation rate. In the past, a thorough understanding of relevant technologies and markets allowed for product innovations to be strategically planned and successfully positioned in the market. However, growing regulatory, technological and market uncertainties in some industries have led such planning-based approaches to lose much of their usefulness. The Swiss energy sector is an example of an industry where poor planning reliability has kept incumbent firms from responding to changing conditions with the introduction of innovative products. In contrast, smaller to medium sized companies (SME) increasingly emerged with innovations on the market. This shows that some firms have found ways to successfully initiate product innovation processes even under conditions of uncertainty. This action-taking in the face of high uncertainties was introduced by Schumpeter with the concept of the *innovative entrepreneur* and will be re-assessed in this work from the angle of modern innovation management.

In order to frame the topic at the intersection point of innovation management and entrepreneurship, new developments in both areas are combined in a theoretical framework incorporating the success factor research of the *Fuzzy Front End* (FFE) literature and the conceptual and experimental literature on *Effectuation*.

Due to the scarce theoretical foundations, an exploratory research design with case studies of tangible product innovations projects from the Swiss energy sector is adopted. By doing so, fundamental mechanisms applied in the FFE are isolated. It can be shown that SME in the FFE resort to a combination of strategic planning and creative control processes. Decisive factors for the practical design of those processes are the kind and extent of perceived uncertainties. The prevalence of the found approaches in the Swiss energy sector is shown in a broad-based survey among SME.

The insights of this study allow for a new perspective on early product innovation processes and a better understanding of the particular circumstances in SME. In extant literature, the approach of this class of firms to the FFE is often seen as an expression of their visionary foresight or a lack of rationality. The study at hand challenges this assumption, highlighting rational processes open to theoretical understanding that are an expression of a firm's aspiration to creatively shape its own environment.

1 Introduction

1.1 Motivation

In 1912, the Austrian economist Joseph A. Schumpeter published his seminal work on the *Theory of Economic Development*. In this book, he describes a type of economic actor called the *innovative entrepreneur* (Balabkins, 2003). Ever since, this concept has attracted great attention by researchers, politicians and business practitioners alike, making Schumpeter one of the most influential economists of the 20th century. According to his theory, change is brought to a stationary economy where economic activity can be described as mere routine, through the actions of the *entrepreneur*. While the stationary economy is characterized by a certain, generally accepted way of engaging production factors, the entrepreneur introduces new combinations of those factors, an activity that Schumpeter calls *innovation*. The entrepreneurial task of introducing new combinations of the existing factors of production in the economy brings about a disturbance of the previously dominant structures and replaces them by new ones, a process called *creative destruction*. The question of why and how entrepreneurs introduce innovations in the economy has been subject to much debate. Schumpeter himself highlighted the tremendous challenges inherent in conducting the function of an *innovative entrepreneur* (Schumpeter, 1934, p.84.ff.): Firstly, as entrepreneurs leave the beaten track of the stationary economy, they lack the necessary data to forecast the consequences of their actions and therefore must take action in the face of *uncertainty*. Secondly, in order to put production factors to new uses, entrepreneurs must break through dominant *habits of thinking* and institutional preconceptions which requires determination and confidence in their own actions. Thirdly, the introduction of the new factor combinations in the market requires entrepreneurs to *persuade market participants* of the superiority of their innovations. The questions of how some entrepreneurs are able to develop an alternative vision of the future, conceptualize innovations in the face of uncertainty and encourage others to join them is still as relevant and valid as it was 100 years ago.

The concept of the innovative entrepreneur is especially prevalent in industries where existing structures are no longer suitable to cope with changing environmental conditions. Lately, the industries gathered under the *energy sector* term have moved into the centre of public debate, as it has become obvious that they will not be able to respond adequately to the immense challenges ahead, thereby putting the long-term prosperity of the entire planet at jeopardy. This industry comprises all activities

connected to the generation, provision and use of energy and has become highly reliant on scarce fossil resources, whose use on the one hand causes damages to the environment and human health and on the other hand leads to their total depletion in the not too distant future. The energy sector has taken a dominant position in the economic system of all developed countries, so that even minor disruptions or deviations can have devastating effects on the economy and society as a whole. However, radical changes will be necessary in order to put the energy system on a more sustainable basis. How this transformation could be accomplished is one of the major political, economic and technological challenges of our time.

One country that exemplifies this challenge in the energy sector is Switzerland. Its unique topography and industrial structure have continuously posed immense demands on and offered great opportunities to the country's energy sector. For the past 200 years, Switzerland has been at the technological forefront in energy-related industries. How the country will manage to adapt its system of energy production and use to the changing circumstances will therefore be of great interest to other countries.

Historically, Switzerland was one of the first countries on the European continent to embark on the path to industrialisation. In contrast to the English experience, Switzerland could not rely on the steam engine to the same extent, as natural occurrences of coal were sparse. However, the abundance of water offered an alternative path to energy generation through turbines. During the times of the Continental Blockade in the early 19th century, first companies like Escher, Wyss & Cie. started to independently develop steam engines and water turbines used for the mechanisation of industrial production, mainly in the textile industry. The ensuing technological and economical dynamics led to a strong culture of engineering excellence that culminated in technological breakthroughs like the presentation of the first AC long-distance transmission line in 1891 by Maschinenfabrik Oerlikon or the construction of the first steam turbine on the continent in 1901 by Brown Boveri & Cie (BBC) that greatly improved the traditional steam engine. In 1905, Sulzer engineer Alfred Büchi invented the turbo charger, further increasing the efficiency of combustion engines. After the First World War, Switzerland was the first country to have their railway network completely electrified and pioneered the large-scale use of water power. In 1939 Baden-based BBC was the first company in the world to deliver a commercially viable gas turbine. Those examples show that the energy sector has traditionally been a field in which Swiss companies have stood out due to their innovative achievements. Not only have those companies helped to advance economic

development inside the country, they also have used their competences to provide products and services all over the world, contributing to Switzerland's export strength.

Today, the energy sector is again subject to major challenges that directly affect the future development of the economy and the people living in it. While the abundant availability of energy and the industrial activity enabled by it have brought the country a high level of affluence, the very basics of this wealth are called into question. The depletion of natural resources like oil and gas, pollution and global warming, as well as the entry of large parts of the world's population into the globalized economy have pushed the traditional energy system to its limits. In such an environment, new and more sustainable ways of meeting the country's increasing energy needs are called for. It is, however, highly uncertain in what direction this system has to develop. Those uncertainties prevail in the political as well as in the economic and technical sphere and make it difficult to forecast what a future, more sustainable energy system will look like.

In such an environment, firms that are willing to face this uncertainty and to take the first steps towards a fundamental transformation of the energy sector are in high demand. Large, vertically integrated companies that have dominated the energy sector in the past have taken note of the various challenges and have directed their efforts towards optimizing the traditional systems by heightening safety standards in nuclear power plants, increasing the conversion efficiency of internal combustion engines or improving oil drilling technologies. Consequently, those firms sustain the traditional industry system by optimizing the current means of production. However, in order to bring about fundamental change in the Schumpeterian sense, the current means of production must be "placed in the service of new purposes" by "stepping outside the boundary of routine" through the "effectuation of new combinations" (Schumpeter, 1934).

The question is, whether the Swiss industry today still has the innovative potential to build the foundations of a more sustainable energy sector for the future. In this context it is evident that established companies still rely on innovation to sustain their long-established competence and market position in the traditional energy-generation technologies. However, an innovative segment of the economy that has in the recent past seized the trend towards a more sustainable energy system can be identified. Most of them smaller industrial companies, they have long been debarred from the industry through high entry barriers based on monopolies and economies of scale. In the wake of the changes that have seized the energy sector many of those entry barriers have been brought down. Smaller firms from outside the traditional energy sector have

already demonstrated that they are able to successfully give new impulses for the transformation of energy-related industries. In line with Schumpeter's assertion that entrepreneurially driven innovation is the crucial engine driving change processes in an industry (1934) and the empirical observation that more and more smaller entrepreneurial firms are developing new products and services with relation to the renewable generation and efficient use of energy, it seems warranted to further study this innovative element of the economy.

The secondary sector of the Swiss economy is characterized by the prominent role of small and medium sized firms (SME) which account for 99.4% of all registered businesses in this sector and 67.5% of workplaces¹ (BfS, 2007a, 2007b). Even though the major part of economic activity is organized in SME, there is no typical SME with clearly defined characteristics and problem statements (Mühlbradt & Feggeler, 2004). Rather, it is an umbrella term that needs further adaptation in order to fit the research problem at hand (Pleitner, 1995). The delineation between SME and large companies is a blurred one and can be done via a variety of criteria, of which the most commonly used are turnover, total assets or number of employees (European Commission, 2003, p.39). Drawing on the number of employees, the Swiss Federal Statistical Office (BfS) defines the cut-off value at 250 full-time equivalents (FTE), a threshold that is in line with the terminology used by the European Commission.

		2nd sector (industry)	
Category	Employees (FTE)	% of firms	# of firms
Micro	1-9	79.4	57'569
Small	10-49	16.6	12'026
Medium	50-249	3.4	2'496
SME	1-249	99.4	72'091

Table 1: Share of SME categories in the secondary sector (BfS, 2007a, 2007b)

The figures for Switzerland as outlined in Table 1 are in line with most Western European countries, who exhibit a high percentage share of SME in both workplaces and number of registered firms. However, Swiss SME distinguish themselves from their European counterparts through their innovative behaviour. Table 2 lists those European countries with the highest share of innovators among smaller (10-49 employees) and larger (50-249 employees) SME (Arvanitis et al., 2004; BfS, 2007a;

¹ 67.5% relate to all workplaces in the entire economy that are situated in SMEs

Eurostat, 2008)². Innovators in this context are defined as firms that have conducted at least one product or process innovation over the past three years. The figures point out the very high share of innovating companies among the population of smaller Swiss SME. With an average of 13.8 employees (BfS, 2007a) the typical Swiss industrial firm is such a smaller SME.

In the context of this work, smaller and medium-sized firms clearly are promising candidates for the entrepreneurial function required to bring about a fundamental transformation of the Swiss energy sector. It is reasonable to assume that, if unleashed, the innovative potential of those firms will be able to jumpstart the necessary developments needed to overcome the current situation of uncertainty that paralyses incumbent energy firms. However, despite the fact that SME from outside the traditional energy sector are a driver of change in the transformation of the energy sector, little is known about how those companies actually do choose to engage in this journey. How do they decide to become active in an environment where others are afraid to move? How do they handle situations ridden by uncertainties that others shy away from? What enables them to develop new, innovative products when neither the future regulatory environment, nor the future technological standards, nor consumer demand can be forecasted or even approximated? How innovative companies overcome those challenges when entering the energy sector with a product innovation is the central question of this study.

Country	% of firms	% of jobs	% innovators among small firms (10-49 FTE)	% innovators among medium firms (50-249 FTE)
CH	99.4	67.5	66.5	69.7
DE	99.5	60.6	56.8	73.7
AT	99.7	67.4	41.6	65.3
BE	99.8	66.6	45.0	64.2
FR	99.8	61.4	31.4	52.3
NL	99.7	67.4	39.0	59.2
IT	99.9	81.3	33.2	55.6

Table 2: International comparison of innovative SME (Arvanitis et al., 2004; BfS, 2007a; Eurostat, 2008)

² Micro SME with less than 10 employees are not considered, as the vast majority are situated in the range of 1-4 employees (Federer, 2007) and due to their limited size are in many countries not captured by innovation statistics.

1.2 Research Gap

Schumpeter in 1912 introduced the phenomenon of constructive destruction of the economic system through the innovating entrepreneur and thus highlighted a powerful mechanism that drives economic development and technological change. Over the past 100 years, mainly two fields of research have devoted great scientific effort into more closely analysing and explaining this major force.

On the one hand, the discipline of entrepreneurship research has been concerned with explaining how the individual entrepreneur comes about an opportunity and mobilizes the resources required to exploit and capitalize on it. According to Shane & Venkataraman (2000), “entrepreneurship is a mechanism by which society converts technical information into [. . .] products and services”. Entrepreneurship research therefore centres on the theoretical construct of the opportunity that can be described as the introduction of a new product, service, process, raw material or geographic market that is potentially valuable, new, risky and viable for exploitation by the entrepreneur (Grichnik et al., 2010). Thereby, the element of entrepreneurial action is at the heart of the opportunity definition, since only through taking action a mere idea is transformed into an entrepreneurial opportunity (Dimov, 2007).

On the other hand, the discipline of innovation management research, especially the literature on new product development (NPD) has occupied itself with further analysing the process through which an idea is transformed into a successful market offering, granting sustained competitive advantage for the firm. The focus of researchers in this field was to better understand how the innovator (as opposed to the *inventor* whose task it is to solve technical problems) handles the task of administering and co-ordinating innovative activities with the aim of integrating them into an economically viable innovation. An innovation can be described as the "process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace" (Baregheh et al., 2009; based on a content analysis of 60 definitions in key journals). As an analogy to the opportunity construct in entrepreneurship research, the innovation construct is characterized by the properties of newness (as implied by "*new/improved products, service or processes*"), usefulness (the aspect of implementation as implied by "*in order to advance, compete and differentiate themselves*") and viability (the aspect of performance impact as implied by "*successfully in their marketplace*"). The aspect of riskiness implied in the opportunity construct can equally be attributed to the innovation construct, as innovation is an inherently risky endeavour “involving uncertainty in an essential way” (Nelson &

Winter, 1977, p.47) and “*most innovations fail*” (Chesbrough, 2003). Innovation management researchers adopt a process perspective and focus their studies on how resources and activities are allocated and coordinated in order to accomplish this transformation.

Even though sharing the same historic roots and examining a somewhat similar phenomenon, the two fields of research have since developed separately. While entrepreneurship researchers have long focused their attention on the process of new firm formation by entrepreneurial individuals, innovation research has been busy with examining the process of new product development in established companies and the challenges inherent in coordinating larger groups of individuals inside those organizations. As a result of the different levels of analysis (the individual in entrepreneurship and the firm or process in innovation management research), two separate bodies of knowledge have been built, systematically reducing overlaps between the two communities of researchers.

Over the past decade, however, both entrepreneurship and innovation management research have increasingly turned towards examining their respective phenomena in empirical settings characterized by high levels of uncertainty. Consequently, theoretical paradigms in both areas of research have been challenged and new approaches to both opportunity identification and innovation management have emerged. In the process of those developments a convergence of both streams of research can be observed that offers the potential for mutual cross-fertilization.

Product Innovation Processes

Several decades of research in the area of innovation management have resulted in a variety of process models and management frameworks that have proved to be highly effective in improving the innovative output of larger companies and have been welcomed by practitioners in all areas of the economy. As an expression of the focus of innovation management research on larger companies, those models centred around the co-ordination of a large amount of individuals and the activities performed by them. The state-gate-Model by Cooper (Cooper, 1988; Cooper & Kleinschmidt, 1993), the open innovation model by Chesbrough (2003) and Gassmann et al.(2010) or the Crowdsourcing method by Gassmann (2010) are some examples of research results that have found wide application in practice. An implicit assumption that underlies most if not all of those approaches is that in order to conduct product innovation processes efficiently and effectively, firms must strive to incorporate as much and the most reliable information as early on as possible in the innovation process. It is therefore seen as a critical task to make sure that all relevant technical know-how

(technologies), market know-how (market research, future customer requirements) and know how about future development of the society in general (scenario planning, futurology) is utilized. As such information does not necessarily have to be located inside the boundaries of the own organization, firms are encouraged to tap into the wealth of knowledge held by customers (lead user method (von Hippel, 1986)), locally embedded research (listening posts (Gasco, 2005)), other companies (innovation networks (Pleschak & Stummer, 2001)) or the general public (crowdsourcing (Gassmann, 2010)). When applied correctly, the information collected helps to reduce uncertainties about future developments to a degree that allows managers to base their decision-making on it. Because of their focus on forecasting, planning and adapting to environmental conditions, those techniques and their theoretical underlying can be subsumed under the “positioning approach” (Wiltbank et al., 2006).

The limitations of the positioning approach become evident, when the necessary information about future technological, regulatory, political, and market developments is not available and therefore no reduction of uncertainty is possible. The question of how product innovation processes can be initiated in environments that are not susceptible to uncertainty-reducing techniques has not yet received much theoretical attention.

Notable exceptions are researchers like Buchanan (1992) or Kim & Mauborgne (1997, 2005). Buchanan’s (1992) research on so called *wicked design problems* has led to a better understanding of how designers can initiate a design process in situations where the given problem cannot be tackled by the linear process of analysis, synthesis, planning and implementation. In such situations, where problems as well as possible solutions necessarily need to remain ill-defined, a creative action-based approach called *Design Thinking* can help to initiate a process in the face of uncertainty. The application of Design Thinking principles on the process of product innovation is, however, still in an early phase. Kim & Mauborgne (1997, 2005) in their research focus on the phenomenon that some companies deliberately refrain from positioning themselves according to the dominant industry logic. Rather than accepting the pre-determined rules of competition in their traditional markets, they aim at creating markets and making competition irrelevant. This approach represents a general change of perspective, as firms are no longer required to heavily invest in uncertainty reduction through the analysis and forecasting of developments outside their immediate control, but are rather encouraged to ignore uncertainty and create certainty through their own actions which are subject to their immediate control. By taking action, individuals or firms can influence the environment around them which releases

them from the difficult or even impossible task of predicting it. A recent contribution by Kobe (2010) illustrates on a conceptual level how such a perspective could be applied to the early phases of an innovation process. However, how exactly those *control strategies* could be applied in the context of product innovation processes has not yet been subject to extensive empirical research.

Product Innovation in SME

In light of their theoretical and practical advances, innovation researchers in the recent past increasingly turned their attention towards smaller and medium sized companies (SME) that had traditionally not been the focus of innovation management research. This neglect is in stark contrast to the empirically observable dominance of SME in many Western economies. An increased attention furthermore seemed warranted, as statistical and empirical results showed that SME were drastically less innovative than larger companies (Aschhoff et al., 2008). Initial results of exploratory research into the innovation processes of SME showed that those companies often lacked the financial and personnel resources as well as methodological and procedural know-how to install innovation processes that proved to be highly successful with larger companies. The all-encompassing authority of the CEO in SMEs and the lack of consensual decision-making were identified as a major barrier to the establishment of effective innovation management structures. The consequence of those insights was, that SME were encouraged to invest in a more structured and systematic innovation process (Bessant & Tidd, 2007) involving a set of people with different backgrounds and perspectives. Process models and software packages were developed based on experiences collected with larger companies in mind and adapted to the smaller dimensions of an SME environment (König & Völker, 2003).

However, along with the introduction of formal innovation management structures in SME came the realization that established frameworks and process models did not always apply equally to this kind of companies. Companies that abstained from formalizing their innovation process, implementing role descriptions or establishing an ideation process still managed to be highly innovative (Franke & Dömötör, 2009). Other companies that – in an attempt to improve their innovation performance – did follow all steps often found it difficult to bring those new structures to life.

The application of coordination and planning-oriented innovation management approaches to innovative SME and their limited success in this area of application has led some researchers to question the fundamental assumptions behind those models. Notably the importance that innovation management scholars traditionally place on the aspect of process formalization has been challenged (Brettel, 2011). While a strict

process perspective is useful in increasing high levels of efficiency, the resulting formalization and bureaucracy can also be detrimental to innovation performance if goals are not fully specified and the project environment is highly uncertain (Stringer, 2000; Benner & Tushman, 2003). Poskela & Martinsuo (2009) found, that process formalization in the early phases of a product innovation was negatively related to innovation success under conditions of uncertainty. Reid & Brentani (2004) therefore propose a stronger focus on the role of focal individuals in highly uncertain innovation projects. Along those lines, König & Völker (2003) propose to conceptualize innovation management in SME as a behavioural rather than a process-led function. The literature on innovation management in SME has not yet paid attention to the question of how the behaviour of focal individuals in smaller companies contributes to the initiation of innovation projects in SME under conditions of high uncertainty.

Both the emergence of control-based approaches in innovation management and the more prominent role of individual behaviour in SME's product innovation processes give rise to the question of *how individual behaviour directed at exerting control in uncertain environments can contribute to the initiation of product innovation processes within SMEs.*

Contribution of Entrepreneurship Research

As highlighted above, the discipline of entrepreneurship research has a tradition of focusing on the individual entrepreneur. Mostly neglected by innovation management scholars, this stream of research has developed a variety of theoretical explanations of how individuals manage to take action and capitalize on opportunities to bring about change under different levels of environmental uncertainty. Even though entrepreneurship has traditionally been associated with the new venture foundation, by no means is the phenomenon restricted to this setting. Rather, entrepreneurship can also occur within existing organisations (Casson, 1982; Shane & Venkataraman, 2000). Recently and virtually in parallel to the developments in innovation management research, control-based approaches to opportunity identification have emerged among entrepreneurship scholars. Entrepreneurship scholars have long followed a positioning approach that conceptualized entrepreneurs to shape their ventures in relation to opportunities that were abundant in their environment. More recent approaches assign a more prominent role to the exertion of control by entrepreneurs through creative action-taking in uncertain environments. The bricolage approach introduced by Baker & Nelson (2005), the logic of effectuation (Sarasvathy, 2001) and the adaptation of Giddens' (1984) structuration theory to entrepreneurship

(Jack & Anderson, 2002; Sarason et al., 2006) represent elaborations of a control-based approach to opportunity identification, i.e. opportunity creation.

First attempts to harness those elaborations for the advancement of theory on innovation management have been conducted by Brettel et al. (2011) and Küpper (2009) who have applied Sarasvathy's (2001) logic of effectuation on product innovation processes. However, no research to date has applied those approaches to product innovation processes in SMEs.

1.3 Research Question and Design

1.3.1 Research Question

Based on the high practical relevance of the topic and the lack of theoretical insights illustrated above, this study aims at answering the following central research question:

How are product innovation processes in SMEs initiated under conditions of uncertainty?

Based on the central research question, further sub-questions were formulated in order to guide the subsequent theoretical and empirical inquiry:

- What are the differences in the early phases (fuzzy front end) of product innovation processes in uncertain environments between larger companies and SME?
- How does the degree of uncertainty influence the choice of positioning versus control strategies by SME in the early phases (fuzzy front end) of the product innovation process?
- How can SME apply the different principles of the effectuation approach in the early phases (fuzzy front end) of product innovation processes?

1.3.2 Object of Research

In order to operationalize the stated research goal and to focus the subsequent field work, the object of this research must be refined along a variety of dimensions.

This study will focus on existing Swiss SMEs in production industries that have introduced a product innovation with relation to the energy sector. In contrast to trading companies or service providers, producing companies are faced with particular challenges in the process of new product development. While the development of a new service or the listing of a new product is relatively inexpensive and can be done incrementally through a probe-and-learn process, the development of a new product generally requires a higher resource commitment and is connected to higher degrees of uncertainty.

As the setting of this research is in a sector of industry that is characterized by high levels of regulation, a national focus was chosen in order to control for environmental influences caused by different regulatory regimes (Dean & Sharfman, 1996). Inside the energy sector, those industries were chosen as a research setting that exhibit a high degree of uncertainty relating to the future regulatory, technological and market developments. This is in line with the focus of the study, the introduction of an innovation under conditions of uncertainty.

Even though a threshold of 250 full-time employees is generally accepted as a cut-off criterion between SME and larger companies, this research also considers firms that exceed this value provided they exhibit structures that are typically found in SME (i.e. owner-led, concentration of decision-making authority, etc.). Furthermore, since this research aims at elucidating the process that precedes an SME's decision to offer a new product to the energy sector, start-up companies are not in the focus of this study. In the case of start-ups, the simultaneous decision to introduce a new product and to found a new company allow for the establishment of an innovation process that is customized for the specific product innovation. The product innovation therefore does not entail a creative transformation of existing factor combinations. In contrast, existing companies have to take existing structures, processes and path dependencies into account.

Additionally, only the early phases of the innovation process fall under the focus of this work, as this is when the idea to develop a new product is first conceived, assessed and decided upon. Accordingly, the level of analysis is on the early process of new product development and the individual(s) that have a major influence on activities conducted in this process.

Dimension	Specifications			
Activities	Early Phase	Development Phase	Commercialisation Phase	After-Sales Services
Innovation Object	Business Model Innovation	Process Innovation	Product Innovation	Service Innovation
Innovation Subject	Producing Company	Trading Company	Service Provider	User
Geographical Focus	Global	International	National	Regional
Level of Analysis	Industry	Firm	Process	Individual
Firm size	> 5'000 FTE	250 – 5'000 FTE	50 – 249 FTE	1- 50 FTE
Firm age	Existing Company		Start-up	
Type of environment	Stable environment	Risky environment	Uncertain environment	Highly uncertain environment

Figure 1: Identification of the research object for this study

1.3.3 Research Conception and Methodology

Research conception

The current study adopts a concept of management research as an applied social science (Ulrich & Hill, 1976). In this view, while advancing the academic field, the researcher aims at “explicating perceived extracts of reality (precise, inter-subjective description), generalizing them (universalizing abstraction of individual cases) and highlighting alternative actions for their design” (p.306). In order to live up to this ambition, a close interaction with entrepreneurial practice is mandatory. This study therefore follows the model of engaged scholarship put forward by Van de Ven (2007). As highlighted in Figure 2 the engaged researcher follows an iterative path (Kubicek, 1977, Tomczak, 1992) that addresses the criteria of relevance, validity, coherence and impact. By first grounding the research problem in reality, the practical relevance of the study is ensured. Subsequently, the problem can be addressed under a theoretical lens by applying existing theories or developing new ones that can explain the problem. An adequate research design will allow applying the theoretical

framework to the problem by involving people from practice that provide access and information. As a result, the theoretical framework may have to be adapted in light of the evidence collected through empirical fieldwork. In a last step, the problem solution will have to be communicated to the intended audience by means of practical and theoretical implications. By following those steps, research in the social sciences has the potential to become more significant and fruitful and to help attenuate the theory-practice gap (Mahoney, 2008).

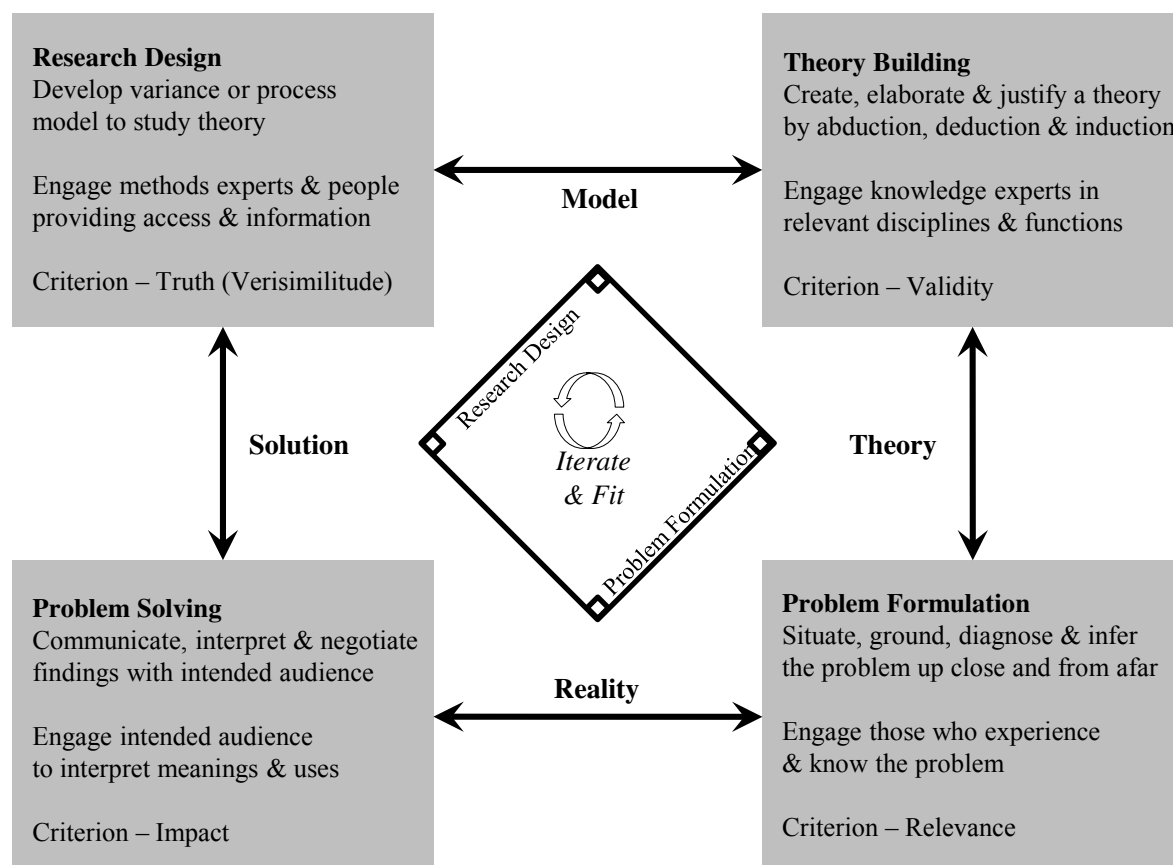


Figure 2: The diamond model of engaged scholarship (Van de Ven, 2007, p.10)

Research methodology

The choice of a research methodology is largely determined by the nature of research endeavour. In broad terms, a basic distinction can be made between exploratory research that aims at theory building or phenomenon description and explanatory research with the aim of theory testing (Bortz & Döring, 2006). While qualitative research methods are typically applied settings concerned with theory building or generation, quantitative researchers rely on methods focused on theory testing and verification (Punch, 2005). While some theorists highlight the mutually exclusive nature of the two approaches (Bortz & Döring, 2003, p.298ff.), others state that a mixed method approach can be useful and should be applied in a pragmatic way (Cropley, 2002, p.111f.).

This study combines qualitative methods of inductive field research with quantitative methods of deductive theory testing and thus applies a sequential mixed methodology approach. Such a design emphasizes the complementarities of both methods (Jick, 1979) and respects the basic principles of engaged scholarship, which “is essentially a pluralistic methodology” (Mahoney, 2008, p.1017). The notion that a combination of both approaches can contribute to the better understanding of research problems and complex phenomena is a central premise of mixed method studies (Molina-Azorin, 2012). Particularly, the benefits of both methods can be brought to bear in the different phases of the research process (Tashakkori & Teddlie, 1998).

Part I: Case Study Research

The research question stated above entails an exploratory approach for the study of the management of innovation in SME. The aim of the research is to achieve an in-depth understanding of a phenomenon on which only limited theoretical insights are available. As a first step, theory therefore has to be developed inductively from empirical insights. Based on the early writings of Glaser & Strauss (1967), a variety of methods can be used for the purpose of theory creation. In this study, this process will rely on Eisenhardt’s (1989b) approach to theory generation from case study research, as they allow for discovery rather than confirmation (Henning, 2004). According to Yin (2003), this method is appropriate for empirical studies that aim at investigating a contemporary phenomenon in great depth and within its real-life context.

Case studies are especially suitable in the context of research endeavours that combine an inductive, qualitative and a deductive, quantitative approach, as they are “one of the best (if not the best) of the bridges from rich qualitative evidence to mainstream deductive research” (Eisenhardt & Graebner, 2007, p.25). In the field of small business and entrepreneurship research, case studies are a generally recognized research method that has attracted increased popularity with scholars in the field (Perren & Ram, 2004).

Criteria

A number of criteria have been established that serve as guidelines to the rigorous conduct of case study research (Gibbert et al., 2008). Those criteria incorporate internal validity, construct validity, external validity, and reliability of results (Cook & Campbell, 1979). While presented individually below, the four criteria are interconnected and mutually dependent. Rigorous case study research must suffice all validity and reliability criteria simultaneously.

Internal validity refers to the internal logic and plausibility of the argument put forward by the researcher. The aim therefore is to demonstrate that a certain outcome is actually a consequence of the influence of a proposed variable and not caused

spuriously. Internal validity is a function of the quality of the process of data analysis that should be based on a research framework derived from existing literature and prior empirical studies. By triangulating and applying different theoretical lenses and bodies of literature, internal validity can be increased (Yin, 2003).

Construct validity is a measure of the degree to which a study investigates what it claims to investigate (Gibbert et al., 2008). In order to increase construct validity, the relevant concepts must be operationalizing in such a way that observations accurately mirror reality. Key remedies for poor construct validity are the use of several sources of evidence (interview data, archival data, observations) and the precise description of data collection and analysis procedures. By having key informants review the draft case studies, an additional reality check can be obtained.

External validity indicates to what extent the findings can be generalized to other settings than the one the study was conducted in. Generalizability in a case study context does not refer to statistical generalization but to a process that Eisenhardt (1989b) calls analytical generalization. Generating between four and ten individual case studies and conducting a cross-case analysis may be sufficient to fulfil the minimum requirements for drawing generalized conclusions. Furthermore, researchers can increase the confidence in their results by highlighting details of the relevant context (i.e. industry context, business cycles) of their case studies and giving a clear rationale for the selection of the specific cases analysed.

Reliability is a criterion that aims at ensuring replicability and transparency of the research endeavour. By transparently indicating how case studies were conducted and data was collected, other researchers are enabled to replicate the study along the same lines. Ideally, the actual names of the case study organizations are given instead of being anonymised.

Case Selection

This study follows a multiple case study approach where the firm's activities in the fuzzy front end of product development are the unit of analysis (Yin, 2003). In order to suffice the requirements for external validity, a typical study will rely on four to ten individual case studies (Eisenhardt, 1989b). In contrast to theory-testing research, the process of choosing those cases from the total population is not guided by random sampling or the objective of representativeness. When theory is to be advanced or developed, cases are selected with an eye on how suitable they are in illuminating the problem under scrutiny (Yin, 2003). Those cases are sampled that are expected to provide the most insightful information or reveal contrasting patterns in the data

(Eisenhardt & Graebner, 2007). The selection criteria for the cases in this study are outlined in chapter 3.2.1. Through this process of theoretical sampling, it was made sure that the heterogeneity of the population of possible cases was mirrored in the sample.

Data Collection

According to Stake (2005) a case study is merely “a choice of what is to be studied” (p.438) which does per se give any indication of how the researcher actually has to proceed in conducting the study. In order to engage in case study research, data collection techniques have to be chosen that best suit the particular research context and the formulated research questions. Examples of well-known techniques are document analysis, interviews, or participant observations. The main data collection technique in this study was the personal face-to-face semi-structured interview of 60-150 minutes in length. Interview partners were generally CEOs or managing directors with comprehensive decision making authority and deep personal involvement in the analysed product innovation projects. The interview guideline contained standardised questions but allowed both the researcher and the interviewees to deviate from these questions and pursue issues that arose in the discussion (Du Plooy, 2001). Interviews are the prevalent research instrument in the social sciences with almost 90% of all studies in this field using data acquired this way (Cropley, 2002). They offer the advantage that information on perceptions and insights of actors can be gathered that would otherwise be very difficult to attain. However, the connected drawback of this technique is the reliance on possibly selective or biased answers of the interviewees, especially on historical events (Meijer et al., 2007). Interview data in this study was therefore complemented by written internal and external documents (internal memos or presentations, newspaper reports) and on-site visits at the interviewees' firms. The technique of triangulation was further employed by generating several case studies for all industries studied and by interviewing partner firms that were also involved in the innovation projects studied.

Data Analysis

The case sampling and data collection stages are guided by a research framework deducted from different streams of existing literature. The research framework gives an overview of the key factors, constructs and variables deemed as relevant for the current study and their presumed relationships (Miles & Huberman, 1994).

The analysis of the collected data is done in two steps. Starting with a within-case analysis, each case is regarded as a stand-alone entity (Eisenhardt, 1989b) for which a

condensed write-up of the collected data is generated. Based on the research framework a first structure is imposed on the wealth of available data that is reduced into categories. Even though there is no commonly agreed upon procedure on how to do a write-up, “the overall idea is to become intimately familiar with each case” (Eisenhardt, 1989b, p.540).

Following the write-up of cases, a cross-case analysis is conducted with the aim of searching for patterns present in all or a subset of cases. By looking for similarities and differences among the different cases, they can be grouped in several categories and compared along a variety of dimensions. While the categorization of cases should follow theoretical considerations but is open to the inclusion of additional relationships arising from the case data.

As a result of the cross-case analysis, hypotheses can be formulated about cause-effect relationships that are open to confirmation or falsification through theory-testing, quantitative research.

Part 2: Survey Research

This study follows the third of the three types of multi-method studies outlined by Yin (2003, p.150f.), where case studies are used to elucidate underlying processes and another method is to determine the prevalence and frequency of such processes. As compared to the inductive case study research, where theory emerges from empirical data and hypotheses are formulated after the observation, deductive research methods aim at theory confirmation through the use of empirical data (McBurney & White, 2007). The formulation of hypotheses therefore precedes the collection of data which, according to the paradigm of Popper (2005), serves to falsify incorrect theories. Based on the insights gained in the qualitative part of the research project, particular questions will be further addressed by operationalizing key constructs and testing them with quantitative methods. The instrument chosen for data collection in this study was the questionnaire

Details on item development, questionnaire design, sampling procedure and data analysis can be found in chapters 5.2 and 5.3.

1.4 Thesis Structure

Based on the research goals and chosen methodological approach, the thesis is organized as shown in Figure 3.

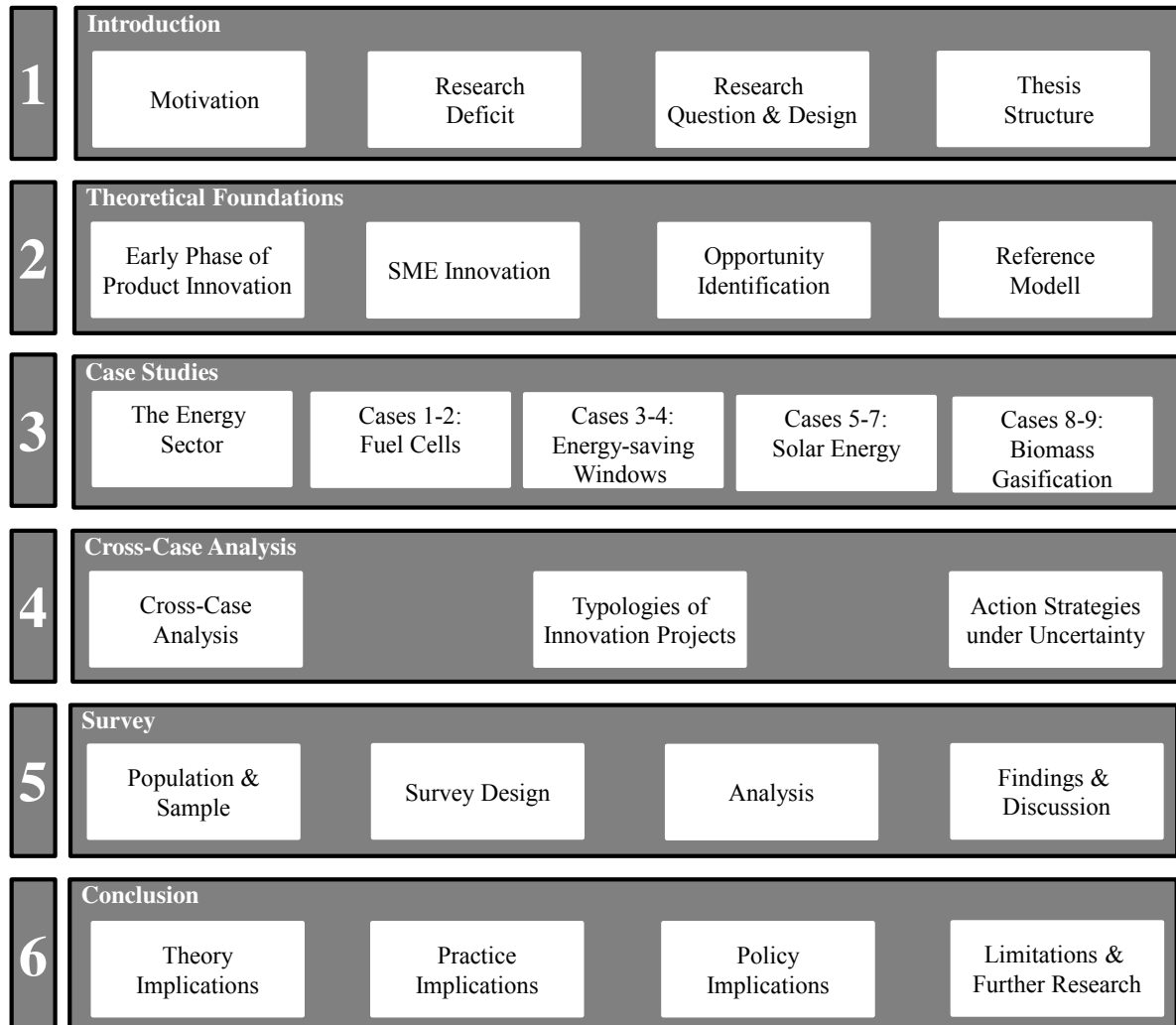


Figure 3: Thesis structure

The current introductory chapter outlines the practical as well as theoretical relevance of the research endeavour for which a research question is formulated and a suitable research design and methodological approach is proposed. Chapter 2 discusses extant theoretical foundations deemed necessary for answering the research question. The focus on the early decision making process in innovation projects of SME operating in uncertain environments positions this research at the intersection of multiple literature streams. This constellation asks for an eclectic, multi-theory approach. Consequently, the current state of research in the areas of the early phases of new product development (FFE), innovation management in SME, and entrepreneurial opportunity identification are presented in order to derive a theoretical reference framework. In chapter 3, the theoretical framework is applied to a real-world setting, i.e. the Swiss

energy sector. After introducing the empirical context and the uncertainties prevalent in it, nine individual case studies involving ten companies in four different energy-related industries will be presented in depth. Chapter 4 is devoted to a thorough analysis of the empirical data by means of a cross-case comparison. By identifying general conditions of early product innovation processes in uncertainty-ridden environments, a typology of different approaches can be identified. In order to provide further evidence for the propositions put forward, chapter 5 presents the results of a survey conducted with 156 entrepreneurs that have recently entered the Swiss energy sector with a product innovation. Next to methodological explanations, the findings of this study are presented and related to the findings from prior case study research. To conclude, chapter 6 summarizes the contributions and implications of this thesis for theory and practice and points out main limitations and suggestions for further research.

2 Theoretical Foundations

The discussion in chapter 1.2 has shown that SME operating in highly uncertain environments often find it difficult to adopt well-established management frameworks for their early innovation processes. Literature has not yet come up with adequate theoretical explanations for this practical problem. Therefore, chapter 2.1 will outline the traditional understanding of the early phases of the product innovation process (FFE) in innovation management research. The two tasks of idea generation and uncertainty reduction as well as the related planning and positioning processes will be described. By adopting this classical understanding of the FFE to an SME context, several shortcomings will be illustrated. Chapter 2.2 will address those shortcomings by analysing recent developments in entrepreneurship research. Researchers in this domain have developed alternative explanations to opportunity identification that go beyond a positioning/planning perspective. Rather than planning to exploit a generally recognized opportunity or positioning oneself to discover opportunities in one's environment, some entrepreneurs are seen as exerting control over their environments and create opportunities themselves. The main contribution of this additional perspective is that an underlying assumption of the planning/positioning approach – i.e. individual actors have to adjust to an objectively existing environment – can be relaxed under conditions of high environmental uncertainty. This offers the opportunity to broaden the traditional understanding of the FFE as a planning and positioning task by including control-based approaches.

2.1 Opportunity Identification in the Innovation Management literature

2.1.1 Approaches to the Management of Innovation

As introduced above, the discipline of innovation management is concerned with describing and analysing the process through which an idea is transformed into a successful new product, service, or process. The ultimate success benchmark for any activity in the innovation management sphere therefore is its contribution to market success in terms of improved profits. In order to manage this process more successfully, a variety of different and complementary strategies have been developed, all of which addressing the task of more efficiently transforming an idea into an innovation (Lynn & Akgün, 1998):

Inspired by the works of Schumpeter, for a long time the leading strategic imperative for new product development was that of *technology push*. A company's R&D department was seen as the source of innovative new technologies that could be further developed into products and introduced in the market. The main task of innovation management therefore was to identify the right technologies that would allow the company to capitalize on them. Instruments like the technology life cycle framework (Abernathy & Utterback, 1978) or the technology portfolio analysis (Pfeiffer et al., 1982) were developed to help managers make those decisions.

In the 1970's, Japanese companies revolutionized the process of new product development through a speed-based approach to optimizing the whole development process from design to manufacturing. Platform management, just-in-time production, concurrent engineering and standardization were used to minimize slack times, while holding up the quality of the entire process.

In the 1980's, the process orientation of general management research increasingly was applied on the sequential segmentation of development projects (Gassmann & Sutter, 2008). A systematic approach to new product development inspired by Cooper's (1988) introduction of the Stage-Gate process, led to a more process-oriented view of how ideas should be transformed into products. Wheelwright & Clark (1992) applied this view on the management of innovation and introduced the funnel model of the innovation process (Figure 4) that still dominates the thinking of practitioners and academics alike.

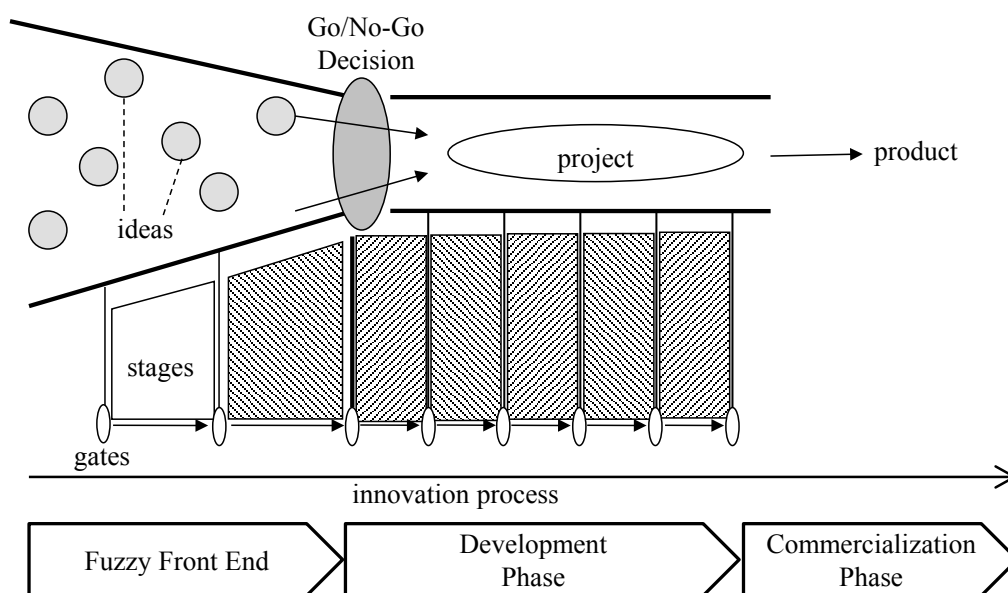


Figure 4: The innovation funnel and stage-gate process (according to Dooley et al., 2000, Boutellier et al. 2000)

The formalization of the innovation process with stages and gates required managers to frequently assess an innovation project and to justify its further continuation. As the

innovation funnel is characterized by a high number of innovation ideas in the beginning and few projects in the end, managers are also faced with the task of abandoning less promising projects in favour of more promising ones. In order to be able to justify those decisions in the face of an uncertain future, objective assessment criteria had to be found in the form of internal hurdle rates, expected returns, net present value calculations, or expected sales volumes (Lynn & Akgün, 1998).

Also starting in the 1980's, innovation researchers increasingly paid attention to the early involvement of customer needs in new product development. Traditional instruments like market research or competitor analysis were complemented with methods like lead user involvement (von Hippel, 1986) or empathic design (Rayport & Leonard, 1997).

In the 1990's the introduction of the knowledge-based view of the firm through Nonaka & Takeuchi (1995) encouraged companies to pay closer attention to the management of explicit and implicit knowledge in their innovation processes. Knowledge management tools were implemented and the aspect of documentation gained in importance. In order to initiate a learning process at the individual and organizational level (Lynn et al., 1999) documentation systems were required to comprehensively record information from many sources, store them in an easily accessible way and allow for analysis of the data.

With the introduction of the open innovation paradigm by Chesbrough (2003) and the subsequent works of Gassmann et al. (2010), the aspect of collaborative innovation processes was put to the center of attention by innovation researchers. Inspired by the insight that no one single company or institution could possibly unite all the necessary knowledge and skills inside the confines of their organization, ways of tapping the resources beyond the limits of the firm were explored.

Taken together, innovation management scholars in the past have strived to explain higher success in the management of innovation processes through the elements of technological R&D, process standardization, process formalization, quantitative prediction, market research, process documentation, and collaboration.

2.1.2 The Early Phase of the Innovation Process (Fuzzy Front End)

While most strategies to improve the effectiveness of the NPD process focus on the later stages of design, production, or market entry the early up-front activities have long been neglected in literature (Brodbeck et al., 2001; Talke et al., 2006). Even though up-front activities can take up to 50% of total development time (Smith &

Reinertsen, 1991), they were long seen as defying systematic management due to their unstructured and chaotic nature. However, many causes of overall project delays or cost overruns can be attributed to poor execution of up-front activities (Gupta & Wilemon, 1990). Empirical research showed that one of the main drivers of success in innovation processes was the quality of up-front activities (Henard & Szymanski, 2011 for an overview of empirical studies). According to Bürgel & Zeller (1997), up to 85% of total project costs, 80% of project deadlines and 70% of the product quality are determined before the formal start of a development project. At the same time, only 5-7% of costs accrue at this stage. Consequently, the “the greatest opportunities for improving the overall innovation process lie in the very early phases of NPD (Backman et al., 2007, p.18) and a better understanding of those early phases – specifically better processes – seems to be called for (Reid & de Brentani, 2004; Verworn, 2009).

In the early 1990’s, researchers developed a heightened awareness of the critical role that up-front activities in the new product development played for the success of subsequent downstream development activities. In line with Cooper’s (1996, p.466) notion that “up-front or pre-development activities stand out as activities that separate winners from losers”, innovation management scholars started to systematically analyse the early phases of innovation. Although success factor research dominated the literature in the 1990’s (Kohn & Hüsigg, 2003 for a comprehensive overview of success factor research), more recent studies offer a more detailed insight into the activities carried out in the early phases (Verworn, 2009). Recent contributions range from theoretical papers (Zhang & Doll, 2001; Reid & de Brentani, 2004) to qualitative (Khurana & Rosenthal, 1998; Montoya-Weiss & O’Driscoll, 2000; Koen et al., 2001; Rosenthal & Capper, 2006) and quantitative studies (Verworn, 2009; Verworn et al., 2008; Langerak et al., 2004).

While in literature several terms exist to denominate those early activities, the term *Fuzzy Front End (FFE)* as introduced by Smith & Reinertsen (1991) became widely accepted both with researchers and practitioners. For the purpose of this study, *FFE* will be used synonymous to other terms like *Front End of Innovation* (Bröring et al., 2006), *(Pre-)Phase Zero* (Khurana & Rosenthal, 1997), *Pre-Development Activities* (Cooper & Kleinschmidt, 1990), *Discovery Stage* (Cooper et al., 2002), *New Concept Development* (Koen et al., 2001) or the German term *Frühphase* (Herstatt & Verworn, 2003). In line with existing literature the focus is on the development of new products, as the concept of FFE has not yet been applied to the development of new services or process innovations (Brem & Voigt, 2007).

The FFE process starts, when the organization first comes across a new opportunity or idea for a new product (Kim & Wilemon, 2002) and ends with the formal decision of management to invest significant resources and grant official project status (Globocnik, 2011) or to terminate the project (Murphy & Kumar, 1997). The project then enters a structured development process with the aim of eventually introducing a new product in the market. Throughout the FFE, several activities have to be conducted in order to transform an initial opportunity or idea into a product concept that can serve as a basis of top-management decision-making. The main output of FFE processes therefore typically represents a business plan (Koen et al, 2001) comprising information about potential customer needs, target market segments, competitive situation, technological specifications, funding requirements, expected returns and a rough time, personnel and resource plan (Khurana & Rosenthal, 1998).

2.1.3 Activities in the FFE

Even though a consensus on the usefulness of the value of the FFE concept exists among innovation researchers, authors have adopted different views concerning what activities should be subsumed under the term. Table 3 gives an overview of FFE process models found in literature and the activities deemed relevant for the FFE. This synopsis illustrates that mainly two sets of activities are considered, both relevant to the primary goal of the FFE to generate a reliable basis for decision making regarding the initiation of a full-scale development project. However, as Sandmeier & Jamali (2007) stress, those activities do not necessarily have to be conducted in a sequential way but are subject to feedback loops as the process evolves.

On the one hand, the FFE must be organized in a way as to allow for a steady stream of new ideas to emerge. This process, called *ideation*, should inform the company of valuable opportunities for the development of new products to pursue (Poskela, 2009). Idea generation, processing and selection therefore are main activities to be performed in the FFE (Brem & Voigt, 2007; Nyffenegger, 2006, Wahren, 2004). According to Berger (1998), the company should define strategic spaces for the deliberate search for new ideas and establish an efficient process for their assessment and selection.

On the other hand, activities in the FFE should contribute to reducing the uncertainty inherent in the new ideas generated through the ideation process. The term *fuzzy* in *Fuzzy Front End* relates to the high degree of uncertainty dominating the early phases of the product innovation process. This uncertainty can relate to consumer responses, the competitive situation, technological feasibility or resource requirements (Moenaert & Souder, 1990). As managers typically feel that they cannot decide on the allocation

of R&D budgets based on uncertain or vague ideas (Boeddrich, 2004), high levels of uncertainty are a major obstacle to making Go/No-Go decisions in product development (Kim & Wilemon, 2002). Activities in the FFE therefore have to be structured in a way so as to allow for the reduction of uncertainty through a structured accumulation of additional information (Reinertsen, 1999). Those activities have been a focus of the FFE literature (Andersson, 2010).

Author	Ideation	Uncertainty Reduction
<i>Cooper (1988)</i>	i. Discovery ii. Initial Screening iii. Project Scoping	iv. Technological Assessment v. Detailed Investigation
<i>Albach (1993)</i>	i. Strategy Formulation ii. Idea Search iii. Invention	iv. Technical Feasibility v. Prototyping vi. Economic Feasibility
<i>Khurana & Rosenthal (1997)</i>	i. Opportunity Discovery ii. Idea Generation	iii. Market Analysis iv. Competitive Analysis v. Technological Feasibility vi. Resource Requirements
<i>Gruner (1997)</i>	i. Product Idea Search ii. Product Idea Assessment iii. Product Idea Selection	iv. Product Concept* Development v. Product Concept Assessment (economical, technological, operational feasibility) vi. Product Concept Selection
<i>Koen et al. (2001)</i>	i. Opportunity Identification ii. Opportunity Analysis iii. Idea Genesis iv. Idea Selection	v. Concept & Technology Development (<i>Business Plan</i>)
<i>Brodbeck et al. (2001)</i>	i. Innovation Requirements Determination ii. Technological Trends iii. Strategic Alignment	iv. Technological Assessment v. Market Assessment vi. Risk Assessment vii. Product Specifications viii. Competitor Analysis ix. Business and Project Plan
<i>Herstatt & Verworn, (2003)</i>	i. Innovation Requirements Determination ii. Idea Generation iii. Idea Assessment	iv. Market Analysis v. Product Specifications vi. Prototyping

Table 3: Process models of the FFE and corresponding activities

2.1.3.1 Ideation

As identified above, one of the main functions of the FFE is to generate a steady stream of new ideas on opportunities for product innovations. The continuous generation of new ideas is especially important, because only few ideas have the potential to eventually result in a formal development project and eventually in a new product. The survival rate of new ideas is generally very low (Berth, 1993) and can be located in the order of 3000:1 for raw ideas and 300:1 for formulated ideas (Stevens & Burley, 1997). Figure 5 illustrates the circumstance that conversion rates of ideas into development projects are very low (Chandy et al., 2006) and failure rates in the early phases of over 99% of all ideas are common.

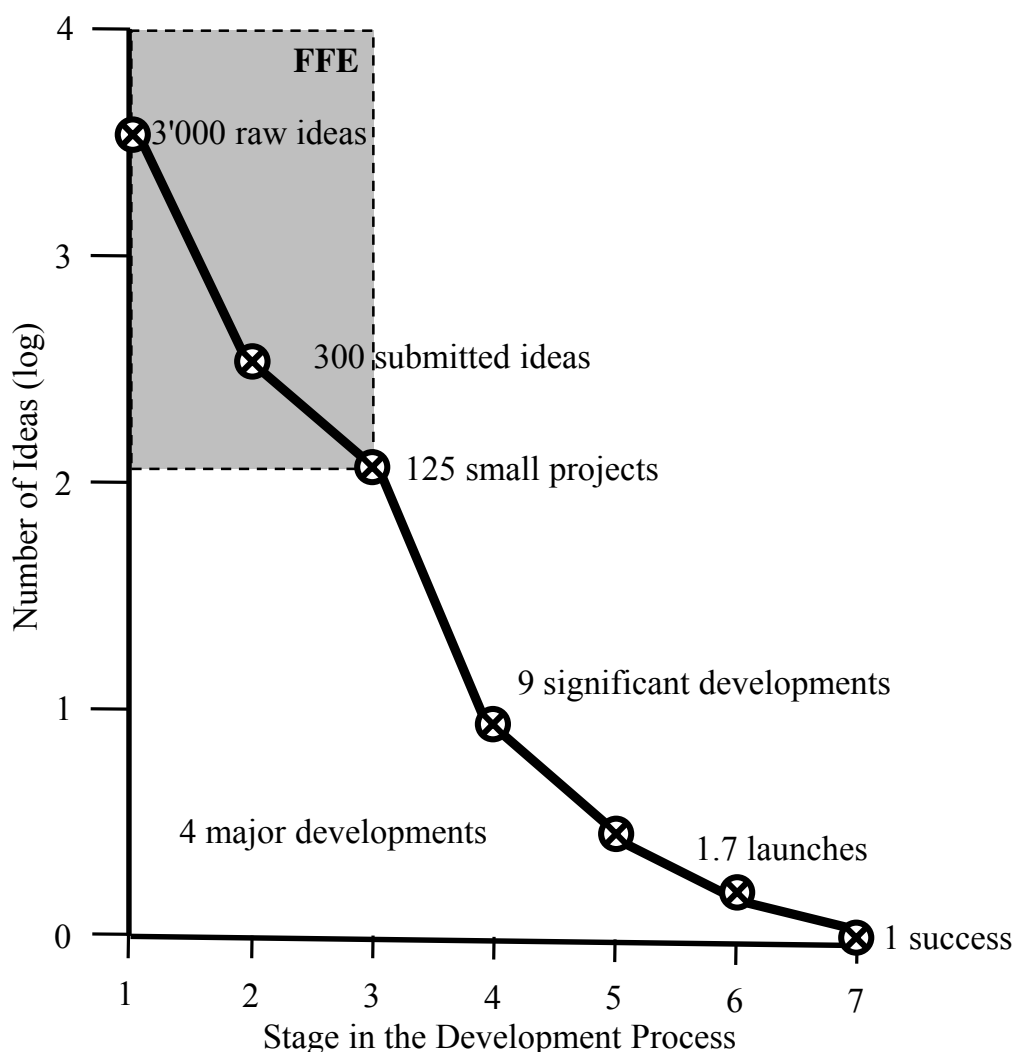


Figure 5: Idea selection curve in the FFE (adapted from Stevens & Burley, 1997)

In order to be able to generate the high numbers of raw ideas necessary, companies must introduce some kind of systematic and methodological approach to the ideation process (Pleschak & Sabisch, 1996) and cannot rely on serendipity alone. Additionally, due to the amount of information to be collected, several persons will

likely have to share the task, which requires – at least informally – the definition of roles and responsibilities. Furthermore, the limited resources available for idea generation purposes must be directed and channelled to those fields that are most promising for the company instead of being allowed to roam freely (Minder, 2001). Firms therefore need to manage the creative process of idea generation in such a way that “a fine balance is achieved between overall flexibility [. . .] and the focus and direction needed to ensure product development effectiveness” (Nambisan, 2002, p.406). Taking those considerations into account, Neckel (2004) stresses that efficient and effective ideation processes should a) be based on a *strategy* and provide clear objectives, for which b) *roles* are defined and responsibilities are assigned to individuals and committees, that c) make use of *methods*, checklists and technologies and d) organize their activities along *processes* and structures:

Strategy & Goals: Along the lines of those requirements, FFE process models generally start with the formulation of an innovation strategy (compare Table 3) which defines the thematic, geographical, demographic and technological fields in which the search activities should be focused. The selection of the search fields is on the one hand based on the intended strategic position of the company in their relevant markets. On the other hand, an analysis of the current strategic position and the resulting gap can highlight in what areas further innovative output in the form of new or improved products is required. Following the identification of several strategic search fields, possible sources for ideas inside the search fields are identified. Those can range from customers and suppliers over employees and internal documents to competitors, regulatory bodies, research institutions or even other industries.

Roles & Responsibilities: For each of the identified sources of ideas, activities are defined and assigned to individuals or groups of individuals to be carried out. Those activities can include the periodical collection and analysis of a defined set of data, the participation in events or congresses, the conduction of surveys or interviews, the participation in workshops, meetings, communities of practice, quality circles, or other activities deemed useful in the search for new ideas. Since all of the activities are oriented towards the selected search fields, they can be assigned to several people, who do not necessarily have to interact personally.

Methods & Technologies: In order to support those activities, research and practice have developed a variety of methods and techniques to enhance creativity and the identification of relevant information. Depending on the potential idea source to be scrutinized, companies can make use of creativity methods (for an overview: Rochford, 1991), empirical methods (Meyer, 2001) or special forms of early customer

or employee integration (e.g. Meister, 2011; Wecht, 2005). Many companies also make use of information technology tools and dedicated databases for their ideation processes.

Structure & Process: In order to make the ideas accessible for screening and first assessment, they have to be brought in some sort of standardized format, which often is the written form. In the process of explicating the still embryonic idea, a first structure is imposed on it. The documented output generated by the search activities is then fed into a pool of ideas that is periodically reviewed by a designated group of people, following a formalized assessment process and applying pre-defined assessment criteria (Geschka & Schwarz-Gechka, 2000). The ideation process ends with the provision of a pool of ideas that is adjusted for incomplete ideas or those deemed to be of no avail for the company.

2.1.3.2 *Uncertainty Reduction*

Following the generation and first processing of ideas in the ideation process, the subsequent activities of the FFE focus on reducing the uncertainty inherent to those ideas below a threshold level acceptable for decision making (Kim & Wilemon, 2002; Boeddrich, 2004). The FFE is characterized by a high degree of uncertainty (Moenart et al., 1995) as defined by the “difference between the amount of information required to perform a particular task, and the amount of information already possessed by the organization (Galbraith, 1973). It is therefore the “absence of information and knowledge” in the FFE (Chang et al., 2007) that poses the greatest challenge to decision makers who see themselves unable to accurately predict relevant developments (Moenart & Souder, 1990) in the areas of customers, technology, competition (Zhang & Doll, 2001), internal operations, resources and regulations (Globocnik, 2011). The only way to decrease uncertainty therefore is the gathering and integration of further information (Daft & Macintosh, 1981; Song & Parry, 1997; Kohn, 2005), as explicated by the information processing view (Verworn, 2009). According to this view, the success of the subsequent phases of the product innovation process depends on the degree to which uncertainty in the FFE can be reduced through the acquisition of more information.

All FFE process models therefore include a variety of activities that aim at collecting various pieces of information deemed relevant for subsequent decision making by top management. Activities aimed at the reduction of *technological uncertainties* can include the development and testing of prototypes, the establishment of an internal R&D laboratory, or a detailed search for relevant patents. *Regulatory uncertainties*

can be mitigated by early tests of potentially detrimental effects of the intended product on human health or the environment as well as by the participation in lobbying and industry association activities. In order to reduce uncertainties associated with future *customer acceptance*, a variety of market research techniques like conjoint analysis, test markets or lead user workshops can be applied. Uncertainties pertaining to the *competitive situation* can be addressed by means of industry research.

The information gained through the application of those techniques can be used for a first resource plan and the determination of expected sales and profit levels. The uncertainty reduction process ends with the provision of a set of product concepts developed to a point where top management decision makers feel comfortable to make a well-grounded decision about the initiation of a formal development project or the termination of the concept (Elmquist & Segrestin, 2007).

2.1.4 The FFE of Small and Medium Sized Companies

In a turbulent environment, SME are among the first firms to experience the pressure to innovate (Lee et al., 2010). While larger companies can allow taking a defensive or even negating approach to changes in the environment, SME conversely cannot afford to swim against the current. In contrast to larger companies, SME can rarely reach the position of cost leader in an industry and therefore lack the ability to generate entry barriers for new competitors through economies of scale or the setting of standards (Pichler et al., 1996). Consequently, they rely to a much higher extent on the continuous generation of innovations to sustain their position as quality leaders in the marketplace (Meyer, 2006). The often observed focus on niche and key customers can increase this pressure, as larger companies due to their bargaining power tend to pass on the risky task of innovation to their SME suppliers (Kamath & Liker, 1990). Additionally, key customers have a tendency to put a high emphasis on the long-term availability of products and spare parts and often do not appreciate autonomous innovations or diversifications on the part of their suppliers.

In addition to the more immediate pressure to adapt to changing environmental conditions, SME also face greater risks in the innovation process. The failure of an innovation project could lead to a situation where the very survival of the firm is put at risk (Lahner & Müller, 2004). While larger companies can avoid this situation by diversifying their innovation project portfolio, SME – due to their typically lower endowment with financial and personnel resources – can't make use of this strategy and are overexposed to correlation risks. Due to the higher stakes in the innovation process, a strong focus of SME on the fuzzy front end seems critical, as this phase of

the process has been shown to be decisive for the further success of an innovation project (cf. chapter 2.1.2). In light of the potential risks for the firm, it is mandatory that projects with a low probability of success are terminated early on in the process. While larger companies can afford to protract uncertainties into a later phase where more resources and expert knowledge will be available to their clarification, SME will not be able to follow this approach. As the majority of the firm's key personnel will be involved early on in the process, insurmountable problems in the FFE with utmost probability will not be solved later on either. It is therefore reasonable to assume that a very good performance of FFE tasks is even more important for SME than for larger firms.

Considering the circumstances discussed above, it seems surprising that only a small section of the increasing innovation management literature takes place in the context of SME. Neubauer (2000) found this literature to represent 3.8% of all innovation-related publications. In addition to the lack of dedicated research, practitioners alike are still far from recognizing the importance of the FFE in the innovation process. Even though pressures to establish the feasibility of innovation projects early on in the process are high, SME start development projects and even product launches that prove to be unsuccessful. According to a study of Herstatt et al. (2007), only 42% of SME stop innovation projects with a low probability of success in the FFE phase, while another 42% only brought themselves to do so in the subsequent execution phase when significant resources had already been invested. 16% abandoned the project after the market launch when the financial damage was complemented by a loss of reputation. Consequently, SME in general seem to be less successful in their innovation efforts, as empirical studies repeatedly found a significant positive relationship between company size and innovative output (e.g. Aschhoff et al., 2008; for meta-analyses: Camisón-Zornoza et al., 2004 and Damanpour, 1992).

First papers that attributed those differences to size-related factors in the innovation process were published by Acs & Audretsch (1988) and Rothwell (1989). Since then, a variety of studies have focused on the specific challenges of SME in the innovation process. De Jong & Vermeulen (2006) identified 14 such papers that found a range of size-related advantages and disadvantages of SME in the process of innovation. This literature assumes that – all other factors being equal – SME due to their smaller size exhibit particular advantages and disadvantages in the innovation process (Meyer, 2006).

2.1.4.1 *Size-related advantages in the FFE*

Advantages of SME as compared to larger companies arise from the fact, that certain activities important to the FFE can be conducted more efficiently in smaller-scale, more manageable settings. The consequences of this effect are apparent in the areas of a) *hierarchies and communication*, b) *market intimacy*, c) *agility and flexibility*, d) *decision-making* and e) *corporate culture*.

Hierarchies and Communication: Unlike the situation in larger companies, the activities of an SME can generally be overseen by one person. This redundantizes the need for many mediating hierarchy levels and allows for direct communication between the managing director and the employees (Noteboom, 1994). Due to their smaller size, SME are also characterized by a lower level of division of labour than larger companies. The single employees therefore can more easily relate their own activities to the general goals of the company and get more direct feedback about the effects of their own work (Mähr, 2003). Complex process of coordination among the employees can thus be forgone and employees can be granted greater decision-making authority. Information can be spread and obtained quickly via direct and informal communication channels. Those informal structures can be activated for the purpose of ideation processes in the FFE in order to easily tap the knowledge of the organization.

Market Intimacy: While larger companies have to undertake greater efforts to counteract their notorious remoteness from markets, SME often have a more intimate rapport to their customers. A niche strategy typically followed by SME involves the focus on a rather small segment of the market, the satisfaction of whose needs is not seen as profitable by larger companies. Key customers play a major role for niche suppliers and are often taken care of personally by the manager. Due to close interaction with customers, SMEs are characterized by a good sensorium for the needs of their markets, which they ideally can anticipate.

Agility and Flexibility: In their exploratory study, Herstatt et al. (2001) identified the factors of agility and flexibility as the main strengths of SME in the innovation process. Due to their straightforwardness they can operate with less complex structures, entailing lower organizational costs. Smallness and lean structures hence allow them to cater to individual and short-term customer requests in a more suitable and cost-effective way than would be possible for larger companies (Pichler et al., 1996).

Decision Making: As a result of the concentration of decision-making authority in the person of the owner and manager, fast and efficient decision-making is a distinctive

feature of SME (Dailey et al., 2002). This sets them apart from larger companies, where complex processes of coordination and consensus finding lead to the phenomenon of organization inertia (Hannan & Freeman, 1984). The often observed situation that owners of smaller companies can be personally held liable for the negative consequences of their decisions attenuates the principal-agent problem prevailing in large companies (Clark, 2006).

Corporate Culture: Larger companies often experience difficulties in creating a high degree of loyalty and identification among their employees. They are often perceived as impersonal and the relationship between employees and management can be affected by mistrust. Since corporate communication cannot cater to every employee individually, it is difficult to establish a shared vision for the company and the readiness to adopt a speak-up mentality. However, those aspects are vital prerequisites for employees to actively take part in the innovation process (Pervaiz, 1998). In contrast, SME are endowed with preconditions for the establishment of a corporate culture conducive to innovation. Especially for FFE activities and the acceptance of changes triggered by innovation projects, a suitable corporate culture is invaluable.

2.1.4.2 *Size-related disadvantages in the FFE*

Disadvantages of SME as compared to larger companies arise from the fact, that certain activities important to the FFE can be conducted more efficiently in larger settings. The consequences of this effect are apparent in the areas of a) *long-term strategy and objectives*, b) *managerial and methodical competences*, c) *processes, roles and documentation*, d) *financial, personnel and R&D resources*, and e) *cooperation with external partners*.

Long-term Strategy and Objectives: Literature consistently stresses the important role an innovation strategy plays for the activities in the FFE (cf. chapter 2.1.3.1). However, SME have been found to be less likely than larger companies to adopt an innovation strategy. 73% of SME (10-49 employees; for SME with 50-249 employees: 86%) taking part in an empirical study of the University of Bern (2004) had formulated a written corporate strategy, only 17% of SME also had an innovation strategy. In contrast, 70% of larger companies with more than 250 employees had a written innovation strategy at their disposal to guide their FFE activities. The lack of long-term orientation has been attributed to the difficulty of SME managers to detach themselves from the focus on day-to-day business (Menzel & Geithner, 2010). The lack of a long-term orientation has also been evidenced by Deimel & Kraus (2007) who found that 76% of examined SME had a planning horizon of less than four years,

with 19% indicating that their long-term planning does not go beyond the period of 12 months.

Managerial and Methodical Competences: The organisation of FFE activities represents a complex task for managers and requires a broad set of managerial skills. Those skills in the areas of leadership, human resources, marketing, sales, product development and finance are more difficult to bring together in a smaller company, as less specialized management staff is available. Freel (1999) accordingly found deficiencies of SME to mainly lie in the areas of managerial competences. Additionally, the separation of creative FFE and more efficiency-focused downstream development activities, poses a greater challenge to SME. In larger companies, a department with a more participative leadership style and flat hierarchies can be structurally, personally or geographically separated from another department with a more deadline and efficiency driven leadership style. As most employees of an SME will be involved in both the early and in the late phase of the innovation process, such a separation is in most cases not possible. This also to a certain degree puts constraints on the adoption of creativity-enhancing methods in the FFE.

Processes, Roles and Documentation: According to empirical SME studies by Böhler & Sciliano (2004) and Meyer (2001), the lack of a method-based approach is most striking in the early phases of the innovation process. In the FFE, method-based and documented processes are often replaced by ad-hoc processes (Herstatt et al., 2001). Innovation processes are only triggered if external circumstances make fundamental changes necessary. Those reactive processes are not documented and rely exclusively on the experiential knowledge of the persons involved, i.e. the owner or manager who often has an extensive knowledge of the relevant technologies and markets. Consequently, the managing director of the SME takes the most prominent position in the innovation process, especially in the FFE. As Dieckhoff et al. (2001) in their analysis of innovation processes of 39 SME found, all processes were initiated by the upper management. The managing director could be identified as being the primary initiator of the innovation process in more than half of the cases. The FFE in SME is also characterized by a reduced use of participative idea evaluation and decision making in comparison to larger companies. Besides the managing director, SME rarely have established the formal role of a person responsible for the innovation process. Without the help of such a promoter, the fate of an innovation idea stands or falls by the commitment and assertiveness of the person who initially conceived the idea (Gemünden & Walter, 1995).

Financial, Personnel and R&D Resources: Another obstacle for SME in the product innovation process lies in their sparse endowment with financial resources (Franke & Dömötör, 2009). Innovation projects typically exhibit long amortization times and high investment costs with a considerable degree of risk associated. As smaller companies do generally not have direct access to capital markets, they mainly rely on bank loans for the funding of their innovation projects. The riskiness inherent to innovation projects in conjunction with the generally lower credit rating of SME (Berger & Udell, 1998) results in rather high costs for bank loans. It can hence be observed that SME exhibit comparably high self-financing ratios (Börner et al., 2010) with retained profits being the major source of funding for innovation projects (Arvanitis & Marmet, 2002).

The attraction of personal resources represents another challenge for SME in the innovation process. This can be attributed at least partly to the fact that they often pay lower salaries than larger companies (Loveman & Sengenberger, 1991). Empirical studies have shown that highly innovative firms stand out due to their higher share of employees with an academic background (Spielkamp & Rammer, 2006). Those employees generally prefer working in an R&D environment or in an expert or staff position where they can best make use of their specialized knowledge. However, SME only rarely have implemented dedicated staff departments. Moreover, as R&D facilities require a certain minimum size in order to be operated efficiently (Franke & Dömötör, 2009), SME maintain continuous R&D activities to a lesser degree than larger companies. This represents another size-related disadvantage of SME in the innovation process, as continuous internal R&D capacities have been shown to be a major benefiting factor for the ability of a company to develop absorptive capacities for knowledge and technologies generated by external parties (Veugelers, 1997). Additionally, SME have been shown to make fewer investments into continuous education and training necessary for the maintenance of the competences of their specialized staff. In a study of Gray (2006), 41% of SME did not evaluate the training needs of their staff, while only 27% of larger companies displayed this behaviour.

Cooperation with external partners: A possible way to countervail the deficiencies in financial, personnel and R&D capacity endowment is the exploitation of external know-how carriers via purposefully designed co-operations. Through the integration into a network of partnerships, smaller companies can “enjoy relationships and resources typical of more established firms” (Baum et al., 2000, p.267). Co-operations can be entered with a variety of external parties including other companies, universities, sales partners, suppliers, innovative service companies, public agencies

and competitors (Pleschak & Stummer, 2001). Collaborations with external partners are especially useful in the FFE (Schilling, 2005) and in the case of more complex innovations (Kaufmann & Tödting, 2001; Zeng et al., 2010). In this phase, the complementation of internal resources with external knowledge can widen the basis for idea search and grant access to additional information necessary for the task of uncertainty reduction. Despite the potential advantages of external collaboration networks, SME have been observed to be more reluctant than larger companies to make use of them (OECD, 2011b). Concerns about disclosing information and the will to remain independent have been identified as main considerations contributing to this behaviour (Dean et al., 1997), especially in asymmetric collaborations with larger companies (Nieto & Santamaria, 2010). Even though smaller firms have been shown to benefit more from external relationships with technologically more advanced partners (Torbett, 2001), they are less likely than larger firms to enter those collaborations (König, 2002).

2.1.4.3 *The FFE in light of size-related factors*

When matched with the process steps and corresponding activities of the FFE, the size-related disadvantages and advantages can be shown to have a significant influence on the ability of SME to successfully conduct front-end activities. Figure 6 and Figure 7 give an overview of particular challenges of SME in the FFE.

IDEATION				
Strategy / Goals Formulation	Roles Definition	Process Definition	Methods Definition	Documentation
- definition of innovation strategy - definition of search fields	- assignment of roles to individuals or groups - definition of responsibilities	- definition of periodic activities - formalization of interfaces - documentation of processes	- definition of applicable methods - training of methods - definition of evaluation criteria	- definition of format requirements - installation of an idea pooling system
+	hierarchies / communication	agility / flexibility	corporate culture	
-	long-term strategy / objectives	processes / roles / documentation	managerial / methodical competences	processes / roles / documentation

Figure 6: Process steps and related activities of the ideation phase with size-related advantages (+) and disadvantages (-) of SME

Ideation Phase

In the ideation phase, the reluctance to engage in long-term strategy making, the lack of assigned roles, defined processes and documentation systems are major obstacles to efficiently conducting the search for new ideas. Yet, SME can make use of some size-related advantages in order to balance out and overcome those obstacles:

Lower hierarchies and more direct communication channels can counterweight the lack of defined roles, as all employees can be more easily activated to contribute to the search for ideas. However, to what extent this advantage is made use of is highly contingent on the initiative of the SME's general manager, who is the central decision-making authority. In a similar manner, Reid & de Brentani (2004) recommend a greater focus on the individual, i.e. the general manager, to jump-start the activities in the FFE.

Additionally, agility and flexibility arising from less complex organisational structures offer the possibility to compensate for the lack of defined processes. Instead of establishing a continuous innovation process, SME could resort to using ad-hoc structures whenever the idea for the exploitation of an innovative opportunity arises. However, in order to make use of this solution, the SME must make sure that there is some sort of mechanism to ensure that it is made aware of innovative opportunities. Kirner et al. (2006) mention the value of so called innovation routines (Tidd et al., 2005) for smaller companies, which can be described as patterns of action that are used in specific situations, such as learning from unsuccessful projects.

The lack of competencies in the use of methods – which could ideally be used to make the firm aware of innovative ideas – could be offset via a corporate culture which values innovative ideas and a positive attitude to change. Along those lines, König & Völker (2003) propose to conceptualize innovation management in the FFE of SME as a behavioural function with the major aim to establish an attitude conducive to innovation.

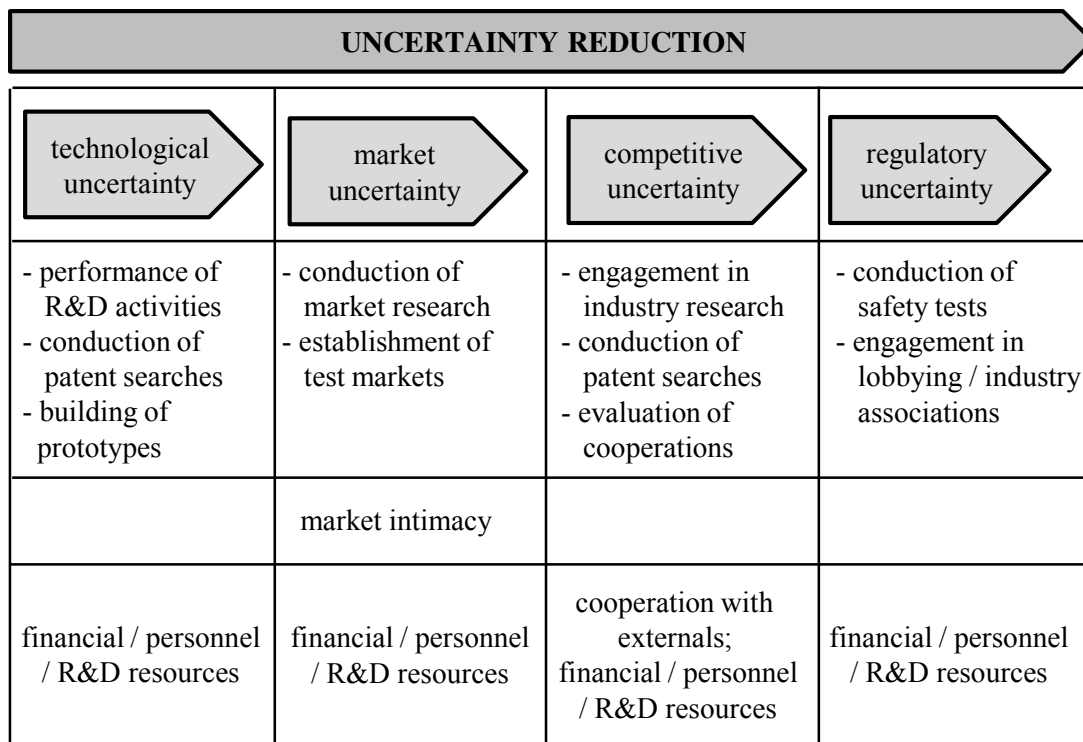


Figure 7: Process steps and related activities of the uncertainty reduction phase with size-related advantages (+) and disadvantages (-) of SME

Uncertainty Reduction Phase

When attempting to reduce uncertainties pertaining to an innovation project in order to provide the foundations for subsequent decision-making, SME mainly suffer from resource disadvantages. The efforts associated with acquiring the necessary financial, personnel and R&D resources for the performance of uncertainty-reducing activities are higher in SME than in larger companies. SME therefore have to find ways to do without those activities, while still continuously reducing uncertainties involved with a project. In order to counterweight the lack of internal R&D resources and expert knowledge in the reduction of technological risks, SME could resort to areas where they already possess good knowledge. In the market sphere, SME can make use of their market intimacy to bypass elaborate and expensive market research and test market activities.

To summarize, the overview in Figure 6 and Figure 7 shows that due to their specific size-related conditions, SME will not be able to follow a structured innovation process in the FFE in the same way as larger companies do. Rather, successful management of FFE activities will require a) a stronger focus on the main decision-maker in the firm, b) the conceptualization of ideation activities as a behavioural function, c) the reliance on informal routines rather than formalized processes, d) a focus of uncertainty reduction tasks on market-related uncertainties and e) ways of decision making under high levels of uncertainty.

Focus on individual behaviour

Those requirements result in a view of the FFE where individual behaviour governed by routines will determine the early phases of the innovation process, ideally leading to the generation of innovative ideas and enable decision-making under higher levels of uncertainty. This view represents a major shift in focus from a formalized process view currently dominating the FFE literature. It is, however, in line with recent notions expressed by innovation management scholars, who question the universal usefulness of rather formalized approaches to managing the FFE (Stringer, 2000; Brettel et al., 2011). Even though Terziowski (2010) found that formality and planning in the FFE of SME are important predictors for successful product developments, he reduces the applicability of this statement to projects where uncertainties can be reduced to a manageable level. When the degree of uncertainty is high and cannot be further reduced, the importance of process formalization decreases (Poskela & Martinsuo, 2009), which can dampen the disadvantages of SME in this area.

A first attempt at describing the interplay between individual behaviour and structures in the FFE was made by Kobe (2010) who introduced a structuration theory-inspired framework of the FFE and demonstrated its applicability with a variety of companies. However, there is not yet any clarity about the nature of those routines-guided behaviours individuals – especially focal individuals in the SME – should engage in, in order to come up with innovative ideas under conditions of uncertainty.

Focus on decision-making under uncertainty

As the discussion above highlights, the issue of uncertainty in the FFE is especially relevant for SME. A situation is not uncertain per se, but the degree of uncertainty depends on the ability of the individual to make sense of a situation. According to Milliken (1987, p.136), uncertainty can be defined as “an individual’s *perceived* inability to predict something accurately”. While a larger company with a dedicated market research and internal R&D department may find it relatively easy to reduce uncertainties pertaining to a certain innovation project, a smaller, less resource-endowed firm may not be able to do so. The level of perceived uncertainty is therefore often higher for SME in the fuzzy front end.

SME, consequently often find themselves in a situation where they face what Knight (1921) called *true uncertainty*. In contrast to risk and uncertainty, true uncertainty characterises those situations, where the individual is not able to make prediction about the future, neither through means of planning (as in the case of risk) nor through trial-and error learning (as in the case of uncertainty).

Following Wiltbank et al. (2006), management literature in the past has proposed mainly two approaches to handling situations where uncertainties prevail: the rational and the adaptive approach. Proponents of the rational approach emphasize instruments like planning and positioning (Ansoff, 1979), competitive analysis (Porter, 1980), the use of real options (McGrath, 1999) or scenario planning (Schoemaker, 2002). In doing so, they make the implicit assumption that the future can be planned if firms only work hard enough to predict the future more accurately and to position themselves more precisely. This assumption echoes a situation characterised by risk in Knight's (1921) classification scheme.

In contrast, scholars favouring the adaptive approach emphasize the difficulties associated with predicting the future and put greater weight on adaptation on the cost of elaborate planning (Gruber, 2007). In doing so, they refer to a situation characterised by uncertainty according to Knight (1921). Frameworks like Mintzberg's (1994) emergent strategy, Teece et al.'s dynamic capabilities (1997), fast decision making (Eisenhardt, 1989a) or incrementalism (Quinn, 1980) fall under this category. However, those approaches also require firms to engage in large-scale planning efforts and the provision of slack resources (Wiltbank et al., 2006), often beyond the scope of an SME's financial and personnel resources. The traditional FFE literature, due to their focus on uncertainty reduction, has by now failed to provide approaches to the management of the FFE under conditions of true uncertainty, as faced by many SME.

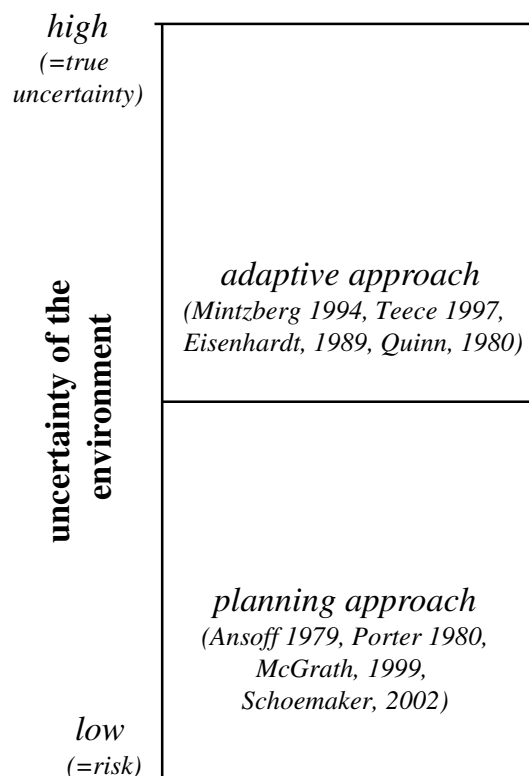


Figure 8: Different FFE strategies depending on environmental uncertainty (adapted from Wiltbank et al., 2006)

While the FFE literature generally sees the inability to reduce high levels of uncertainty in the early phases as detrimental to innovation, entrepreneurship scholars have taken a different stance on the issue. According to Meijer (2007, p.5837), “uncertainty can both create opportunities for entrepreneurs to engage in emerging technologies, as well as hamper entrepreneurs in undertaking action”. In contrast to the research on the FFE, entrepreneurship scholars have included situations of true uncertainty in their analysis instead of disregarding them. The view of uncertainty as a source of opportunities for innovative action thus constitutes a promising avenue for SME to overcome their size-related disadvantages in the traditional FFE process. Schumpeter (1934), in his seminal work on the innovative entrepreneur, described a situation in accordance with what SME typically face in the FFE, namely „the impossibility of surveying exhaustively all the effects and counter-effects of the projected enterprise. Even as many of them as could in theory be ascertained if one had unlimited time and means *must practically remain in the dark*” (p.85, *emphasis added*). In those situations, he points out, a structured approach to uncertainty reduction may prove detrimental: “even if all the data potentially procurable are not available, [. . .] in economic life action must be taken without working out all the details of what is to be done. [. . .] Thorough preparatory work, and special knowledge, breadth of intellectual understanding, talent for logical analysis, may under certain circumstances be sources of failure“ (p.85). As a solution to this dilemma, he mentions a certain kind of behaviour he attributes to entrepreneurs as opposed to managers: „Here the success of everything depends upon intuition, the capacity of seeing things in a way which afterwards proves to be true, even though it cannot be established at the moment, and of grasping the essential fact, discarding the unessential, even though one can give no account of the principles by which this is done” (p.85)

Schumpeter (1926) leaves open, what elements constitute a kind of behaviour described as *the capacity of seeing*. However, the discipline of entrepreneurship research, inspired by Schumpeter’s work, has developed a range of theories on what allows some people and not others to be able to act in the face of uncertainty. The following chapter therefore gives an overview of how entrepreneurship scholars have conceptualized the identification of opportunities and how those approaches relate to innovation management approaches to the FFE discussed above.

2.2 Opportunity Identification in the Entrepreneurship literature

2.2.1 Approaches to Opportunity Identification

At its core, the entrepreneurship field is concerned with finding answers to the questions of (1) why, when and how opportunities arise, (2) why, when and how some individuals are able to identify and exploit those opportunities and others are not, and (3) what the consequences of those actions are for the entrepreneur and the society as a whole (Ucbasaran, 1997).

In their efforts to find answers to those basic questions, entrepreneurship researchers have focused on five dimensions of entrepreneurial fields of action as outlined in Figure 9: the circumstances that give rise to their existence (*Causes*), their types and perception (*Existence*), their assessment by the entrepreneur (*judgement*), their *exploitation* and the *outcomes* resulting thereof.

In line with the questions raised in the preceding chapter 2.1, the focus of the following discussion is on the aspect of opportunity identification, i.e. point 2 in the opportunity map.

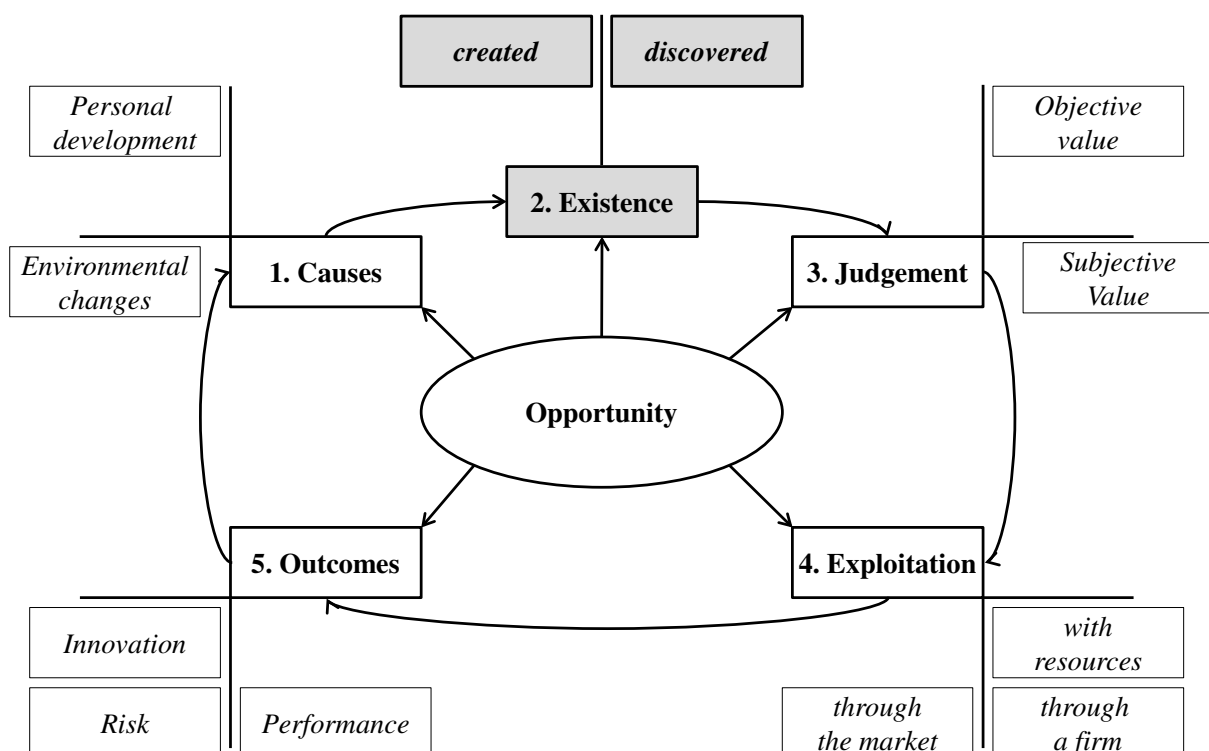


Figure 9: Opportunity map (Grichnik, 2006, p.1306)

Ucbasaran's (1997) first two questions regarding the sources of opportunities and the differences between entrepreneurs and non-entrepreneurs are highly intertwined. Venkataraman (1997) mentions four main areas of difference between individuals that have been considered for the explanation of why certain individuals are better at finding out and making use of opportunities than others. Those areas are (1) psychological differences, (2) knowledge and information differences, (3) cognitive differences, and (4) behavioural differences. Entrepreneurship researchers in the past have systematically analysed differences between individuals in all those areas which resulted in the emergence of three distinctive theoretical views on how individuals come to learn about an opportunity and decide to engage in its exploitation. While the *recognition view* focuses on psychological factors as antecedents to the finding of opportunities, the *discovery view* proposes that cognitive processes and the endowment of individuals with specific knowledge are the decisive factors in seeing opportunities arise. The *creation view*, however, emphasizes the importance of certain behavioural patterns through which opportunities are shaped and developed by individuals.

Proponents of the discovery (Shane & Venkataraman, 2000, p.219) as well as the creation view (Sarason et al, 2006, p.289) explicitly state that their theoretical approaches include new venture creation, individual pursuit of opportunities as well as opportunities pursued within existing organizations. Furthermore, Van de Ven (1996) has demonstrated that there are major commonalities between new independent venture creation and venture creation inside existing firms. As this work takes the perspective of innovation processes within existing SME, we find the literature to be compatible with the FFE literature discussed above (Shane & Venkataraman, 2000).

Over the next paragraphs, the three theoretical views of opportunity identification will be described in closer detail and related to the FFE approaches presented earlier.

2.2.2 The Opportunity Recognition View

Opportunity Recognition, as inspired by neoclassical economists' equilibrium theories (Acs & Audretsch, 2010) has been the main focus of early entrepreneurship research (Shane & Eckhardt, 2003). Drawing on notions of perfectly informed individuals and the power of incentive-based market forces, the matching of individuals and opportunities is mainly seen as an allocation problem of existing demand and supply.

As all market participants have all the information necessary at any point in time to recognize an opportunity arising from under-served demand in the marketplace, everyone could potentially become an entrepreneur. The entrepreneurial opportunity under the recognition view is characterized by known supply and demand and

therefore susceptible to mathematical instruments of optimality calculation (Baumol, 1993). According to Knight's (1921) classification of uncertainty levels, the situation can therefore be characterized as being *risky*. Individuals can a-priori judge what the risk associated with every opportunity is going to be (Sarasvathy et al, 2003) and make an exploitation decision based on their own risk preferences. *Who* will eventually decide to exploit the opportunity is therefore purely based on individual preferences of the individual, i.e. their stable personality attributes or traits. In other words: Those individuals will become entrepreneurs that want to become entrepreneurs (Shane & Venkataraman, 2000). Owing to the long-held view that all individuals will be able to recognize the same opportunities at any given time, entrepreneurship researchers long have focused on the process after opportunities are recognized (Fiet, 1996).

Due to its focus on the characteristics of the individual, the opportunity recognition view has given rise to a rich body of literature on psychological trait research. This research has compared entrepreneurs with non-entrepreneurs in order to isolate defining characteristics of the former (Sarasvathy & Venkataraman, 2011). Tolerance for ambiguity (Begley & Boyd, 1987), risk propensity (Brockhaus & Horowitz, 1986), uncertainty preference (Kihlstrom & Laffont, 1979) or need for achievement (McClelland, 1961) have been among the traits studied. Yet, personality and demographic variables were not able to deliver clear and univocal results (Shaver & Scott, 1991) and have therefore fallen out of favour in entrepreneurship research (Gartner, 1990). Even though many authors still recognize the importance of personality traits for the study of entrepreneurship, they emphasize the need to also include non-personal variables as well as cognitive abilities and strategies as predictors of performance (Rauch & Frese, 2007).

2.2.3 The Opportunity Discovery View

Opportunity Discovery, a theoretical view based on the works of Austrian economists like Kirzner, Hayek and Schumpeter, extends the strict focus on the individual towards a joint consideration of the opportunity and the individual, i.e. the individual-opportunity nexus (Shane & Venkataraman, 2000). In this view, entrepreneurship as a phenomenon takes place at the point where a lucrative opportunity meets an enterprising individual. Following a positivist tradition, opportunities are seen as real and objective phenomena, existing independent of the actions of the entrepreneur (Alvarez & Barney, 2007) and entrepreneurship is the sequential and directed process of their discovery and exploitation (Shane & Eckhardt, 2003).

Taking a dis-equilibrium perspective, opportunities are conceptualized as transient inefficiencies in existing markets that await discovery by an entrepreneur who is willing to capitalize on and therefore eliminate them (Shane & Eckhardt, 2003). Sources of inefficiencies arise exogenously (Alvarez & Barney, 2007) as a result of underutilized resources, new technologies, unsated demand, and political and regulatory shifts (Venkataraman, 1997).

In their basic assumptions about the nature of markets, discovery scholars deviate from the neoclassical notion that prices are a reliable allocation mechanism to incentivize entrepreneurial activities. Rather, market forces are seen as incapable of generating adequate price signals about entrepreneurial opportunities in the future, as it cannot incorporate information about not yet invented products or technologies and not yet existing markets. Information mirrored in market prices therefore is necessarily incomplete (Shane & Eckhardt, 2003).

Another basic assumption underlying discovery theory is the uneven distribution of knowledge (Hayek, 1945), which is widely dispersed among individuals in society. Due to its wider dispersion, it will never be possible for one individual to collect all information necessary to a priori judge the risk associated with the exploitation of an opportunity. All individuals are therefore constantly faced with situations of uncertainty (Knight, 1921) where they cannot accurately predict the consequences of their actions. Due to the scarcity of attention resources (Simon, 1997) they have to engage in routine or heuristics based decision-making. The heuristics applied by individuals are based on their idiosyncratic knowledge, accumulated over time through education and practical experience. Due to their idiosyncratic life experiences, all individuals have different sets of knowledge at their disposal and therefore will not all come to the same conclusion in the evaluation of the same opportunity. This implies that different individuals will come to different judgments of the value of an opportunity presented to them. A famous example of this kind of miss-judgment is then-IBM chairman Thomas J. Watson's estimation that there was a world market for about five computers (Sarasvathy & Venkataraman, 2011). This phenomenon was highlighted by Shane (2000) who observed that eight groups of entrepreneurs, who were exposed to the same MIT invention (*three-dimensional printing technology*) chose to build eight different ventures around this invention, all based on their respective prior experience.

The discovery view posits that due to their idiosyncratic, private knowledge, some individuals at a certain point in time are able to recognize inefficiencies and possibilities for arbitrage in existing markets that are overlooked by other market

participants due to their lack of private knowledge. In other words: some individuals have developed absorptive capacity (Cohen & Levinthal, 1990) based on prior knowledge. The discovery of the opportunity by the entrepreneur is therefore not the result of a deliberate search process, but a spontaneous epiphany or insight of the individual who is alert to inefficiencies in the marketplace. Successful entrepreneurs foresee profit opportunities when they *come across them* (Kaish & Gilad, 1991). This epiphany grants a new access to already existing information or as Kirzner (1985) puts it, the breaking of existing means-ends relationship with the help of private information.

Hence, next to the access to new knowledge via *knowledge corridors* based on relevant prior knowledge, *low search costs* and the *embeddedness in a network of social ties* facilitating the access to peripheral knowledge, the defining characteristic of entrepreneurs is their ability to make the connection between new knowledge and new means-ends-relationships. This individual interpretative scheme is called *entrepreneurial alertness* (Kirzner, 1985) and lies at the heart of the discovery view.

Similar to the abandoned trait research, the discovery view also conceptualizes entrepreneurs as being systematically different from non-entrepreneurs. However, the differences arise from an ability to see opportunities through the cognitive process of entrepreneurial alertness. Hence, departing from the trait school's focus on stable, psychological characteristics, the discovery view examines dynamic, cognitive characteristics of the individual.

A body of empirical research inspired by the notion of systematic cognitive differences between entrepreneurs and non-entrepreneurs has developed over the past decade (Baron, 2006). For example, Gaglio & Katz (2001) propose that alert individuals are more likely to subconsciously engage in activities like counterfactual thinking or mental simulations that make them alert to disequilibrium situation and changes in their environment. The empirical findings give rise to the view that cognitive differences seem to exist and have an influence (Frank & Mitterer, 2009).

The implications of the discovery view are that entrepreneurs can increase their chances of discovery via two main mechanisms. On the one hand, systematic use of data collection and analysis techniques (Alvarez & Barney, 2007) such as market research, lobbying, futurology research or lead user involvement (von Hippel, 1994) will make it more likely that opportunities are discovered. The underlying rationale of this approach is that the more the future can be predicted, the better it can be controlled and thus uncertainties can be reduced (Sarasvathy & Dew, 2005). Under the discovery view, an evaluation and decision to exploit an opportunity can be made at a

single point in time, because there is no way the entrepreneur could influence the opportunity (Sarason et al., 2006).

On the other hand, application of risk-based decision-making tools such as NPV calculations, real options or scenario planning (Alvarez et al, 2010) and the compilation of a comprehensive business plan will secure, that the limited time window for the exploitation of the opportunity is used. Gartner et al (2005) make a strong case for the importance of planning in the entrepreneurial process. They cite a variety of studies (Honig & Karlsson, 2004; Delmar & Shane, 2003; Reynolds, 2007; Shane & Delmar, 2004) that found that completing a business plan and engaging in planning activities increased the chances of actually pursuing an opportunity successfully. By engaging in the process of planning, entrepreneurs make explicit their assumptions about the future and the value of an opportunity, which helps them to better assess the viability of an opportunity and the potential returns of resources to be invested (Delmar & Shane, 2003). It is, however, not necessary that the entrepreneur has those resources on hand. Rather, his role is to discover the opportunity and to bring it to the attention of resource owners by means of a compelling business plan. Stevenson's definition of entrepreneurship as "the pursuit of opportunity without regard to resources currently controlled" (1983, p.10) highlights this understanding of the role of the entrepreneur under the discovery view.

Critics of the discovery view and the connected theory of latent demand aver that the idea of opportunities lying open for discovery by alert individuals make it hard to define what is *not* an opportunity. Applying the theory of latent demand to the cases of Google's search algorithm or Starbuck's coffee shops, Sarasvathy & Venkataraman (2011) show how the logic can be drawn into absurdity. A purely passive discovery of the opportunities in those two examples does not seem to account for the fact, that those companies were only one of many in their respective industries but successfully managed to establish industries of their own by creatively changing their business models. They argue that the discovery view largely fails to acknowledge the creative element of entrepreneurship.

2.2.4 The Opportunity Creation View

Creation Theory, a theoretical perspective based on constructivism (Weick, 1979; Giddens, 1984) or social constructivism (Berger & Luckmann, 1966), is the latest contribution to the theoretical discussion about the interaction of opportunities and entrepreneurs (Edelman & Yli-Renko, 2010).

Opportunities, under this perspective, like much of the world around us are not presented as an objective reality awaiting discovery (Wood & McKinley, 2010). Rather they are thought to be socially constructed through the interaction of entrepreneurs and the environment they find themselves in (Alvarez et al, 2010). The notion of Ardichvili et al (2003, p.106) that opportunities are "made, not found" highlights this difference between the two views. Opportunity creation, hence, relies on the creative acts of individuals (Frank & Mitterer, 2009) and re-introduces the notion of Schumpeter's (1934) innovative entrepreneur (Buenstorf, 2007).

The creation view departs from the dualism of opportunity and individual as put forward in the discovery view, where the two phenomena are seen as separate and distinct from each other and only overlap at one point (Shane & Venkataraman, 2000). Rather, a duality of the two concepts is posited, such that the opportunity cannot exist or be understood separate from the entrepreneur creating it (Sarason et al. 2006).

Even though Alvarez & Barney (2005) note a bias in entrepreneurship research toward opportunity discovery, the creation view has attracted increasing scholarly interest. One reason is that it is seen as especially suited for situations characterized by what Knight (1921) labelled as true uncertainty, that are typical for most entrepreneurship effort taken in reality (Read et al, 2009). In such a situation, the consequences of actions are seen to be unknowable. Since neither supply nor demand can be known in advance, "even entrepreneurs with a great deal of time, or with unusual analytical abilities, will not be able to estimate the relevant probability distributions" (Alvarez & Barney, 2007; Miller, 2007). As opposed to risky or uncertain situations described by the discovery view, entrepreneurs under conditions of true uncertainty cannot resort to traditional risk-based data collection and analysis methods (Alvarez & Barney, 2007). Rather, a more iterative and incremental approach, based on heuristics (Busenitz & Barney, 1997) is called for. Entrepreneurs therefore embark on a learning process (Politis, 2005; Short et al., 2010), during which an initially blurred or fuzzy imagination (Sarasvathy et al, 2003) or idea (Dimov, 2007) is gradually developed into an entrepreneurial opportunity. In this process of sense-making (Weick, 1995), entrepreneurs engage in initial action and subsequent observation of the consequences

in the environment (Alvarez et al, 2010). Cognitive structures of the individual have a moderating role in the process (Frank & Mitterer, 2009).

Unlike in the opportunity recognition or discovery view, entrepreneurs are not seen as being a priori different from other people on any psychological or cognitive dimensions (Alvarez & Barney, 2007). However, the engagement in the entrepreneurial process has the potential to re-inforce certain cognitive patterns, so that characteristic heuristics or structures can be observed in experienced entrepreneurs. Differences, thus, are the result and not the cause of entrepreneurship (Hayward et al., 2006). The opportunity creation view therefore focuses on experienced or habitual entrepreneurs (Sarasvathy et al., 2003), who have engaged in deliberate practice inside the entrepreneurship domain (Sarasvathy & Venkataraman, 2011). They thus position themselves in the tradition of Simon & Chase's (1973) research on chess masters or Hayes (1981) studies of musical composers. Those studies found, that only through a long period of emersion in a field, usually around ten years (Ericsson et al., 1993), entrepreneurs can acquire the cognitive structures necessary for opportunity construction.

The theoretical debate between the dominant discovery and the emerging creation view has up to this point been largely conceptual in nature (Edelman & Yli-Renko, 2010). While discovery is firmly grounded in Austrian economics, opportunity creation has been criticized for lacking articulation as a single, coherent theory in literature (Alvarez & Barney, 2007).

2.2.5 Structuration Theory as a General Theory of Opportunity Identification

In order to connect the several strands of research on the entrepreneurial opportunity construct, the search for a more general theory of opportunity creation has been proposed (Jack & Anderson, 2002). A general theory, in contrast to more data-based grounded theory, has the potential of linking the theoretical and methodological diversity in a field and reconciling the dichotomy of recognition/discovery and creation (Chiasson & Saunders, 2005). Furthermore, a general theory can ensure the connectivity with other research areas (Layder, 1998), such as the fuzzy front end of innovation (FFE) literature (Kobe, 2010). Building on Jack & Anderson's (2002) first introduction to the field, Chiasson & Saunders (2005), Sarason et al. (2006) and Bhomwick (2011) have developed Anthony Giddens' (1984) structuration theory as a general theory of entrepreneurial opportunity creation. This work has proved to be a useful lens on the opportunity creation process (Short et al., 2010) and will be described in the following paragraph.

Structuration Theory, as introduced by Giddens (1984), is rooted in the philosophical school of constructivism. As opposed to more positivistic theories, constructivism sees much of the world not as objective reality but rather as a product of social construction (Wood & McKinley, 2010). The process of the construction of social reality through the lens of structuration theory (ST) takes the form of a reciprocal interaction between human actors and pre-existing social structures (Short et al., 2010). Interaction of *structures* on the one hand and *human actors* on the other hand is thus the main driver for societal change. Figure 10 visualizes the basic mechanism underlying the theory of structuration).

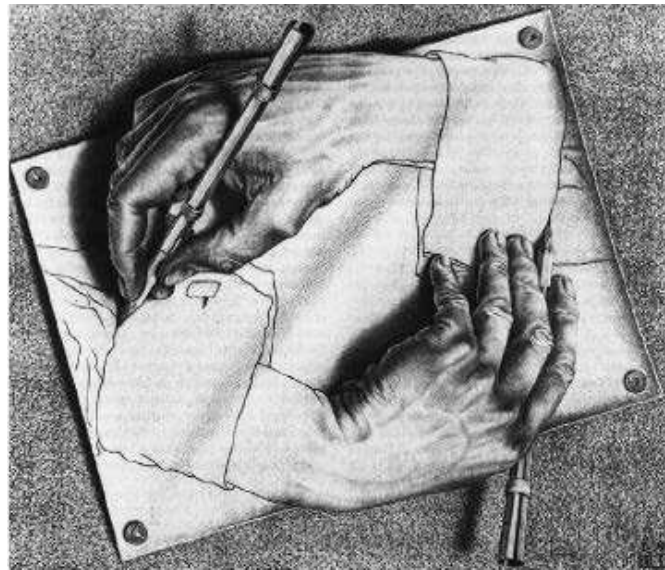


Figure 10: M.C. Escher's "Drawing Hands" as a depiction of the interplay between structure and action (Sarason et al., 2006, p.291)

Structures

Structures have both an enabling and a constraining influence on human action. They are composed of *rules* and *resources*. Rules represent shared knowledge and organizing regimes that guide social interaction (Sarason et al., 2006), including moral rules, linguistic rules or procedural rules (Chiasson & Saunders, 2005). Individuals must draw on this set of rules in order to become active in society (Jack & Anderson, 2002). Rules therefore represent the constraining element of structures.

Resources can be divided into *allocative* and *authoritative resources*. The former grant the individual power over material objects such as means of production or income. The latter represents authority over people such as in formal organizations. Consequently, resources represent the enabling element of structures, as they allow individuals to draw upon them in their actions.

Individual Action

The capability of the individual to engage in purposeful, knowledgeable and reflexive (Sarason et al., 2006) action is at the heart of ST and labelled as *agency*. In contrast to deterministic theories, ST sees individuals as empowered to make a choice to become active and thus to have an influence on the social and economic system (Sarason et al., 2006).

Action by individuals is observed in *scripts*. According to Barley (1986), scripts can be described as "behavioral grammars that inform everyday action". The kind of scripts individuals choose to engage in is inherently dependent upon the *conceptualization* of the individual. By using certain *scripts* in line with their *conceptualization*, individuals engage in *agency* and cause intended as well as unintended *consequences* within a particular business and social structure. In a next step, the individual reflexively monitors the consequences of the action along three dimensions: (1) *legitimation* criteria are used to assess whether the script is morally and practically acceptable by other individuals in a certain structure, (2) *signification* criteria are applied to judge whether the script is seen as competent in allowing the individual to act quickly within a certain structure and (3) *domination* criteria assess the script according to the ability to provide power over social and material resources.

In the process of reflexive monitoring, individuals adapt their scripts and learn to distinguish successful and unsuccessful ways of action within a certain structure (Chiasson & Saunders, 2005).

Application of ST in Entrepreneurship

ST has been first used in the entrepreneurship domain by Jack & Anderson (2002) in order to highlight the interplay of rural entrepreneurs (actors) and their local environment (structure) in the process of creating locally embedded ventures. Through such a lens, the venture represents the outcome of the entrepreneur - opportunity interactions through time and space (Sarason et al., 2006). Applying structuration theory on entrepreneurship results in a conceptualization of opportunities as suggested by the creation view: individuals who engage in action based on subjective interpretations of their environment and resources (Acs & Audretsch, 2010) proactively influence social structures and create idiosyncratic opportunities (Sarason et al., 2006). However, the applicability of structuration theory extends beyond entrepreneurship literature and offers a theoretical bridge to connect entrepreneurial approaches with the planning and adaptation-oriented approaches prevailing in FFE literature. In order to make use of this opportunity, both Sarason et al. (2006) and

Chiasson & Saunders (2005) stress the need to understand the contents of an entrepreneur's script because the contents codify what the entrepreneur believes to be effective, legitimate, and powerful (Gaglio & Winter, 2009).

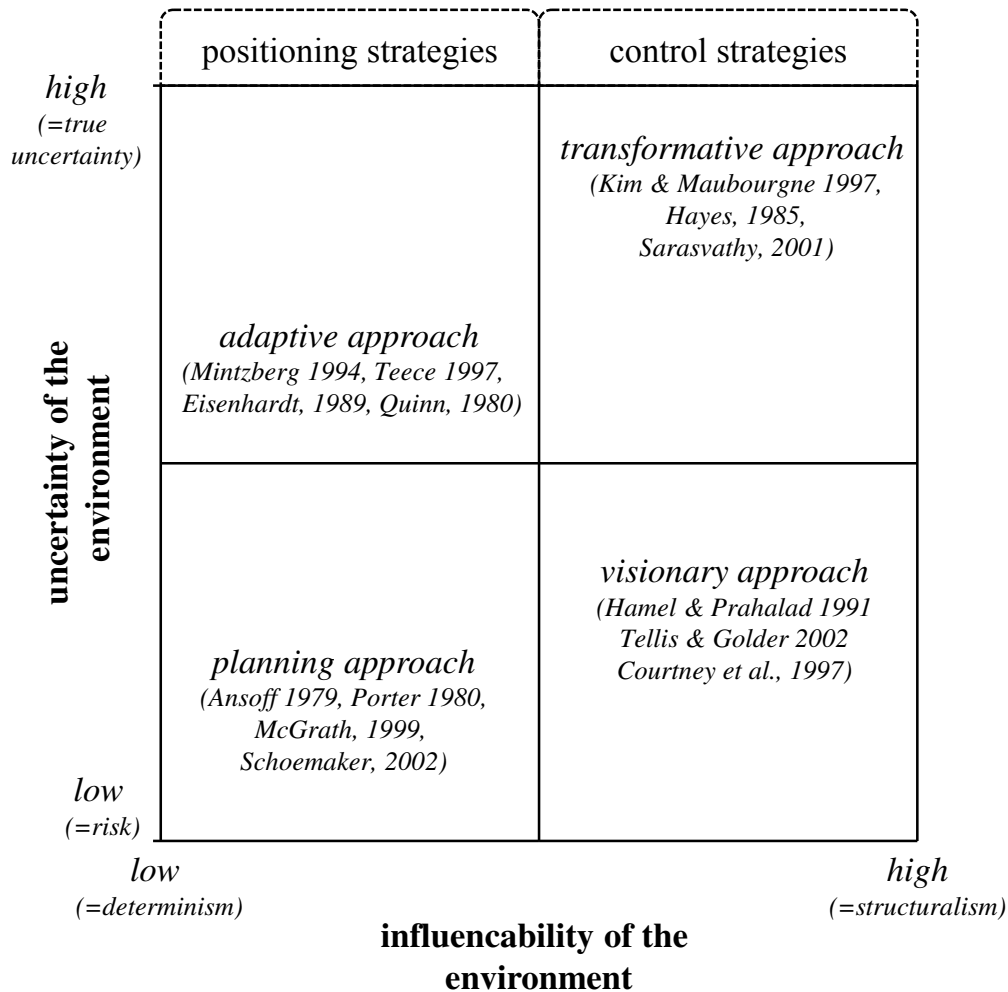


Figure 11: Different strategies for the FFE depending on environmental uncertainty and influencability (adapted from Wiltbank et al., 2006)

By accounting for the notion brought forward by structuration theory that individuals through their actions have the possibility to actively influence their environment, the uncertainty-based dichotomy of planning and adaptive approaches introduced in chapter 2.1.4.3 can be further extended. Both adaptive and planning approaches can be seen in a rather deterministic tradition of implicitly assuming that individual actors have to adjust to an objectively existing environment that cannot be actively influenced. They therefore provide instruments for managers to position themselves in this environment in an optimal way, by reducing uncertainty through extensive forecasting or quick adaptation. In Figure 11 they therefore are labelled as *positioning strategies*.

As opposed to positioning strategies, *control strategies* implicitly assume that the environment is subject to changes through individual action and therefore influenceable. They therefore subscribe to a structuralist tradition. Authors like Hamel & Prahalad (1991) with their theory of corporate imagination or Courtney et al.'s (1997) shaping strategies stress the role of a strong vision that is imposed on the future and made happen. In this sense, they advocate an approach to uncertainty reduction through a strong vision of the future. If the visionary leader pushes hard enough, the vision will be made real. A classic example of a strong vision that was imposed on the environment was Microsoft's idea of the personal computer on every desk (Wiltbank et al., 2006) that revolutionised the computer industry. Tellis & Golder (2002) in their book *Will and Vision* provide a number of other examples where companies – all of them large firms – succeeded in imposing their vision on an entire industry. Those approaches therefore are labelled as *visionary approaches*.

Deviating from the assumption that uncertainty in the environment can be reduced by the adoption of a strong vision some authors that subscribe to a structuralist tradition have developed approaches on how to shape the future amidst uncertainties. Kim & Mauborgne's concept of value innovation (1997) and derived blue ocean strategy (2005) mirror this approach. Instead of focusing on matching rivals in overcrowded markets, they recommend firms to create own markets by modifying their value proposition. They hence should focus on how they can actively influence their environment without trying to overly predict what strategic moves competitors will make next. In a similar manner, Sarasvathy (2001) suggested that successful entrepreneurs focus on their ability to shape their environment in situations characterized by true Knight'ian (1921) uncertainty. In such a situation, reduction of uncertainties through the process of prediction is no longer possible and must be accepted as a given. Based on the observation of entrepreneurs exposed to such situations, Sarasvathy (2001) was able to elicit a set of actions that proved to be successful and that she identified as an *effectual logic*. Approaches like blue ocean strategy or effectuation that are both non-predictive and non-visionary (March, 1979), are labelled as *transformative approaches*.

In the following paragraphs, Sarasvathy's (2001) effectuation principles will be presented in detail as they represent a practical embodiment of an approach that is both suitable to situation with high degrees of uncertainty and emphasizes the role of behavioural routines in the identification or creation of opportunities. It thus addresses the shortcoming observed in *positioning strategies* currently dominating the FFE literature when applied in a SME context (cf. chapter 2.1.4.3)

2.2.6 Effectuation

As opposed to the opportunity discovery view, the opportunity creation view long has lacked a sound theoretical basis (Alvarez & Barney, 2007). Consequently, researchers have focused more on developing practice-relevant construction principles and were less concerned with descriptive theory building (Sarasvathy et al., 2008). Recently, some researchers have made first attempts towards empirically testing the creation view (Sarasvathy, 2001; Baker & Nelson, 2005) with Sarasvathy's logic of effectuation being the one that found greatest response. Effectuation has been found as one logic that works in an environment characterized by *true, Knight'ian uncertainty* (Sarasvathy et al., 2008). It comprises a set of heuristics or cognitive structures observed in experimental settings (Sarasvathy et al., 1998; Sarasvathy & Dew, 2005; Dew et al., 2008; Read et al., 2009) with experienced entrepreneurs or through qualitative field studies (Sarasvathy & Kotha, 2001; Harmeling, 2004; Harting, 2004) and can be characterized as a grounded theory (Küpper, 2009, p.61; Glaser & Strauss, 1967), based on “actually observed experienced entrepreneurs in action” (Sarasvathy & Venkataraman, 2011, p.125).

In line with the opportunity creation view outlined in chapter 2.2.4, effectuation focuses on experienced entrepreneurs (Sarasvathy et al., 2003). The idea, that the behaviour of experts could explain phenomena in the field of entrepreneurship was first introduced by Mitchell (1994) who advocated studying entrepreneurship as a form of expertise. Mitchell observed that “evidence is mounting that entrepreneurship is a profession which is susceptible to expertise [...] luck [...] intelligence [...] [b]ut mainly [...] to the accumulation of ordinary experience” (1997, p. 137). Dew et al. (2009) as well as Read et al. (2003) consequently found out that in the process of accumulating expertise in their particular business environment, entrepreneurs were able to develop certain cognitive structures that set them apart from first-time, novice entrepreneurs. Based on those findings, Sarasvathy & Venkataram (2011) bring forward the proposition that there exists a set of “specific learnable and teachable techniques” for decision-making under conditions of uncertainty. The main message of effectuation is that “instead of ambiguity-loving risk takers, the entrepreneurial mindset rests on the logic of non-predictive control. [...] Effectuation seeks to demystify entrepreneurial decision-making by describing how strategies emerge through the use of specific cognitive approaches [...] and/or through particular problem-solving techniques” (Dew et al., 2008, p.320).

	Causation	Effectuation
View of the future	Prediction: The future is a continuation of the past; can be acceptably predicted	Design: The future is contingent on actions by willful agents
Givens	Goals are given	Means are given (Who I am, what I know, whom I know)
Basis for commitment	Should: Do what you ought to do – based on analysis and maximization	Can: Do what you are able to do – based on imagination and satisficing
Attitude towards others	Competition: Constrain task relationships with customers / suppliers to what is necessary	Partnership: Build your market together with customers / suppliers
Stakeholder acquisition	Instrumental view of stakeholders: Project objectives determine who comes on board	Instrumental view of objectives: Who comes on board determines project objectives
Predisposition toward risk	Expected return: Calculate upside potential and pursue best opportunity	Affordable loss: Calculate downside potential and risk no more than you can afford to lose
Predisposition toward contingencies	Avoid: Invest in techniques to avoid or neutralize surprises	Leverage: Invest in techniques open to leverage surprises Into new opportunities
Underlying logic	To the extent we can predict the future, we can control it	To the extent we can control the future, we do not need to predict it

Table 4: Contrasting effectual and causal reasoning (adapted from Sarasvathy & Dew, 2005)

A popular way of illustrating those cognitive approaches and techniques (Sarasvathy, 2001) is the example of a chef being asked by a guest to "surprise" her with a meal to be prepared with whatever ingredients he would find in his kitchen. Before accepting the challenge the chef will estimate the potential loss of reputation for the case that the menu will be rejected and decide whether he could afford this loss. A novice chef may not be able to prepare a meal without guidance from a cookbook and therefore would be unsuitable for the task. However, an expert chef who has prepared many meals throughout his career will be able to imagine the interplay of different ingredients, tastes and textures. The range of possible combinations of ingredients the chef will be able to imagine is dependent on his prior cooking experience. Based on his

professional network he could then contact other chefs he knows and team up with them in the cooking task. As they start preparing the meal, the guest may show up in the kitchen and provide some information on food allergies, which will make it necessary to totally re-arrange the menu. In the end the cook will serve a meal to the guest.

This example highlights what effectuation is: A set of heuristics applied by experts for the task of decision making under uncertainty. It also demonstrates the basic principles of effectuation, namely: (1) relying on creation rather than prediction, (2) means- rather than goals-orientation, (3) risking what one can afford to lose, (4) openness to collaborate rather than compete, and (5) creatively leveraging contingencies.

Means Orientation / Experimentation

The first principle, namely the rejection of a predictive approach, characterizes effectuation as a control strategy (Dew et al., 2008). Sarasvathy (2001) thus positioned effectuation in opposition to a so called *Causation* approach that emphasizes the importance of planning and positioning (cf. Table 4) and can be seen as encompassing Wiltbank et al.'s (2006) *planning* and *adaptive* approaches and the risk-based approaches presented in chapter 2.2.3 on the *opportunity discovery view*. While causation puts forward a view of entrepreneurship as “the pursuit of opportunity without regard to resources currently controlled” (Stevenson, 1983, p.10), effectuation is conceptualized as explicitly means-oriented and focuses on the creation of something new with given means (Küpper, 2009). The starting point of all entrepreneurial action is the means directly controlled by the entrepreneur: the own identity (Who am I?), own skills and experiences (What do I know?) and the own network (Who do I know?).

Those means on the one hand constrain the possible actions that can be taken and on the other hand enable the entrepreneur to take a multitude of actions towards a variety of possible ends. Contrary to prediction-based causation approaches, those ends or goals are not a priori known and emerge in the process of taking action. In an inversion of traditional predictive means-ends logic, entrepreneurs turn from mobilizing means for defined ends (goals) towards exploring ends for defined means. Those means enable the entrepreneur to take action in the absence of goals. As goal-setting always involves some kind of prediction of the future, accurate goal-setting under conditions of Knight'ian uncertainty is virtually impossible. Means-orientation offers a way out of the dilemma and enables action in uncertain environments.

In their 2004 article, Dew et al. describe how entrepreneurs can create markets by

making use of existing means (existing technologies, competences, etc.) and applying them towards new ends (new processes, new usage contexts, etc.). They mention the example of Edison's invention of the gramophone, which had originally been conceptualized as a dictation machine. Through experimentation, an additional usage of the machine could be found in the entertainment industry as a jukebox. This entrepreneurial process of experimentation with existing means and its adoption in a new domain is seen as characteristic for an effectual approach. In the literature on effectuation, the principle of means-orientation is also called the "bird-in-hand" principle following the saying "a bird in hand is worth two in the bush" (Sarasvathy, 2008, p.88). Rather than relying on the uncertain notion of two birds sitting in the bushes waiting to be caught, the entrepreneur is better off making best use out of the one bird already under direct control. This approach also confronts often-held beliefs of entrepreneurs as pronounced risk-takers (Carsrud & Brännback, 2009). Rather, in line with Schumpeter's (1939, p.104) assumption that "risk taking is no part of the entrepreneurial function. It is the capitalist [banker] who bears the risk", entrepreneurs are seen as being rather cautious in financial matters. This insight gives rise to the second principle of effectuation: affordable loss.

Affordable Loss

In their early investigation on investment decision making of entrepreneurs and bankers Sarasvathy, Simon & Lave (1998) found fundamentally different approaches in the two groups. Bankers tackled the problem by first defining a certain target outcome irrespective of the level of risk associated. In a second step, they attempted to decrease the risk through hedging, insurance or other means. While bankers focused on the upside potential of an investment, entrepreneurs rather looked at the downside potential or the worst case scenario. Their approach was to first pick a certain level of risk they felt comfortable with and subsequently search for ways to improve outcomes at this given level of risk. The two alternative approaches are depicted in Figure 12. Dew et al. (2009b) also observed that experienced entrepreneurs often are reluctant to use the instruments provided by neoclassical investment theory or real options reasoning. Instead of framing an investment problem under an expected return perspective, they rather tried to limit their investments to levels they felt they could afford to lose if worst came to worst (Miller, 2007). Empirical research in different cultural setting shows that entrepreneurs are much more prone to use decision making approaches based on affordable loss heuristics than rational return calculations (Keh et al., 2002; Gustafsson, 2009). In their study on investment behaviour of 37 managers and 27 expert entrepreneurs, Read et al. (2009b) confirmed that entrepreneurs were

more concerned with the cost aspects of an opportunity and applied affordable loss heuristics, while managers were “drawn to the opportunity associated with the greatest possible financial upside, with no mention of cost” (p.10).

While the principle of means-orientation opens the space of possible actions of the entrepreneur, the principle of affordable loss limits those choices by applying a selection criterion. By following the two principles, entrepreneurs can find out which and how many of their existing means they are willing to deploy and possibly lose (Küpper, 2009) in the process of initial experimentation.

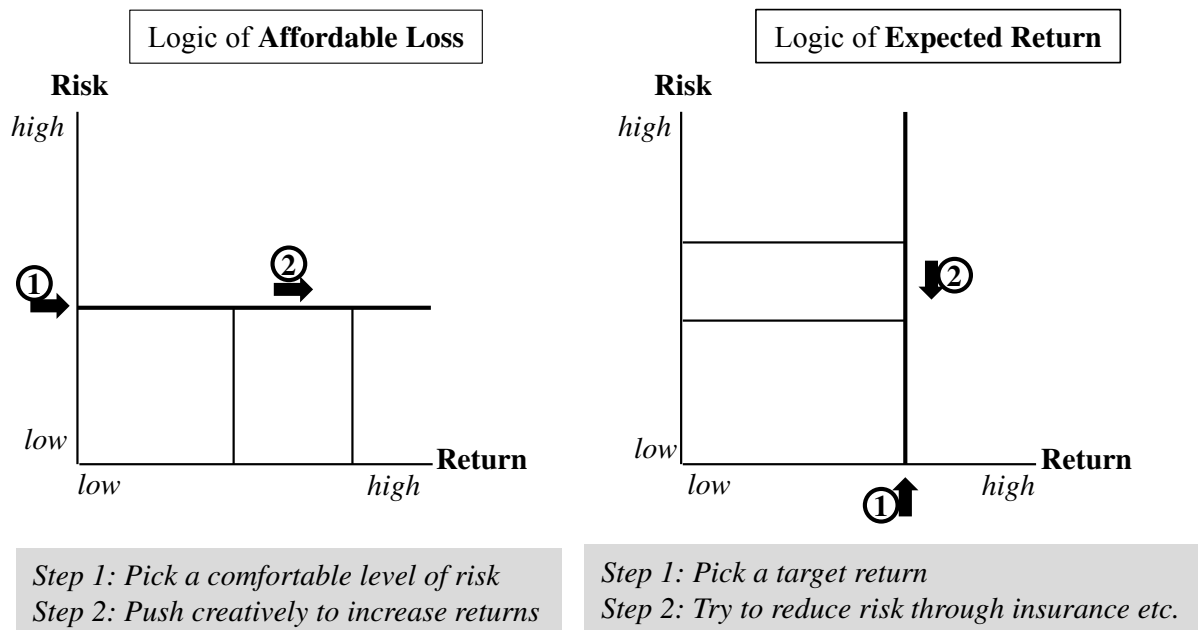


Figure 12: The logics of affordable loss and expected return (Sarasvathy et al., 1998, p.213)

Partnerships / Pre-commitments

Entrepreneurs, however, can both extend their available means and improve affordability by including additional partners in the project. The emphasis on partnerships and early commitments constitutes the third principle of effectuation, which is at times referred to as the *crazy quilt* principle. By encouraging third parties like customers, suppliers or research institutions to make small commitments as the project progresses, a network of relationships emerges that shares a common vision of working together. Who will be accepted to make a contribution is not pre-determined by overarching goals as in the causation approach. Rather, everyone who buys in to the project is allowed to do so. Every new stakeholder that contributes to the project influences the direction of the endeavour, incrementally decreasing the uncertainties involved and narrowing the space of possible outcomes. Furthermore, initial feedback on the experimentation process can be received. In his dissertation on the birth of the RFID industry, Dew (2003) illustrates how through the use of stakeholder commitments, a small group of entrepreneurial individuals were able to wave together

a coalition of stakeholders that drove the evolution of the RFID technology and the related *internet of things*. Küpper (2009) mentions the example of a customer that commits to buying a yet to be developed product and therewith helps to reduce the market risks associated with an innovation project as well as eliminating the need for market studies advocated for by the causation approach. Those *pre-commitments* are seen as a powerful instrument to controlling uncertainties in the market sphere.

According to Venkataraman (1997), experienced entrepreneurs can make use of their social capital in the form of an existing network of contacts and acquaintances in order to reduce moral hazard and adverse selection issues and are especially suited for the task of partnership building. Entrepreneurs following an effectuation logic therefore can serve as a focal point for the building of a coalition of actors contributing to the development of a new product or technology under conditions of uncertainty. Meijer et al., 2007 stress the importance of this approach by “subscrib[ing] to the idea that the development of emerging [...] technologies is the result of actions of multiple entrepreneurs” (p.5837). An effectual logic therefore requires the entrepreneur to imaginatively patch together stakeholder commitments and to continually build and sustain a strong sense of identity (Sarasvathy & Dew, 2005).

Leveraging Contingencies / Flexibility

The fourth principle of effectuation states that in every project there will be some unexpected surprises or contingencies that call initial plans into question. Those contingencies can be seen negatively as an expression of Murphy’s Law or positively as a stroke of serendipity. While a planning-based approach will focus on either minimizing the effect of potential disturbances through avoidance or overcoming them through perseverance, an effectual logic encourages the entrepreneur to exploit those contingencies. Surprises, whether good or bad, can be seen as inputs in the opportunity creation process (Sarasvathy, 2008) and therefore should be welcome by entrepreneurs. A popular example for the creative handling of obstacles is the development of Viagra, which was originally devised as an antihypertensive and showed a number of unwished side effects, which eventually led to the adaptation of its final area of application. In the literature on effectuation, the creative leveraging of unexpected events has been called the *lemonade principle*, derived from the popular expression ‘*when life gives you lemons, make lemonade*’. Entrepreneurs that follow the lemonade principle have a tendency to be flexible as expressed in a willingness to modify and adapt their actions to changing circumstances and to customize their solutions (Read et al., 2009). They also expose themselves actively to new ideas and are open for controversial information.

2.3 Theoretical Research Framework for Data Collection

As discussed in chapter 1.3.3, the collection of empirical data as intended for this study is done via the case study method, using the instrument of semi-structured interviews with CEOs of SMEs. In order to guide the construction of the interview guideline and to ensure that the data collection efforts are well-grounded in literature, a research framework is applied. According to Miles & Huberman (1994), the research framework gives an overview of the key factors, constructs and variables deemed as relevant for the current study and their presumed relationships. For the study at hand, the main factors of interest are the degree and sources of environmental uncertainties as perceived by SME and the strategies applied to enable action-taking under those uncertainties.

The research framework applied is based on the work of Freel (2005) on the sources of environmental uncertainty as perceived by smaller firms (Freel, 2005) and the different strategies to handle those uncertainties as proposed by a control vs. a positioning approach discussed above. Freel (2005), in his study of the effect of environmental uncertainty on the degree of innovation behaviour in SME, developed a model of perceived environmental uncertainty that is shown in Figure 13. Based on a review of prior literature, especially Duncan (1972), Miles & Snow (1978) and Wernerfelt & Karani (1987), the model distinguishes three spheres of a firm's environment where uncertainties can potentially reside: the economic (regulatory), the industrial/market, and the resources (technological) sphere.

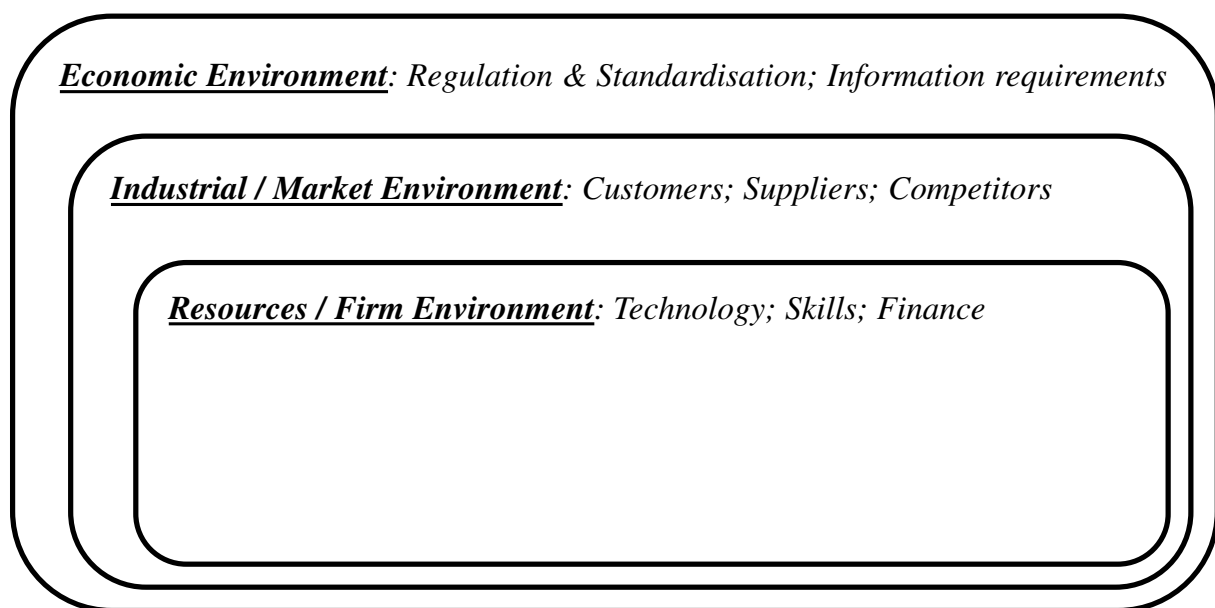


Figure 13: Sources of perceived environmental uncertainty (Freel, 2005, p.51)

The Economic Environment on the one hand includes regulatory uncertainties that make it difficult to accurately assess the future development of standards, legal requirements or available subsidy schemes in an industry. Furthermore, it refers more generally to the amount of information a firm perceives it must be familiar with in order to be able to forecast future developments in the economy. Based on a positioning approach, those uncertainties can be managed by engaging in the more extensive search for information and the more thorough planning of future activities in order to avoid encountering contingencies in the future. A formal business plan could be part of those planning activities. In contrast, a control-based approach would call for less planning and putting a greater emphasis on flexibly adapting to contingencies as they arise. Instead of actively searching for information in the environment, serendipitous ideas can serve as a starting point to consider initiating an innovation project.

The Industrial / Market Environment refers to uncertainties as a result of an inability to accurately forecast the future preferences of customers and the competitive situation that is going to characterize the industry in the future. A positioning approach would suggest applying a number of market research techniques in order to reduce uncertainties in the market domain. Competitive uncertainties can be reduced through a thorough analysis of current and potential players in the industry which can result in the strategic positioning in vis-à-vis those competitors. A control-based approach would reject the option to predict the preferences of a future representative customer and would rather try to get early feedback and commitments from anyone who is interested in contributing to the ensuing innovation project. Rather than trying to develop a product for a not yet existing market, the market is used in order to develop a not yet existing product. Experimentation, the setting-up of collaborations and the securing of early commitments fall under this approach.

The Resources / Firm Environment contains those uncertainties that make it difficult to accurately forecast the future development of relevant technologies and therefore the skills required to successfully conduct an innovation project. Additionally, a lack of information about future funding needs leads to financial uncertainties. Based on a positioning approach, those uncertainties could be managed using the instruments of traditional corporate finance subsumed under the expected return approach. A clear goal orientation can help the firm to deduct the necessary skills required to reach those goals and to invest in their acquisition. As opposed to this strategy, a control based approach would call for a strict means orientation. Instead of trying to bring additional skill-sets under the own control to reach an identified goal, rather the means under

direct control define the space of possible goals that could be reached. Financial uncertainties can be controlled by subjectively defining a maximum affordable loss for the project.

Figure 14 summarizes the sources of perceived environmental uncertainties for SME as proposed by Freel (2005) and the kinds of activities and behaviours they would call for under a control or positioning approach. This theoretical framework is used in order to support the theory-guided within-case analysis of the empirical data presented in chapter 3.2. Next to the different sources of environmental uncertainty, its degree in a specific case is indicated using a black-and-white coding scheme. Therefore, the three boxes in the middle of the framework are highlighted in black (high), grey (moderate) or white (low). While a low degree of uncertainty represents a Knight'ian (1921) situation of *risk*, a moderate degree points to a situation of *ordinary uncertainty* and a high degree can be interpreted as indicating *true uncertainty* in the respective environmental sphere.

Likewise, the prevalence behaviours based on either positioning and/or control approaches (arrows on the left and right side of the framework) is indicated using the same black-and-white scheme.

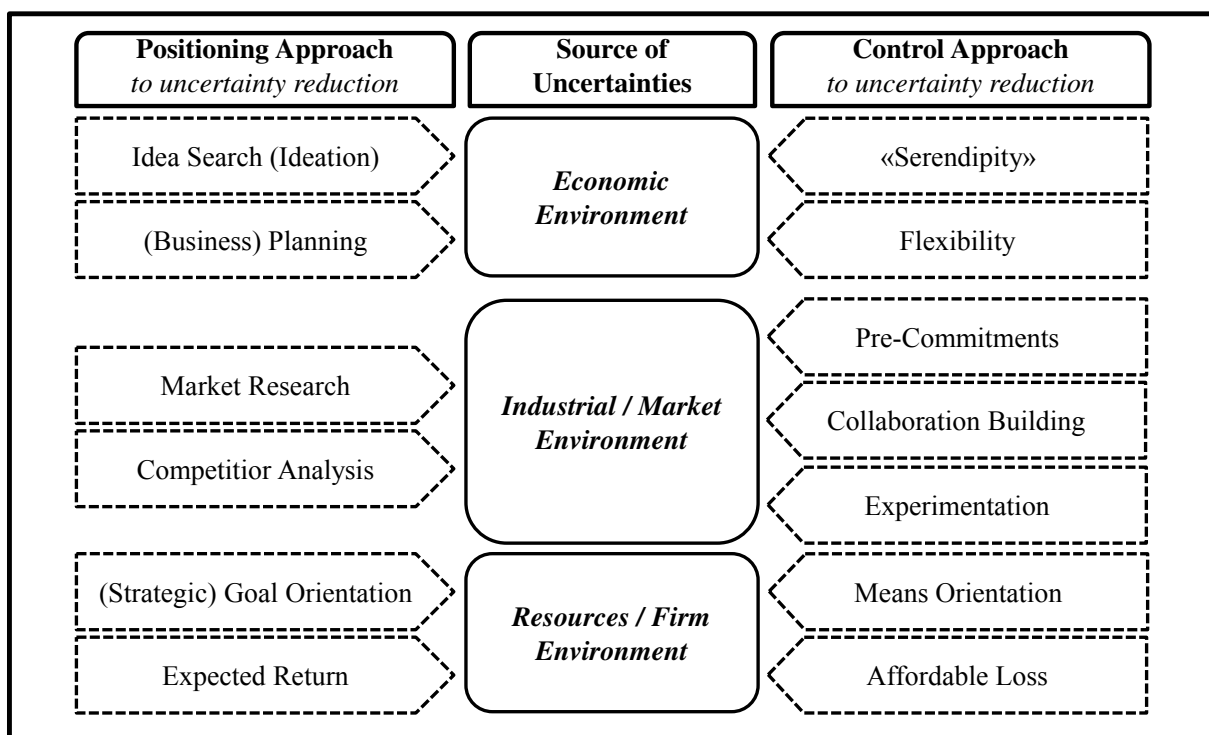


Figure 14: Theoretical framework for data collection and within-case analysis

3 Case Studies of SME Innovations in the Swiss Energy Sector

3.1 The Energy Sector

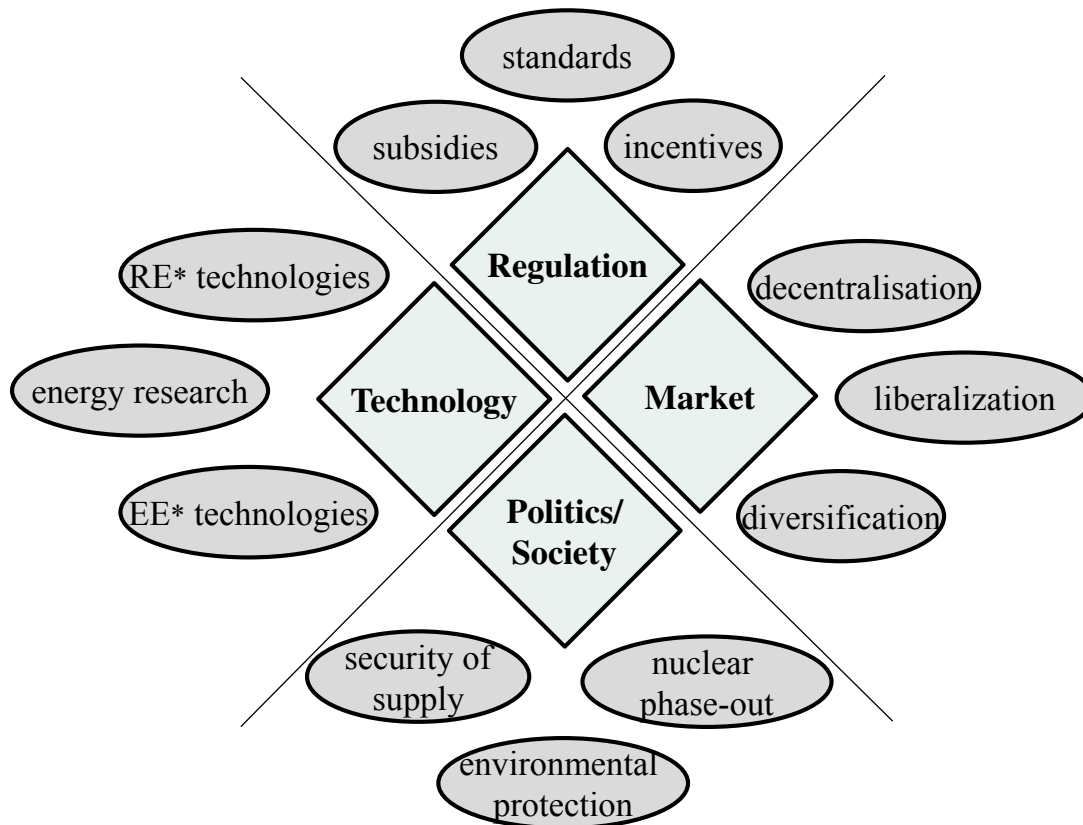
3.1.1 Fundamental Changes and Uncertainty in the Energy Sector

The empirical setting for this study is the energy sector, more precisely the Swiss renewable energy and energy efficiency (RE/EE) industries. The sectoral focus was chosen because it is characterized by a dynamic environment and changing circumstances in a variety of spheres, which lets it appear suitable for the study of how entrepreneurs handle situations of uncertainty. Schumpeter identified technological, political, regulatory, social and demographic changes as likely sources of exogenous shocks (Frank & Mitterer, 2009) that can cause an industry to abandon its equilibrium state. The subsequent re-alignment of industry structures is characterized by a high degree of uncertainty, as new products, services, raw materials, geographic markets, production methods or organizational forms may be introduced by entrepreneurial individuals (Schumpeter, 1926).

The energy sector in general and the Swiss RE/EE industries in particular provide a suitable empirical context for this study, as they are characterized by fundamental changes in all of the spheres mentioned by Schumpeter (1912). According to several authors, the renewable energy sector in many countries is characterized by high levels of uncertainty (Foxon et al., 2005; Jacobsson & Bergek, 2004; Kemp et al., 1998). While over a long time the energy sector has been dominated by a few large companies, the complex interplay of changes has only recently led to a collapse of traditionally high industry entry barriers. In the wake of those developments, smaller companies start entering the energy sector that is still in flux. As those companies are currently in the process of developing new products for this sector for the first time, an ideal window of opportunity has opened for case study researchers. Figure 15 gives an overview of the multitude of areas that recently have been subject to fundamental changes. The following chapters provide further details on how those changes contribute to increasing uncertainties in the Swiss RE/EE sector.

Another factor contributing to the newly won attractiveness of the energy for SME is its location at the intersection point of a variety of traditionally SME-dominated industries like construction, recycling, heating, IT or biotechnology industries. Thus,

as market entry barriers decrease, SME find a situation where their prior knowledge and experience is transferable to a new situation. This transferability – together with high growth rates –, according to Shane & Venkataraman (2000), increases the probability of SME entering the sector.



* RE = renewable energy; EE = energy efficiency

Figure 15: Sources of uncertainty in the regulatory, political, technological and market spheres of the Swiss energy sector (own illustration)

Over the next chapters, the recent developments in the different spheres will be analysed in greater detail, illustrating in what ways they contribute to the trend towards increased uncertainty in the energy.

Based on a definition of the RE/EE industries that gives consideration to those trends, four different technology-based industries will be chosen in order to illustrate more closely how in nine specific cases, ten Swiss firms have attempted to introduce product innovations in the face of those uncertainties.

3.1.2 The Swiss Energy Sector

While the fundamental trends towards greater dynamism and resulting uncertainty in the energy sector apply for most developed countries, there are considerable differences in how each country chooses to respond to those trends. For the purpose of this work, the focus is on Switzerland. This is justified by the characteristics of the Swiss energy sector that make it especially suitable for the study of the consequences of increased dynamism and uncertainty.

- i. The country is landlocked without natural occurrences of oil or gas and has by law given up the nuclear energy option. Apart from a roughly 20% share of water power, it will in the medium-term have to rely on energy imports. Switzerland is therefore directly exposed to fundamental changes and resulting uncertainties in the (geo)political sphere outlined in chapter 3.1.3.
- ii. The Swiss government, in the context of international agreements and national laws, has agreed to reduce emissions of CO₂ until 2020 by 20% and to increase the share of renewable energy sources to 50% (BFE, 2008). In order to reach those goals, new regulatory mechanisms, subsidy schemes and taxes have been introduced. The Swiss energy sector is therefore characterized by a dynamic development and resulting uncertainties in the regulatory sphere outlined in chapter 3.1.4
- iii. Furthermore, some of the most advanced research centres and companies in the areas of renewable energy technology and energy efficiency are based in Switzerland. Private and public funding of applied and basic research in the areas of energy efficiency and renewable energy technologies are among the highest in the world (SBF, 2011). The Swiss energy sector is therefore at the forefront of the dynamic developments and resulting uncertainties in the technological sphere outlined in 3.1.5.
- iv. With its federalist structure, diverse geography and scattered settlement structures Switzerland makes high demands on the provision of energy under a multitude of heterogeneous environmental conditions. Those characteristics of the Swiss energy sector make it especially suitable for the early deployment of renewable energy technologies, whose cost structures are highly sensitive to local circumstances.
- v. Moreover, as a result of Switzerland's small and open economy, its companies are heavily export-oriented. The intense competitive pressure on the world market has led firms to focus on high productivity levels in order to achieve a competitive cost structure. Therefore, substantial incentives exist for the deployment of efficiency technologies in order to ensure the productive use of energy as an input factor in the production process.

3.1.3 Changes in the Geopolitical Sphere

For the satisfaction of their energy needs, developed countries today are heavily reliant on fossil fuels and nuclear energy. Taken together, fossil fuels including oil, coal and natural gas in 2009 accounted for 81.1% of OECD countries' primary energy supply. Another 11.3% was contributed by nuclear energy.

As most OECD countries with the notable exception of the U.S., Canada and some European countries are not endowed with considerable natural gas or oil occurrences, they are reliant on imports. Major exporters in 2009 were Saudi Arabia, Russia and Iran for oil and Russia, Norway and Canada for natural gas. In order to match supply with demand, a global and reliable system of international trade in fossil fuels had been established in the 1950's. Under the relative peace offered by the military and political conditions during the Cold War period, the system was able to provide the economies of industrialized nations with inexpensive fuels and thus enabled enormous industrial progress and wealth creation in those countries. However, starting in the 1970s and culminating in the fall of Communism, major geopolitical developments led to a destabilization of the well balanced system of international energy trade. Both the supply and the demand side were affected.

On the *supply* side, important oil exporting countries like Iran or Russia underwent fundamental political changes, giving cause for serious concern regarding their continuing reliability. Politically motivated suspension of deliveries as first used by OPEC countries in the 1970s oil crises have since added to those concerns and showed the economic vulnerability of developed countries in the energy sector. In such an environment, new ideas raised by progressive scientists and researchers like the notion of the finite nature of fossil fuels, and their economical and sustainable use fell on fertile ground. Some of the technical measures taken at the time like the introduction of daylight saving time and maximum speed limits made broad levels of the population familiar with the concepts of environmental protection, sustainability and energy efficiency.

On the *demand* side, incipient globalization led to the integration of larger parts of the world population in the international trade system. As countries like China, India and Brazil started their rapid industrial and economic development, energy demand of those countries rose dramatically. With hundreds of millions of people being brought out of poverty, the demand for energy-intensive appliances like refrigerators or cars experienced a major increase. In China alone the number of private cars has risen from 4 million in 2000 to 85 million in 2010 (Gordon & Zhang, 2011).

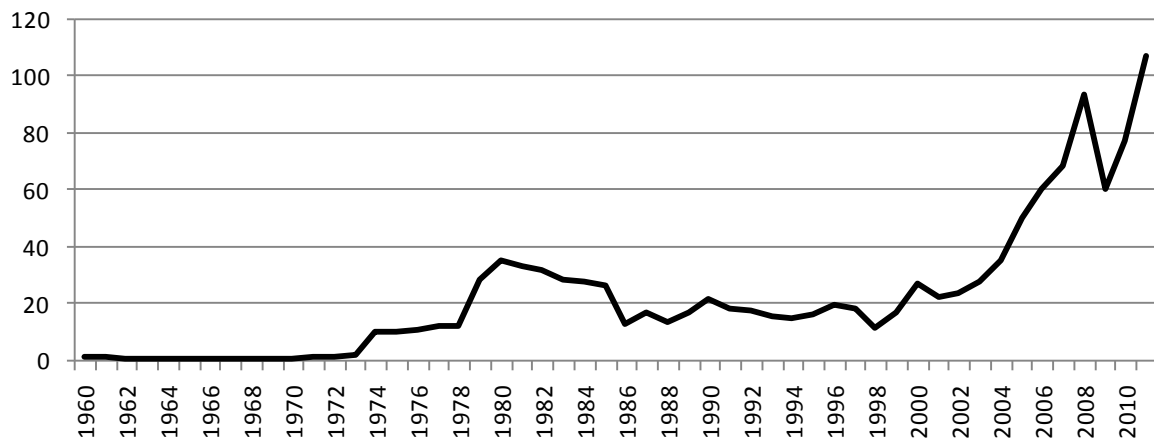


Figure 16: Average prices for OPEC crude oil from 1960 to 2011 in U.S. dollars per barrel (Statista, 2012)

The increased demand for fossil fuels in conjunction with the growing awareness of their limited availability has led to a considerable increase in prices as depicted in Figure 16. This price increase had several implications, the three most important of which include:

Coal as a source of energy has attracted new interest by developing countries. Having long been one of the major exporters, China has turned into being the biggest producer as well as the biggest importer of coal on the world market in 2010. Although relatively inexpensive, coal is a less efficient energy carrier than oil or even gas and its incineration leads to significantly higher levels of pollutant emissions. Those pollutants are environmentally damaging and potentially pathogenic. Furthermore, due to its high carbon content, coal causes twice the amount of CO₂ emissions caused by natural gas. CO₂ is by many scientists regarded as being a major source of global warming and worldwide climate change.

Increased fuel prices allowed for the development and deployment of more advanced oil and gas prospecting and recovery technologies. Oil recovery from bituminous sands or offshore drilling in extreme depths as well as gas extraction through induced hydraulic fracturing are some of those cost-intensive activities that require a constantly high oil price in order to be profitable. However, they also pose a much higher danger to the environment. The explosion of the *Deepwater Horizon* drilling platform with subsequent oil spills as well as large-scale damage caused to the Canadian environment through oil sand extraction are examples for the negative external effects connected with the exploitation of the planet's last remaining fossil fuel deposits.

Nuclear power plants have been re-discovered by some countries as an alternative way to establish a more self-sufficient and clean domestic supply, less vulnerable to external price shocks. While almost no nuclear power plants had been built after the Chernobyl disaster in 1986, new generations of plants allow for higher safety levels.

However, the explosions in the Japanese power plant of Fukushima in 2011 highlighted the still existing risks and potentially devastating consequences of an incident in the field of nuclear power production. Furthermore, many open questions concerning the disposal of the accruing nuclear waste are still unanswered and cast the sustainability of this technology into doubt.

Taken together, those recent developments have led to a situation where over 90% of the energy supply in developed countries is covered by energy sources that are connected with serious political risks as well as major potential damages to the environment and human health. Additionally, those energy sources are not in unlimited supply and are being depleted at an ever increasing rate. In the mid to long term, alternatives for over 90% of today's energy sources have to be found, if current levels of industrial production and quality of life are to be maintained.

This general situation also holds for Switzerland. 55% of its current energy demand is accounted for by oil and natural gas and another roughly 14% by nuclear power. With the nuclear power plant Beznau 1, the country has the oldest operating nuclear power station in the world. With a trend of increasing oil prices and the phase-out of nuclear energy, the transformation of the energy sector brings about major political and technological challenges. Those challenges will have to be met both on the supply and on the demand side.

The major challenge on the supply side is the search for alternative energy sources with the potential for long-term replacement. In order to be able to permanently replace fossil fuels and nuclear power, those new sources must be readily available over extended periods of time and preferably not be afflicted with the problems of CO₂ emissions and limited availability (Mulvaney, 2011). There are a variety of such alternative energy sources on earth in the form of the sun's energy (solar radiation and the connected phenomena of rain, wind and waves as well as biomass production), gravitational forces (tides) and the energy of the earth's core (geothermal). All of those sources are potentially accessible to human use via technology. As they do not rely on the provision of finite stocks of fossil fuels, they are called renewable energy sources (Lund, 2010). The development of technologies for the exploitation of renewable energy sources therefore is an answer to the supply side challenge. On a worldwide basis, those energy sources in 2009 contributed to around 16% of total energy supply with annual growth rates between 15 and 50% (Sawin & Martinot, 2011).

Alongside the search for new supplies, a second challenge lies in the more efficient use of existing energy sources throughout the value chain. Process improvements and new technology at all stages from energy generation over transport and storage to end

use offer potentials for waste energy reduction and efficiency factor enhancements. If all technological possibilities are taken advantage of, a significant impact on the demand side could be achieved. According to Nordmann (2011), the consequent deployment of the most efficient technologies on the market could result in an overall reduction of almost a third of Switzerland’s total net energy consumption. According to a study of Roland Berger (BBT, 2009), both the worldwide renewable energy as well as the energy efficiency sector are expected to continue to exhibit high annual growth rates of 5% and 7% respectively until 2020.

3.1.4 Changes in the Regulatory Sphere

As a result of the worldwide developments mentioned in chapter 3.1.3, the Swiss energy sector over the last twenty years has been subject to a wave of regulatory changes. New legislation has dramatically altered the regulatory environment faced by companies in the area of energy technologies and laid the basis for a realignment of the entire energy sector. Figure 17 gives an overview of major milestones in the development of the regulatory regime of the Swiss energy sector. The timeline (not to scale) highlights the dynamic and accelerating development of different and ever more far-reaching decisions made and legislations introduced.

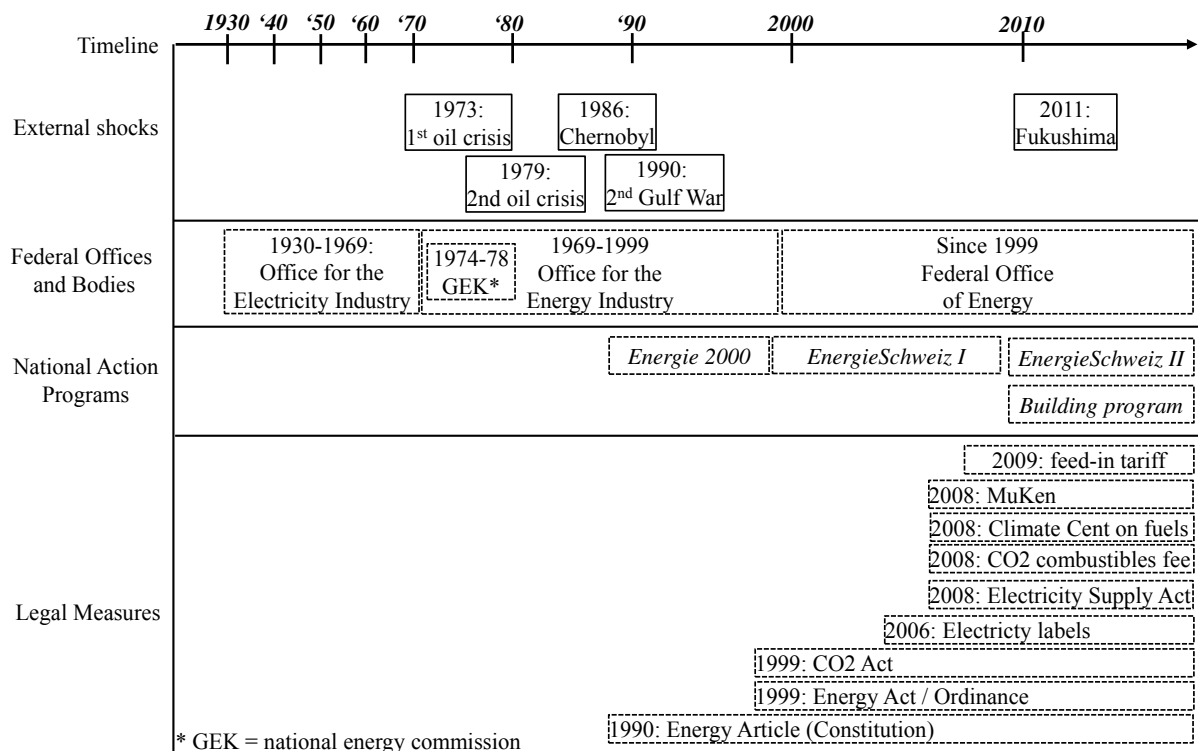


Figure 17: Major milestones in Swiss energy policy

Partly due to its federalist structure, Switzerland only in 1990 introduced federal legislation in the energy sector. For most of the 20th century, the responsibility for the

provision of fuels and electricity was left to the private sector. Government activities were limited to the compilation of statistical data and the supervision of electricity exports. The *Office for the Electricity Industry* was founded in 1930 to serve this purpose and its competences were expanded to the gas & oil and the nuclear sector in 1961 and 1969 respectively. Being limited in its mandate to the areas of energy statistics and infrastructure monitoring, the re-named *Office for the Energy Industry* concentrated on purely technical aspects (BFE, 2005).

The actual starting point of Swiss energy policy can be identified in the oil crisis of 1973 that hit the country as a result of the suspension of oil deliveries by OPEC countries. In reaction to this traumatic experience, a commission was appointed to work out the legal foundations for a federal energy strategy. As a result, first projects in the areas of energy saving, energy research and self-sufficiency were initiated. Yet, there were no legal foundations for an energy policy worthy its name. A first attempt to establish such a law failed in 1983 due to the opposition of the cantons. A second attempt in 1990, now under the impression of the 1986 Chernobyl disaster, was accepted by popular vote and established the basis for an energy policy in the Federal Constitution. This *Energy Article* (BV, Art. 89) stated that legislators on both the federal and the cantonal levels have the responsibility to "endeavour to ensure a sufficient, diverse, safe, economic and environmentally sustainable energy supply as well as the economic and efficient use of energy" (BV, 2011). While the cantons are primarily responsible for measures relating to the buildings sector, the Confederation oversees legislation in the areas of renewable energy sources, energy efficiency, mobility, installations and appliances. In the same year, the first federal program *Energie 2000* was launched. The focus of *Energie 2000* was on the general reduction of energy use and CO₂ emissions. Instruments to reach those objectives were subsidies on the one hand and dialogues with the aim of voluntary commitments by industry on the other hand.

In 1999, the *Energy Act* and the *Energy Ordinance* were enacted, followed by the *CO₂ Act* in 2000. Those laws included a variety of mechanisms to further promote energy efficiency and renewable energy production. As a vehicle to coordinate the measures taken, *Energie 2000* was replaced by the *EnergieSchweiz 2000-2010* campaign. The most important actions under the program are the *CO₂ fee on combustibles* and the *Climate Cent on fuels*. Their aim is to create incentives to reduce the consumption of fossil fuels and to compensate for CO₂ emissions resulting from it. In 2009, the instrument of the *cost-covering feed-in tariff* was introduced in order to advance the deployment and economic viability of renewable energy technologies. Along with this

development the *Federal Electricity Supply Act* in 2008 started the de-regulation process in the electricity sector. The operation of the high-voltage network was given over to the national operator *Swissgrid* and consumers will gradually be allowed to choose their own suppliers. Since 2006, utility companies also have to label their electricity by sources and provide a certificate of origin to the end consumer.

In 2008, the cantons agreed on shared standards for energy efficiency and the use of renewable energy in the building sector. The *MuKEN (Mustervorschrift der Kantone im Energiebereich)* require a maximum heat demand of 4.8 liters of oil equivalent per square metre in new buildings, as compared to 22 liters that an average new building required in 1975. The share of renewable energies used in new buildings was set to at least 20%. For existing buildings, a federal *Building Programm* was launched to promote renovations resulting in improved energy efficiency. In 2011, 135.5 million francs were paid out to house owners. Sellers of electrical appliances and new cars are required to provide an *Energy label* that allows for a classification of its energy efficiency class. Products in lower efficiency classes like traditional light bulbs are continuously being phased out.

In 2010, the federal government decided to continue the *EnergieSchweiz* program for another ten year period until 2020. In 2011 government and parliament alike agreed not to allow the installation of new nuclear reactors in Switzerland, aiming to phase out nuclear energy over the next 20 years.

In order to reach the goals set in the various programs, both public and private organizations are engaged in the funding of basic and applied R&D. Total 2008 investments in energy-related research by public and private sources (excluding nuclear fusion and fission) represent 0.26‰ of GDP, which puts Switzerland on 5th position internationally after Finland, Canada, Japan and Sweden (SBF, 2011).

The major part of energy-related applied research is conducted by the private sector. The amount invested in 2008 is estimated to exceed 730 million francs (SBF, 2011) with a focus with 520 million on energy efficiency. Renewable energy technologies received 180 million of private applied research funding.

Public basic research funding in the areas of energy efficiency, renewable energy and socio-economical aspects in 2009 amounted to 159.26 million francs. Energy efficiency research accounted for 49%, renewable energy research for 42% and socioeconomic aspects for 9% of this sum. The largest funding agencies are the *ETH Council* (50%), the *Federal Office of Energy* (19%), the cantons and local communities (12%) and the *European Union* (9%). Research organizations that get

funding are the *Paul Scherrer Institute PSI* (25% of efficiency research funding and 12% of renewable energy research funding), *ETH Zurich* (26 and 15%), *EPF Lausanne* (9 and 27%), *Universities of Applied Science* (11 and 14%) and the *EMPA* (7 and 11%). The private sector accounts for 14% of research funding granted. Public funds available for energy-related basic research today are again on the nominal level of the early 1990's after being decreased considerably throughout the late 1990's.

The combination of more far-reaching regulation in combination with high levels of research funding in the energy sector is hypothesized by some authors to have a stimulating effect on technological progress, industrial production and employment levels (Nordmann, 2011). Those considerations have made regulatory action in the energy sector particularly popular in the context of the recent economic and financial crises. According to Wüstenhagen (2009), regulations and subsidy schemes in the energy sector have the advantage of quickly triggering local private investment activity, substituting imports through domestic production and having a direct effect on the labour market. Furthermore, some of the instruments such as the feed-in tariff can be realized on a redistribution basis, eliminating the need to further rise public debt levels. In the case of Germany, some studies attribute the creation of up to 300'000 new jobs to the country's pioneering role in the promotion of the feed-in tariff mechanism and the ensuing wave of economic activity in the sector. According to a study by Ziegler & Bättig (2010) the measures taken by Swiss authorities will have a significant impact on the labour market. By 2020, they predict the loss of around 14'000 jobs due to cost saving measures. At the same time, subsidies and new regulations are likely to generate 17'000 jobs in construction, 1'000 in transportation and 7'000 in the renewable energy sector.

3.1.5 Changes in the Technological and Market Spheres

Changes in the regulatory sphere, triggered by broader political and societal changes, have led to an increasingly dynamic development in the technological sphere.

On the one hand, increased research funding levels have led to a wealth of new scientific insights into the areas of renewable energy and energy efficiency technologies. More and more technologies have been developed to a degree of maturity that they exhibit a competitive cost structure. Under favourable usage conditions, some technologies even reach grid parity, i.e. the cost of electricity or heat is comparable to those of non-renewable energy technologies. On the other hand, high energy prices and public subsidy schemes have created incentives for investors and

consumers alike to consider renewable energy and energy efficiency technologies as a real alternative.

The dynamic technological developments and resulting cost levels have also led to new options and alternatives in the application of those technologies. Those changes in the economic sphere (*de-centralization, diversification, nega-watts*) result in an increased attractiveness of the renewable energy and energy efficiency sector for SME, as traditional entry barriers start to collapse. Those developments will also be part of this chapter.

Levelized Costs of Electricity and Heat (LCOE, LCOH)

Renewable energy technologies in both the electricity and heat area are characterized by a wide variety of different technologies at various levels of maturity. This circumstance is highlighted by Figure 18 and Figure 19, that summarize all major studies on the levelized costs of electricity (LCOE) and heat (LCOH) for different generation technologies conducted by the *Intergovernmental Panel on Climate Change* (IPCC, 2012). As evidenced by the horizontal bars in both graphs, each renewable energy generation technology exhibits a considerable fluctuation margin of LCOE/LCOH. For each technology, a host of factors affect the effective costs per unit of electricity or heat produced, such as environmental conditions like location and grid connectivity, costs for initial investment, operation, maintenance and fuels, facility size or discount rates applied by investors. In the graphs, the medium values for the individual technologies are indicated by vertical bars, assuming a 7% discount rate and medium arithmetic averages of the input parameters affecting LCOE/LCOH. Overall, the figures show that the development of renewable energy technologies has reached a point, where all technologies - except ocean electricity - under favourable circumstances can achieve competitive cost levels. However, competitiveness is highly situational and a technology that might be an economical choice for one project could prove to be excessively expensive under slightly different circumstances.

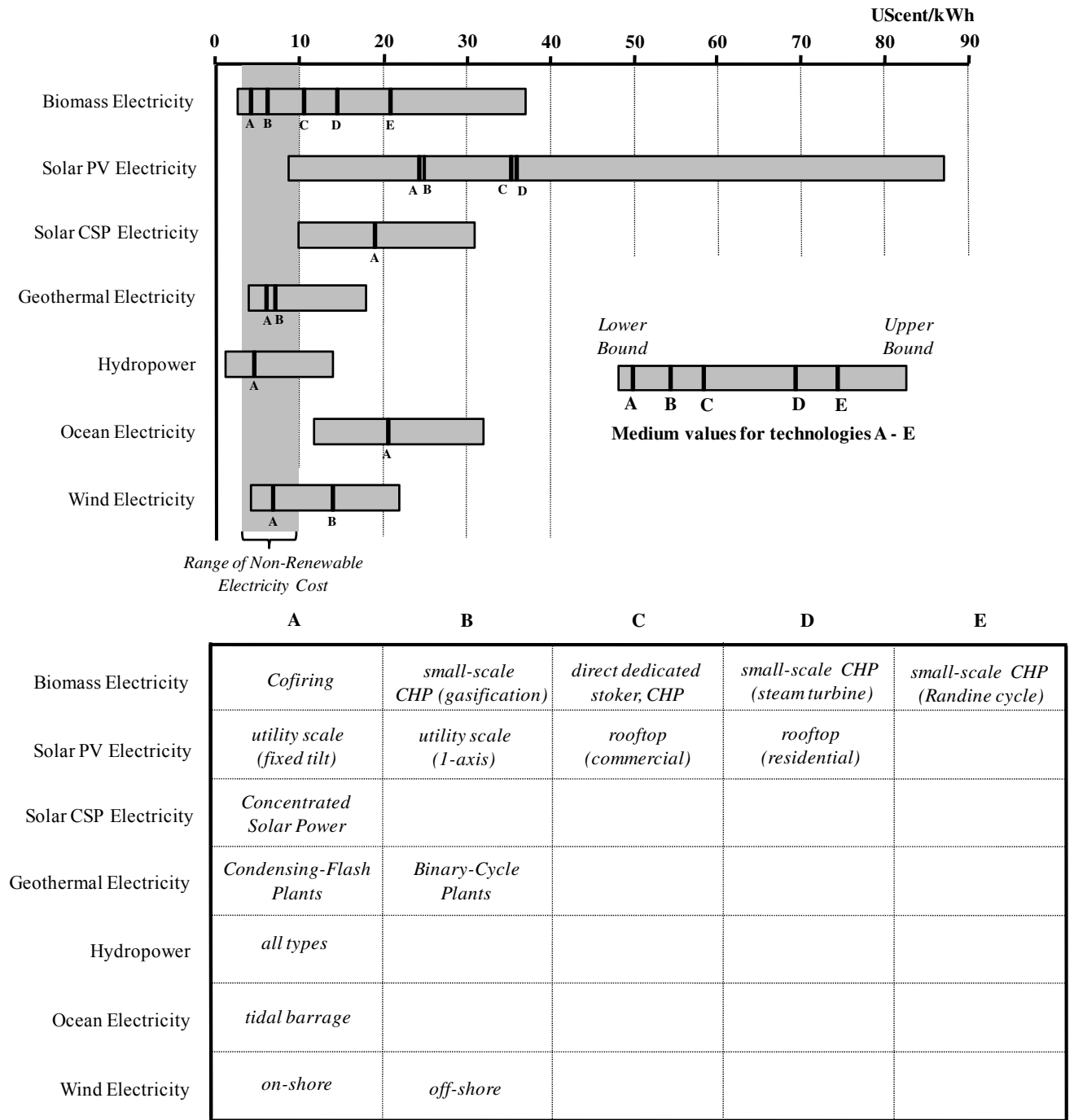


Figure 18: Levelized costs of electricity for commercially available renewable energy technologies (IPCC, 2012)

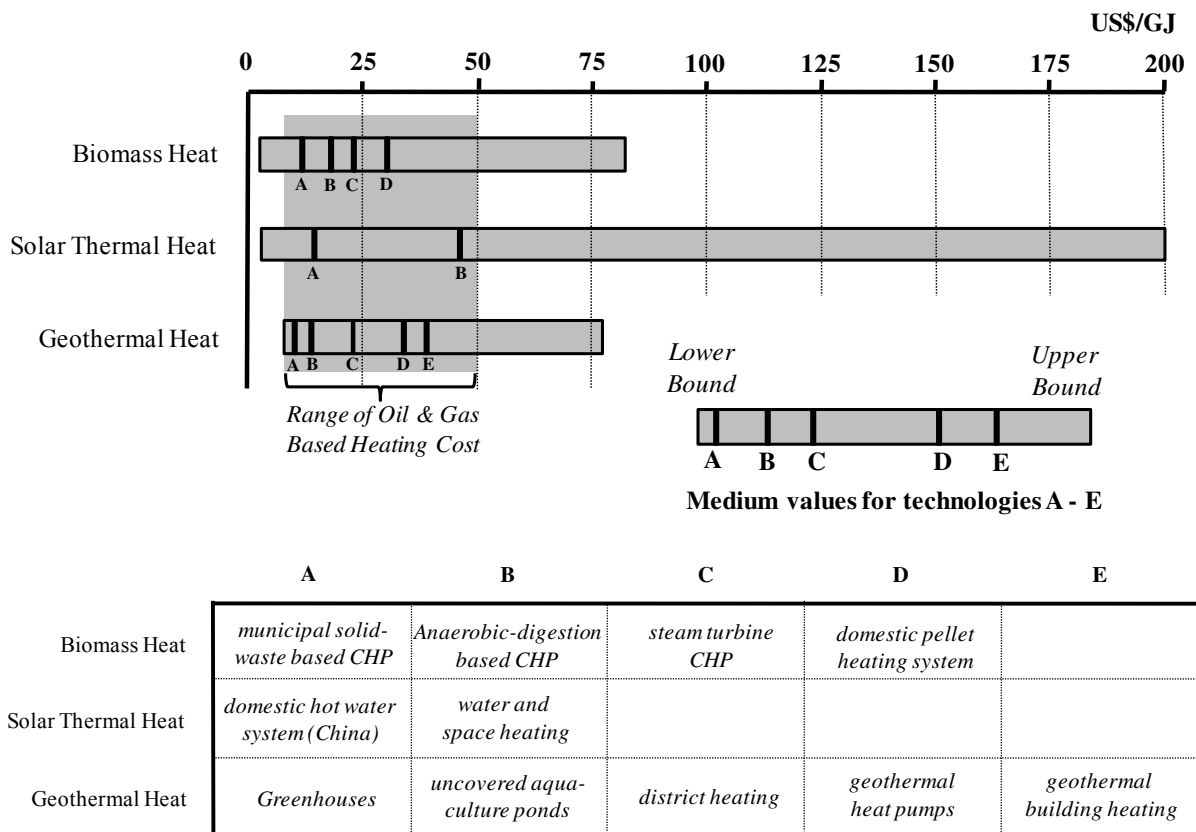


Figure 19: Levelized costs of heat for commercially available renewable energy technologies (IPCC, 2012)

The high sensitivity of the cost structure to environmental conditions and the rapid technological development imply a high degree of uncertainty with regard to the further development and the long-term perspectives of technologies in the field of electricity and heat generation. As investments in energy generation infrastructure typically generates a lock-in effect and is done with longer time horizons in mind, investors are faced with an increasingly complex choice. This increased uncertainty and complexity has several implications:

De-centralization

Traditional energy infrastructure was characterized by large investments in centralized generation capacities like nuclear power plants. Those projects exhibit long planning and amortization periods and heavily rely on stable political, technological and economic circumstances over the whole lifetime of the plant. Changes in either of those spheres can increase the likelihood that investments could end up obsolete or stranded (Lovins, 2002, p.351f.), starkly reducing the attractiveness of such projects for investors. In contrast, an environment of uncertainty favours smaller-scale, less complex projects that can be realized with smaller investments and shorter amortization periods. Small renewable energy projects with a focus on local demand typically fit this description. If local circumstances allow for competitive cost

structures, the investment can be split among numerous investors like house owners and the risks involved are easily overseable (European Commission, 2000). Those changed investment incentives on the one hand lead to a higher number of smaller energy generation units and on the other hand promote the greater geographical dispersion of those units (Norberg-Bohm, 2001, p.144). To illustrate this trend, in the years of 2008-2010, 8941 applications for the installation of small photo-voltaic installations have been filed with the Swiss authorities, which – if realized – would produce over 200 GWh of electricity (KEV, 2011).

Furthermore, the trend towards *de-centralized generation* puts into perspective the hitherto overarching role of economies of scale in the energy sector, which were seen as a major market entry barrier for smaller companies in the past (Hering, 2007). While large central power plants required vertically integrated companies for their efficient operation, the usefulness of such companies for the design of a decentralized infrastructure is no longer obvious. For instance, by means of modern information technology infrastructure, de-centralized generation units can be pooled locally and managed as a virtual power plant by the local community. In contrast to large centrally administered power plants, installation, construction and maintenance work for decentralized facilities at remote locations can better be done by local businesses and craftsmen (Zinkl, 2007). As a result of the decentralization trend, large incumbent companies are therefore increasingly faced with competition from more specialized, locally embedded, smaller companies that are typical for peripheral regions (Pichler et al, 1996).

Diversification

With a broad variety of renewable energy technologies currently reaching situational grid parity, investors are faced with an increasingly complex task of choosing among alternatives. Depending on the location, the specific electricity or heat requirements, existing infrastructure and available subsidy schemes, several energy technologies have to be assessed in terms of reliability and costs. While in the past, only a few standardized, fossil fuel-based options per area of application were available, several alternative technologies vie for investors' attention. For example, in the domestic heating sector the traditional choice was between electric, oil, or gas heating. House owners today are additionally faced by a complex choice between solar (with or without photovoltaics), pellet, wood chip, several kinds of heat pumps, fuel cells or a combination thereof, the feasibility of all of which is highly dependent on local conditions and must be adapted for the individual project. This increased diversity leads to increased competition among technologies and a transformation from a

seller's to a buyer's market. Especially in the fast growing renewable energy industries, this complexity can lead to the establishment of niches and opportunities to specialize (Shane & Eckhardt, 2003). Larger companies tend to neglect niches, as they do not offer the potential for scale economies (Cohen & Levin, 1989), opening the way for entrepreneurial companies to establish in those areas. A refinement of technologies for niche applications can be the starting point for such companies for the subsequent development of broader markets (Kemp et al., 1998).

The need for individual advice and guidance by providers of energy products hand complicates the sales process, but opens the way to a variety of new business models (Wüstenhagen & Boehnke, 2006) both in the area of renewable energy generation and energy efficiency technologies. As larger incumbent companies in the energy sector often find it difficult to react quickly to those changes, smaller, more agile companies have the opportunity to introduce more customer-friendly solutions (Federer, 2007). In line with this trend, Wüstenhagen et al. (2003) found that smaller companies in the field of renewable energy products were better at diffusing new technologies.

Energy Efficiency Technologies

While renewable energy technologies have gone through a phase of rapid technological development, technologies for the efficient use of energy have also gained in attractiveness. Energy efficiency technologies allow for the elimination of wasted energy, which is a direct cost benefit. Due to high oil prices and thus increasing energy costs, companies and house owners alike are looking for ways to save on energy-related expenses. Investments in efficiency measures are generally regarded as the least expensive source of energy. The idea of tapping into the great potential of unused or wasted energy has been introduced in the public debate by Lovins (1989) under the concept of *Negawatts*. Depending on the investment required to eliminate energy waste, the investor can yield a return on investment after a certain time. Technological progress as well as increased energy costs and public subsidies lead to shorter amortization periods and therefore more attractive investment opportunities in efficiency measures. A study by McKinsey (2007) identifies efficiency measures in the area of lighting, building shell, electronic appliances and combined-heat-and-power (CHP) as potential investment opportunities with a short amortization period and attractive returns for investors.

3.1.6 The Energy Sector in the context of this work

The trends highlighted in chapters 3.1.3 to 3.1.5 have shown that a considerable degree of dynamism has seized major parts of the energy sector. However, due to the broad scope of the energy sector, not all industries are affected by those changes to the same extent.

The focus of this work therefore is on firms active in a certain part of the overall energy sector, i.e. the areas of renewable energy and energy efficiency. Those areas are characterized by a high degree of uncertainty and ambiguity concerning their further development in the regulatory, technological and economical spheres. They therefore offer a suitable empirical context for the analysis of the innovative behaviour of SMEs in situations characterized by uncertainty. The sectoral focus is justified by the presumption that the affiliation with a certain sector is a decisive factor for the ability of SME to realize innovative results (Nieto & Santamaria, 2010; Rothwell & Dodgson, 1994). As early as 1939, Schumpeter in his work on business cycles observed that "innovations are not at any time distributed over the whole economic system at random, but tend to be concentrated in certain sectors and their surroundings" (p.100f.). Following Nelson & Winter (1982) an industry's competitive situation and the resulting pressure to innovate constitutes the most important driver for an SME's innovation behaviour. Furthermore, the conditions for inter-firm cooperation and therewith the access to external resources important for SMEs, vary starkly among the different sectors of the economy (Freel, 2003).

The goal of any sectoral definition is the specification of a group of firms that on the one hand exhibits a high degree of internal homogeneity and on the other hand has a high degree of discriminatory power for delineation against firms not belonging to the group. Depending on the underlying motivation, a variety of different and conflicting approaches to the classification of industries exist. As all firms do perform some kind of process, transforming input factors into products or services, attempts at defining an industry can either take an input-oriented or an output-oriented approach.

An example for an *input-oriented approach* is the North-American Industry Classification Scheme (NAICS). It focuses on the supply-side and groups industries around common input factors and production processes (Lind, 2005). NAICS does not provide a set of industry classes that constitute the energy sector. Although NAICS classes 21 (*Mining*) and 22 (*Utilities*) are sometimes referred to as such, they only comprise firms engaged in energy generation and distribution. Due to its supply-side focus, the efficient use of energy is completely spared from the definition. An

approach based on industry classifications has been applied in the study of Ernst Basler + Partner (BBT, 2009) that has the Swiss Cleantech sector as its empirical context. Based on interviews with industry experts, a list of 35 NOGA classes (the Swiss equivalent of NAICS) was compiled. However, as industry classes are largely process-oriented, the affiliation with a certain industry does not necessarily imply that a company is active in the energy sector. For instance, NOGA class 45.22 (carpentry, roofing, plumbing, and sealings) comprises manufacturers of highly energy-efficient windows as well as firms manufacturing windows that allow for major waste of heating energy. While the former group of companies should be included in the definition of the energy sector, the latter should not.

Output-oriented definitions of industries are, among others, applied by anti-trust authorities. Their approach is characterized by an output-side focus on the delineation by similarity of products for a certain market. Similarly, the IPCC's (International Panel on Climate Change) definition of the energy sector relies on the output of greenhouse gases (GHG) as a defining characteristic. According to its definition 1A1 "the energy sector mainly comprises 1) exploration and exploitation of primary energy sources, 2) conversion of primary energy sources into more useable energy forms in refineries and power plants, 3) transmission and distribution of fuels, 4) use of fuels in stationary and mobile applications" (IPCC, 2006). While accounting for the fossil-fuel based part of the energy sector, this definition does not allow for the inclusion of companies whose activities do not result in GHG emissions (like water power) or help reducing them (like energy recuperation). Moreover, firms like logistic companies are included under the title of "use of fuels in mobile applications", even though they do not have their primary focus of activity in the energy sector.

A possible solution to the inadequacies of an either input or output oriented view is the definition of a sector not based on the activities or environmental impacts of the firms that constitute it. Rather, the kinds of technologies that are applied by firms could form the basis of a more accurate definition. Both the generation of renewable energy and the more efficient use of energy require some sort of process or product improvements. The technologies that enable those improvements can be clearly identified and assigned to companies that use them. The international patent system can serve as a basis for this systematic approach, as it has developed a comprehensive list of technologies applied for commercial purposes. For the definition of the renewable

energy and energy efficiency (RE/EE) sector we therefore rely on the patent-based definition provided by OECD (2011)³.

Based on the technologies covered by the OECD definition, four major areas of the RE/EE sector can be identified:

- a. Renewable energy generation, comprising
 - i. wind energy
 - ii. **solar energy** (photovoltaics, solar thermal, and combinations thereof)
 - iii. geothermal energy (both near-surface and hydrothermal as well as enhanced geothermal systems)
 - iv. hydropower (both conventional and small hydro)
 - v. tidal energy
 - vi. **biomass-based energy** (both biofuels and biogas/methane)

- b. Energy efficiency in appliances and buildings, comprising
 - vii. **insulation** (including facades, windows and insulation materials)
 - viii. heating
 - ix. lighting

- c. Energy efficiency in industrial processes, comprising
 - x. combined heat and power generation
 - xi. energy efficiency technologies (energy recuperation and monitoring)
 - xii. energy storage
 - xiii. hydrogen production
 - xiv. CCS technologies

- d. Energy efficiency in transportation and mobile applications, comprising
 - xv. hybrid vehicles
 - xvi. electronic vehicles
 - xvii. vehicle design
 - xviii. fuel cells**

³ The OECD (2011) definition of environment-related technologies includes the sections A to G, with section A ("*general environmental management*": *air and water pollution abatement, waste management, soil remediation, environmental monitoring*) referring to technologies outside the energy sector. While those technologies would fall under the broader "Cleantech" definition, they are not included in our definition of the energy sector, as their contribution does not entail the generation of energy from renewable sources or the efficient use thereof. For the same reasons, efficiency improvements of existing fossil or nuclear based energy technologies are not included (and are also not part of the OECD's (2011) definition). The energy sector, as defined for the purpose of this work, therefore comprises sections B ("*Energy generation from renewable and non-fossil sources*": *wind, solar thermal, photovoltaic, solar hybrids, geothermal, marine, conventional hydro, tidal, biofuels, methane*), C ("*Combustion technologies with mitigation potential*": *combined heat and power, improved input efficiency*), D ("*Technologies specific to climate change mitigation*": *CCS technologies*), E ("*Technologies with potential or indirect contribution to emissions mitigation*": *energy storage, hydrogen production, fuel cells*), F ("*Emissions abatement and fuel efficiency in transportation*": *hybrid vehicle, electric motor, vehicle design*) and G ("*Energy efficiency in buildings and lighting*": *insulation, heating, lighting*) of the OECD's (2011) ENV-Tech patent search list. The comprehensive list for patent search strategies is provided under the following permanent link: www.oecd.org/environment/innovation/indicator

3.2 Case Studies

3.2.1 Selection of Cases

Based on the above definition of the RE/EE sector, four technology areas were chosen as empirical contexts for the subsequent selection of case studies: fuel cells, energy-saving windows, solar energy and biomass gasification. The selection of the technology areas was guided by the following considerations in order to mirror the heterogeneity of firms in the energy sector:

- It was made sure, that energy efficiency and renewable energy technologies were considered equally. While fuel cells and energy-saving windows represent energy efficiency technologies for both mobile and stationary applications, solar energy and biomass gasification are examples for renewable energy technologies.
- It was taken care that technological areas with different levels of technological sophistication were chosen. While energy-saving windows represent a rather low-tech, less science-driven area, the development of fuel-cells and biomass gasification plants require a high degree of scientific knowledge. The solar energy technologies considered in the case studies can be located in the area of applied science.
- Only those technological areas were chosen that were affected by at least one major new legislation or subsidy scheme in Switzerland. While energy-saving windows benefit from the recently launched *building program*, solar energy is covered by the *feed-in tariff*. Fuel-cells are an efficiency technology whose use has been incentivized by a variety of regulations such as the building efficiency norms prescribed in the *MuKE* framework or the steering taxes on fuels and combustibles. The same applies for the area of biomass gasification, that – among others - provides renewable energy to power fuel cells.
- Inside each technological area, only small or medium sized companies were chosen. While some companies in the meantime have been integrated into larger companies, those events are beyond the time period covered in the case studies. One case study of a large company (*Hilti Energy & Industry*) was added as a contrasting example.
- All the companies chosen for the case studies are entrepreneurial firms in the sense that they are led by an entrepreneurial person who owns the company. Where the company was not led by an entrepreneur (*Erne Holzbau*), it was made sure that a central person with all-encompassing competences was entrusted with the management of the firm.
- All companies chosen are based in Switzerland or the Principality of Liechtenstein.

3.2.2 Technology I: Fuel cells

3.2.2.1 Industry and Technology

Fuel cells are a technology that allows for conversion of a fuel into electricity via an electrochemical process. The most commonly used fuel is hydrogen. In comparison to fuel conversion via a mechanical process like a diesel generator, fuel cells are characterized by higher levels of conversion efficiency. If applied in a combined heat and power plant, up to 90% of the energy content of a fuel can be used. Fuel cells therefore can be described as an energy efficiency technology.

All different kinds of fuel cells share a basic functional principle. The core of the fuel cell is a sandwich construction of three layers which results in two interfaces. The three layers are the anode, the cathode and the electrolyte between them. At each interface, a chemical reaction takes place. First, the fuel is split into a positively charged ion and a negatively charged electron. Both the ion and the electron have a tendency to move towards the opposite of the two poles of the fuel cell, which are separated by the electrolyte. Since only one the ions can pass through the electrolyte, the electrons are left behind and have to choose another way through a provided wire. On their way through the wire, the electrons generate an electric current. On the other side, the two particles meet again and react with oxygen to water and CO₂.

Traditional SOFC fuel cells operate in the high-temperature range and use a solid oxide or ceramic as electrolyte. Due to their high operating temperature of 700 - 1000° C, lighter hydrocarbon fuels like natural gas can be used without prior external reformation into hydrogen. For electricity generation, conversion rates up to 60% can be achieved. Due to the high temperature of the generated waste heat, additional heat recovery in SOFC fuel cells can be useful and increase the overall efficiency up to almost 90%. Thus, high efficiency, the use of flexible fuels and relatively low costs are the main advantages of this class of fuel cells. Major areas of application today are auxiliary power plants and distributed generation of electricity and heat. The case study on *Hexis AG* below is situated in this technological area.

Despite their advantages, high-temperature fuel cells, due to their size and expensive materials involved, have the liability of being restricted to stationary applications. Furthermore, start-up times are quite high. Because fuel cells are quieter and more reliable than diesel generators and lighter than accumulators, the technology has initially been applied in the military and aerospace industry. The increased focus on energy efficiency and technological developments have led to the development of further areas of application. An alternative is offered by another kind of fuel cell that

uses a polymer electrolyte membrane and a platinum catalyst. Those Proton Exchange Membrane (PEM) fuel cells operate at a lower temperature range. Since their first development in the 1960s, their costs have continuously come down. They thus are increasingly considered as an alternative for all kinds of portable and mobile applications from mobile phones to electro cars. For instance, in the automotive sector, fuel cells due to their high overall efficiency are seen as an alternative to the internal combustion engine commonly used in cars. Their main advantage is the compact design and their high levels of efficiency in mobile applications. The following case study *CEKA* is located in the PEM fuel cell industry.

Switzerland has a long tradition in fuel cell research both by research institutions and smaller companies. SOFC research is mainly conducted at *EPF Lausanne* and *EMPA* with three companies (Hexis, HTceramix and Fiaxell) active in the area of SOFC application. Centres of competence for PEFC research are *Berner Fachhochschule* in Biel and *Paul Scherrer Institute PSI*. Industrial applications of this technology can be found in the companies Michelin, Belenos and CEKAetc (BFE, 2010, p.77). All of the firms mentioned above are small to medium sized enterprises, making the fuel cell industry a clearly SME-dominated part of the energy sector. As most stationary and mobile applications are still in an early phase, technological uncertainty as well as market uncertainty can be described as high.

3.2.2.2 **CEKA: Development of a PEM fuel cell**

CEKA Elektrowerkzeuge was founded in 1979 as a manufacturer of power tools such as angle grinders, drill hammers or drilling machines. As a classical OEM service provider, CEKA offers brand manufacturers a full range of services along the value chain from requirement specifications over design, electronics, and manufacturing to the organization of the entire supply chain and delivery under the customer's brand. Initially, the manufacturing was heavily automated for large batch production, but under increasing competitive pressure in the 1990's, the company left the mass production segment. A changeover of the manufacturing facilities led to a specialization on small-series production for the professional segment. One of the major customers in this segment is an international group in the area of fastening technology based in Liechtenstein. With the help of a consulting company from the automotive sector, changeover time between production batches was heavily decreased and efficiency raised. Today, around 100 employees work for the company.

In 2002, along with the appointment of a new operating CEO, the owner of the company saw the need to build a new business segment to complement the power tools

production. The CEO was given great freedom in the development of the new segment, but had to make sure that existing infrastructure and competences were used and no acquisitions or additional investments in manufacturing facilities were allowed. A first internal idea generation workshop did result in a list of incremental product modifications that were rejected as they did not offer any potential for differentiation.

While reading the newspaper, the new CEO oversaw a report on a portable current generator (*PowerPac*) on the basis of PEM fuel cells that had been developed since 2000 by ETH Zürich and PSI. A subsequent conversation with PSI's technology transfer officer took place on the occasion of the Hannover Messe in 2003. Even though the CEO recognized the potential overlap of CEKA's competences with PSI's research project, no cooperation came about. While CEKA was more interested in an engineering project, PSI's interests were in the further development of the *PowerPac* technology. Furthermore, CEKA did lack any competence whatsoever in the area of hydrogen handling, which is used as the fuel cell's energy source.

In order to build the additional competences internally, CEKA 2005 started a consortium project financed by the Federal Commission for Technology and Innovation (KTI) together with the more practice-oriented University of Applied Science in Biel (FHB). The FHB project leader was one of three former PhD students involved in the initial *PowerPac* project. The PSI as the holder of patents associated with the technology was involved as a consultant. At the end of the project in 2008, CEKA had a low-cost prototype called "*Independent Hydrogen Power System*" (*IHPoS*) at its disposal, appropriate for industrial-scale production.

In a next step, CEKA aimed at developing a market-ready product based on the prototype. As there was a demand for pure fuel-cell stacks like *IHPoS* by not more than 10 companies worldwide, the intended market offer would have to be a systemic solution. The vision was to provide customers with a system where hydrogen would be plugged in on one side and electricity could be drawn on the other side. Clearly, CEKA did only control parts of the competences necessary to develop such an offer in-house. Thus, in order to implement the vision, another KTI-sponsored consortium of companies and research institutions was organized by the company. As a first potential customer, the company Helvetino was won. Helvetino provides catering services for passengers in Swiss trains and for this purpose uses mobile "Mini-Bars". Those small vehicles are equipped with a coffee machine and a microwave and therefore need a mobile power source. So far relying on batteries, the lower lifetime costs of fuel-cells caused Helvetino to change to this new solution. While CEKA specified the requirements for the mini-bar fuel cell, FHB again took over the

engineering part and worked together with PSI to conduct technical inquiries. In order to guarantee a know-how transfer towards CEKA, one of the two remaining PhD-students involved in the initial *PowerPac* project joined CEKA as their new head of fuel cell department. Furthermore, CEKA's head of electronics was involved in all technical works.

Other consortium partners included EMPA (a materials research institute concerned with the design of the storage unit), Serto (a cabling company that contributed expertise on the choice of material for wires and contacts) and PanGas (a manufacturer of technical gases that developed a logistics concept for the supply of Helvetino with oxygen pressure tanks).

At the end of the project in 2011, CEKA was in a position to develop market-ready fuel-cell based products autonomously. The establishment of a new business area was successfully accomplished. The new competences had been acquired with surprisingly low investments. Throughout the development process, most engineering costs were born by or shared with partners and only very few own infrastructure had to be invested in. Due to the focus on pre-existing competences, no major internal re-organizations had to be conducted.

Having accomplished the development of a new business segment, the company now realized that it had entered new markets that followed a different logic than the classical OEM services. New customers in the fuel-cell business were no longer branded power tool producers but mainly companies from the food sector looking for alternative energy supply systems. As a reaction to market uncertainties, the system was developed with a high degree of modularity in order to allow for applications in different power ranges to be offered. CEKA's current system offers solutions for the range of 200 W_{el} up to 5 kW_{el}. Due to the competence in small-series production, niche applications are the main focus of the further business development in the fuel-cell area. Examples include mobile ATMs or vending machines.

While the classical business involved only very limited business risks, i.e. the technical risk of not being able to deliver against the promised specifications, the fuel-cell business was laden with much higher uncertainty. One factor is safety concerns in the general public towards oxygen as an energy source. Although oxygen is objectively not more dangerous than fossil fuels, CEKA still went through a certification process together with TÜV SÜD to prove the operating safety of the entire system. In order to limit the business risks for the traditional power tool business, the fuel cell and kitchen tool segment was split off from the power tools production and electronics segment via a Management Buy-Out (MBO) in 2011.

Within-Case Analysis

In the case of *CEKA*, the interview data shows that the perceived uncertainty in both the technological, market and general regulatory environment were high at the outset of the product innovation project. Even though the technology had already been in use for some time, it was far beyond the company's initial skill set and its potential applications were largely unclear. Starting with the overall strategic goal to build a new business segment with nothing but the existing means at hand and with no additional investments, the ensuing innovation project exhibits all elements of the control-based approach. An initial attempt was made at conducting a structured idea search process and was quickly abolished. The actual innovation project was triggered by a discussion with members of an external research project that took place randomly at a trade fair. From then on, the company was able to use its own means in the area of small-series production and systems design to bring together a large amount of stakeholders with technological and market know-how in all relevant areas not commanded by the firm itself. Instead of conducting market research or attempting to copy the solutions of other competitors, market uncertainties were mitigated using the pre-commitments of an early customer (*Helvetino*) and further stakeholders interested in advancing the product. Furthermore, *CEKA* managed to not only orchestrate those combined efforts but to also integrate the necessary skill-set to independently develop market-ready fuel-cell based products for mobile applications. In line with an affordable loss approach, the firm achieved this position with minimum investments.

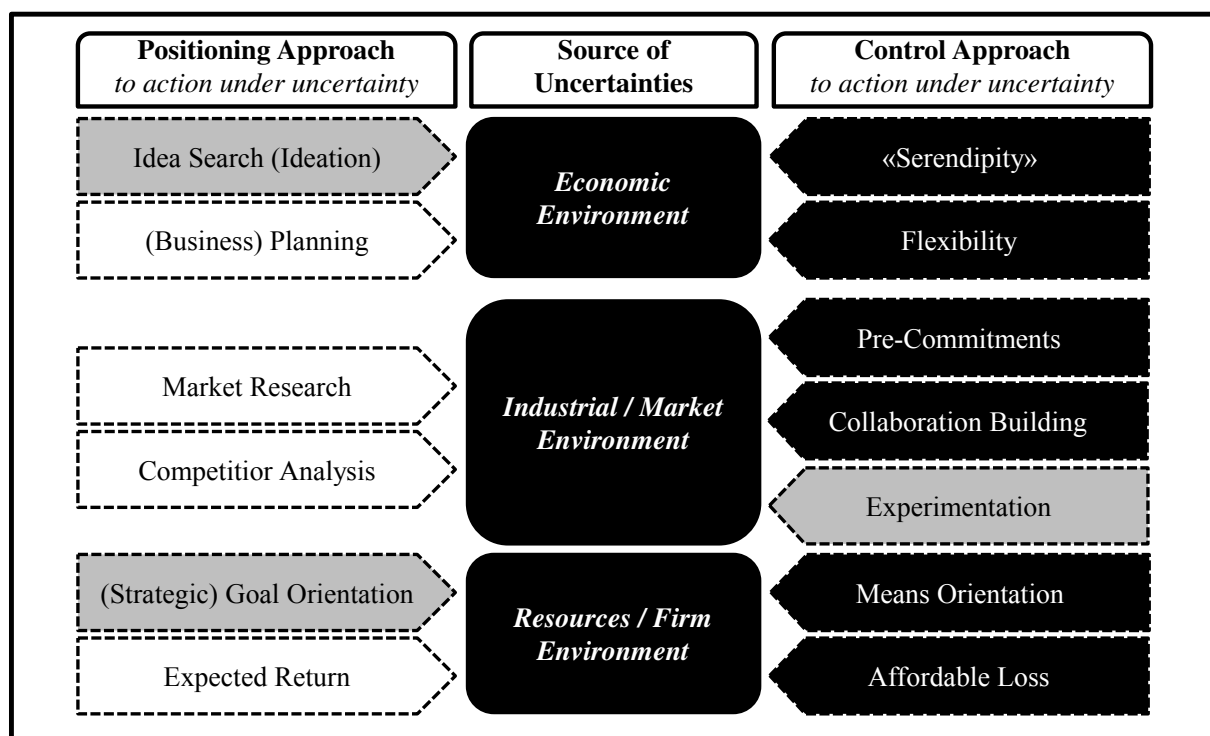


Figure 20: Within-case analysis of CEKA case study

3.2.2.3 HEXIS: Development of a solid oxide fuel cell (SOFC)

The origins of HEXIS can be found in the Sulzer Group, a multinational industrial engineering company based in Switzerland. In 1991, the Sulzer R&D department came up with the idea of a fuel-cell project called "*Heat Exchanger Integrated Stock*" (*HEXIS*). The development project was one of a series of initiatives started by Sulzer's then-CEO in order to lead the company beyond established business segments. With the aim of developing a fuel-cell for the application in households, the engineers developed a first SOFC (solid oxide fuel cell) prototype. SOFCs operate in the high-temperature range of 800-950° C and therefore are equipped with ceramic electrolytes. The energy source is natural gas that is internally transformed into oxygen and subsequently burned inside the fuel-cell stack. The resulting heat as well as electricity can be used for heating purposes of a single household. The latest version of Galileo 1000N has a performance of 1kW electrical and 2.5kW thermal energy.

Following initial conceptualization, the HEXIS project was founded as a venture division of the Sulzer Group in 1997. Until 2005, basic research in the areas of material science, process control and system integration had led to the development of a working prototype (*Galileo 1000N*), yet with zero hours of operating service. Up to that point, the venture had an annual budget of 12-15 million francs and a workforce of around 50 people. The Sulzer Board monitored the project closely based on ROI and strategic fit criteria and decided that the following step was to commercialize the prototype. In order to prepare market entry and to complete product development, a partnership with an established company in the heating market was aimed for. However, established heating companies had a sceptical stance on the technology that had not been demonstrated to properly work under conditions of use. As no partner for commercialization was found, Sulzer decided to divest the venture and to sell all assets to the highest bidder. A new operative manager was appointed.

At this point, the new operative manager approached one of his colleagues, then head of system development, with the idea of buying the assets and continuing the venture's activities at a smaller scale. The team drew up a basic business plan comprising four Power Point slides and five key performance indicators and approached several financial investors. One investor was ready to guarantee a long-term commitment and the payment of wages. Development costs would have to be funded through third parties via development partnerships. Under those conditions, key infrastructure and patents as well as twelve former Sulzer employees were taken over in 2006 to form the new company HEXIS AG. While the operative manager took the position of President

of the Board, the former head of system development became CEO of the company with comprehensive authority.

In the following years, HEXIS AG further developed *Galileo 100N* and started first field tests. All important development initiatives are based on a business plan that is updated in 18-month intervals by the four managers of the company. One-day workshops are used in order to get feedback from all employees. While at least 15 different technologies compete in the domestic heating market, the vision of HEXIS is to provide one complete, ready-to-install fuel-cell system. While the company only adds 10-12% of net value to the product, it commands all important patents covering the core technology. As the value chain in the fuel-cell industry is still in the making, HEXIS therewith leaves itself a high degree of flexibility to react to different developments in the market and technology sphere. In order to secure the access to relevant complementary competences outside of the own company, HEXIS positions itself as a highly innovative Lead Customer for suppliers and a competent project partner for research institutions.

In order to get a foothold in the German market, where most government subsidies were available, a final assembly plant was established. Furthermore, the company was allowed to join a large government-sponsored field test (*Callux*) to prove the operational performance of the *Galileo 100N*. Entry into the end customer market is planned for 2013.

Within-Case Analysis

The **HEXIS** case can be seen as a good illustration of how a product development project that was initiated and abandoned by a large company experiences a considerable re-definition when continued by an SME. Based on the rather well-established SOFC technology that was applied to the residential heating sector with its heterogeneous product landscape, the environmental uncertainties can be seen as moderate in the economic (*regulatory*) and high in the market environment, especially since only few data on the efficiency of fuel cells in this application are available. The degree of technological uncertainty can be considered as moderate.

Originally initiated within the confines of a larger company, the product innovation was the result of a structured idea search process conducted with the aim of building new business segments to complement the existing core business. Based on the strategic goal of constructing a fuel cell-based heating solution for the residential sector, a business plan was developed that was monitored with the classical instruments of the expected return approach. However, while the project was well

under way in the technological field, the high uncertainties in the market had not been sufficiently considered in the business plan, which led to insurmountable problems and eventually to the abandonment of the project. The subsequent new start in the form of an SME organisation led to some re-definitions of the project. While the strong goal orientation and the emphasis on business planning were still prevalent, the uncertainties in the market environment that had led to the original failure of the development project have been tackled differently. Encouraging collaboration with other stakeholders in the industry (e.g. setting up the SOF-CH network with a variety of research institutions) and securing pre-commitments by early customers (i.e. participation in the Callux field test) or financial sponsors that subscribed to a more affordable loss oriented approach proved to be useful strategies that enabled the firm to take action under uncertain market conditions.

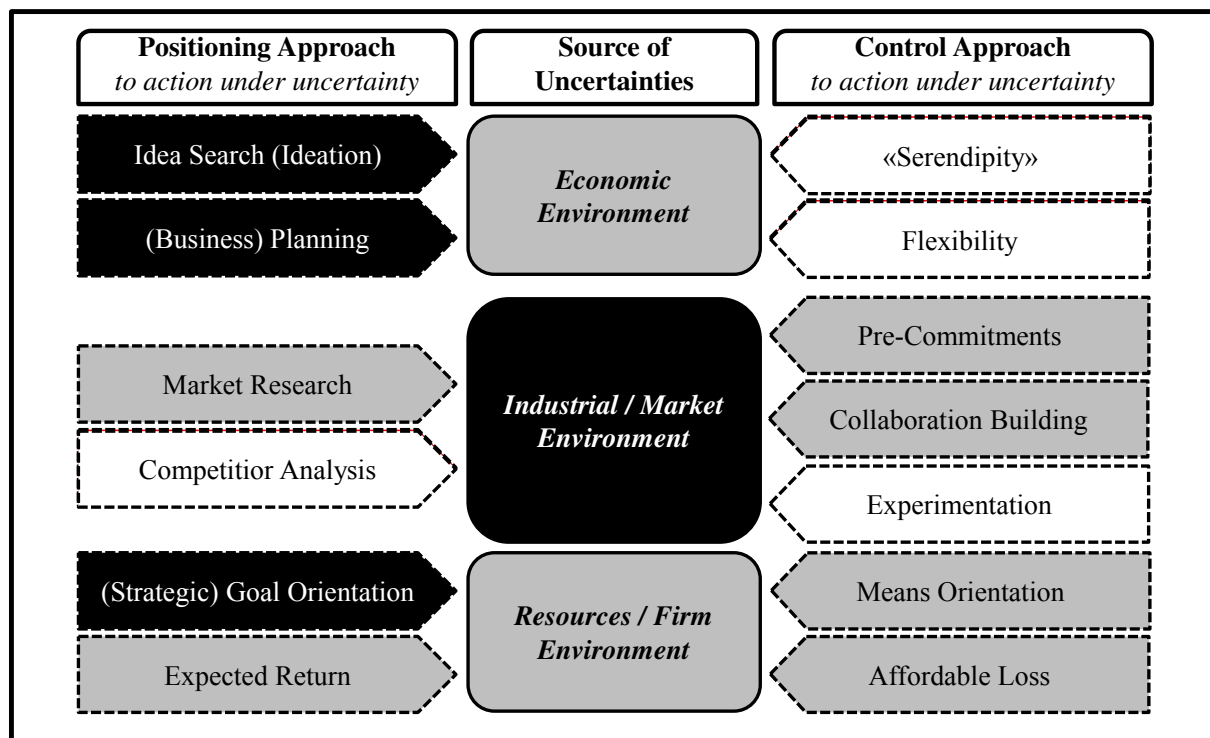


Figure 21: Within-case analysis of HEXIS case study

3.2.3 Technology II: Energy-saving Windows

3.2.3.1 Industry and Technology

Next to renewable energy production, storage and conversion, another major challenge in the energy sector is the efficient use of energy. In Switzerland, private and commercial buildings account for almost 50% of total energy consumption. While only one fifth of this energy is used for the initial construction, 80% are operating inputs. In private households, over 70% of those inputs are needed for the provision of room heating. However, a large part of this heat is quickly lost by diffusion through the roof, façade or windows. Unsurprisingly, the highest energy saving potentials of up to 70% therefore lie in the area of improved room heating (SAM, 2002, p.23). In buildings older than 60 years, which account for a good half of existing buildings in Switzerland, the largest heat losses occur over the windows. The ability of windows to retain heat inside the building is expressed by the heat transfer coefficient U . While common windows in the 1950s had a U value above 5, the current standard for *Minergie* buildings is 1. An increase in U and the renovation with energy-saving windows is therefore seen as one of the most inexpensive ways for large-scale energy saving. Hence, investments in new windows are a typical example of the "negawatts" phenomenon (McKinsey, 2007, p.20) where a short-term positive return can be obtained with an investment in energy-efficient technologies.

However, some practical difficulties still prevent efficiency technologies in the building sector to be broadly applied. While efficiency technologies in industrial production processes often can help bring down operating costs and investors in times of rising energy prices have an incentive to invest in them, the incentive structures in the building sector are less obvious. In Switzerland, the majority of the population is renting their homes, leading to a situation where people who use and pay for heating room energy are not the people who could invest in energy-saving technologies. Many governments in Europe have therefore engaged in incentive-based promotional programs to encourage house owners to engage in renovation of their buildings, including the replacement of older windows.

The Swiss window market is characterized by extensive fragmentation and regional niches with only three larger companies having a national presence. Most window manufacturers are in the SME segment and part of a license scheme of a larger system supplier, leading to a certain degree of product uniformity in the market. Initial investments in production lines are high and a system change is connected with

considerable switching costs. In the past, consolidation pressure in the industry was low, but recent trends have led to increased dynamism. Firstly, the trend towards renovations leads to smaller and more complex projects. The additional consideration of monument conservation laws and pre-existing infrastructure require manufacturers to put more time into planning and customizing the production and installation process. Secondly, the trend towards lower U values of the windows has turned the glass elements into high-tech products. Several layers of glass and inert gases like argon or krypton are connected under vacuum and additional functions like self-cleaning properties, security features or sound protection are possible. While in the past, the glass element used to be the energetically weakest element of the window, it is now the frame that offers the greatest potentials for improvement. Pressure on window manufacturers to improve frame design and properties is increasing, pushing some firms towards the edge of their technical capabilities. Additional pressure comes from architects who have discovered windows as a constructive element for modern houses. They ask for ever larger and more extravagant constructions.

Additionally, the multitude of possible frame materials like wood, metal or plastic, adds to the already increasing variety of products. While metal offers stability, it is a good heat conductor and therefore must be increasingly combined with plastic or wood elements. The resulting additional bonding processes add to the complexity of the production process. Wood, in comparison, offers great insulating properties but as a natural product is more difficult to handle and process. Aesthetical considerations of the frame design further complicate the task.

Overall, the window manufacturing industry can be described as exhibiting a low degree of market uncertainty but, especially from the point of view of smaller companies, a medium to high degree of technological uncertainty.

The following two case studies highlight two alternative approaches to the development and commercialization of an innovative energy-saving window, chosen by Swiss window manufacturers.

3.2.3.2 Erne Holzbau: Development of the Vision3000 window

Vision 3000 is a group of eight independent window manufacturers as well as the name of a product line of energy-saving windows developed by this group.

The spiritual father and initiator of the group is the CEO of ERNE AG Holzbau's window and façade department, who has held this position since 1986. The ERNE group with 760 employees is active in all areas of the construction industry such as

building services, gravel plants, pipeline construction, facility services and timber works. Inside this group, the business unit CEO is granted full operative freedom and sees himself as an entrepreneur responsible for a team of 60 people. According to his business philosophy, ERNE Holzbau should strive to work on highly ambitious projects at its technical frontiers and as a reliable partner in large projects.

Traditionally, *ERNE AG* did not develop their own windows but was a licensee of a larger system supplier. This allowed the company to benefit from the supplier's buying power and technological competence. On the other hand, the system supplier was not interested in *ERNE's* requests for special developments asked for by customers. More and more often, *ERNE* had to improvise and contribute own supplementary work in order to gain major project orders. The inflexibility of the system supplier led to the desire to develop an own window in order to better be able to operate in the market.

The contact with the president of the Swiss Society of Engineers and Architects (SIA), who is described by the CEO as "visionary", made *ERNE AG* aware of the trend towards larger window sizes while decreasing the size and increasing the depth of the window's frame. The resulting larger glass surface allowed architects to construct ever more ambitious and more spectacular constructions. So while window glass and especially functional glasses developed into a high-tech product with even better heat insulation properties than wood, the development of the frame did not keep pace with those developments. Additionally, with windows getting heavier and bigger, window manufacturers in ambitious projects like *ERNE AG* were increasingly forced to take over logistics and coordination tasks with other companies which was outside their actual core business.

In 2002, those considerations led the CEO to the idea of designing an innovative window that was compatible with his vision of the future development of the industry. The initial idea was to design a window with one component less, which would represent a real advantage over existing windows. An external consultant was asked to analyse *ERNE's* internal processes and the necessary changes for the changeover of manufacturing lines. The result of the analysis was that in order to share the costs for the necessary investments in new equipment, mainly tools for the rubber parts, additional partners should be involved. The consultant also established first contacts with three other window producers looking for development partners and provided his office as a neutral meeting point for the initial talks.

After first encouraging contacts, the newly forming group looked for additional members and selected potential applicants based on whether they exhibited an entrepreneurial attitude and got along well with the other members. Since *ERNE* had

negative experiences with a lack of commitment in inter-company cooperation and industry exchange groups, they wanted to make sure from the start that only entrepreneurs or entrepreneurial CEOs with full decision authority would be allowed to participate. Furthermore, a geographical dispersion was striven for, even though direct competition was not ruled out. Within a short time, four more window manufacturers joined the group, making it now eight members.

One of the other members of the Vision 3000 group is the company *Fenster Schär AG*, led by the current CEO since 1990 in the fourth family generation. Founded in 1876, the company with around 30 employees has specialized in fire protection windows where it has a leading market position. In 2004, the company was faced with the challenge of completely renewing its manufacturing lines. In the course of this investment project, several equipment manufacturers and other window manufacturers that had recently renewed their machinery were contacted. Advice by a consultant in the area of production planning was also sought. Investment decisions in new product lines are among the most critical and uncertainty-laden decisions for smaller window manufacturers. Due to the multitude of trends in the areas of glue technology, functional glasses, fire protection, anti-burglary and safety as well as energy efficiency it is very difficult to forecast which technologies will be successful in the future. For that reason, most window manufacturers put the decision off until they have to renew their machinery in order to stay competitive. Such a reactive strategy does not allow for competitive advantages. The window market is therefore characterized by a high degree of uniform products with few system suppliers (tool or metal manufacturers) dominating this segment.

Even though there was no initial intention to develop a new product, the external consultant established a contact with the Vision 3000 group. In the ensuing talks, the CEO realized the opportunity to connect the renewal of the machinery with the development of a new product, whereby costs and risks could be shared with partners. Even though the project would delay production by half a year, the decision was taken to join the group. The basis for the decision was an immediate enthusiasm for the product idea that corresponded well with the CEO's day-to-day experiences in handling non-standard customer requests. There were no market studies conducted at this point. As the second-largest member of the group, *Fenster Schär's* CEO took over the position of vice-president with the special task of managing the relations with the inter-trade organization, where he also was a member of the technical commission. In 2009, Vision 3000 windows accounted for roughly 30% of *Fenster Schär's* turnover.

After all group members had been selected, a meeting was held every second week in order to quickly advance the project and use the initial momentum. The initial vision of doing without a whole component was dropped in favour of a new frame design. One of the partners compiled first CAD drawings which served as a basis for supplier requests. Those early drawings found their way to one of the market-dominating system suppliers, who approached the group and pressured them to buy the components from him. However, this incident encouraged the group to build system supplier competences internally. This would also allow the product to be designed as modularly as possible and to be adapted to the individual needs of the group members. For instance, in the case of *Fenster Schär*, 500 variations of a single window can be produced without having to change tools once, using an automated, online-controlled production machine. With around 110 window systems on offer, the resulting variety of individual windows is extremely large.

The idea of founding a company for the project was found to be too costly and rejected by the members. Instead, a virtual inter-company organization was chosen. Meetings of all entrepreneurs are held four times per year. The basis for the cooperation is the relationship of the entrepreneurs among each other. Every member of the group is endowed with one vote, irrespective of its size or duration of membership. All incurring costs are split equal among all members. No member is required to participate in and pay for any development project, but only those who participated are allowed to use the respective product.

No formal contracts other than a confidentiality agreement were set up. Each member was assigned a task based on their respective competences such as CAD drawings, website design, marketing and events, accounting and purchasing. *ERNE*, as the largest company of the group, was entrusted with the sourcing of raw materials. Due to the pooled demand of the group members, raw materials like aluminium could be sourced on the world market. The fact that a large call-off warehouse for aluminium was established for all members of the group constituted de-facto joint liability and high mutual dependencies of the group members.

After two years, the first product was ready for market introduction and proved to be a major success. In 2009, some smaller members of the group generated up to 95% of their turnover with Vision 3000 windows. Further development projects with the aim of improving the product and developing additional markets at home and abroad were jointly undertaken. In 2009, Vision 3000 windows were EC certified and *ERNE*'s production facilities were recognized as an "A window" producer for the English market.

Within-Case Analysis

The information given in the case of *ERNE* shows that the company was faced with a rather high uncertainty in the technological environment, as technologies along several dimensions of its main product experienced major alterations. Even though it was obvious that bigger changes were to be expected in the whole industry and new regulations and subsidy schemes were about to be introduced, perceived market and general environmental uncertainty were at a moderate level.

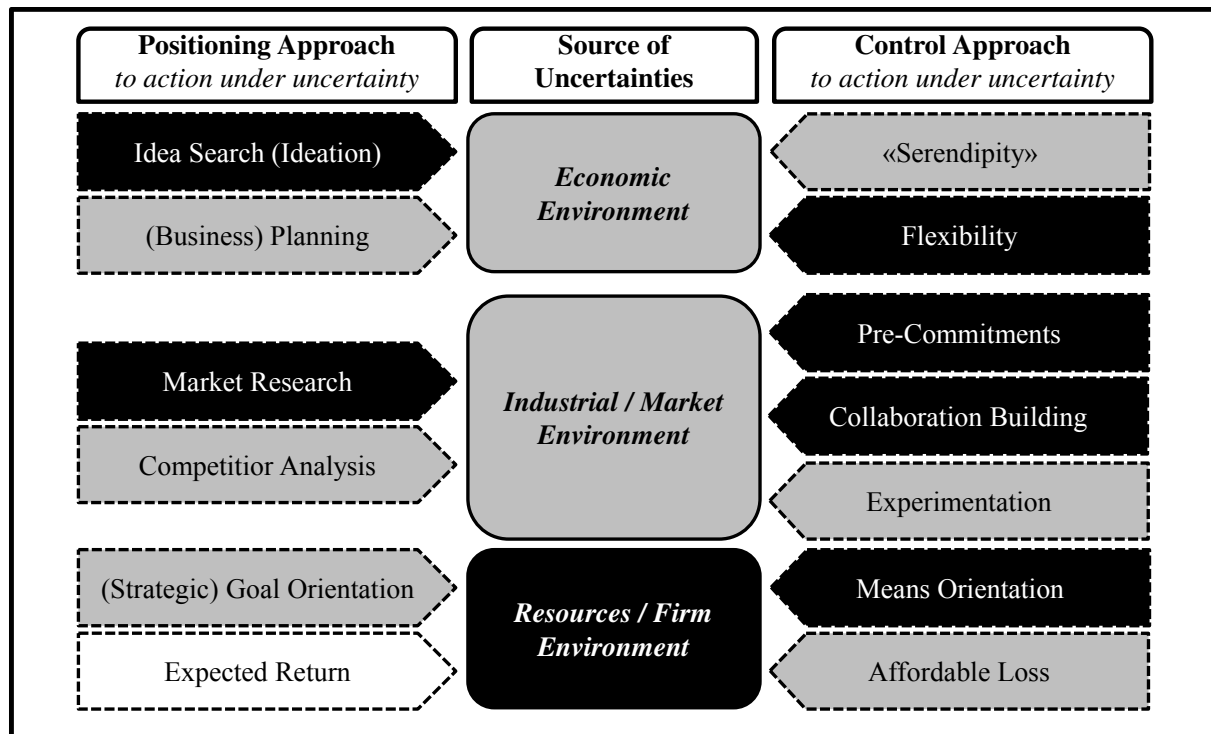


Figure 22: Within-case analysis of ERNE case study

In order to cope with the moderate level of information requirements in the industry, initially a semi-structured ideation process was used that included user workshops as well as frequent discussions with industry experts and visionaries. However, the element of serendipity or the unplanned emergence of an idea was also an important element in the beginning of the project. The approach chosen to tackle the perceived risks in the technological environment mirrors a control-based approach, as the company focused on the existing means, such as the ability to produce technologically challenging and custom-made windows as well as the ability to coordinate a group of suppliers in the context of complex development projects. Apart from a general vision to produce a less complex window, no strategic goal orientation could be found in the beginning of the project. Likewise, the chosen approach to make upfront investments without further profitability calculations reflects the general attitude of the firm towards conducting their development projects, where it is often willing to effect prior performance in order to win a contract or to advance a project. In the area of market-

related uncertainties, at first a positioning approach with user workshops was applied. In a second step, a strong emphasis was laid on the building of a group of stakeholders that were willing to advance the project. The group, having no contractual basis and relying solely on the relationship of the CEOs of its members, allowed for a dynamic development of the product innovation project. By fostering regular face-to-face meetings and making larger investments early on, a high commitment of the members towards the common vision could be generated. This emphasis on working together helped the group to overcome first contingencies that arose when the initial plans found their way to a competitor. Instead of giving in, they doubled their efforts and brought the project on a new level by aiming at building system supplier competences internally. Together with the readiness to drop the initial vision and to concentrate on a new frame design, this clearly is a sign of flexibility as advocated by the control approach.

In the case of *Schär*, many similarities with the *ERNE* case can be found. Sharing the same industry setting, both firms are faced by similar levels of perceived environmental uncertainties. However, the company relied to a far lesser degree on the elements of market research and business planning. Rather, the decision to develop a new product emerged as a serendipitous side-effect from the search for suppliers to replace a production line. With a fixed investment sum at hand, the firm decided to take part in the Vision 3000 group as the idea was in line with the company's existing strengths and the CEO's vision of the future development of the industry.

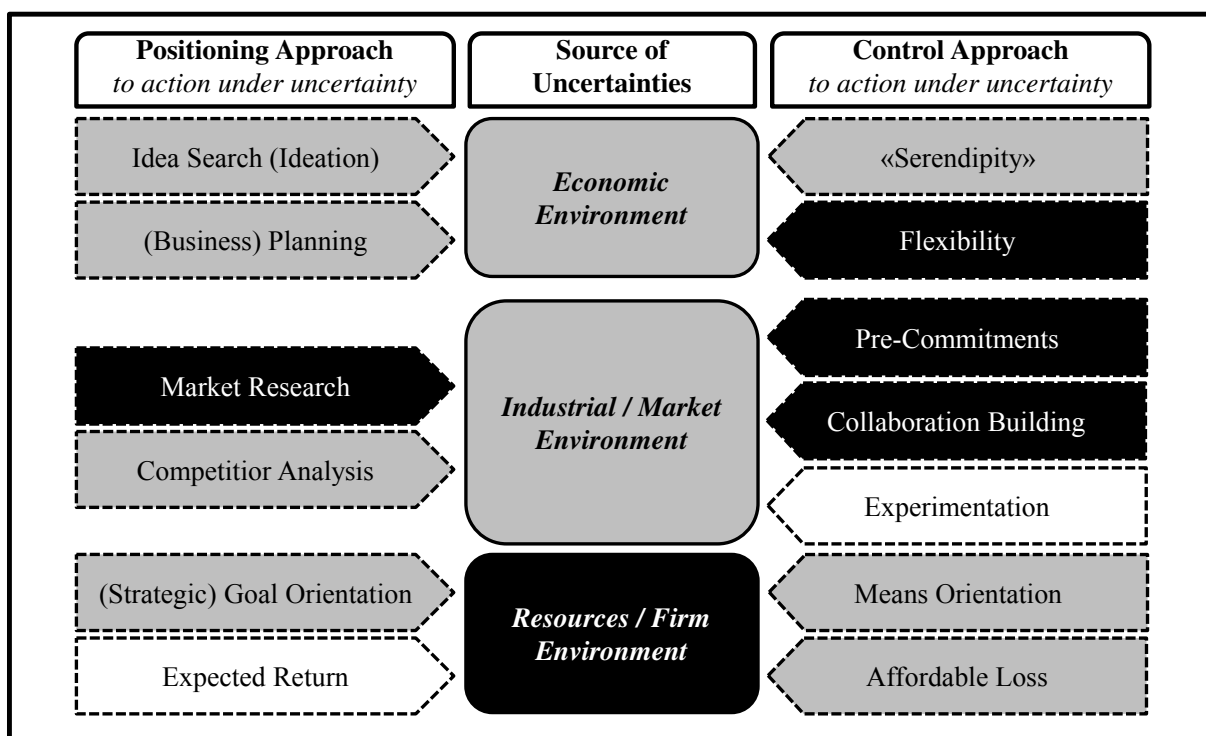


Figure 23: Within-case analysis of Schär case study

3.2.3.3 Wenger Fenster: Development of the Eiger window

Wenger Fenster was founded in 1932 as a manufacturer of solid wood furniture and beehive equipment. The family firm in Switzerland's rural Berner Oberland region only in 1963 started production of windows. Recently, the fourth generation of the Wenger family became active in the firm. Wenger Fenster prides itself on its high ethical and ecological standards along with a long-term orientation. Today the energy-saving window under the name of Eiger is one of the best-selling windows of its class in Switzerland. With a turnover of around CHF 25 million, the company employs 130 people.

The idea for the development of the Eiger window came to the company's CEO in the form of a vision while sitting on a train back to his home town in 1995. First sketches were drawn during the train ride. At the time, the company was very active in the business of window renovations in the rural part of the canton of Bern (Emmental), where houses traditionally have very small windows. If it was possible to reduce the thickness of a window's frame, the glass surface could be increased and far more light would be allowed to enter the house. This could give the company an advantage in the local renovation business. The energy saving aspect, however, was not an issue at the time. A first presentation of the idea to the management board which was made up of family members provoked rather negative reactions. Feasibility of this technically very challenging concept was doubted.

In 1996, the CEO assigned a student doing his internship in the company with the task of further investigating the product idea. This student identified the main technical challenges and produced the first technical drawings. Encouraged by his vision, the CEO developed the ambition to produce the window in a very short time. Market research or customer feedback was not sought at this stage. However, the project had to overcome very high internal as well as external obstacles. Internal technological capabilities did not allow for the production of the originally conceived visionary window and suppliers were unable to cope with the requirements specified and the low volumes initially ordered. Most objections were overruled by the CEO and after several adjustments to the original vision a first marketable product under the name of *Eiger* was presented at an industry fair in 1997. The window did not attract much attention by competitors who regarded it mainly as a niche product. The very good insulating performance was not yet a common quality criterion, since the first *Minergie* standard for energy-efficient construction was only defined in 1999.

The new product was also presented at a meeting of a regularly attended industry exchange workshop. Wenger Fenster had been a member of this group since 1976. It is

composed of 12 window manufacturers throughout Switzerland who regard themselves as belonging to the most innovative segment of their industry. Meetings are organized by an external consultant, who provides a platform for exchange and conducts research for presentation on mainly pre-competitive, technical topics. In an atmosphere of mutual trust, the CEOs compare information on key performance indicators and the latest technological trends with regard to window production technology. The reaction of the group members to the new *Eiger* window was rather sceptical.

The market response, however, was starkly different. Two years after the introduction of *Eiger* in 1997, the company increased its turnover by 50%. This encouraging response triggered further development works. Based on the original product, variations were introduced for anti-burglary protection, cell-phone radiation shielding and energy-efficient buildings.

Wenger Fenster has always put great emphasis on establishing good relationship with all its suppliers and is seen by them as a suitable partner for new developments and custom-made products. That allows the company to do without own R&D resources. A request by one of the suppliers to apply a technology developed in the automotive industry was seen as an opportunity to further develop the window and to come closer to the original vision. Sika had acquired the competence of directly glueing together metal and glass in car production which led to the idea of transferring this competence to the gluing of wood and glass. A completely glued window would represent another radical improvement compared to the conventional bonding techniques used so far.

Together with another window producer, a glass supplier, a fittings company, the chemical company Sika and the University of Applied Science in Biel (FHB), two large projects sponsored by the Federal Commission for Technology and Innovation (KTI) were conducted. At the end of the project, Wenger was able to precisely glue together the glass and wood components of its windows in a computer-controlled assembling machine. The new window was offered under the name of *Eiger Pollux* in 2004 and resulted in another sharp increase in revenues. As the own production capacities were not sufficient to cover market demand, licenses for the *Eiger* window were given to other window producers. In the case of some of the licensees, the *Eiger* window accounts for up to 80% of their turnover.

Within-Case Analysis

As the *Wenger* case is situated at an earlier point in time than *Vision 3000*, slightly different levels of perceived environmental uncertainty prevail. The major challenges at the time were in the market sphere, as the trend towards greater energy efficiency in buildings was not foreseeable at the time. However, the dynamic technological development in the glass elements had already set in and created a considerable level of uncertainty in the firm-level environment, even though the company kept itself at the forefront of technological trends in the industry. The conception of the original idea can be described as being purely serendipitous. As the interview data allows concluding, structured ideation methods were not made use of. Oriented at the means at hand, i.e. the skills in the renovation business and the good relationships to suppliers and research institutions, a first small-scale project was set up with limited means. Even though competitors were regularly contacted and market research was conducted, the actions of the CEO were mainly guided by his high ethical and ecological standards for conducting business that were emphasized throughout the interview. Notwithstanding the sceptical reactions of both competitors, suppliers and family members, the project was advanced through experimentation and the organisation of a collaboration of stakeholders. Changes in the regulatory environment, such as the *Minergie* standard, were incorporated and the project flexibly advanced through experimentation and positive customer feedback. Furthermore, licensees were allowed to produce the window in order to secure its market success.

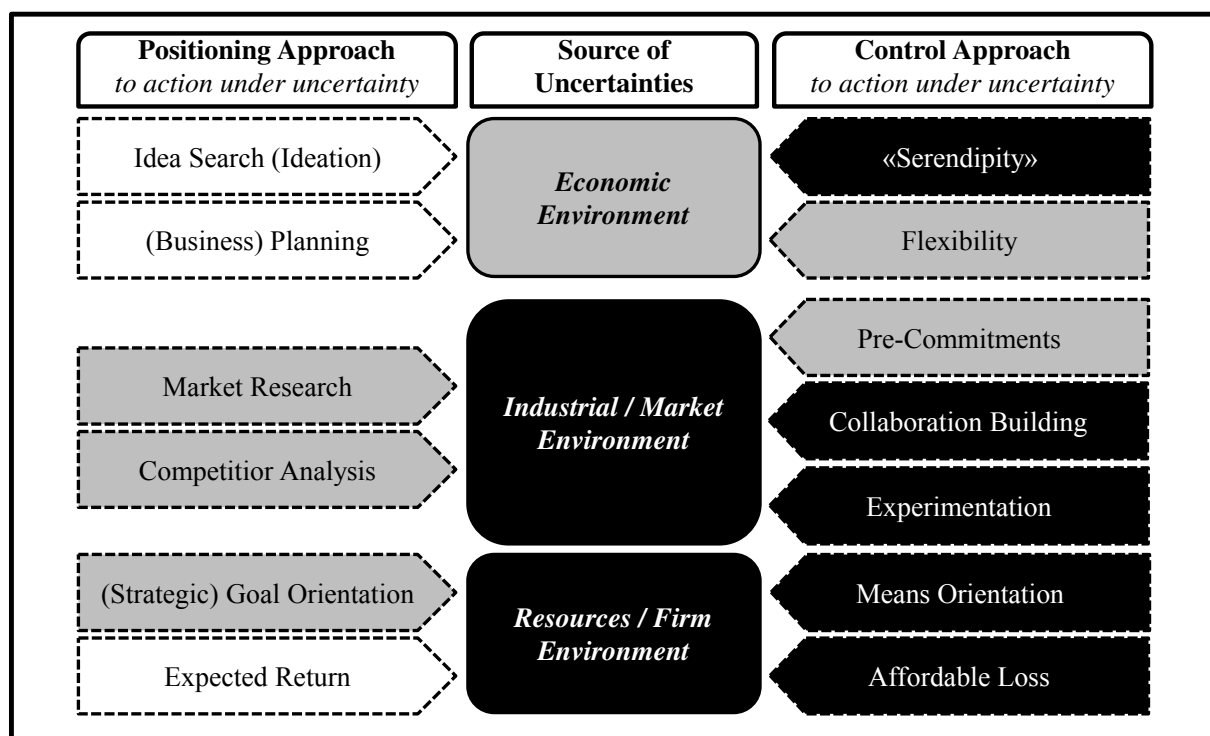


Figure 24: Within-case analysis of Wenger case study

3.2.4 Technology III: Solar Energy

3.2.4.1 Industry and Technology

Next to gravitational forces and radioactive decay, the sun is the third energy source on earth. The use of heat and light from the sun forms the basis of most energy technologies today. In the process of heating up the land and sea masses, the sun causes a variety of phenomena including the water cycle and atmospheric circulation, the energy of which can be harnessed with wind turbines or hydroelectric power technologies. Furthermore, the ability of plants to absorb solar radiation via the chemical process of photosynthesis gives rise to the availability of biomass-based energy carriers such as fossil fuels like petroleum, natural gas and coal. A narrower and more common definition of solar energy technologies is the direct use of sunlight for heating (solar thermal) and electricity generation (photovoltaics or concentrated solar power). For those purposes, a variety of technologies have been developed at varying degrees of maturity and efficiency.

For the direct generation of electricity, the photovoltaic effect can be taken advantage of. This effect has been known for over a century and has since its discovery been implemented into **photovoltaic (PV)** devices. Initial areas of application were the aerospace and telecommunications sector. Recently, a variety of technological developments have led to increased conversion rates of light into electricity. Higher efficiency levels allowed for large-scale electricity generation at especially well-suited locations and for niche applications. Today, PV cells can reach conversion efficiencies of up to 40% and PV-generated energy has reached a competitive cost level in some regions. As a consequence, worldwide PV capacities have grown at an average annual rate of 50% between 2005 and 2010, with an increase of 72% in 2010 alone. (Sawin & Martinot, 2011). Forecasts for Switzerland predict a share of up to 5% of total energy consumption that could be generated from photovoltaics in 2035 (CS Economic Research, 2007).

Due to their modular and flexible construction, PV cells can be found in a variety of applications and locations: As an energy source for calculators, integrated into facades and windows or in dedicated PV plants. A major shortcoming of this sort of electricity generation is its dependence on the availability of direct sunlight, resulting in an unsteady supply. Due to the unpredictable and stochastic availability of sunshine, PV energy cannot be regarded as a reliable and undisruptive source of electricity. It thus has to be combined with some sort of conventional energy or energy storage

technology. Furthermore, electricity generated by photovoltaics is available in the form of direct current (DC), while the electricity network is laid out for alternating current (AC). The necessary conversion requires further technical components to be installed.

Production of standard PV cells has become highly industrialized with multinational companies mainly based in far-eastern countries, dominating the world market. For special purpose PV modules and at the level of components and periphery installations, smaller companies dominate.

An alternative to direct PV is the use of **Concentrated Solar Power (CSP)** technology. The fundamental principle behind this approach is the use of mirrors to reflect and concentrate solar rays on a specific area, where high temperatures are reached. The heat is absorbed by a medium and carried to a turbine for electricity production. One of the advantages of this system is the temporal decoupling of sunshine and electricity generation through the use of a medium like steam. The delayed release of the medium for electricity generation allows for extended working hours and therefore increased reliability. On the other hand, the increased complexity and costly maintenance of the system requires it to be used in larger power plants. Four major designs for such plants have emerged: the parabolic trough, the solar power tower, the linear Fresnel reflector, and the parabolic dish design. The overall efficiency of CSP plants is high and the technology is on the verge of competitiveness. Further improvements can be expected in installation and maintenance costs as well as conversion efficiencies and heat storage technologies. However, it is still largely uncertain, which CSP layouts and technologies will eventually emerge as a dominant design. The industry is still prevalingly project-based with no major companies dominating the market. According to Sawin & Martinot (2011), worldwide CSP capacities increased by 77% in 2010.

Solar **thermal technologies** comprise the use of the sun to directly heat up a fluid stored in a collector. They are usually installed in exposed locations like rooftops, facing the sun. The working fluid, in a separate loop, is allowed to release its heat into a tank of water used for different warm-water processes in the house. The technologies applied are mature and widely used in many countries. Major markets are China, America, India and parts of Europe. In comparison to other countries like Israel with a penetration rate of solar thermal collectors in houses of more than 90%, there is a high potential for market growth in Switzerland. According to Berg & Real (2006), the number of installed devices could increase by a factor of 20 until 2070. In 2009,

Switzerland experienced a growth in installed thermal collector space of more than 160'000 m² (Hostettler, 2010)

As most solar thermal systems require an external electricity source to power a pumping system for fluid circulation, a combination with a PV module can make the system independent from the power grid. Such hybrid or integrated systems have the additional advantage of allowing the PV modules to be cooled to their optimal operating temperature. Furthermore, the house's water tanks can be used to store PV energy generated during the daytime for retrieval later.

The competitiveness of PV, CSP and solar thermal technologies alike is highly dependent on the specific applications, pre-existing infrastructure and regulatory regimes. Therefore, their further development is characterized by a significant degree of uncertainty.

3.2.4.2 3S: Development of PV laminating machine

3S was founded in 2001 by four former employees of the company Atlantis in Bern. Atlantis was a small company that engaged in a range of sustainability-related technologies such as photovoltaics, solar heating, water desalination and recycling and finally had to be declared bankrupt. As a result of their previous company's failure the founders focused on one technology, building-integrated photovoltaic modules (BIPV). Those PV modules are used to replace parts of a building's façade and therefore offer particular challenges in production and installation. This was especially the case for 3S, as the company was focused on tailor made modules for individual customers. With a technical background and equipped with venture capital, the founders had the vision of achieving quality leadership in the market. Due to the high quality standard, the founders were increasingly dissatisfied with the manufacturing equipment for the modules available on the market. The major part of the manufacturing process is the lamination step, the quality of which determines the effectiveness of the produced PV module. One of the founders therefore designed an own laminating machine, which was assembled by another founder with the means at hand. Soon after, first BIPV customers were also interested in buying the laminator itself. This prompted the development of another line of products: laminating machines for manufacturers of mass-market standard PV modules. Since 3S was not active in the standard-PV market, there was no direct competition with buyers. Rather, customers in the technologically less demanding standard-PV market could benefit from 3S' experience in the high-end BIPV market. As of 2009, laminating machines contributed 90% towards 3S' revenue, with BIPVs accounting for 10%. The laminator

in 3S' own manufacturing facility is only used by the company 20% of the time and is available for tests, demonstrations and customer training most of the time. After the early years of success, three out of four funders gave up operational duties and the remaining founder and CEO, after successfully making the company public, completed the management team with persons from outside the company. The position of COO was assigned to a long-serving industry expert. Additionally, a new CFO was engaged. The new management team initiated a clear shift in strategy and formulated the vision of integrating the whole production process of PV modules. Towards this end, a company specialized in the process step of Flashing/Testing (downstream from laminating) was acquired in 2007 and another company in the area of string soldering (upstream from laminating) in 2008. All acquired companies were assigned a local CTO (Chief Technology Officer) and continued their operations in the dispersed firm network. 3S now was the only company worldwide to offer a wholly integrated production line for PV module manufacturers.

In 2008, the position of CIO (Chief Innovation Officer) was newly created. The new CIO had acquired experience with large companies in the heavily process-focused chemical industry. In his first months in office, he began to replace the formerly unstructured and chaotic development process by a formalized one. The goal of the new stage-gate process is to identify promising and to reject unpromising ideas at an early stage. Explicitly, innovation approaches from larger companies such as Philipp's "proudly copied elsewhere" slogan, job rotation, purposefully-designed interdisciplinary and multicultural teams are applied in 3S' SME setting. As the documented idea search and evaluation process focuses on the optimization of the existing process, main sources of ideas are user observations, customer interaction and the scientific literature. There is a weekly meeting of the innovation group, which consists of employees from all areas assigned to the group on a part-time basis as well as three project leaders. The project leaders have an engineering, science and patent background respectively. Typically, between zero and three innovation ideas are brought to the meeting. Each idea is evaluated by the group according to the following criteria: patent situation, technical feasibility, customer benefit, main obstacles and benefit for 3S. After this evaluation, the contributor of the idea is asked to answer a catalogue of questions and assigned a coach. The next step is a detailed project plan with milestones, deliverables and deadlines. In 2010, 3S was taken over by Meyer-Burger AG, a Swiss company active in the process of cutting silicon blocks into wafers. Meyer-Burger and 3S complement each other in further integrating all process steps from the raw silicon blocks to the tested PV modules. Meyer-Burger in 2011 had around 2500 employees and turnover above 1 billion francs.

Within-Case Analysis

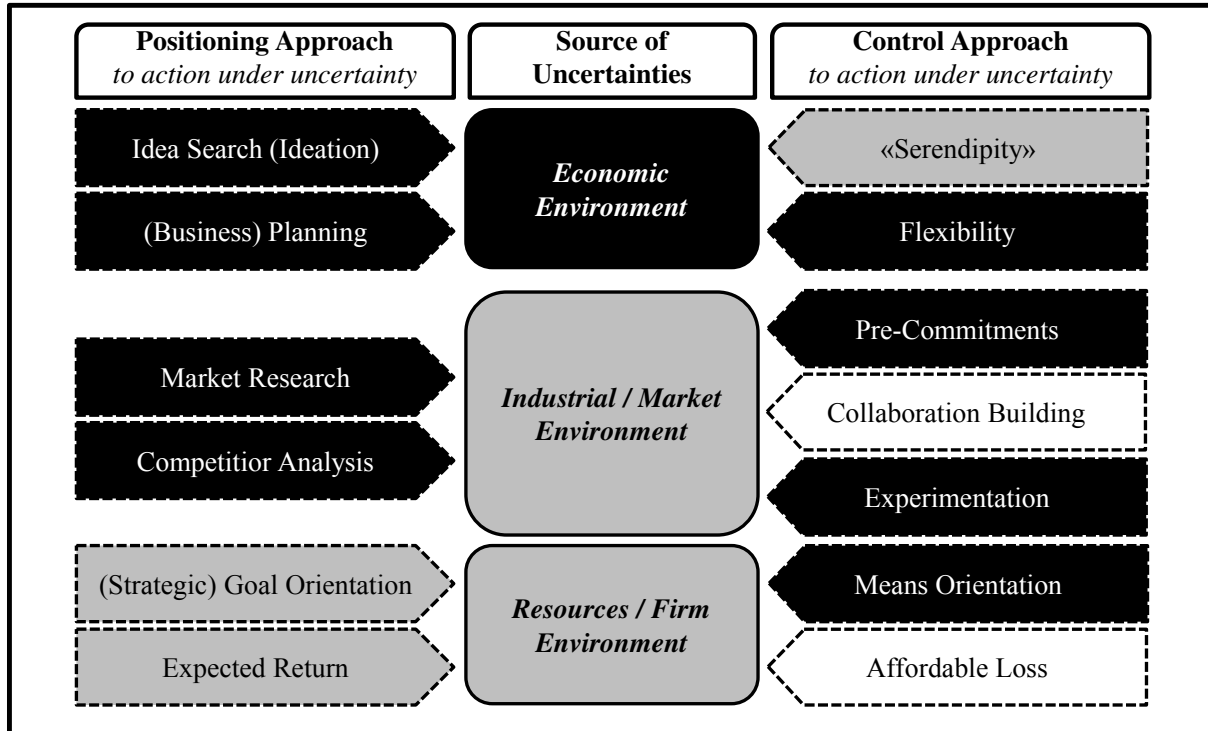


Figure 25: Within-case analysis of 3S case study

The **3S** case data show that the company operates in an environment that is characterized by a moderate degree of technological and market uncertainties. Even though PV panels have almost become a commodity, the firm is active in the BIPV industry, which exhibits higher technological challenges. Furthermore, new PV technologies are emerging with yet lower conversion efficiency levels. However, the regulatory environment especially in the PV industry is changing as subsidy schemes are beginning to fade and competitive pressures as well as protective tendencies in major solar energy producing countries are recognizable.

The approach the company has chosen to face those uncertainties has changed over time. At the outset, a clear means orientation of the founders together with a focus on experimentation, pre-commitments from customers in related industries and flexibility in responding to unexpected contingencies was dominant. Entry into the laminating business was clearly an unplanned and serendipitous one. Once the company had established itself in the BIPV market and additionally had a foothold in the mainstream PV industry via its laminating machines, the original founders retired and gave way to a management team with a background in larger, process-oriented companies. Consequently, a change from a control to a positioning oriented approach resulted in a structured ideation process and large-scale acquisitions to position itself in the competitive environment. However, some of the control-inspired elements like means experimentation and flexibility were retained.

3.2.4.3 Airlight: Development of a low-cost CSP plant

Airlight Energy is a company founded in 2007 and active in the area of concentrated solar power (CSP) and concentrated photovoltaics (CPV). Both technologies are based on the principle of concentrating solar rays through mirrors on a small area. The concentrated solar rays impact an absorber medium (in the case of CSP) which is heated and subsequently transported to a gas turbine for electricity generation. In the case of CPV, electricity generation is conducted directly via photovoltaic cells which can operate at their optimal capacity due to the total concentrated impact of 500 suns. In order to allow for round-the-clock electricity production, CSP plants store parts of the heat generated, which can be released during hours without sunshine to power the steam turbine. In contrast, CPV plants only generate electricity during sunshine hours. The focus of *Airlight Energy* is on CSP technology, where it has developed a radically new, low-cost system based on several new construction principles and materials.

The founders of *Airlight Energy*, two brothers, both had been entrepreneurially active in the past:

One of the founders has acquired expertise in the area of structural engineering since the 1970's and had founded two companies specialized in lightweight structures, bridges and pneumatic structures. The latter of the two companies was *Airlight SA*, which was founded with the aim of applying an invention in the area of tensegrity. Tensegrity is a construction principle in which isolated bars that make up the structure do not touch and are kept in position by cables. The invention consisted in the use of compressed air to replace steel struts commonly applied in those constructions, leading to a massive reduction in overall weight. The resulting pneumatic beams under the name of *Tensairity* were thought to have a broad range of applications in areas such as footbridges, sport arenas, greenhouses, temporary structures, sport equipment or even in the aerospace sector.

The second founder has a background in structural engineering and has founded two companies in the e-commerce area before joining *Airlight SA*.

Potential applications in the field of solar energy were initially not thought of, as the focus was on bridges or roof constructions, more in line with the professional background of the founders. This area only came to the attention of the founders through a phone call from an Australian student, asking about the possible use of membranes for solar collectors. This led to the idea of a solar power plant based on the parabolic trough principle. For this end, the new company *Airlight Energy* was founded in 2007.

Based on the idea, that a new concept for the use of solar power should be radically different from existing solutions, a first prototype was developed. The starting point was the initial competence in the *Tensairity* technology, which involved the handling of tension and compression, membrane technology and substitution of materials. Through experimentation and initial failures, the two-chamber principle was found to be the best technical solution. A strict cost reduction led to the vision to develop the most inexpensive alternative for solar power production. Several low-cost ways for the replacement of commonly used materials were found through experimentation and luck. For instance, the idea to use air instead of thermal oil or liquid salt as an absorber material was found at an industrial fair in Seville. Furthermore, the use of concrete instead of metal for the whole structure allows for inexpensive local sourcing of materials and labour and the avoidance of transport costs. By reinforcing the concrete with fibres instead of metal bolts, corrosion by salt water is greatly reduced and longevity increased, making the collector suitable for all kinds of harsh environments. Another example is the reduction of the number of screws in the construction from initially 6'000 to zero. In contrast to similar conventional plants that rely on expensive and/or dangerous energy storage technologies such as steam, oil or molten salt, Airlight Energies uses a low-tech alternative in the form of pebble bed storage. This technology has been proven to work since the 1920's and pebbles can be sourced locally at the location of the power plant.

In order to build the prototypes and to conduct the necessary technical enquiries, *Airlight Energy* has collaborated with a variety of other companies and research institutions. The ETH Zürich, PSI, University of Applied Sciences in Lugano (SUPSI) as well as the Federal Office of Energy (FOEN) have co-funded the development. The cement engineering company Concretum contributed a special kind of concrete recipe for the structure that weighs about 200 tons.

Within-Case Analysis

In the case of *Airlight*, perceived environmental uncertainties can be described as high in all spheres. As mentioned above, there is still no indication as to where the rivalling technologies for CSP will develop and what dominant design will eventually emerge. In connection with the typically high investment costs of CSP facilities, making the technology commercially successful constitutes a major challenge.

The company's way of acting under those perceived uncertainties is strongly influenced by the control approach. Concentrating on the *Tensairity* technology and leaving a concrete area of application open mirrors a means rather than strategic goals orientation that is at the core of the original firm. The decision to develop a product

with relation to the energy sector came about as a pure coincidence, as the application of *Tensairity* structures to CSP plants was completely outside the prior field of activity in the bridge and light weight building sector. In light of the many unknown factors the product development process followed an experimental approach. As a result of the experiments, a vision emerged of building the most inexpensive alternative to solar power production.

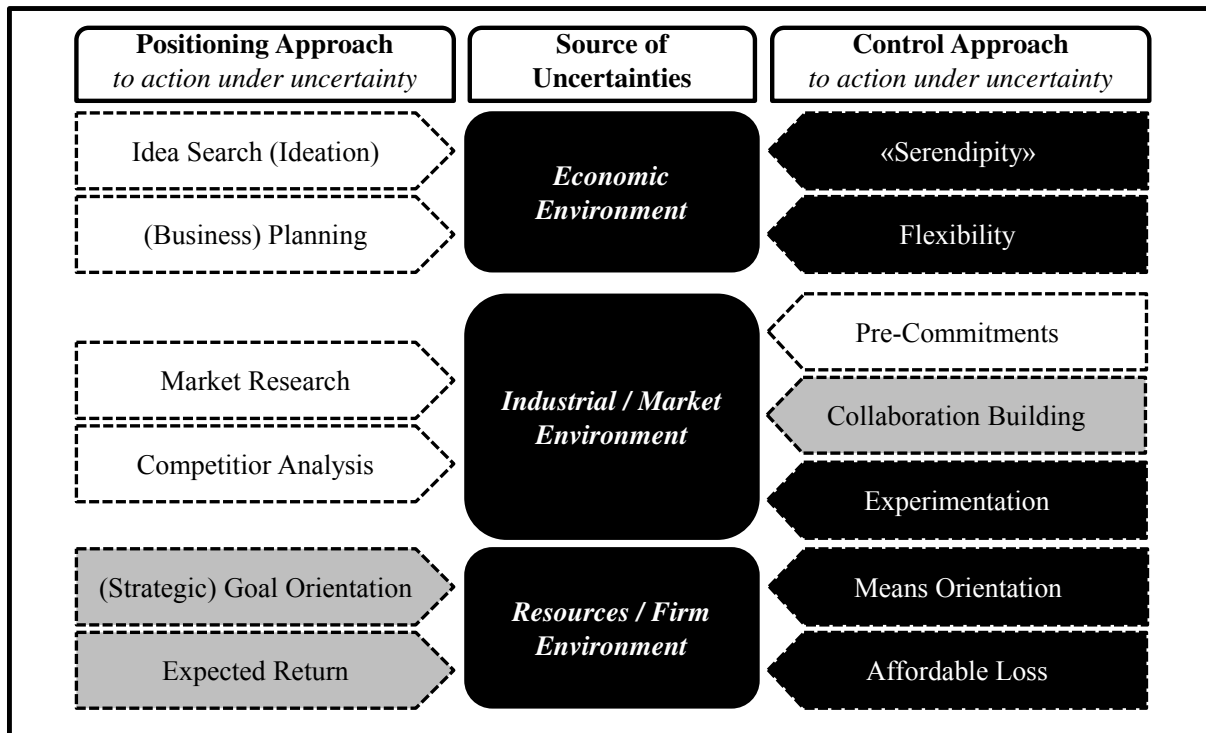


Figure 26: Within-case analysis of Airlight case study

The initial pure means orientation was therefore complemented by a strategic goal orientation, while still leaving the solution space rather open. Instead of tailoring a product to a certain segment of the market, the product should be very low-cost so that customers could be won despite the many uncertainties still prevailing about the future technological and regulatory conditions. A competitive orientation was not warranted, as only few other firms were active in this segment of the CSP industry. Rather, collaborations with stakeholders interested in advancing the overall system and the involved technologies were built. Even though the project started out as an experimental project involving low levels of capital, later on further investors were taken on board to shoulder the financial burden of prototype building. This is in contrast to the control-based approach that would suggest finding a customer willing to pre-commit to the early product and help finance the first prototypes.

3.2.4.4 Hilti: Establishment of the Energy + Industry segment

Hilti AG is an international group in the area of fastening technology based in Liechtenstein. Founded in 1941, the company has a workforce of over 20'000 people in about 120 countries that generate a turnover of more than CHF 3 billion. Hilti has traditionally been organized in a matrix structure. Customers that are mainly smaller handicraft businesses are served by a strong sales force in country organizations. The business units' product development departments add the innovative element and are organized as cost centres.

The group sees itself as an innovation-driven company which is stated in their "Vision 2015". Part of this vision is to bring about a sharp increase in the group's turnover, one billion of which is expected to be contributed through business areas that are new to Hilti. Most of this new business comprises the areas of mining, energy (i.e. oil and gas) and solar. The focus on the energy sector was driven by high potential for applications of Hilti products in the related industries. The company systematically conducts studies on possible further applications of existing competences. The search for analogies yielded a wealth of results. For instance, there is a need in the mining industry for fastening walls with anchors, which is a core competence of Hilti. However, the anchors would have to be provided at a considerably bigger size. Direct jointing of elements on concrete, another competence of Hilti, was found to be useful in the development of direct jointing solutions on metal on drilling platforms.

While mining and energy were entered in 2003, the solar business started in 2008, together with the establishment of a new organizational unit "Energy & Industry". The new organization is led by Hilti's former head of business development with a background in large industrial and consulting companies. Unlike the traditional matrix set-up, *Energy & Industry* was designed as a vertical organization outside the matrix, falling back on national sales forces on a case by case basis. The reason for this unusual organizational form is the different business logic in the targeted industries. Sales situations are complex, with Hilti being integrated as a junior partner in larger worldwide and project-based supply networks. Projects are characterized by long lead times and one-to-many relationships. The national sales forces therefore are not suited to support projects that go beyond country boundaries.

Energy & Industry is free to develop necessary technological competences in several ways. Firstly, joint development with R&D resources of other business units and central Hilti R&D resources is possible. External product development is also an option, provided all intellectual property rights stay with Hilti. Secondly, acquisitions

are a strategic option as shown by the acquisition of the American company Unirac, the North American market leader in mounting systems for photovoltaic appliances. Due to the dynamic environment in the energy sector, the planning horizon does not exceed three years. Management is free to adapt the strategy along the guidelines provided by Hilti's overall vision. Opportunities to generate more business should be taken as they arise, regardless of duplication or synergy considerations. In 2010, the solar segment contributed almost 50% towards the group's overall growth in turnover.

Within-Case Analysis

The *Hilti Energy + Industry* highlights the approach of a larger company that aims at exploring into new markets that exhibit a significantly higher level of uncertainties than the markets normally catered for by the company. In the case of *Hilti* this means that the perceived uncertainty in the market sphere is high, while the regulatory and technological environments are well understood by the firm.

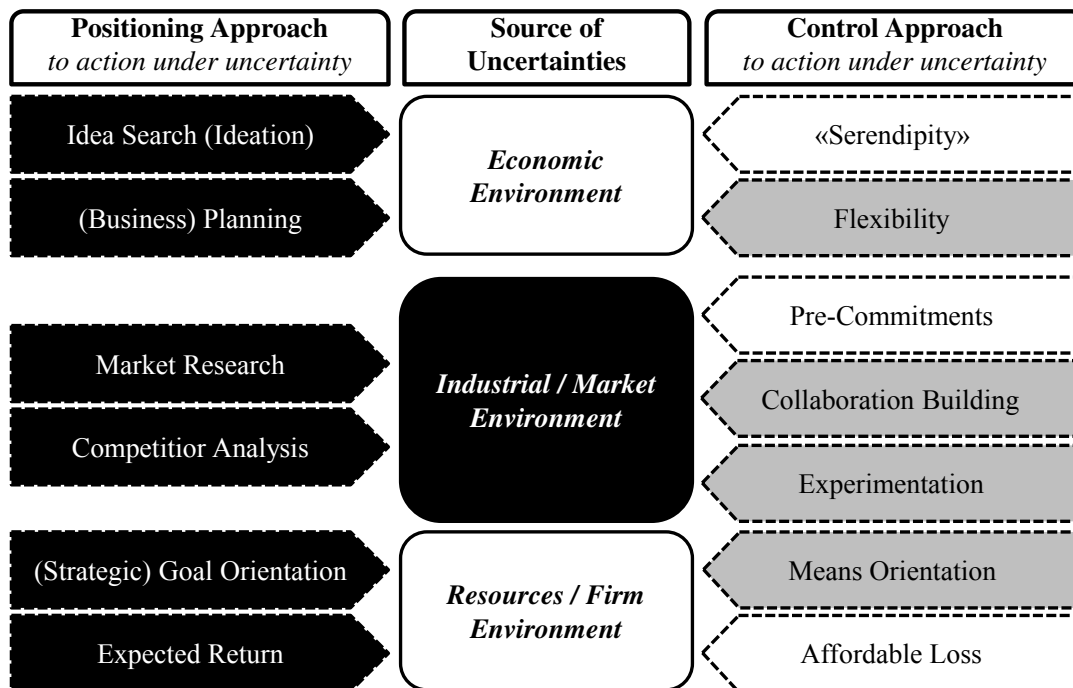


Figure 27: Within-case analysis of Hilti Energy + Industry case study

The data illustrates clearly, that the company follows a strategy that is vastly inspired by the positioning approach's focus on uncertainty reduction through means of planning and adaptation. However, it is noteworthy that in the area where uncertainties are high, elements of the control approach have been considered. For the purpose of this exploration, an industry focus has been chosen that is in line with the existing means of the firm and for which existing products and skills can be adapted through experimentation. Additionally, planning is seen much less strictly than in the rest of the organization and the members of the division are allowed more flexibility in responding to market requirements and to collaborate with third parties.

3.2.5 Technology IV: Biomass Gasification

3.2.5.1 Industry and Technology

Biomass as an energy source is based on the ability of plants to absorb and chemically bond solar energy via the process of photosynthesis. In order to recover this energy, a number of physical and chemical processes have to be applied which depend on the kind and condition of the biomass at hand. Possible recovery processes are

- direct incineration, mainly of wood, in order to generate thermal heat.
- physical extraction of plant oil and its subsequent transesterification into biodiesel.
- Ethanol fermentation in order to generate biogas which can be used in combined heat and power (CHP) plants or further refined into synthetic natural gas (SNG).
- ethanol fermentation in order to generate biofuels used as a substitute for traditional fossil fuels.
- pyrolysis.

Biomass has the longest history of all energy sources used by man. Over most of history, wood has been the main input factor for all thermal processes. In Switzerland it is, only second to water power, the most important source of renewable energy. Classical wood stoves, wood chip and wood pellet stoves as well as thermal storage heating stoves are the main facilities to transform wood into useable thermal energy. Especially automated wood firing achieves high levels of efficiency and reliability.

Forecasts for Switzerland attribute biomass the long-term potential of providing the largest part of new renewable energy generation. Estimations are in the dimension of up to 5.5% (CS Economic Research, 2007).

In recent years, further organic resources have been unlocked for energy generation purposes. Palm oil, canola and soy are used for biodiesel production, sugar cane and other plants for biofuels, and organic wastes, manure, sewage sludge and wood for biogas generation. Biomass therefore has the potential of contributing to renewable heat as well as power generation and the gradual substitution of fossil fuels in the mobility sector. In the area of power generation, efficiency levels up to 80% in combined heat and power plants are achievable. In the mobility sector, flexible fuels allow for the mixing of fossil-based fuels with biofuels. However, the use of comestible goods in the production of biofuels represents a direct conflict with food production, hence involving a variety of ethical challenges. Newer-generation biofuels therefore focus on cellulose incorporated in plant parts that are not suitable for human consumption. Due to its local availability and the absence of rivalry in consumption, waste wood still is the biomass category with the highest potential for Switzerland.

Challenges for the more widespread use of energy generated through the incineration or gasification of wood mainly lie in the technical processes. While the different process steps have long been available in different industries, their new combination and increases in efficiency levels are still in progress. Due to the variety of potential conversion technologies, the ethical and legislative challenges as well as the high infrastructure costs and switching costs, the industry can be characterized as exhibiting both a high level of technological uncertainty and a high level of market uncertainty.

3.2.5.2 CTU: Entry into biomass gasification

The roots of *CTU* reach back into the 1960's, when the Sulzer Group, a multinational industrial engineering company based in Switzerland, established its water and waste water treatment department. The growing importance of environmental issues in the 1980's led to further expansion of Sulzer's activities into the area of air pollution control and hazardous waste incineration plants. During those years, the technical and process know-how as well as key personnel of *CTU* was built up. After the sale of Sulzer's environmental department, those assets were integrated into the Babcock Borsig Group, one of Europe's largest suppliers of thermal plants offering the whole range of technologies in the areas of incineration, steam generation and stack gas cleaning. In 2002, after the bankruptcy of Babcock-Borsig, *CTU (Conzepte, Technik Umwelt AG)* was founded through a Buy-Out through a member of the management (MBO), who subsequently acted as the company's CEO. *CTU* initially with 22 employees concentrated on smaller hazardous waste treatment plants and stack gas treatment. Next to plants with a total volume not exceeding CHF 20 million, retrofits of existing plants were a major business area.

Over time, *CTU* grew to a size of 50 employees and it became obvious that the retrofit business would be fading out in the foreseeable future and that new plants would increasingly be built in the price range of above CHF 100 million. Furthermore, competition was becoming more pressing as new companies were entering the market. For larger projects, *CTU* as an SME was unlikely to be considered as a partner and it also did lack some critical technical competences, such as those associated with the combustion grate. Hence, *CTU* decided to continue the existing business as long as possible and to use the proceeds in order to build up a new business area.

When considering possible development projects, *CTU* puts major emphasis on the criterion that an existing *CTU*-developed or *CTU*-licensed technology lies at the heart of the new development. Based on *CTU*'s existing main competence in waste treatment, the next step was to look for other input materials with similar properties.

Some of the materials examined were poultry slaughterhouse waste or car shredding waste. Experimentation together with customers in those areas led to the rejection of most of those ideas.

Another idea, the distillation of wood for methane production, arose from already established contacts with the *Paul Scherrer Institute (PSI)*, a research institute in the area of energy technologies. Due to previous project partnerships and the fact that the father of *CTU's* CEO had already worked for *PSI*, there was a well-established contact to this research institution. Together with *PSI*, the project idea "wood-to-methane" was developed with the aim of gaining synthetic natural gas (SNG) through the gasification of wood, which could then be fed into the existing gas distribution system. The main challenge in this project was to transform gas directly generated from wood into methane. This transformation is done via a catalytic process. Since the construction of an own plant was considered to be too expensive, an Austrian plant was approached and could be won as a partner. The official project sum was CHF 8.5 million. Funding was organized through Swiss Electric Research and the European Union. *CTU* acted as the practice partner and invested own funds in the project. *PSI* contributed another CHF 2 million in the form of research hours.

Due to his professional career inside the Sulzer and Babcock-Borsig Groups, *CTU's* CEO has an extensive network of personal contacts to experts in the industry. This allowed him to win further partners for particular technical challenges in the project. In the course of the project, a pilot plant was built and conversion rates up to 80% from wood to methane were reached. The capacity of the plant in 2008 was one MW. In 2009, the project team was awarded the Watt d'Or prize of the *Federal Office of Energy* for the most innovative project in the *energy technology* category.

At the end of the project in 2009, *CTU* with its newly acquired competence in wood distillation was able to win first contracts in Sweden and France. In order to further develop and commercialize the technology, a cooperation and licensing agreement with the *PSI* was signed.

Additionally, a new technology was licensed in the area of gasification of wet biomass. This additional reactor technology complemented the upstream and downstream capabilities of *CTU* and had the potential of developing into yet another business area. Moreover, in the area of smaller-scale wood gasification, a co-operation with another Swiss SME, *Pyroforce* was started. The *Pyroforce* case study deals with this particular project.

Within-Case Analysis

In the case of *CTU*'s development of the wood gasification technology, the uncertainties in the technological as well as in the market environment were rather high. The wood-to-methane plant is an infrastructure-like product that relies on specialized technological knowledge in a number of areas that in parts are still at a fundamental research state. In order to act in the face of those uncertainties, the company chose an approach that exhibits many elements of a control-based approach. In the search for new business segments, an experimental approach was chosen that on the one hand relied on an active search for ideas and on the other hand was also open to serendipitous ideas that emerged on the way. The emphasis on using only CTU-developed or CTU-licensed technologies for the development of a new business segment is characteristic for a means-oriented mind-set. This approach is complemented by the focus on the proceeds of the fading retrofit business that delimit the available financial means for the task. In order to get the necessary skills together and to develop a marketable product, pre-commitments from stakeholders along the value chain were secured. By leveraging existing networks and building a coalition of interested firms, institutions and organizations around an EU-sponsored project, a first plant could be built.

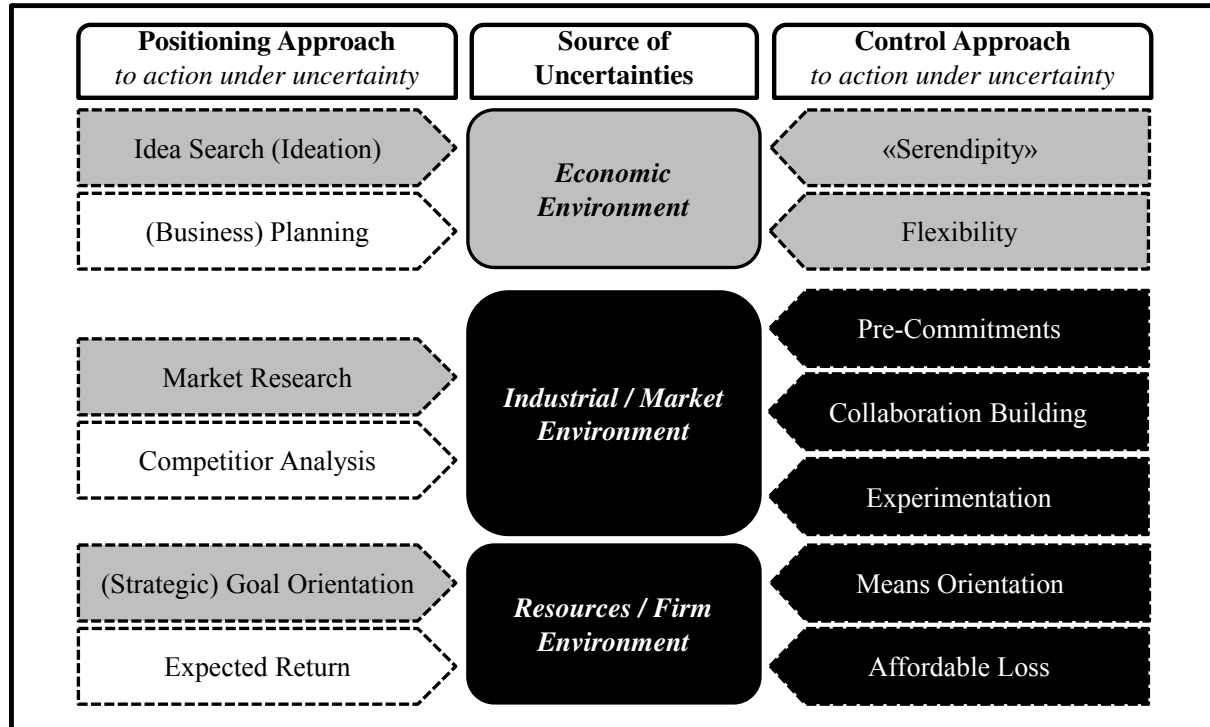


Figure 28: Within-case analysis of CTU case study

3.2.5.3 Pyroforce: Entry into wood gasification

The history of *Pyroforce* started in 1974 with the foundation of *Hydrotest* engineering office. The initial focus of the company with around 5 employees was on sanitary environmental engineering, mainly in the area of sewage plants. Main competences were the handling of pumps and pipes for those facilities. Over time, the conditioning of liquid special wastes, such as sewage from slaughterhouses, garages, pharmacies and hospitals became more important. The accumulated competence allowed the company to win a major project order by the canton of Lucerne to realize a concept for sludge treatment and processing. As the canton was not willing to operate the proposed treatment facility under its own name, *Hydrotest* decided to build and operate the plant itself. Over the years, around CHF 30 million were invested in the facility and the company grew, through the hiring of new employees especially in the area of chemical engineering, into an interdisciplinary team.

Having its own facility at hand, *Hydrotest* won further research projects. Among them was the study of the exploitation of the stomach content of slaughtered cows. In the process of scientific research, one employee came up with the idea of energetic exploitation of the material through composting or fermentation. In discussions with other engineers, the idea of gasification was found to be the most intelligent approach for this particular challenge. This led to the establishment of an internal group dedicated to the installation of a pilot plant and first experiences in the area of high-temperature gasification in 1994. Based on those competences, another research project worth around CHF 650'000 was won in 1996 with the aim of studying the gasification of fractions of wood.

This project brought *Hydrotest* to the limits of its technical capabilities, so that external experts had to be called in. It became obvious, that the traditional process of gas production, treatment and exploitation had several potentials for improvements. The wood gasification project offered an opportunity to address those shortcomings of the existing technologies. While the **gas production** was a core competence of *Hydrotest*, the other two process steps were new to the company.

In the area of **gas treatment**, the hitherto used process of wet scrubbing led to considerable amounts of waste and intense odour. An alternative would have been a dry scrubbing system, which was outside the technological competences of *Hydrotest*. One employee therefore contacted a former colleague from his PhD time at ETH Zurich who was at the time working for *CTU*. *CTU* had a reputation in the field of stack gas cleaning and was willing to work out a concept for dry scrubbing. A

collaboration contract was set up, ruling that each company was to further develop their respective technologies at their own expense. *Hydrotest* subsequently sold its own sludge treatment facility and invested the proceeds of around CHF 11 million in the development of the new technology. The company's name was changed to *Pyroforce*. Later on, the two companies formalized their collaboration in a joint company, *Pyroforce Conzepte AG* with the aim of commercializing the technology for wood gasification and electricity generation. Over the years, *Pyroforce* was able to build up considerable technological knowledge in all process steps.

In the area of **gas exploitation**, there was a marked need for efficiency improvements. Therefore, all major engine producers were approached with limited response. Only one producer, the Austrian company Jenbacher (later: GE Jenbacher) was able to supply an engine with the required efficiency factor of 40%. The company already had acquired experiences with special gases and was willing to change over an existing engine at own costs. However the retrofit was only possible in connection with a sales contract. In the following ten years, the collaboration between *Pyroforce* and GE Jenbacher deepened, even though only a limited number of engines were ordered. The first installation with a customer was in 1999 as a research, pilot and demonstration plant. Three market-ready plants followed in 2006 and 2007.

Within-Case Analysis

While exhibiting the same environmental condition as *CTU*, the *Pyroforce* case is characterized by an even more control-inspired approach towards action under perceived uncertainty. The history of *Pyroforce* and its precursor firm shows a strong emphasis on experimentation with existing means and the development of additional skills and market offerings in the context of challenging research contracts.

The flexible response to external contingencies as in the case of the purchase and later sale of the sewage treating plant are an expression of a rather control than planning inspired behaviour on the part of the company. Furthermore, in the wood gasification projects, considerable pre-commitments could be won by the engine producer Jenbacher and through the collaboration with *CTU*. The collaboration allowed the firm to bring the necessary technological means together and to advance the project even though uncertainties in the market environment were high. The financial uncertainties involved in the development of the new technology were countered by selling the company's major asset – the sewage plant – and in the process completely changing the focus of the company's activities.

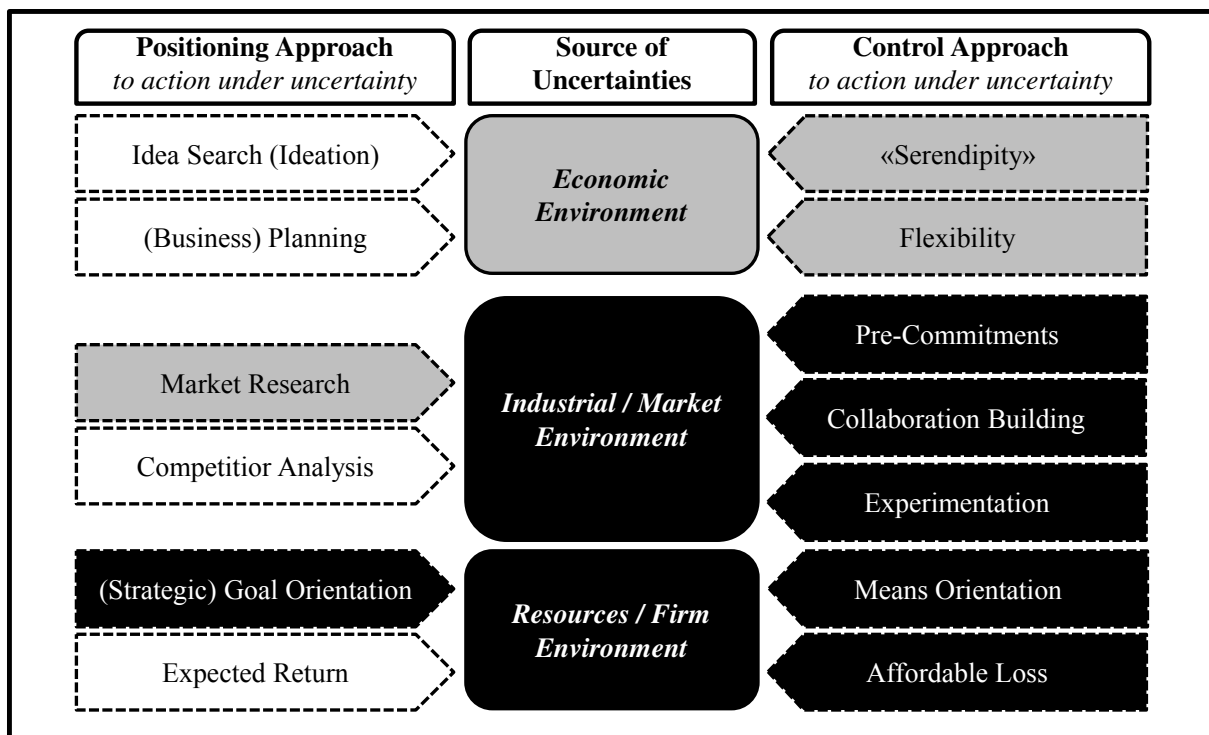


Figure 29: Within-case analysis of Pyroforce case study

4 Cross Case Analysis

4.1 Overview of Within-Case Analyses

The case studies conducted in chapter 3.2 will be used in the following to answer the second research sub-question of “How does the degree of uncertainty influence the choice of positioning versus control strategies by SME in the early phases (fuzzy front end) of the product innovation process?” Data that has been condensed through within-case analyses is presented in Table 5.

The overview shows that the case study firms exhibit a considerable degree of variation in their utilization of control and/or positioning inspired approaches to taking action in the face of perceived environmental uncertainties. It also highlights the appropriateness of the chosen industries of the RE/EE sector, as all case study firms were located in industries that are characterized by high levels of uncertainty in at least one environmental sphere.

Case study	Environmental Uncertainty			Control Approach to action under uncertainty							Positioning Approach to action under uncertainty					
	e	i	f	c1	c2	c3	c4	c5	c6	c7	p1	p2	p3	p4	p5	p6
CEKA	h	h	h	h	h	h	h	m	h	h	m	l	l	l	m	l
HEXIS	m	h	m	l	l	m	m	l	m	m	h	h	m	l	h	m
ERNE	m	m	h	m	h	h	h	m	h	m	h	m	h	m	m	l
Schär	m	m	h	m	h	h	h	l	m	m	m	m	h	m	m	l
Wenger	m	h	h	h	m	m	h	h	h	h	l	l	m	m	m	l
3S	h	m	m	m	h	h	l	h	h	l	h	h	h	h	m	m
Airlight	h	h	h	h	h	l	m	h	h	h	l	l	l	l	m	m
Hilti E+I	l	h	l	l	m	l	m	m	m	l	h	h	h	h	h	h
CTU	m	h	h	m	m	h	h	h	h	h	m	l	m	l	m	l
Pyroforce	m	h	h	m	m	h	h	h	h	h	l	l	m	l	h	l

Table 5: Overview of case study data from within-case analyses

Abbreviations

Environmental spheres (e, i, r): e = economic (regulatory) environment; i = industrial / market environment; r = resources / firm (technological) environment

Control Approach (c1-c7): c1 = serendipity; c2 = flexibility; c3 = pre-commitments; c4 = collaboration building; c5 = experimentation; c6 = means orientation; c7 = affordable loss

Positioning Approach (p1-p6): p1 = idea search (ideation); p2 = (business) planning; p3 = market research; p4 = competitive analysis; p5 = (strategic) goal orientation; p6 = expected return

Variable Values (h, m, l): h = to a high degree; m = to a moderate degree; l = to a low degree

4.2 Clustering of Cases

The overview of within-case analysis data highlights that the prevalence of the different approaches cannot be attributed to a certain industrial setting, as companies that operate in the same sub-industry like Schär and Wenger or CEKA and HEXIS did not choose identical approaches in the early phases of their product development projects. Apparently, the particular technological area (fuel cells vs. biomass gasification vs. energy-saving windows vs. solar energy) or the size and age of companies do not seem to be reliable predictors for the choice of approaches to action under uncertainty.

Furthermore, a clear preference of control-based over positioning-based strategies or vice versa is not observable. While companies like CEKA, Airlight or Pyroforce are characterized by a predominantly control-based approach, positioning-based approaches are prominent with firms like Hilti E+I or HEXIS. Some firms like 3S or Wenger combine elements from both control and positioning based approaches. The latter shows that there does not have to be a dichotomy between a control and positioning orientation and that elements of both approaches can be combined.

A closer comparison of the individual cases reveals that the degree and quality of perceived environmental uncertainties actually has a major influence on the choice of how to combine control-based and positioning-based approaches in the early phases of product innovation management.

The main difference between the cases seems to be the motivation that was behind the product innovation project. This motivation, in turn, is highly dependent on the particular situation the individual company finds itself in. While some companies are mainly interested in developing more advanced products for a market they are already familiar with, other firms are interested in transferring their already well-established technological competences into new markets. In the former case, the situation of the firm is characterized by high technological uncertainties but lower market uncertainties. In the latter case, the opposite situation is prevalent. The kinds of uncertainties that are connected with a particular product innovation project therefore are the deciding element influencing the choice of control vs. positioning-based approaches. For the purpose of this delineation, Freel's (2005) three spheres of perceived environmental uncertainty can again be drawn on:

On the one hand, there is the uncertainty at the level of the firm that arises from the inability to adequately assess the future value of the own (financial and technological) means and competences. The main reason for this inability can be seen in

technological changes, the lack of common standards and a multitude of competing technological solutions. Due to the idiosyncratic resource base of every firm, this kind of uncertainty is highly firm-specific.

On the other hand, there are uncertainties that reside in the broader environment of the firm, either in the market or in the general economic sphere. Freel (2005) summarizes those uncertainties as “extra-organisational” (p.50), as they do not refer to a particular firm but are equally applicable for a multitude of firms. However, the possibilities of a firm to react to uncertainties in the extra-organisational spheres also depend on their idiosyncratic ability to recruit and retain the necessary firm-level resources (technologies, funds, skills). The two classes of environmental uncertainties (idiosyncratic firm level and extra-organisational market/economic level uncertainties) can therefore not be analysed in isolation but have to be considered jointly.

Idiosyncratic and extra-organisational uncertainties can present themselves in a variety of combinations. Those combinations and the resulting degree of perceived environmental uncertainty characterize the concrete setting of a particular product innovation project. Figure 30 shows the six possible settings for innovation projects, based on the degree of uncertainty.

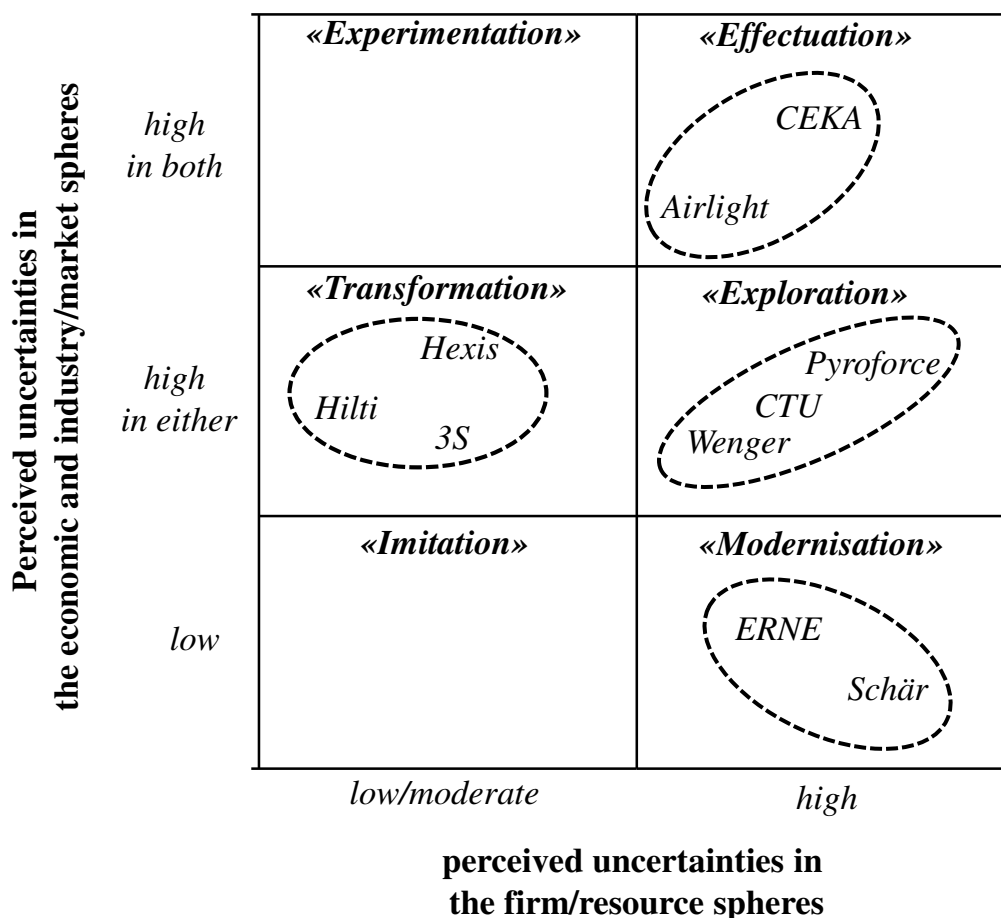


Figure 30: Archetypes for product innovation projects in uncertain environments

The x-axis differentiates between situations of *true uncertainty* (high level of uncertainty) and situations of mere *risk* or *ordinary uncertainty* (low or moderate level of uncertainty) in the *firm-level* sphere of the project.

The y-axis highlights the degree of *extra-organisational* uncertainties by indicating the number of environmental spheres characterized by *true uncertainty* (high level of uncertainty). The three possible values are

- none (neither market nor economic sphere exhibit high level of uncertainty)
- either (either market or economic sphere exhibit high level of uncertainty)
- both (both market and economic sphere exhibit high level of uncertainty)

Based on the results of the within-case analyses, the ten case study firms are classified into the six different settings (*archetypes*). The individual settings are subsequently analysed in detail:

4.2.1 Imitation

A company that is faced by a low or moderate degree of perceived environmental uncertainty in both the resources/technological as well as the market and regulatory sphere can be classified under this category. In such a situation, it is predictable to a reasonable degree which skill-set and resources are needed and what the expectations of customers and the future regulatory framework will look like. A practical example from the energy sector could be a forest owner who decides to no longer sell the lower quality part of his wood to the nearby cement mill but to press and package it into wood pellets and sell it to the local school's wood pellet heating. The investment costs and expected returns can be calculated with sufficient reliability and market demand can be forecast based on the regionally installed capacity. Pricing and distribution strategies can be based on a thorough market and competitor analysis. Overall, a positioning approach is best suited to initiate a product innovation in such an environment.

As the focus of this study was on the initiation of product innovation processes in SME under conditions of *true uncertainty*, none of the case studies discussed above falls under the imitation category. However, it is reasonable to assume that most product innovations take place under this kind of environment and that the instruments provided by the classical innovation process model are effectively applicable under those conditions.

4.2.2 Transformation

Environments characterized by a low degree of technological or firm-level uncertainty and at the same time high uncertainty levels in one of the two extra-organisational spheres pose specific challenges to the early phase of product innovation. As it is hardly possible to predict future market demands or regulatory requirements accurately, there is an inherent challenge that existing technological competences have to be adapted to a market whose characteristics and internal logic are not yet understood.

Firms therefore cannot fully deploy a positioning-based approach of the *imitation* archetype, as the logic of prediction and adaptation cannot completely control for perceived uncertainties in the environment. How companies can endorse a more control-oriented approach is shown by the **HEXIS** case. The company aimed at using an already well-understood technology in a market environment that was still in the making and where customer preferences and requirements had yet to be established. After the initial pursuit of a pure positioning-based approach failed to cope with the uncertainties in the market environment, the company complemented its approach with a more control-based strategy in the market sphere. Instead of developing a new product for a not yet existing market, the firm decided to contribute building the market by further developing the own technological competences together with other partners. By forming collaborative relationships and encouraging pilot customers to make pre-commitments, a first marketable product was developed. In order to bring about this new approach, a stronger market orientation was necessary. This was achieved through a Management Buy-out (MBO), the set-up of a separate organisation and a new kind of long-term financing with a focus on bringing in additional third-party funds. Those changes induced an increased means orientation, a stronger market focus and a greater freedom to choose appropriate partners for the further development of the product. By complementing the positioning-based approach with those control-based elements, the high uncertainties in the market sphere could be overcome through the creation of a first, yet limited market for the product. In a further step, the experiences collected in this pilot market can serve as a starting point for further developing the product and convincing more customers to invest in the new technology.

The induction of control-based elements into a company formerly using a predominantly positioning-based approach can also be observed in the case of **Hilti E+I**. The energy sector targeted by the company exhibited an industry logic and customer requirements that were fundamentally different from the traditionally served

markets. Therefore, the normally used market research instruments like *industry studies* and the concentration on well-known national markets and competitors was no longer able to overcome market-related uncertainties and guide the actions of the firm. Consequently, the new division was partially cut off from the company's traditional matrix organisation and was allowed to follow a more flexible approach, leaving room for experimentation in the context of external collaboration projects. The overarching goal shifted from positioning itself optimally in a previously defined market to building a new business segment based on previously defined technological skills and competences. This partial change in perspective from a purely positioning-based to a partially control-inspired approach enabled the company to initiate action more effectively in the face of uncertainties in the market sphere.

In contrast, the case of *3S* illustrates the opposite situation where a company that had originally followed a rather control-based approach to product innovation chose to introduce aspects of a positioning-based approach as uncertainties in its environment began to decrease. At the time of its foundation, the company was faced with high degrees of perceived uncertainty in all environmental spheres. Consequently, a control approach was chosen, characterized by heavy experimenting and flexibly making use of the many technological and market-related contingencies on the way. However, as the company grew, uncertainties in the technological and industrial environment decreased and a control-based approach threatened to slow the firm down in an industry that quickly evolved towards technological standards and mass production. In this situation, the transition towards a more positioning-based approach to product innovation was successfully conducted. With uncertainties in the general economic sphere still being high, some control-based elements, however, are still retained.

4.2.3 Experimentation

The challenges faced by companies under a *Transformation* setting are further aggravated when uncertainties in both of the extra-organisational spheres are high, with the uncertainties in the resource/technology sphere being low to moderate. In such a case, a company that introduces a product to the energy sector has a good understanding of the technological challenges connected to it and feels that it is able to handle those challenges. The financial resource needs can be rather well forecast and investors can be won with the prospect of making an adequate return on investment. However, it is highly unclear what the market environment is going to look like when the product will be introduced and what regulatory regimes will govern it. Such a constellation is typical for an industry that is well-understood from a technical point-of

view but poses further challenges that go beyond this sphere. The nuclear power plant industry could be an example of such an environment, where in-depth technological knowledge exists and high levels of reliability can be guaranteed, but future marketability and regulatory schemes are highly uncertain. Another example is the geothermal industry, where the heat from low levels of the earth's crust is used for electricity and heat generation. The company *Geothermal Explorers* (not among the case study firms) is active in this industry and is renowned as a globally leading expert in the involved technologies. Having its origins in the oil and gas sector, the company commands the technological skills of digging deep holes and fracturing rocks so as to inject water and regain hot steam. It is generally agreed that this technology is mature and economically viable. However, there is a small risk that an earthquake could result at an early point in the fracturing of the underground rock, making it very difficult to judge the overall economic risks of the technology. Consequently, the regulatory situation is completely unpredictable and there is a high risk of a company being subject to legal prosecution. Furthermore, other market participants are highly reluctant to embark on this technology, as the costs associated with it are not yet known and almost no functioning prototypes have ever been built.

In such a situation, a control-based approach to dealing with uncertainties in the market and overall environment seems warranted. The product innovation project should be designed very flexibly in order to allow to an adaptation to further regulatory changes and the element of experimentation in the context of collaborations with suppliers and early customers can allow to prove marketability in a first confined segment of the market. Since the technological basics are well understood, a strategic goal orientation can be applied to guide the project. As the CEO of *Geothermal Explorers* mentions, it is highly advisable to plan the financial aspect of the project in great detail and to enlist strategic investors. Those investors are interested in the long-term profitability of the project and are willing to make high up-front investments. The control-oriented approach can therefore be complemented with the positioning-based elements of *strategic goal orientation* and *expected return*.

4.2.4 Modernisation

Yet another setting is given when a company's product innovation project is characterized by a low degree of uncertainty in none of the extra-organisational spheres but a high degree of uncertainty in the technological/resource sphere. In such a situation, the company has a rather good ability to adequately assess the future market and regulatory developments. This ability enables the firm to formulate a rather clear

picture of the future. Such a situation is prevalent among many SME that have an intimate knowledge of their respective markets and industries.

However, the company sees itself unable to develop - with the available means - innovative products that are based on their vision of the future. This high level of uncertainty about the value of the own skills and resources is based on an inability to adequately assess the direction of technological change in the environment. The formulation of a strategic goal and the subsequent acquisition of the necessary means to achieve this goal therefore is not a feasible way, as it does not help to reduce uncertainties. In order to be able to cope with those uncertainties and take action, the firm is better off to focus on what own means, skills and resources it has on hand. Starting from this means orientation, the resource base can be broadened by integrating the means of collaboration partners that find themselves in a similar situation. The pooled skills and resources can then be used to jointly develop a vision of an innovative product to be developed that is in line with the partners' picture of the future development of the industry. This approach is inspired by both control-based and positioning-based elements that complement each other. While the search for new ideas and the generation of market information can be done rather analytically and the development project can benefit from upfront planning activities to reduce uncertainties in the market and regulatory spheres, a control-based approach using means-orientation and a focus on collaboration-building can help overcome the uncertainties in the resource sphere.

The case of the Vision3000 windows that were developed by a group of SME including the case study firms *ERNE* and *Schär* is a good illustration of this approach. Both the CEO of ERNE and the CEO of Schär due to their intimate knowledge of the market had a rather good picture of where their industry was likely to develop. Yet, they found that with their current set of means it was not possible to develop new products that corresponded to this vision. Rather, the development of new products was restricted to the few large system providers that dominated the industry and had the critical mass to set technological standards.

Initially, ERNE's CEO started to imagine possible new products that were in line with the current technological skills and competences of his company. As a result, he developed a first general vision and found that additional partners were needed in order to tackle the high technological and financial uncertainties involved in the project. In a next step, he chose to communicate the vision to other firms in the same industry. The vision then fell on fertile ground with the CEO of Schär and several other firms that were willing to join the newly forming group. Based on the joint skills

and resources, the universe of potential new products increased and a new product idea emerged that (even though different from ERNE's initial vision) was in line with both the combined means base of the group and the vision of the future market and industry developments shared by the partners.

4.2.5 Exploration

In contrast to a *modernisation* setting, the uncertainties in the resource environment are complemented by a high degree of uncertainties in the extra-organisational sphere, be it in relation to future market or regulatory developments. However, the company has a certain idea of at least one of the extra-organisational spheres, typically about the long-term trends in the industry (economic sphere).

Those companies therefore are able to get a rough idea of where they want to develop in the long term and to develop a rough vision of the future. Consequently, even though generally adopting a strongly control-based approach, the three case studies of *Pyroforce*, *CTU*, and *Wenger* exhibited a remarkable (strategic) goal orientation that is advocated for by the positioning-based approach. By making use of the relatively low degree of uncertainty in one of the environmental spheres (the general economic sphere), they were able to initiate a product innovation process that subsequently was characterized by a strong control orientation.

Along those lines, *Pyroforce* formulated a general goal to strengthen its activities in the area of energetic exploitation of biomass. Based on this rough strategy, first projects could be lined up that helped in further isolating the technological and market uncertainties. Based on the means available and their limitations, potential partners could be identified that were willing to buy in to the broader objective of energetically exploiting biomass feedstock. Those partners were willing to bring in own competences and make first commitments. Through the joint development work, it was possible to bring technological uncertainties under control and to develop a first prototype that helped to decrease market uncertainties.

Similarly, the CEO of *Wenger* was able to initiate the project for the development of a new kind of energy-saving window. By means of a strong vision based on own beliefs about the future general development of the industry, a rough strategy and first steps in an early phase could be implemented in spite of high technological and market uncertainties. At a later stage, Wenger was also able to convince partners along the value chain to make considerable pre-commitments in the form of investments into a new production line for the glueing of wood and glass.

Common to all three case studies is the deep knowledge that the CEOs of the companies have acquired of their respective industries due to long-term experience. They were involved in industry associations and invested in the maintenance of a large network of contacts and good relationships with other companies and institutions. Through this exposure, they were able to reduce the perceived uncertainties in the general economic sphere to a moderate level. Even though they were not able to predict the precise technological and market developments, they nevertheless managed to formulate a rough vision of the general trends in their environment that could motivate others to join in and help put the vision into practise.

4.2.6 Effectuation

Product innovation projects in companies faced with high degrees of perceived uncertainty in all the environmental spheres used in the theoretical framework fall under the last setting. Companies that see themselves in such a situation will find it hard to use elements of the positioning approach, as data that could help to reduce uncertainties in the different spheres are not available to them. Firms trying to strategically position themselves in their environments are therefore likely to refrain from pursuing a product innovation project.

A control-based approach, however, offers better prospects of getting a product innovation project started under conditions of true uncertainty. The case studies of *CEKA* and *Airlight* provide good illustrations of how this can be accomplished. Both companies have used all the elements suggested by the control-based approach and have largely done without business planning, systematic idea search, market research or competitor orientation. The focus in both companies was first to envision possible options of using their existing skill-sets for the development of a new product, regardless of what future market requirements or general economic conditions were connected to it. In the case of *CEKA*, the existing skill-set in small-series system-like products was the starting point. *Airlight* focused on the experiences in constructing light-weight *Tensairity* structures and the expertise in replacing expensive and heavy construction parts by low-cost and light-weight ones. With this general idea in mind and limited by financial restrictions, the companies started first experiments and incorporated feedback from different sources to flexibly direct their development efforts. In the case of *Airlight*, the first attempts went towards building light-weight structures for tents, stadiums, bridges, or even space installations. By incorporating the unsought feedback from an outside person, the project turned towards a low-cost CSP plant. *CEKA*'s first efforts concentrated on the tool-making sector and were guided in

the direction of mobile fuel-cells only through a random discussion with a research institution that was initially not even interested in a collaboration project. Those examples show, that in environments of high uncertainty about the future extra-organisational environment it can be beneficial to refrain from a directed idea search and to rely on serendipitous events to guide the own small-scale experimental efforts based on what means are at hand and what initial small-scale investments can be made. Those experimental projects do not necessarily have to be initiated by the CEO in order to build new business segments as in the case of *CEKA* or *Airlight*. Rather, they can also be unguided when employees are given the time and limited resources to pursue own, personal projects with relation to the company's overall activities, as in the case of 3M's 15% rule.

Once the initially experimental project has incorporated a certain amount of feedback and the company feels that it can with a certain confidence determine what additional means are needed, other partners can be approached. By presenting the idea to other companies or institutions with a potential interest in advancing the product innovation, a coalition can be built that increases the available means. In the case of *CEKA*, the company felt that it had acquired a sufficient amount of feedback on its fuel-cell project that it could define its further development needs. By forming several alliances with research institutions and value chain partners as well as a first customer who was willing to make initial investments in the product, first steps in the market sphere could be taken. At this stage, there was still no market research conducted to reduce market-related uncertainties. Rather, a small segment of the market, represented by the first customer *Helvetino*, was concentrated on. Similarly *Airlight* found after first experiments with the existing *Tensairity* technology, that further resources were necessary to build the envisioned CSP plant. Rather than focusing on light-weight structures, the focus had to be on a quite heavy, stable structure with concrete being a major part of the frame. Additionally, the focus on low-cost, locally sourced materials was another part of the vision. In order to carry on with the project, further partners had to be brought on board. This was done by organising a consortium of firms around the construction of a first full-scale plant. As a first customer, a local utility company could be won that brought additional funds into the company.

Overall, the approach to taking action under very high degrees of uncertainty in both cases was characterized by a control-based logic in line with Sarasvathy's (2001) principles of effectuation.

4.2.7 Strategies for Action Taking

Based on the previous clustering and discussion of the case study firms, a general strategy for action taking in different settings of environmental uncertainty can be derived. As observed in the case study firms, a trend towards a particular combination of control-based and positioning-based strategies was observable in each of the case study clusters. Those generic strategies are shown in Figure 31.

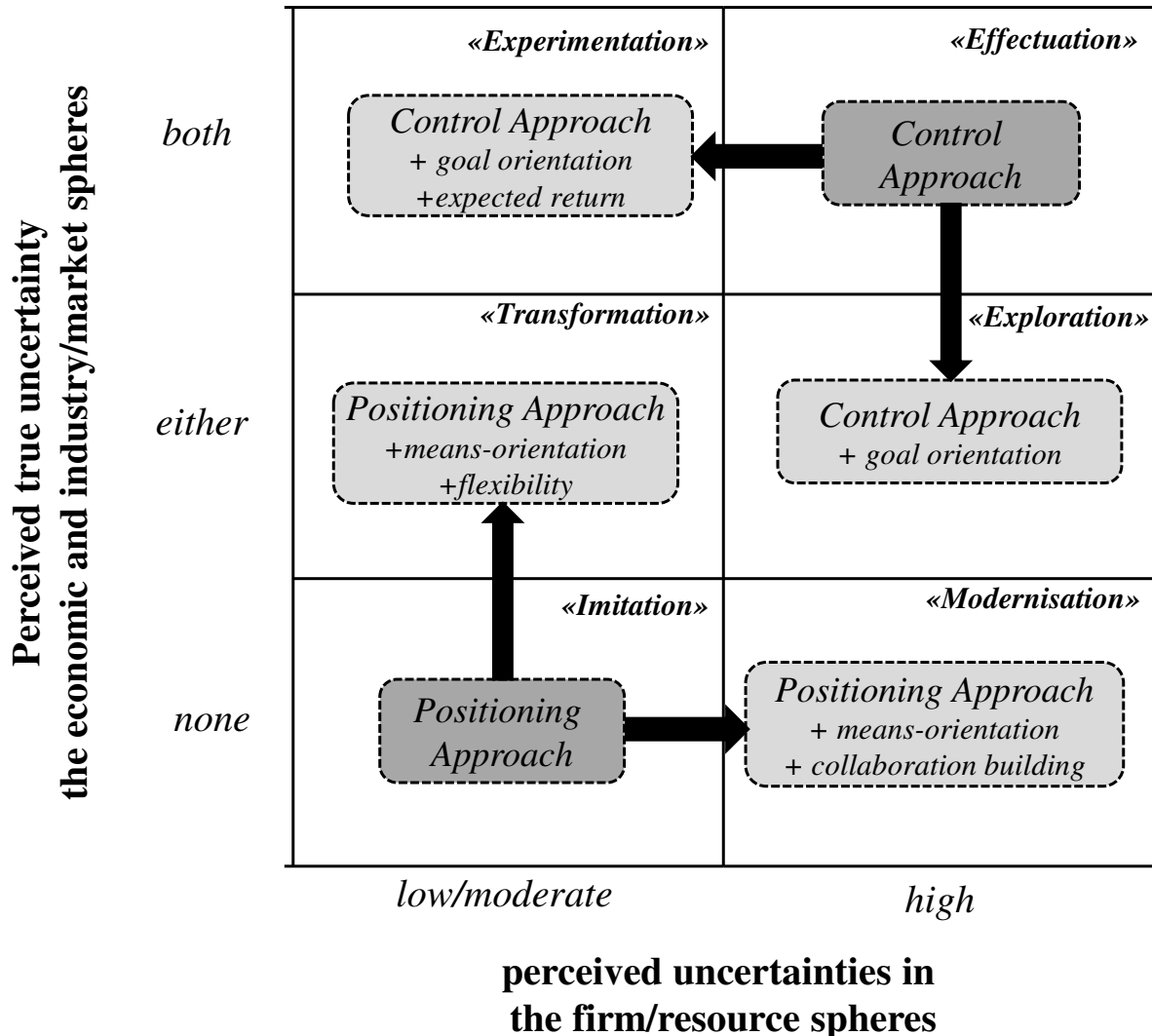


Figure 31: Generic strategies to action under different uncertainty settings

The breakdown of the different generic strategies shows that there are two influential approaches on how to initiate innovation project and – depending on the level of perceived environmental uncertainties – several combinations thereof. On one end, a pure positioning approach can be found in companies that are faced with high uncertainties in none of their environmental spheres. A pure control approach prevails among firms that have to deal with highly uncertain conditions in all three spheres. Companies in environments characterized by high Knight’ian conditions in only one of their environments lean towards a positioning approach which is complemented by

the inclusion of certain control-based elements. Vice versa, when only one of the environmental spheres is susceptible to forecasting, a control approach dominates that draws upon certain positioning elements.

Those insights can be used by firms in order to determine the optimal combination of planning and control strategies in the fuzzy front end of the product innovation process. The ultimate goal and outcome of the FFE for all companies is the establishment of a basis on which decisions can be made on the eventual introduction of an innovative product in the market. However, in order to come to this point, the firm must be able to establish the technological, regulatory and market-related specification the product has to fulfil. Where uncertainties in either of those areas prevail, they must (1) be reduced through planning-based positioning processes, and (2) where they cannot be reduced through planning, alternative ways must be created to cope with them through creative control processes.

Once the company has established a good understanding of the uncertainties in its environment, the demands for the specific situation can be formulated. The questions are: “In which spheres can we reduce uncertainties through better planning?” and “In which spheres will we have to find alternative ways of coping with them?”. Depending on the answers to those questions, the focus of the FFE should lean more towards control or towards positioning activities. This arbitration process is symbolized in Figure 32 by a slider whose position determines the relation between the share of control activities aiming at reducing uncertainties (lower, shaded area in the innovation funnel) and the share of positioning activities aiming at creating opportunities or action taking despite uncertainties (upper, blank area in the innovation funnel). By optimally adjusting this ratio in light of the environmental conditions of a product innovation project, the firm can create a basis decision making and subsequent action taking in the later phases of the innovation process. For instance, if a firm comes to the conclusion that the prevailing environmental situation classifies the intended innovation as a “modernisation” project, it may want to adopt a rather positioning-based approach and reduce the lower shaded area in the innovation funnel. It will, hence, focus on reducing uncertainties in the two environmental spheres susceptible to forecasting in order to establish a sound basis for decision making. However, some control elements will be necessary in order to find alternative ways to cope with the high uncertainties in the remaining environmental sphere, i.e. the technological environment. The result of this analysis may be that the firm decides to abandon a strict competitor orientation and looks for potential development partners, gradually opening up its innovation process.

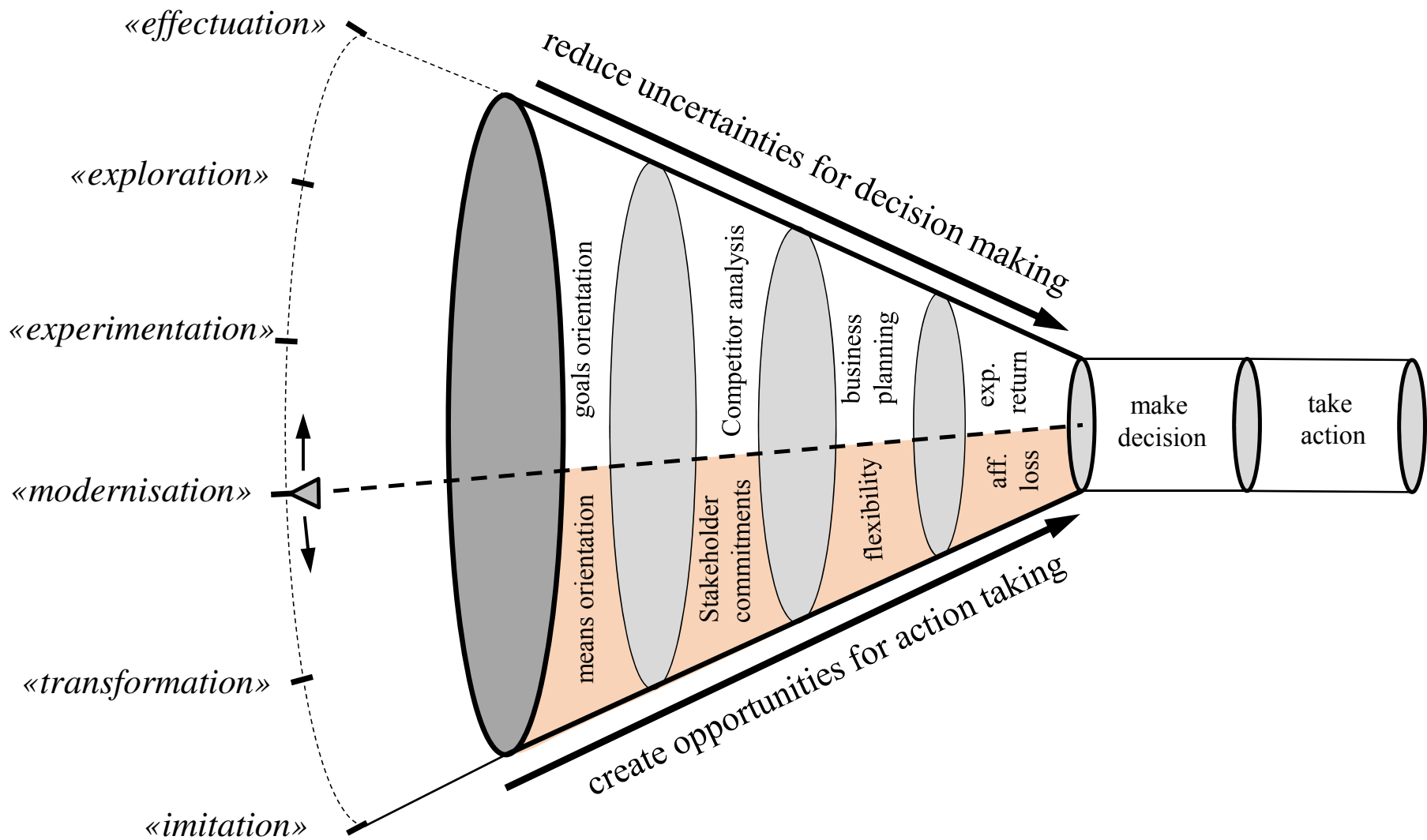


Figure 32: Prioritising front-end activities under different levels of uncertainty

5 Survey Evidence from SME in the Swiss Energy Sector

In the preceding case study section, the focus was on chosen sub-sectors of the RE/EE industries which were selected to mirror the heterogeneity of firms engaged in this sector. Furthermore, the studied firms represent the most innovative segment of this population, which is the consequence of a theoretical sampling characteristic for case study research. The goal of such an approach is to capture the whole breadth of possible manifestations of the phenomenon under scrutiny through the selection and analysis of contrasting, polar cases or such cases that are expected to provide the most insightful information (Eisenhardt & Graebner, 2007). Eisenhardt (1989b) refers to this goal as achieving analytical generalization. By following this approach it was possible to isolate a set of archetypical combinations of control and positioning-based approaches towards managing the early phases of product innovation processes as a function of the degree and nature of environmental uncertainties. Those results are helpful in guiding our general understanding of how a particular firm under particular circumstances can increase the likeliness of successfully initiating a product innovation project.

In practice, however, it is often desirable to get an insight not only into possible theoretical manifestations, but also to know more about the empirical prevalence of the phenomenon. Since qualitative case study research cannot satisfy the requirements of statistical generalization, quantitative methods must be applied towards this goal. In the case of this work, it was chosen to complement the case studies by applying the survey method, using the data collection instrument of an online questionnaire.

The goal of the survey is to find out whether and how control-oriented effectuation and positioning-oriented causation strategies are actually being applied by innovative SME in the Swiss RE/EE industries. Additionally, it shall be analysed whether different levels of environmental uncertainty have an influence on the use of both strategies and whether there is a difference in the approaches taken by more versus less successful firms.

The presentation of the survey results will be restricted to descriptive statistics, as they are sufficient to answer the research questions guiding this work. In the context of the survey, further parameters pertaining to theoretical constructs in the product innovation and entrepreneurship literature will be collected. Avenues for their analysis and further statistical methods will be proposed under the outlook section in chapter 6.5.

5.1 Population & Sample

5.1.1 Sectoral Focus

The sampling frame for the survey was chosen in accordance with the preceding parts of this work to contain small and medium sized companies (SME) from the Swiss RE/EE industries. This industry-specific sampling approach is in line with Chandler et al.'s (2011) recommendation to focus on industries of which the researcher (1) has a good knowledge and understanding, (2) can be confident to predict that the phenomenon of interest is prevalent among the firms active in the industry, and (3) assumes that the specific research objects are well represented in the industry.

Considering the discussions in the qualitative part of this work, the RE/EE industries satisfy those criteria. Recent developments in the energy sector are well understood and the prevalence of both planning-oriented causation and control-oriented effectuation approaches has been demonstrated through the analysis of a number of case studies in the industry. Additionally, the energy sector in Switzerland has recently experienced a sharp increase in dynamism and complexity, following the adoption of new policies and regulations in the context of re-shaping the country's energy supply system and public funding for renewable energy and energy efficiency technologies in the home as well as major export markets. Those developments have led to declining entry barriers for smaller firms into an industry formerly dominated by large incumbent companies and a rise in the level of entrepreneurial activity and innovation. The high degree of uncertainty combined with the attractiveness of the industry for SME constitute a conducive environment for the use of effectuation by existing firms.

5.1.2 Sample Construction

The starting point for the construction of the sample for this survey was a list of companies provided by the "Energy - Economy - Society" Research Programme (ESE), the socio-economic basic research programme of the Swiss Federal Office of Energy (SFOE). This office oversees a major part of the relevant subsidy and regulatory programmes in the RE/EE industries and has a first-hand insight into innovative activities by companies in their areas of authority. In a first step, the firms on the list were double-checked and completed with additional sources such as attendance and exhibitors lists of the relevant industry fairs and exhibitions [*Hausbaumesse BEA, Energissima, Innovationsbörse Energiecluster, BlueTech, Sun21, Forschungstagung Verkehr*], member lists of relevant industry associations

[*Trendwatching-Gruppe "Motoren", Energiecluster, IG Vehicle-to-grid, Schweizerischen Verband Dach und Wand, Verein für umweltgerechte Elektrizität, Swiss Technology Network Section 17, Verband Schweizer Isolierfirmen, Schweizerische Vereinigung für Geothermie, Interessensverband Schweizerischer Kleinkraftwerk-Besitzer*] and relevant industrial supplier directories [*Spektrum der Gebäudetechnik, Windenergie-Daten der Schweiz, energie.ch, wer-liefert-was⁴, Hydrogen Report Switzerland*].

In a second step, all consulting engineers and pure trading companies were excluded. The rationale for their exclusion was, that they are not involved in entrepreneurial decision making as they develop new products on order or are merely involved in marketing an already developed product in an assigned market.

In a third step, additional information on the remaining companies was collected through internet and telephone enquiry, with the objective of identifying those firms that had recently entered the energy sector with a new or improved product. The focus on new entrants was chosen in order to select product innovators for whom the introduction of a new product was connected with overcoming a high degree of uncertainty, as they had not previously been exposed to the specific environment of the energy sector. All firms that did not meet this requirement were excluded. Additionally – due to our focus on SME - all companies with more than 250 employees were excluded. However, companies with up to 300 employees were retained if background research suggested that they could be characterized as SME due to their turnover or general organisational features. If the exact number of employees could not be determined, firms were only retained if they clearly fell in the SME category of firms. In Table 6, the size class of those firms is indicated as *not determined*. Due to the focus on Swiss owner-managed firms, subsidiaries of larger companies and firms headquartered outside of Switzerland or Liechtenstein were also excluded.

In a final step, the sample list was compared and double-checked with a list provided by another research group active in the ESE-SFOE programme (Dr. Carsten Nathani). The final sample contained 515 companies representing renewable energy technologies (n=199), energy storage and transmission (n=45), energy efficiency in buildings, appliances and mobility (n=192), and general efficiency technologies (n=79). Table 6 shows the distribution of the sample firms' size classes, while Table 7 gives an overview of the different technology areas.

⁴ Suppliers in the areas: Biogasanlagen, Fotovoltaik-Steckverbinder, Solaruhren, Solarkollektoren, Befestigungssysteme für Solarmodule, Anlagen für die Solarzellenfertigung, Kabel für Solaranlagen, Frostschutzmittel für Solaranlagen, Solarkollektoren (unverglaste), Solare Grossanlagen, Solarheizungen/ Solarklimaanlagen/ Solarwarmwasserbereitungsanlagen, Komponenten für Biogasanlagen, Rührwerke für Biogasanlagen, Biogasspeicher, Hilfsstoffe für die Biogaserzeugung, Quarzglas Komponenten für Fotovoltaikanlagen, Windkraftgeneratoren, Rotoren für Windkraftanlagen, Stanzteile für Windkraftanlagen

	n	%
Small firms (1-10 FTE)	143	28%
1-5 FTE	60	12%
6-10 FTE	83	16%
Medium firms (11-250 FTE)	312	60%
11-50 FTE	185	36%
51-100 FTE	63	12%
101-150 FTE	27	5%
151-200 FTE	24	5%
201-250 FTE	13	3%
Large firms	21	4%
> 250 FTE	21	4%
not specified	39	8%
Total	515	100%

Table 6: Size classes of firms considered in the study sample

	n	%
Renewable energy	199	39%
Biogas	22	4%
Biomass	26	5%
Solar	73	14%
Water Power	10	2%
Wind	23	4%
Geothermal	36	7%
Fuel cells	9	2%
Energy storage & transmission	45	9%
Storage	9	2%
Infrastructure	32	6%
Hydrogen	4	1%
Energy efficiency in buildings, appliances, and mobility	192	37%
Windows, façade	43	8%
Building technology	31	6%
Insulation	39	8%
Lighting	20	4%
Heating	30	6%
Pumps	5	1%
Mobility	24	5%
General efficiency technologies	79	15%
Measurement	43	8%
Recuperation	21	4%
Process efficiency	15	3%
Total	515	100%

Table 7: Technology areas considered in the study sample

5.2 Survey Design

5.2.1 Measures

The goal of the survey in the context of this study is to study the use of planning (causation) and control (effectuation) processes in successful product development processes in an uncertain environment. Therefore, the relevant constructs have to be operationalized for inclusion in the questionnaire. For this purpose, a careful review of prior research was conducted and all measures were adopted from scales existing in literature. Appendix C includes a copy of the survey, comprising all items and scales used.

Effectuation/Causation: For the purpose of the survey questionnaire, the scale of Chandler et al (2011) was as it represents the first validated measure of causation and effectuation. As opposed to another recently introduced measure by Brettel et al. (2011), Chandler et al. (2011) do not see causation and effectuation as representing two opposing, polar modes. Rather, they conceptualize causation and effectuation as two separate constructs that need to be measured separately. While causation is seen as consisting of no sub-dimensions, effectuation is proposed to be a formative construct of the sub-dimensions of affordable loss, flexibility, pre-commitments, and experimentation. The decision to prefer Chandler et al.'s conceptualization over the one of Brettel et al. was motivated by the insights from case study research discussed earlier in this work that demonstrated the simultaneous application of both principles by innovative firms in the energy sector. Furthermore, Perry et al. (2011) advise researchers to “develop effectuation measures that are not contrasted as polar opposites of causation measures, and [...] to also account for causation separately“ (p.19).

Environmental Uncertainty: The survey study relies on a measure of environmental turbulence recently used by Lichtenthaler (2009), which is based on Jaworski & Kohli (1993). The final construct in the study consists of the items “The technology in our markets is changing rapidly,” “Technological developments in our markets are rather minor” (reverse-coded), “Technological changes provide big opportunities in our markets,” and “A large number of new products in our markets have been made possible through technological breakthroughs.” The original item “It is very difficult to forecast where the technologies in our markets will be in the next five years” was included in the survey but excluded in the final analysis, as it constituted a future-oriented assessment and could potentially distort the measurement of uncertainty as

intended for this study. Since the focus of the study is on ex-post analysis of past product innovation processes, an assessment of future uncertainties does not necessarily apply to the conditions at the time when the innovation was undertaken.

Performance: According to Shane (2003), there are four different categories of performance measures in entrepreneurship research: *survival*, *growth*, *profitability* and *experiencing an IPO*. Each of those performance dimensions are important because they are rare. Only 25% of new ventures survive the first 5 years, fewer than 10% of new organizations ever grow on the sales or employment dimension and only 21% of male entrepreneurs achieve an income above their cohort's median in any year. However, in choosing performance measures for a particular study, the traditions of the applicable field of research must be accounted for. The most comprehensive and up-to-date review of established performance variables in the Effectuation domain is offered by Read et al (2009). In their meta-analysis of 48 studies on the relationship between different effectuation principles and performance measures they found that performance indicators used were mainly: financial profitability measures (75% of studies; of which 48% ROI, 44% sales/revenue, 14% ROA), financial growth measures (35% of studies; of which 67% general growth, 13% sales/revenue growth, 10% market share growth), non-financial survival measures (16% of studies) and non-financial size measures (12% of studies). However, this meta-analysis is not based on studies that actually had the objective of analysing the link between use of effectuation and performance. Rather, due to the newness of the field, a variety of studies were collected that had studied the performance impact of some phenomenon associated with effectuation principles. It is therefore advisable to also consult additional research on already well-established performance links of entrepreneurship constructs. Entrepreneurial Orientation is such a construct, whose performance implications have been extensively studied over the last decades. In their comprehensive meta-analysis of studies analysing the EO-performance relationship, Rauch et al (2009) found that researchers tend to measure success using perceived rather than archival measures (80 vs. 20% of studies), financial rather than non-financial measures (80 vs. 40% of studies (with some studies using both) and profitability rather than growth measures (80 vs. 20% of studies). Based on the results of both Rauch et al (2009) and Read et al (2009), it can be stated that researchers in the Effectuation as well as in the EO domain have a clear preference for perceived (self-reported) financial profitability measures. They also include financial growth measures and non-financial measures in their measurement instruments, though to a lesser extent. Following this reasoning, this study asks entrepreneurs to report the development of their firm's profit, sales and growth over the past three years.

5.2.2 Questionnaire and Data Collection

The standardized electronic questionnaire was generated with the Unipark software package based on validated academic procedures (Dillman, 2000). Before being sent by email to the CEO or owner of the company, the arrival of the questionnaire was announced in a personal letter. The informants were given an account of the aims of the study and were guaranteed confidentiality. As an additional incentive to cooperate, a summary of the study results were offered. Reminder emails were sent 8 and 16 days following the initial mailing. Data collection was closed after 28 days.

Of the 515 companies contacted, 156 fully completed the online questionnaire for a response rate of 30.29%. Missing data was not an issue, as all questions in the questionnaire had to be answered in order to submit the data. Hence, all 156 observations could be retained for analysis.

Common Method Bias

The main respondent in the study is the owner of the firm, which is in line with previous research that states that a single respondent scheme is applicable in small firm research when the respondent is the owner or manager of the business (Chandler and Lyon, 2001). Previous research has shown, that owner/CEO assessment of business activity can accurately reflect objective, archival measures (Chandler and Hanks, 1993). However, when answers in a survey are obtained from a single respondent, the data may be susceptible to common method bias. The easiest way of countering common method bias is to include an additional respondent and to triangulate the obtained data with archival records. Yet, the triangulation with archival data is not always possible, as small firms under Swiss law are not required to publicly disclose business data. Alternatively, the bias can be mitigated if measurement instruments are well designed (Starbuck and Mezias, 1996), using multi-item scales (Bergkvist and Rossiter, 2007) in varying formats that do not appear consecutively in the questionnaire (Lindell and Whitney, 2001). The likelihood of post-hoc rationalisations of single respondents can be further lowered if the information asked for deals with an event of significant importance (Akerlof and Yellen, 1985) that occurs infrequently (Sudman and Bradburn, 1973). Podsakoff et al. (2003), especially recommend the psychological separation of predictor and criterion variable measurement. Even though all of the above applies to the survey used in this study and due care has been exercised in the design of the questionnaire, common method bias may still be an issue that will have to be addressed when analysing the data.

5.3 Analysis

5.3.1 Factor Analysis

Following factor analysis, 24 items forming eight scales were retained for the purpose of this study. The loadings, cross-loadings and communalities for all items are summarized in Table 8. The direct factor loadings exceeded the 0.6 threshold in all but one case (the reverse coded item *EFF_EXP_2* loaded with -0.5290 on the *Experimentation* factor) with merely four cross-loadings going beyond the value of 0.3.

Overall, factor analysis confirmed the scales adopted from literature with one exception: The causation items did not load on one factor as proposed by Chandler et al. (2011), but on two factors. One factor comprised items indicating that the firm engaged in a great deal of planning activities in order to reduce uncertainties like developing a formal strategy, compiling a business plan and the introduction of monitoring processes. It was therefore labelled *Formal Planning*. The other factor was made up of items that mirror a firm's preference for thorough market analysis in order to position itself optimally vis-à-vis the competition. Items indicated that market and competitor studies were conducted early on in the process, potentially lucrative market offerings were analysed and decided upon and market introduction was planned at an early stage. This factor was therefore labelled *Competitor Orientation*.

The emerging eight scales cumulatively account for 67.58% of variance and measure the firm's performance (Cronbach's alpha = 0.7595), the degree of environmental uncertainty ($\alpha = 0.7532$), the effectuation dimensions of affordable loss ($\alpha = 0.8434$), pre-commitments ($\alpha = 0.7437$), flexibility ($\alpha = 0.6450$), and experimentation ($\alpha = 0.6102$) as well as the causation dimension of formal planning ($\alpha = 0.686$) and competitor orientation ($\alpha = 0.6723$). Following the procedure proposed by Dess & Davis (1984), scales were constructed by dividing the sum of individual item scores by the number of items in the scale. All constructs are measured on a 7-point scale.

With eight factors emerging from the data and none of them explaining more than 10.37% of variance, a first indication is given that common method bias caused by the use of a single informant is not a major issue. According to Podsakoff & Organ (1986), cases of substantial common method variance would manifest themselves through the emergence (a) of a single factor in factor analysis or (b) a general factor accounting for a high proportion of variance.

items	loading on varimax-rotated factor								Commun- ality
	1	2	3	4	5	6	7	8	
	<i>Affordable Loss</i>	<i>Uncertainty</i>	<i>Performance</i>	<i>Experi- mentation</i>	<i>Causation (competitive)</i>	<i>Causation (planning)</i>	<i>pre- commitments</i>	<i>flexibility</i>	
EFF_CAUS_1	0.0714	0.0875	-0.0344	0.0816	0.738	0.2481	0.1702	0.0030	0.6588
EFF_CAUS_2	0.1613	0.2176	0.0587	0.0334	0.0794	0.7131	0.0517	0.1436	0.6160
EFF_CAUS_3	-0.2194	0.0207	-0.0552	0.0497	<u>0.3284</u>	0.7240	0.1729	0.0264	0.7166
EFF_CAUS_4	0.1098	-0.1040	0.0064	0.0169	0.0572	0.8018	0.1766	-0.0985	0.7102
EFF_CAUS_5	0.0212	0.0112	-0.0887	0.0270	0.7813	0.0967	0.0943	0.0565	0.6411
EFF_CAUS_6	0.0595	0.1622	0.0409	-0.2100	0.6183	0.1110	-0.0080	<u>0.3709</u>	0.6078
EFF_AL_1	0.8834	-0.0829	0.3258	-0.0010	0.0139	0.0065	0.0226	0.0386	0.7907
EFF_AL_2	0.8479	0.0168	0.0869	0.0218	0.2024	0.0153	0.0027	0.0477	0.7706
EFF_AL_3	0.8414	0.0420	0.0349	-0.0727	-0.1192	0.0441	0.0251	0.1420	0.7539
EFF_EXP_1	0.1487	0.1483	0.0982	0.6531	0.2750	-0.0018	0.0115	0.0032	0.5561
EFF_EXP_2	0.0674	0.1241	<u>-0.4014</u>	-0.5290	0.0784	0.1904	-0.0860	0.2339	0.5654
EFF_EXP_3	0.0250	0.1726	0.0673	0.7121	0.0753	0.0484	0.0134	0.1600	0.5758
EFF_EXP_4	-0.1952	0.0981	-0.0975	0.7189	-0.225	0.1309	-0.1876	0.1383	0.6962
EFF_FLEX_1	0.1413	0.1057	0.0004	0.1985	0.1017	0.0944	0.0966	0.7261	0.6264
EFF_FLEX_2	0.1289	0.1096	-0.0141	0.0251	0.0716	-0.0558	0.1411	0.8337	0.7527
EFF_PRECOM_1	-0.0626	0.0462	-0.1423	-0.0813	0.1069	0.2057	0.8196	0.0583	0.7618
EFF_PRECOM_2	0.0929	0.0968	-0.0323	-0.0032	0.0777	0.0896	0.8636	0.1316	0.7962
PERF_SALES	0.0724	0.0375	0.8693	0.0031	-0.0756	0.0531	-0.0542	0.0013	0.7738
PERF_GROWTH	-0.0425	-0.0333	0.8206	0.0982	-0.0021	-0.0076	-0.1379	-0.0291	0.7058
PERF_PROFIT	0.2036	0.0783	0.7382	-0.0316	0.0239	-0.0508	0.0089	0.0386	0.5983
DYNAM_1	-0.0046	0.8356	0.0530	0.0200	0.1500	-0.0003	0.0475	0.0448	0.7283
DYNAM_2	0.1388	-0.6382	0.0307	0.0335	-0.0069	0.0431	0.0192	<u>-0.3331</u>	0.5418
DYNAM_3	0.0532	0.7666	0.776	0.1204	0.0140	0.0374	0.2594	-0.0394	0.6814
DYNAM_4	-0.0286	0.6914	-0.0867	0.2373	-0.0255	0.0868	-0.0966	0.1930	0.5975
<i>Eigenvalue</i>	2.492	2.39	2.22	1.92	1.91	1.90	1.69	1.69	
<i>proportion of variance explained</i>	10.37%	9.97%	9.27%	8.00%	7.96%	7.90%	7.06%	7.05%	
<i>cumulative variance explained</i>	10.37%	20.34%	29.61%	37.62%	45.58%	53.48%	60.53%	67.58%	

Table 8: Varimax-rotated factors retained from factor analysis

5.3.2 Sample Demographics

Table 9 displays the demographic parameters of the sample of n=156 respondents. It can be inferred that the different technology areas constituting the RE/EE industries are adequately represented, as their respective shares mirror the distribution in the original list of firms as specified in Table 7. The sample therefore can be seen as being representative for the whole population of SME in the RE/EE industries.

Firm-level parameters show that the sample firms indeed represent the innovative SME segment of the sector. With a mean firm size of around 80 full-time equivalents (FTE) and an average age of 36 years (minimum: 2 years, maximum: 154 years) the data does not represent a start-up sample but one of more mature firms. As mean annual expenditures in R&D are rather high and products introduced over the last five years in average account for a rough third of the current turnover, the firms in the sample can be characterized as being rather innovative.

Respondents typically have almost 30 years of overall work experience and those respondents who indicated that they owned the firm they were working for had an average entrepreneurial experience of roughly 15 years. Only one fifth of respondents acquired their current position through family succession. On the individual level, the high share of male respondents stands out.

	Mean or %	S.D.	N
Technology areas			
Renewable energy	38%		60
Storage/transmission	7%		11
Buildings/appliances/mobility	44%		68
General energy efficiency	11%		17
Firm characteristics			
Firm size [<i>FTE</i>]	80.65	180.22	156
Firm age [<i>years</i>]	35.97	31.59	156
R&D expenditures [<i>kCHF/year</i>]	1'163	6'787	148
Innovativeness [<i>new products in % turnover</i>]	32.22	29.34	156
Individual characteristics			
Gender			
male	96%		150
female	4%		6
Experience of CEO [<i>working years</i>]	27.40	9.41	156
Experience of CEO [<i>years as entrepreneur</i>]*	14.65	9.48	74
CEO through family succession	21%		33

*only respondents indicating that they owned the firm were considered in the computation.

Table 9: Sample demographics (N=156)

5.3.3 Data Analysis

After having assured that the respondents actually represent the population of firms targeted by the study and that the phenomenon of interest was adequately measured with the questionnaire items employed, the data can be judged as suitable for analysing the guiding questions for this study as mentioned in the introduction to chapter 5:

Question 1: How prevalent is the use of effectual and causal strategies among firms?

Since this survey was mainly motivated by the intention to demonstrate the actual prevalence of effectuation and causation strategies among firms in the RE/EE industries, this question is addressed in Figure 33 and Figure 34.

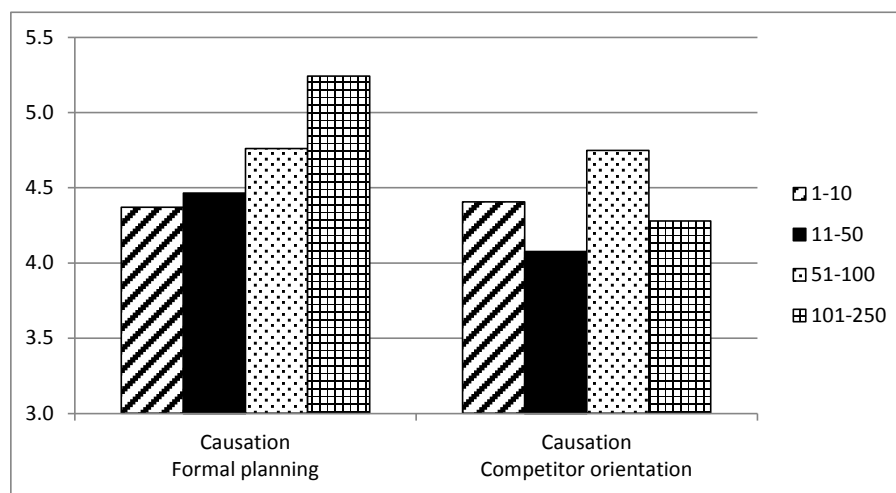


Figure 33: Prevalence of causation strategies among firms of different size classes (in FTE)

As the mean values for four different size classes of firms indicate, all of the effectuation and causation principles are used in practice, yet to different extents. While the positioning and planning approaches are especially popular with larger firms, very small firms score higher in the effectuation dimensions.

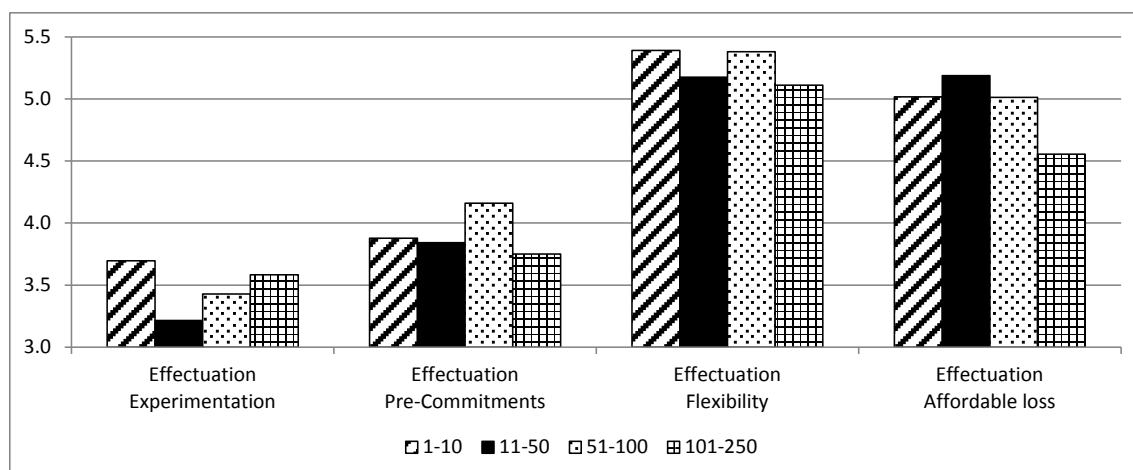


Figure 34: Prevalence of effectuation strategies among different firm size classes (in FTE)

However, the effect of firm size on the use of different effectuation principles does not seem to be uniform for all the principles. While the preference for the affordable loss principle diminishes as a firm grows, the affinity to experiment shows an opposite trend, with the notable exception of very small companies.

Question 2: Do different levels of uncertainty influence the choice of firms between effectual and causal strategies?

In order to answer the question of how different levels of environmental uncertainties affect the use of control and positioning strategies, the firms were divided into three categories. According to the level of perceived uncertainty reported by the firms, they were assigned in the categories “low uncertainties” (score of <3 on the 7-point scale), “moderate uncertainties” (score between 3 and 5) and “high uncertainties” (score of >5). For all categories, their use of positioning-based causation and control-based effectuation is shown in Figure 35.

The result of this analysis shows that an increase in the level of environmental uncertainty affects both the use of causal and effectual strategies. Furthermore, an increase in uncertainties affects both strategies in the same way. The only notable exception is the use of the affordable loss principle, which is most prevalent in environments with either low or high uncertainties. Notably, this overall relationship between environmental uncertainty and use of causation and effectuation strategies does not change if only those firms are included in the analysis that scored very high on the performance scale.

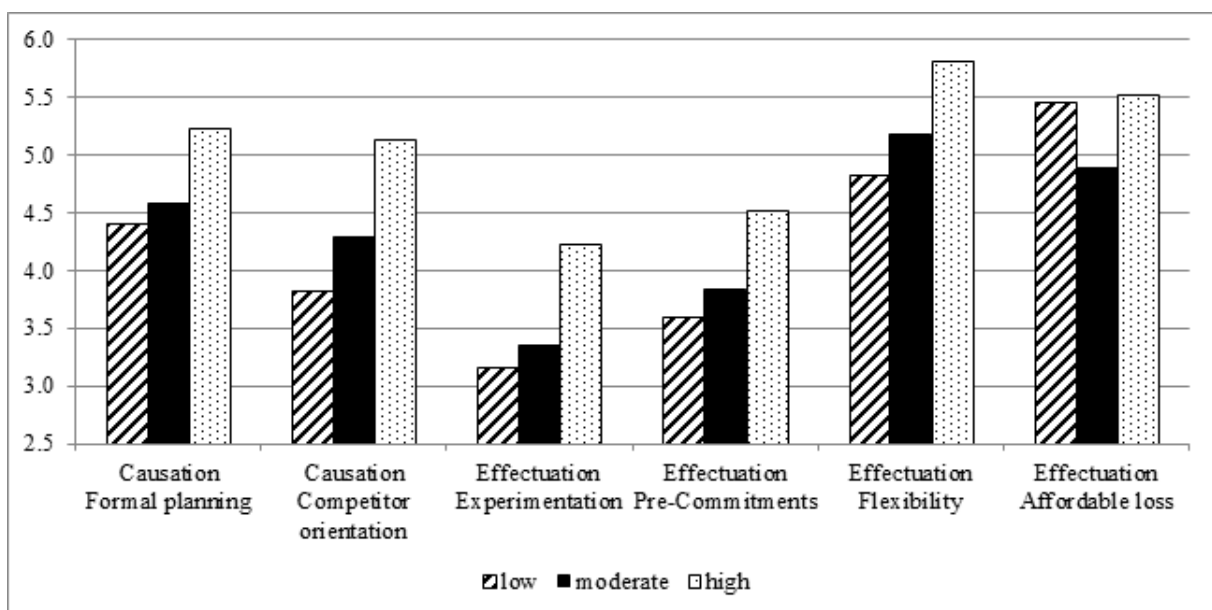


Figure 35: Use of causation and effectuation strategies under different uncertainty levels

Question 3: Is the use of effectual and causal strategies mutually exclusive (substitutes) or mutually conducive (complements)?

In literature, the use of effectuation and causation principles is sometimes regarded as mutually exclusive, by conceptualizing them as two opposing polar approaches. In contrast, the case study research performed in the first part of this work points to a view of the two approaches as complements. In Figure 36, the use of effectuation principles was therefore analysed under different degrees of causation orientation. For this purpose, firms were categorized as either exhibiting a low (score of < 3 on the 7-point combined scale), moderate (score between 3 and 5 on the combined scale) or high (score of >5 on the combined scale) degree of use of the causation principles.

For each of the three resulting groups of firms, their use of the different effectuation principles are indicated.

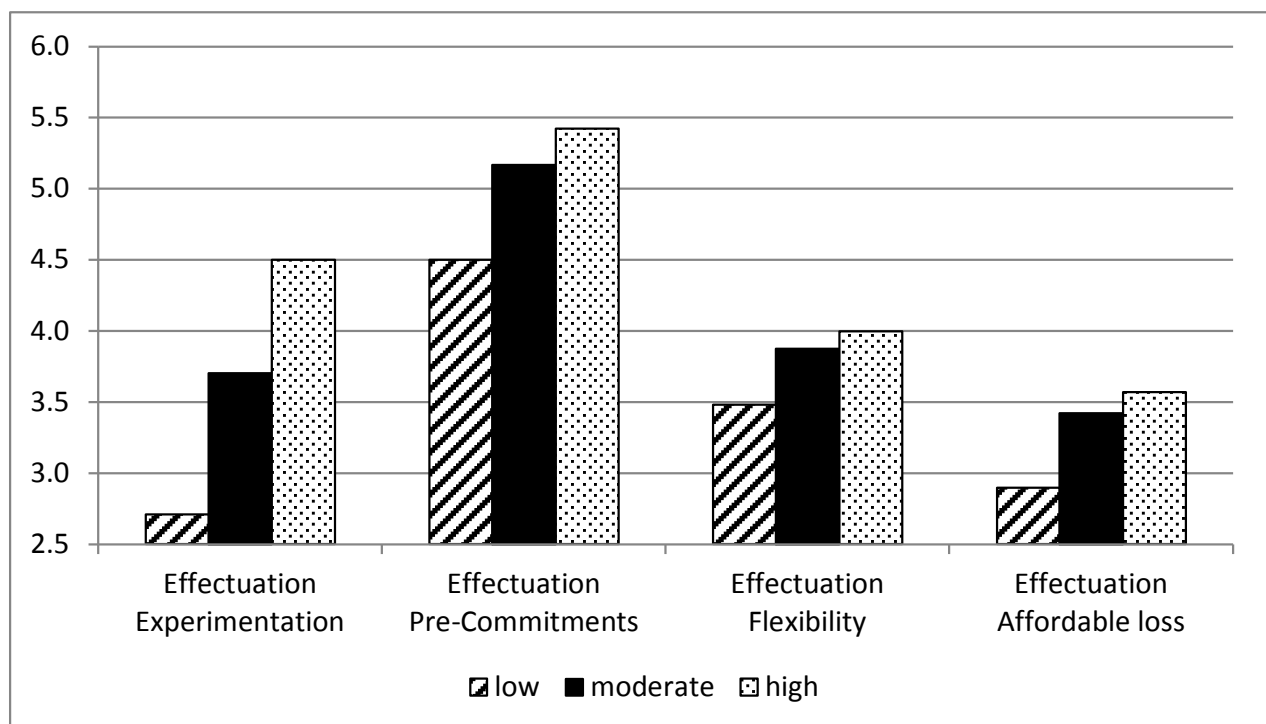


Figure 36: Use of effectuation strategies under different levels of causation orientation

The resulting graph points to a complementary rather than a rivalling relationship. Firms with a low use of the causation principles “competitor orientation” and “formal planning” are also characterized by a lower use of effectuation principles than more causally oriented companies. This trend applies for all the four sub-dimensions of the effectuation construct.

Question 4: Are expert entrepreneurs characterised by a higher use of effectuation or causation strategies?

According to Sarasvathy (2003), the introduction of the effectuation construct was motivated by the need to explain the behaviour of experienced entrepreneurs. Relying on the notion of entrepreneurship as a form of expertise, expert entrepreneurs are seen as exhibiting different strategies in comparison to novice entrepreneurs. This differentiation lies at the heart of a view of effectuation as a learnable and teachable technique (Sarasvathy & Venkataraman, 2011). The question of whether expert entrepreneurs are characterised by a higher use of effectuation or causation strategies therefore is of high relevance and was addressed with the survey data.

Literature suggests that it takes an individual around ten years of practice in order to reach the status of expert in a particular field (Ericsson et al., 1993). Expert entrepreneurs therefore were defined as respondents indicating that they had more than 10 years of experience working as entrepreneurs. In contrast, respondents that declared to having 10 years or less of entrepreneurial work experience were considered to be non-experts.

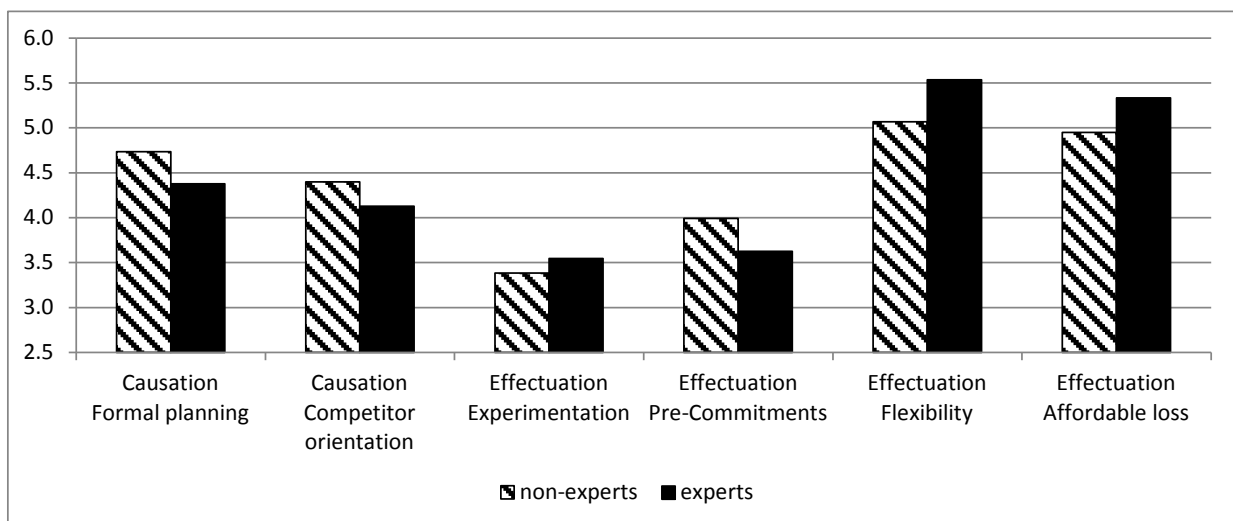


Figure 37: Use of causation and effectuation strategies by expert entrepreneurs

Figure 37 shows that expert entrepreneurs score lower in the use of positioning-oriented causation principles and higher in control-based effectuation principles than non-experts. An exception is the pre-commitments dimension. This result gives support to Sarasvathy & Venkataraman's (2011) the notion of effectuation as a form of expert script in the entrepreneurship profession.

Question 5: Are more successful firms characterized by a higher use of effectuation or causation strategies?

Finally, the performance implications of the use of effectuation or causation strategies have been addressed in a meta-analysis by Read et al. (2009). The authors reported evidence that such a positive performance link exists for all the sub-dimensions except for the affordable loss principle.

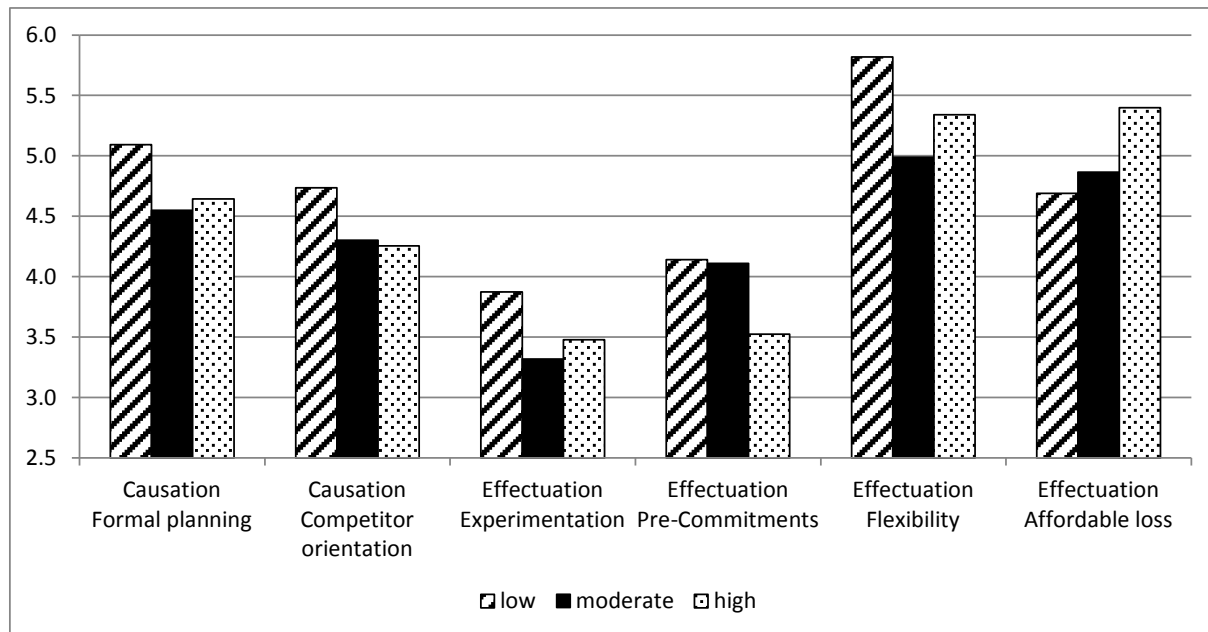


Figure 38: Use of causation and effectuation strategies under different performance levels

The graph in Figure 38 relativizes the results obtained by Read et al. (2009) in their meta-analysis. Among the sample firms, low-performers generally are characterized by a higher use of both causation and effectuation strategies. A notable exception is the affordable loss principle that is more prevalent among high-performing companies.

The results can, however, only give a rough impression of the actual mechanisms at work. Given that both causation and effectuation approaches seem to be more prevalent in more uncertain environments, this could partially explain their connection with rather low performing firms as it is reasonable to assume that high levels of performance are more difficult to achieve in more uncertain environments. This could also explain the exception of the affordable loss principle, as the analysis in Figure 35 has shown that its use is least affected by environmental uncertainties.

In general, the descriptive analyses conducted in the context of this chapter make it seem recommendable to apply more advanced statistical methods such as regression analysis or structural equation modelling in order to more closely examine the correlations in the data. While such an analysis would go beyond the scope of this work, some avenues for further analysis are highlighted in chapter 6.5.

5.4 Discussion

Some insights have emerged from the analysis of the data that have an impact on our understanding of the use of control and positioning strategies by SME.

Firstly, control-based effectuation strategies to action taking could clearly be shown to prevail among the firms in the sample. It could also be shown that both causation and effectuation principles were used simultaneously by the respondents and that their use is not mutually exclusive but complementary. This finding is in line with the results of the case-study research.

The size of the firm does seem to have some influence on the use of a control-based approach to product development, but the effect of entrepreneurial experience clearly seems to dominate. Expert entrepreneurs have been shown to exhibit a preference for the effectuation over the causation approach, even though both are used. This further substantiates the central role the CEO as the focal individual in an SME plays in shaping firm-level behaviour.

An unexpected result of the analysis is that increasing environmental uncertainties do not lead firms to prefer a control-based over a positioning-based approach. Rather, like the rising tide lifts all the boats, both positioning and control are increased. A possible explanation for this result is that firms react to increasing uncertainties in their environment by strengthening their forecasting activities, while at the same time trying to take control over their immediate environment. In such a situation, both approaches could reinforce each other, as effectuation lowers the degree of perceived uncertainty and therewith makes the firm more comfortable to engage in planning and forecasting activities. However, conclusions should be drawn with caution, as the uncertainty measure applied in the analysis does not account for different environmental spheres that have been shown to play a role in the cross-case analysis section of this work.

Finally, the analysis of performance implications of the use of effectuation principles has shown a negative impact. This seems to be counter-intuitive at first, as it applies for both the use of causation and effectuation principles. It must therefore be assumed that trying to establish a direct relationship between a rather cognitive construct like effectuation and tangible performance outcomes may be too simplistic.

However, the first results of the data analysis together with the conclusions drawn from case study research provide a good basis for future research to formulate more precise questions and to advance our understanding of early product innovation processes in SME.

6 Implications

6.1 Implications for Management Theory

The contribution of this study to the advancement of management theory mainly lies in a better understanding of the influence of environmental uncertainties on the early phases of product innovation processes in SME. It could be shown how, in response to differing levels of perceived uncertainty, smaller companies draw on planning as well as control mechanisms in order to generate ideas, mobilise resources and make decisions. The study can therefore contribute to existing theory in two ways:

In the area of *innovation management in SME* it was made apparent that existing frameworks and process models cannot live up to the particular challenges that smaller companies face in the early phases of product innovation. This is mainly due to their strong focus on the tasks of systematic ideation and uncertainty reduction as inspired by a planning and positioning approach to new product development. The main underlying paradigm of such an approach is the belief in the inability of the firm to actively influence its environment. Like a single farmer whose harvest cannot influence the price of corn on the world market, the single firm is faced with a set technological, regulatory and market environment that cannot be influenced by the actions of a single company. It is therefore of paramount importance to understand this environment, predicting trends in its future development and to optimally position oneself to benefit from those developments. An optimal position, under this perspective, can be reached through the systematic introduction of new products in response to those trends. However, positioning-based approaches are bound to fail in situations where either the resources necessary for those tasks cannot be raised or future developments cannot be adequately predicted.

Paradoxically, even though innovation management scholars deal with the actions of creative individuals and the process of creating new products, the innovation function itself is seen as a passive one. Firms that still initiate innovation projects even though uncertainties could not be reduced through planning instruments must appear as either irrational or characterized by high risk propensity, hubris or overconfidence. Given that such behaviour is typically observed in smaller firms, innovation management scholars have long neglected SMEs as they did not seem to be susceptible to managing their innovation process in a rational way.

By drawing on recent theoretical works in the field of entrepreneurial opportunity identification and applying them to the FFE field, the research in this study has contributed an alternative way of looking at the early phases of product innovation. Adopting a structuralist perspective as introduced by the recently emerging opportunity creation view, the fundamental paradigm of an unchangeable environment was relaxed. The creative individual was regarded as not only being subject to environmental forces but also as being able to influence its environment through purposeful action. Introducing a control-based approach that does not rely on forecasting and planning of an uncertain future lets early innovation processes in SME appear in a different light. Rather than trying to position themselves in relation to an uncertain environment, some firms may choose to focus on influencing their relevant environments through own actions. Doing so, they take control over their environments and do not need to rely on prediction. This alternative, control-based way of mastering the early stages of the innovation process is not less rational and open to theoretical understanding than the planning-based approaches are, that have received much attention in the innovation management literature. It is the contribution of this study to have shown that early product innovation processes can be understood as a sequence of activities that follow both a predictive logic of planning and a creative logic of control. It will be up to future research in the field to incorporate those insights and to develop theories that advance our understanding of the interplay of those activities.

Another contribution of the research in this study lies in the emerging theory on *effectuation*. By studying effectual processes in product innovation processes of existing SME, the applicability of this control-based approach has been extended from new ventures (Wiltbank et al., 2009) and innovation processes in larger firms (Küpper, 2009) to yet another empirical setting. The insights gained in this particular environment can help in the transition of the research field from a rather conceptual to a more empirically grounded one. By focusing on effectual processes in existing organisations, the particular practical challenges and obstacles that effectuation has to overcome on its way to a “specific learnable and teachable technique” (Sarasvathy & Venkataraman, 2011) are becoming more clear. While extant empirical research has mainly studied the empirical phenomenon of effectuation using MBA students or entrepreneurs in an experimental setting, this study provides real-life case studies and survey responses from actual entrepreneurs. By doing so, the study demonstrates on the one hand the prevalence of the phenomenon in practice and on the other hand highlights the ingenuity of entrepreneurs to avail themselves of both effectuation and causation processes as circumstances demand. Researchers interested in the empirical

operationalization of the effectuation construct may also be interested in our observation that in most cases both effectual and causal processes were at work simultaneously in the product innovations analysed throughout the study. This gives strong support to the recommendation of Perry et al. (2011) to “develop effectuation measures that are not contrasted as polar opposites of causation measures and [...] to account for causation separately”.

6.2 Implications for Management Practice

Next to theoretical contributions, the study also holds some implications for management practitioners. This research focused on the fuzzy front end of product innovation processes and did so in an SME environment. The insights gained through the analysis of this particular empirical setting therefore are of primary interest to smaller companies. However, larger companies that wish to foster a more entrepreneurial approach to product development or are faced with a highly uncertain environment in some of their operations can also benefit from them. The central implications and recommendations of this research can be summarized as follows:

Organise processes around people and not people around processes. The starting point and central motivation of this study was the insight that smaller companies often find it difficult to adapt well-established innovation management frameworks to their particular circumstances and therefore are reluctant to adopt them. The insights of this study reveal some of the causes for this discomfort. As most of the planning-based approaches to innovation management were developed in the context of larger firms, their main advantage is to co-ordinate and guide the creative actions of a large number of people in an organization. They can, however, not contribute creative ideas or innovations themselves. Larger firms adopting such process models will therefore proceed by assigning specific tasks to people until all competences and knowledge areas required by the process blue-prints are covered. Consequently, the creative potential of many people can be effectively drawn upon, yielding great results for the organization. A similar way of organizing people around processes has, however, only limited use in an SME setting, where a constrained pool of competences is available to work with. In such settings, the knowledge and competences already available in the heads of the firm’s employees must constitute the starting point for the initiation of innovation processes. The means-orientation of a control-based approach highlights the contribution of every persons’ knowledge, experience and skills to the means base of the entire firm. It is therefore more suited to smaller companies, because it allows organising processes around people. SME can therefore be recommended to ask the

questions of “who am I?”, “what do I know?” and “whom do I know?” before proceeding to formalize their innovation processes.

A thorough understanding of environmental uncertainties is the starting point of successful product innovation processes. The insights of this study have shown that the kind and degree of uncertainties faced by the firm has a decisive impact on the choice of planning and/or control-based approaches in the FFE. There is no doubt that planning-based processes promise a faster and potentially less painful option for the development of new products, but they can only be applied in settings that are susceptible to forecasting. Yet, the inability to reduce all uncertainties does not mean that an innovation project should not be started at all. Rather, uncertainties can be turned into opportunities through the use of control strategies. Firms must, however, be able to recognize in which areas they feel that they can adequately forecast future developments and where uncertainties prevail. The central questions are: “what are the dark spots?” and “where can we plan?”. As the Hexis case showed, this is not always easy in larger companies, as there is a tendency to overestimate the own market knowledge and to extrapolate past developments into the future. Not only SME can benefit from a differentiated approach: The case studies have shown how larger firms benefit from spinning off some of their activities into smaller, more control-oriented entities in times where uncertainties prevail. A case study from outside the energy sector that mirrors this approach is *CeWe Color*: In times where their core business of analogue picture development was threatened by digital technology, a small spin-off was initiated with the objective to find new applications for existing competences and with limited financial commitments. Through extensive experimentation and leveraging of the partner network, the technological and market uncertainties could be brought under control. Subsequently, the spin-off was re-integrated into the main business, where a planning-based approach prevailed.

Means orientation does not mean favouring exploitation over exploration. In recent years, companies have been recommended by management researchers and consultants alike to strike a balance between what March (1991) coined as exploration and exploitation and achieve a state of ambidexterity. Ambidextrous organizations on the one hand manage to engage in incremental innovation in their existing business operations through “the use and development of things already known” (Levinthal & March, 1993) while on the other hand developing radical innovations outside the existing core business. Such radical innovations can lead to the creation of new business models, new markets or new ways of playing the competitive game (Ireland et al., 2003). In order to achieve exploration success, Levinthal & March (1993)

recommend firms to engage in activities like “basic research, invention, risk taking, building new capabilities, entering new lines of business, and investments in the firm's absorptive capacity”, all of which mirror a planning-based understanding of the innovation process. Even though exploitation and exploration are often seen as two antipodal activities, it would be premature to classify a control-based, means-oriented approach to product innovation as being an expression of a purely exploitative attitude. Rather, the results of this study have shown that firms applying a means-oriented approach often come up with radically new products that have the potential to change the competitive game. Indeed, the very characteristic of a control-based approach like effectuation is the disregard of existing competitive structures and the creation of new markets or business models in the spirit of exploration. For firms that wish to live up to the requirements of ambidexterity but find it difficult to engage in the activities outlined by Levinthal & March (1993), a control-based approach to the early phases of product innovation processes could therefore be an elegant way to combine exploitation of existing means with exploration of new means-ends relationships.

Control and Positioning approaches are complements, not substitutes. A main result of this work is the insight that SME in the energy sector draw on both control and positioning-oriented approaches simultaneously and in several combinations in order to initiate product innovation processes. Managers can benefit from this insight as it shows that they can use effectuation principles in their daily operations as the need arises. For example, a manager might want to allow some of his expert staff to work on own projects that are potentially promising for the company without compromising the company-wide forecasting-based innovation process. By resorting to control principles like affordable loss and means orientation, the employees can be asked to hand in project ideas that make use of the company's existing competences and put them to use for new ends. A limited fund, as in the example of Shell's game changer program (www.shell.com/gamechanger), could be set up to cut the potential losses from such experimental work. The manager could then decide whether or not employees should be asked to get financial pre-commitments from other sponsors in the organization or whether the output should be a sketch for a potential patent application, which could be fed into the planning-based ideation process of the company. By making use of those individual building blocks, managers can instil a bias to action-taking into a rather planning-based process or, inversely, bring about more focus and direction into a highly creative, control-based process. From a management point of view, control and positioning approaches should therefore be seen as complementary rather than substitutes.

6.3 Policy Implications

It is a stated goal of the Swiss Federal Government to optimise the long-term general conditions of SME in the Swiss economy, an important hallmark of this strategy being the facilitation of innovation by SME (EVD, 2009). In recent years, a focus was laid on some sectors of the economy that are subsumed under the *Cleantech* category and that include the RE/EE industries analysed in this study. Among the measures proposed in the *Master Plan Cleantech* and adopted by the Swiss government is the analysis of current regulatory frameworks and their influence on innovative activities in the economy (BBT, 2011). As the discussion in chapter 3.1.4 showed, changes in the regulatory sphere over the recent years and decades have been an important source of uncertainties in the Swiss RE/EE industries. In this study, environmental uncertainties have been identified as having a relevant influence on the innovation behaviour of SME in an early phase. SME are on the one hand directly affected by increasing regulatory uncertainties as a result of new subsidies, laws or standards. On the other hand, uncertainties in the technological and market spheres also depend on regulatory developments. Hence, regulators have the ability to influence and optimize the long-term general conditions for innovation by SME in the energy sector over several mechanisms: Firstly by mitigating the uncertainties resulting from regulatory activities and secondly by providing an environment for SME to optimally cope with them.

Mitigating uncertainties. It is generally acknowledged that regulatory activities play a major role in the development of the RE/EE industries. Subsidy schemes, taxes, standards, bans, and requirements influence the cost development paths of technologies, investments in infrastructure, or consumer choices. Regulatory activities of the state and its agencies are the result of a political negotiation process among a variety of stakeholders in society with often divergent interests. In areas like energy policies, where the public debate is still under way, this process is especially multifaceted. Furthermore, in an export-oriented country like Switzerland, the different regulatory regimes in foreign markets add to the complexity that companies face. Regulators aiming at mitigating the resulting uncertainty for smaller firms therefore should focus on increasing transparency in the regulatory process. This transparency can only be achieved through the provision of early, accessible and meaningful information to interested firms. A possible mechanism through which this provision can take place is the building of platforms where decision-makers from regulatory agencies can meet and exchange directly with decision-makers in smaller firms.

Coping with uncertainties. However, even with the best of intentions it will not always be possible to considerably lower the uncertainties resulting from regulatory, technological and market developments. In those situations, regulators aiming at supporting SME in their early product innovation processes can make use of the findings of this study.

Today, official innovation support and promotion agencies in the areas of RE/EE often rely on SME to come forward with a concrete demand or request. In order to formulate a request, the firm has to know what kind of product it intends to develop and what concrete financial or non-financial means are necessary to initiate this development. Such an approach implies that SMEs generally adopt a planning-based approach to FFE activities, engage in business planning and can articulate their support needs. However, the results of this study have shown that under conditions of high environmental uncertainties, innovative SME often deviate from this practice and rely on a more control-based approach. By understanding and seizing the principles of a control-inspired approach, such firms can be reached at an early phase, increasing the chances that a product innovation project will actually be launched:

Make the visionary heard (by the right people). An important mechanism of control-inspired firms is to create a coalition of stakeholders around a first, still vague idea of a future product innovation. In an early phase, those firms rely on other interested parties to know about and share their vision. The resulting feedback will enable the initiating firm to gradually adapt and substantiate the developing ideas. However, smaller firms often do not have the extensive contact network and munificent resources required to make their ideas heard with all the relevant and potentially interested stakeholders. Official agencies therefore should strive to promote easily accessible platforms for the exchange of smaller firms in industries where uncertainties are especially prevalent. This task could also be assigned to groups or individuals outside of government agencies that are highly connected in the respective industries. Those individuals can be mandated to set up and maintain a publicly accessible database of key firms and experts in relevant areas of expertise pertaining to RE/EE technologies.

Help create a demand, not a product. Often official support agencies ask firms to demonstrate a potential market demand for the yet to be developed product. In uncertain environments, however, firms have to first create a demand before they can even start thinking of the product. As the case studies in this work have shown, few innovation projects will be initiated if not at least one potential customer has shown an interest and is ready to commit resources to the project. In some instances, public

procurement guidelines that place value on highest energy efficiency standards can result in pioneering projects. However, if the state cannot take over the role of an early adopter, it can incentivise private actors by rewarding investments in efficient or renewable energy products.

Encourage and facilitate experimentation. Experimentation, i.e. the creative re-combination of existing means and competences in the early phases of an innovation process is the main mechanism through which technological uncertainties are reduced by SME using a control-based approach. However, SME often do not have the slack resources required to perform such activities as a stand-alone project. Rather, experimentation is done in the context of especially challenging projects where the firm reaches or goes beyond the limits of its current competences. Such projects are more frequent in areas where high standards for energy efficiency or renewable energy provision are in place. By setting such ambitious standards and leaving it up to the creativeness of firms to come up with ways to fulfil them, regulators have a strong lever to encourage experimentation. By additionally providing easy access for SME to certain equipment and services present at universities or research institutes, this important mechanism can be further facilitated. As the cases analysed in this study show, the provision of services by such actors (e.g. the PSI or Universities of Applied Science) has proven to be highly valuable.

Propagate possible ends. A unifying feature of most of the presented case studies on successful product innovations is that the initial idea was not developed with a potential application in the RE/EE sector in mind. Rather, the decision to focus on the energy efficient or renewable aspects of the product was made later in the innovation process. Consequently, the firm would not have initially turned to energy-related public agencies for support. In the beginning of all innovation projects inspired by a control-based approach, the main focus is on existing means and the current competences. In a second step, potential ends that can be reached with those means are imagined. However, only those means can be imagined that are within the entrepreneurs' powers of imagination. If a person has never heard about new trends in the energy sector, he or she cannot imagine possible ends in those industries. By informing SME about the developments and potential new opportunities in the energy sector, they will be more likely to think of how their existing means could be used to introduce RE/EE product innovations. An example of how a regional governmental agency has been very successful in promoting a certain technology for smaller as well as larger companies is the "Aktionslinie Hessen Nanotech" (www.hessen-nanotech.de). Under this heading, a series of well-researched information brochures on

possible application of nanotechnology in a variety of industries (automotive, bionics, optics, environment, energy, electromobility, etc.) was released. Those publications on the one hand demonstrate the agency's role as a partner for firms in the area of nanotechnology. On the other hand they encourage firms in different sectors of the economy currently not using the technology to imagine possible nanotechnology-based product innovations based on their own competences.

6.4 Limitations

The current study has provided a number of valuable insights that advance the understanding of the early phases of product innovation processes in SME. However, those insights must be interpreted with caution, as they are subject to limitations.

Limitations pertaining to the focus of the study

Motivated by the desire to focus on a practically relevant phenomenon and to achieve insights that are relevant for management practitioners, the empirical setting of SME in the Swiss RE/EE industries was chosen for this study. Additionally, only product innovation processes were considered. The focus on a certain geographic space, kind of innovation and specific industries therefore sets boundaries to the general interpretation of the results. The question of whether innovations in business models, services or new processes for the energy sector are subject to the same mechanisms cannot be derived from the results and must remain unanswered.

Limitations pertaining to the applied methodology

In the course of the study it was possible to show that control-based approaches to early product innovation processes can be found in SME and that their application is influenced by the degree and kind of environmental uncertainties. However, those insights are gained by applying an exploratory research design, involving qualitative case studies and descriptive statistical analyses of survey data. The study does not give solid statistical evidence as to what the antecedents and consequences of the use of control vs. positioning (effectuation vs. causation) approaches on the individual, firm and environmental level are. Neither does the study isolate quantifiable cause-effect relationships that could be found through the use of more advanced statistical methods. Possible avenues for such analyses of the survey data, which go beyond the scope of the current work, are shown in section 6.5.

Limitations pertaining to the results of the study

According to the philosophy of engaged scholarship, this study aimed at contributing towards better understanding and overcoming relevant problems in the practical world. The motivation behind this endeavour was the insight that the traditional, planning-based view of early product innovation processes was deficient, as it restricted the entrepreneurial innovator to innovations in areas that could be planned and forecasted. Towards this end, norm strategies and recommendations for initiating product innovation processes under conditions of uncertainty have been developed. However, it can be asked whether entrepreneurs in practice can actually benefit from such recommendations. Possibly, the goal of understanding and classifying the effectuation-inspired entrepreneurial mind-set is just another futile attempt towards formalizing the FFE and making it accessible to formal planning and forecasting. The question of whether the adoption of a control approach in response to environmental conditions can be deliberately planned and managed has to remain open and constitutes a limitation to the current study.

6.5 Outlook

While this research broadens our understanding of the early stages of product development processes in SME, those insights also offer new research opportunities.

Consequences of Effectuation inside existing companies

Throughout this study, existing firms rather than new ventures were in the focus of interest. This is in contrast to the extant literature on effectuation. The empirical findings in this area mainly rely on experiments during which entrepreneurs were given the task of starting a new venture (for a review of experimental and field research: Perry et al., 2011; Küpper, 2009, p.243). In those situations, the individual entrepreneurs are not restricted in their actions, as no existing organization sets limits to what they can do. However, in the context of existing firms, the entrepreneur is faced with an already established corporate environment. In order to understand effectuation-based innovation processes in existing firms, firm-level characteristics therefore have to be taken into account. The most widely used measure to determine the degree of entrepreneurship present in a firm is Entrepreneurial Orientation (George, 2011) as introduced by Lumpkin & Dess (1996). According to this concept, a firm is seen as exhibiting a high degree of entrepreneurial orientation if it scores high in the dimensions of risk taking, innovativeness and proactiveness. Risk taking is defined by Lumpkin & Dess (1996) as “focusing on the upside potential of risk”. This

definition is very similar to a causation-based approach, while an individual is seen as exhibiting a high degree of effectuation if it focuses on the downside potential of risk. Proactiveness, which among other elements comprises an attitude of “beating competitors to the punch” (Miller, 1983) can also be seen as an expression of a rather causal, positioning-based mindset. Effectual individuals, in contrast, would be expected not to position themselves primarily in relation to competitors and would rather be interested in collaboration and mutually beneficial relationships. Those apparent conceptual differences between the individual-level construct of effectuation and the firm-level construct of entrepreneurial orientation give rise to a number of interesting research opportunities. Firstly, future research will have to clarify the consequences of causation versus effectuation mind-sets of the entrepreneur on the entrepreneurial orientation of the firm. Will a firm be able to maintain a high degree of entrepreneurial orientation while still adopting effectuation-inspired control approaches to product innovation processes? Or is the entrepreneurial orientation construct too much focused on a causation-based approach to discovering opportunities that has dominated the entrepreneurship literature in the past and should be complemented by additional sub-dimensions?

Performance Implications of Effectuation

The above consideration of the use of effectuation inside existing firms also gives rise to another relevant issue: the “*so what?*” question. It is generally accepted in literature that the link between entrepreneurial orientation and performance is solid and strong (Wiklund & Shepherd, 2005; Rauch et al., 2009). If there actually should be a conflict between the use of effectual reasoning on the individual level and actions reflecting a strong entrepreneurial orientation on the firm level, this could compromise the bottom line of the company. The case studies in this work have contributed a first indication of when the one or the other approach is more likely to contribute to the initiation of an innovation project in the early phases. However, this research has not considered any performance implications on the firm level or whether the new products developed by the case study firms have actually contributed to their success in the medium term. Analysis of the survey data has yielded inconclusive results, while generally pointing towards a negative relationship between effectuation and performance. Future research could therefore further explore the link between the adoption of an effectuation vs. causation inspired mindset by the entrepreneur and actual performance outcomes on the firm level. Next to trying to establish a direct effect, potential mediators and/or moderators for this relationship could be tested. This could help researchers to further enlighten the question of whether using an effectuation-inspired control approach is

universally beneficial for the firm and under what circumstances a causation-inspired positioning approach is to be preferred. The extant work on the entrepreneurial orientation construct points towards the role of the environment and industry life-cycle in moderating the performance impact (Lumpkin & Dess, 2001).

The role of the environment

The conclusions drawn from this study posit that the degree and kind of environmental uncertainties play a major role in an SME's decision to adopt a control over a positioning-based approach to the development of new products. However, the survey results have also contributed the insight that higher uncertainties do not unilaterally favour the use effectuation over causation principles. Rather, the rising tide seems to lift all boats and increasing uncertainties may lead some firms to both try harder to predict and try harder to create new ends. This study, however, only offers a snap-shot of the current situation of the energy sector and how innovative SME deal with the environmental uncertainties inherent to it. As the RE/EE industries offer a highly dynamic setting, this sector would lend itself to longitudinal studies. Such data could give insights into how SME adopt their approaches over time as the environmental conditions change. In other sectors, such as the biotechnology industries, longitudinal data (Rothaermel & Hill, 2005) have been helpful in uncovering how firms react to changes in their environment

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Appendices

A) Interview Guideline for Case Studies

The following guideline was used in order to conduct the interviews listed in Appendix B for the case studies outlined in chapter 3.2

A. Introductory Questions

The first set of introductory questions was asked in order to get a general impression of the company and the industry environment. Not all questions were asked in every interview, as some information could be retrieved from publicly available sources or additional corporate documentation provided by the interviewee.

A1: History of the Firm

- *When was your company founded and what were the most important milestones in its development?*
- *Was your company founded in a university or research institution environment?*
- *What was the most important innovation in the history of your company? When did this innovation happen? How does it influence your activities today?*

A2: Personal Background

- *For how long have you been with the company?*
- *Would you describe yourself rather as an entrepreneur or as a manager?*

A3: Size of the Firm

- *How many people does your company employ? How many full time jobs does that equate to?*

A4: Industry Affiliation

- *What are the market offers of your company?*
- *Does your company focus more on the development of products or services?*
- *How would you assess the degree of uncertainty in respect to future technological developments in the industries relevant for you? (degree of technological dynamism)*
- *In general terms, how would you describe the current and future importance of the energy sector for your company?*

-
- *Is there a pronounced pressure to continuously adapt your market offerings to changing customer demands? (degree of market dynamism)*
 - *Do you feel that the regulatory environment rather restrains or promotes your ability to develop new market offerings?*

A5: Customer Segment & Structure

- *Do you rather serve customers in the private (B2C) or the commercial (B2B) sector?*
- *Are there key customers that account for a significant part of your company's total turnover?*

A6: Strategic Alignment

- *Do you follow a niche strategy in your industry? What does that niche look like?*
- *How important is technology for the provision of your market offerings?*

A7: Conception of Innovation

- *What is regarded as an innovation in your company?*
- *What is generally regarded as an innovation in your relevant industry?*

A8: Drivers of Innovation

- *Does the development of new market offerings in your company rather depend on the availability of new technologies or on identified market needs (technology vs. market driven)?*

A9: Cooperation with External Parties

- *When looking for and assessing ideas for new products, do you co-operate with external parties like customers, suppliers, other companies or consultants?*
- *Do you have established contacts with universities or research institutions that you frequently use?*
- *Are you integrated in structures of industry associations or larger supplier networks?*
- *What are the major obstacles when co-operating with external partners?*

B. Product Development Project

This set of questions was aimed at getting a first-hand narrative of a specific development project identified before the interview. The interviewee was asked the following general question:

- I am especially interested in knowing more about a particular product of your company that you recently introduced in the energy sector. If I understand correctly, this was the first time that your company developed a product for this market. Please tell me more about how you came to develop this product and what were the main challenges and activities in an early phase.

The following additional questions were asked, if the issues were not raised by the interviewees themselves:

- How did you get to know about the threats and opportunities of the energy sector?*
- What kind of market research did you conduct at an early phase?*
- How did the idea develop from the first inception until you were sure that a product development project would be initiated?*
- How did you approach the task of funding the project?*
- How did you make sure that you had all necessary competences for the product development project on board?*

C. Size-Related Factors

The following set of questions addressed factors that are mentioned in literature as areas where SME exhibit size-related advantages (C1-C5) or disadvantages (C6-C13):

C1: Hierarchies

- How many hierarchical layers exist in your company? How many employees is a manager normally responsible for?

C2: Decision Finding

- Does the managing director of your company have the authority to make all strategic and day-to-day decisions alone?*
- Are decisions pertaining to the selection of new product ideas or the launch of a new product development project normally made by a single person or by a group?*
- Is the managing director of your company personally liable for financial losses?*

C3: Culture & Employee Loyalty

- *How would you describe the corporate culture of your firm? What are the most important values?*
- *How do you assess your personnel turnover rate by industry standards?*

C4: Market Intimacy

- *Do you assess your customer relationships as rather close or distant by industry standards?*
- *Are the buyers of your market offerings identical to the end customers / end users?*

C5: Agility & Flexibility

- *Are the requests and demands of your customers rather uniform or very individual?*
- *Is it common practice in your company to respond to unusual or non-standard customer requests?*

C6: Use of Methods

- *What is the educational background of the managing director of your company?*
- *When looking for and assessing ideas for new products, do you make use of proven and tested methods? What sources do you get those methods from?*
- *Does your company promote certain well-established routines in the search for new product ideas?*
- *Does your company systematically incentivize its employees to come up with new product ideas?*

C7: Roles and Responsibilities

- *Does your company use role descriptions for its employees that contain responsibilities for activities in the early phases of new product development and idea generation?*
- *Has your company established committees or institutions that decide on the further development of new product ideas? What criteria do those committees apply? Are the criteria transparent for all employees?*

C8: Planning, Processes and Documentation

- *Does your company follow a formalised process when developing new products? Is this process based on a reference framework? What is the overlap between the formalized process and the informally practiced process?*
- *Has your company formulated an explicit innovation strategy? How and to whom is this strategy communicated?*

-
- *Are activities pertaining to the development of new products systematically planned and documented?*

C9: Financial Resources

- *To what extent do you rely on the possibilities of debt capital financing? What are your preferred sources of capital?*
- *How would you assess your ability to raise debt capital and/or subsidies for the early phases of a new product development project?*

C10: Hiring & Development of Experts

- *Does your company have academics among its staff?*
- *Do you see yourself as disadvantaged in the recruitment of expert staff as compared to larger companies in your industry?*
- *How does your company support its highly specialized staff in the area of professional and methodological training?*

C11: Diversification of Project Risks

- *How many new product development projects are you currently conducting in your company? How many have there been over the last two years?*

C12: Economies of scale

- *Is the provision of your market offerings connected with high fixed costs?*
- *Is your company able to flexibly expand and scale down production capacities?*

C13: Continuous R&D

- *Does your company run an own research and development department?*

B) Interview Partners for Case Studies

Company	Name	Position	Date
3S Swiss Solar Systems	Dr. Roland Lange	Chief Innovation Officer	01.09.2009
Airlight Energy	Andrea Pedretti	CTO	19.01.2009*
CEKAtec	Dr. Marco Santis	Head Fuel Cell Department	07.02.2012
CTU – Conzepte Technik Umwelt AG	Martin Schaub	CEO	11.08.2009
ERNE AG Holzbau	Erwin Eschbach	Head of windows & facades	03.08.2009
Fehr, Management- und Wirtschaftsberatung	Stefan Fehr	CEO	07.10.2009
Fenster Schär AG	Martin Schär	CEO	28.08.2009
Hexis AG	Dr. Alexander Schuler	CEO	01.03.2010
Hexis AG	Volker Nerlich	Head of Business Development	20.01.2011*
Hilti Energy & Industry	Dr. Stefan Odenthal	CEO	23.04.2010
Paul Scherrer Institute PSI	Alfred Waser	Technology Transfer Officer	04.09.2009
Pyroforce Energietechnologie AG	Herbert Gemperle	CEO	20.10.2009
Wenger Fenster AG	Markus Wenger	CEO	12.08.2009

* *the two indicated interviews were conducted and recorded by a third person (A.Truffer)*

All interviews were conducted in person and face-to-face at the interviewees' company. The duration of the interviews was between 1 and 2.5 hours each.

C) Questionnaire for Online Survey

The following questionnaire has been made available on the internet via the internet link below:

[http://ww3.unipark.de/uc/hrzeler_Universit__t_St_Gallen/9849/?code=\[individualized code\]](http://ww3.unipark.de/uc/hrzeler_Universit__t_St_Gallen/9849/?code=[individualized code])

The link was active from November 2, 2011 until November 25, 2011

Ihr Unternehmen

Mit diesem Fragenblock möchten wir einige Eckdaten über Ihr Unternehmen herausfinden. Diese Daten werden uns auch dabei helfen, Ihren Feedback-Bericht so anzupassen, dass wir Ihre Daten mit anderen Unternehmen ähnlicher Grössenordnung und Ausrichtung vergleichen können:

1. Eckdaten:

- a) In welchem Jahr wurde Ihre Unternehmen gegründet?
- b) Wieviele Mitarbeiter beschäftigt Ihr Unternehmen?
- c) Wieviel gibt Ihr Unternehmen (schätzungsweise) für Forschung & Entwicklung aus? *[in CHF]* _____
- d) Wurde Ihr Unternehmen als Abspaltung ("spin-off") eines anderen Unternehmens gegründet? Ja Nein

2. Geschäftsentwicklung

Wie hat sich Ihr Unternehmen über die letzten 3 Jahre hinweg in Bezug auf folgende Kennzahlen entwickelt?



3. Mitarbeiter

Wie verteilen sich Ihre Mitarbeiter auf die folgenden Personalkategorien?

	Anteil
Lehrlinge, An- und Ungelernte	ca. _____ %
Gelernte	ca. _____ %
Personen mit einem Abschluss höher als Berufslehre	ca. _____ %
AkademikerInnen	ca. _____ %

4. Kompetenzprofil

Bitte geben Sie für die aufgelisteten Bereiche an, wie stark Sie Ihr Unternehmen jeweils einschätzen:



Weiter

Branchenumfeld und Veränderungen

Die letzten Jahre waren durch grosse Veränderungen und Unsicherheiten im technischen, regulatorischen und wirtschaftlichen Bereich gekennzeichnet. In diesem Abschnitt des Fragebogens interessiert uns daher, wie sich diese Veränderungen im Umfeld Ihres Unternehmens bemerkbar gemacht haben.

1. Veränderungen in Ihrem Markt

	Sehr stark geschrumpft			gleich geblieben			Sehr stark gewachsen
a) Wie hat sich Ihr Absatzmarkt in den letzten 3 Jahren verändert?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	keine	1	2	3-5	6-10	11-20	mehr als 20
b) Wieviele Wettbewerber haben Sie in Ihrem Hauptmarkt?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c) Wieviele davon sind in den letzten 3 Jahren neu dazugekommen?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. Dynamik bei Technologie und Kunden

Bitte geben Sie an, wie gut die folgenden Aussagen die Situation Ihres Unternehmens beschreiben:

	trifft überhaupt nicht zu						trifft vollständig zu
"Die in unseren Absatzmärkten relevante Technologie ändert sich sehr rasch"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Die technologischen Entwicklungen in unseren Absatzmärkten sind eher unwesentlich"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Technologische Entwicklungen eröffnen uns grosse Möglichkeiten in unseren Absatzmärkten"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Wie sich die Technologien in unseren Absatzmärkten in den nächsten 5 Jahren entwickeln werden, ist sehr schwer vorherzusagen"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Viele neue Produkte in unseren Absatzmärkten wurden durch bahnbrechende technologische Entwicklungen erst möglich gemacht"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	trifft überhaupt nicht zu						trifft vollständig zu
"Die Kunden in unseren Absatzmärkten sind gegenüber neuen Produktideen sehr aufgeschlossen"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"In unseren Absatzmärkten ändert sich der Geschmack der Kunden relativ schnell"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Neukunden haben an unsere Produkte tendenziell andere Ansprüche als bestehende Kunden"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Wir bedienen mehrheitlich die gleichen Kunden wie in der Vergangenheit"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. Auslandsaktivitäten

a) Welchen Anteil Ihres Umsatzes erwirtschaften Sie im Ausland (<i>Exportanteil</i>)?	ca.	%
b) Produziert Ihr Unternehmen auch im Ausland?	Ja <input type="radio"/>	Nein <input type="radio"/>
c) Wie wichtig ist es für Ihr Unternehmen, einen Standort in der Schweiz zu haben?	unwichtig	sehr wichtig
	<input type="radio"/>	<input type="radio"/>

[Weiter](#)

Verhalten im Markt

Bei den folgenden Fragen geht es darum, wie die Führung Ihres Unternehmens mit den "Spielregeln" im Markt umgeht. Sie sehen im Folgenden jeweils zwei verschiedene Aussagen, welche zwei verschiedene Verhaltensmuster zum Ausdruck bringen. Bitte positionieren Sie Ihr Unternehmen zwischen diesen Aussagen. Ein Kreuz ganz links bedeutet, dass Sie vollkommen mit der linken Aussage übereinstimmen. Ein Kreuz ganz rechts bedeutet, dass Sie sich vollständig mit der rechten Aussagen identifizieren können.

Im Umgang mit der Konkurrenz...

- | | | |
|---|-----------------------|---|
| ...reagiert mein Unternehmen normalerweise auf Aktionen, die von der Konkurrenz ausgehen. | <input type="radio"/> | ...startet mein Unternehmen normalerweise Aktionen, auf welche die Konkurrenz dann reagiert. |
| ...ist mein Unternehmen sehr selten die erste Firma, die neue Produkte oder Dienstleistungen einführt | <input type="radio"/> | ...ist mein Unternehmen sehr oft die erste Firma, die neue Produkte oder Dienstleistungen einführt. |
| ...vermeidet mein Unternehmen Konfrontationen nach der Devise "leben und leben lassen" | <input type="radio"/> | ...sucht mein Unternehmen die Konfrontation mit dem Ziel, die Konkurrenz auszuschalten. |

In unsicheren Entscheidungssituationen verfolgt meine Firma...

- | | | |
|---|-----------------------|--|
| ...eine vorsichtige und abwartende Haltung, um möglichst keine teuren Fehlentscheidungen zu fällen. | <input type="radio"/> | ...eine gewagte und aggressive Haltung, um sich bietende Möglichkeiten möglichst auszunutzen |
|---|-----------------------|--|

Die Leitung meines Unternehmens hat...

- | | | |
|--|-----------------------|--|
| ...eine starke Vorliebe für Projekte mit geringem Risiko (und dafür nur durchschnittlichen Gewinnchancen) | <input type="radio"/> | ...eine starke Vorliebe für Projekte mit hohem Risiko (und dafür sehr hohen Gewinnchancen) |
| ...einen starken Fokus darauf, bewährte Produkte zu vermarkten. | <input type="radio"/> | ...einen starken Fokus darauf, im Bereich Forschung/Entwicklung und Innovation führend zu sein. |
| ...die Ansicht, dass wir unsere Geschäftsfelder am besten schrittweise, durch zurückhaltendes Auftreten erschliessen können. | <input type="radio"/> | ...die Ansicht, dass wir unsere Geschäftsfelder nur mittels umfangreichen und gewagten Aktionen erschliessen können. |

Anpassungen an unseren Produkten waren in der Vergangenheit...

- | | | |
|---------------------------|-----------------------|------------------------------|
| ...meist eher unbedeutend | <input type="radio"/> | ...meist ziemlich dramatisch |
|---------------------------|-----------------------|------------------------------|

Weiter

Organisation des Unternehmens

Dieser Teil des Fragebogens dreht sich um die Frage, wie Ihr Unternehmen im Tagesgeschäft geführt wird.

Sie sehen im Folgenden jeweils zwei verschiedene Aussagen, welche zwei verschiedene Ansätze in der Organisation zum Ausdruck bringen. Bitte positionieren Sie Ihr Unternehmen zwischen diesen Positionen. Ein Kreuz ganz links bedeutet, dass Sie vollkommen mit der linken Aussage übereinstimmen. Ein Kreuz ganz rechts bedeutet, dass Sie sich vollständig mit der rechten Aussagen identifizieren können.

In meinem Unternehmen...

<p>..ist klar geregelt, wer mit wem über welche Informationen spricht. Der Zugang zu wichtigen Finanz- und Geschäftsinformationen ist stark eingeschränkt.</p>	<p>..haben wir keine Regeln für die Kommunikation. Wichtige Finanz- und Geschäftsinformationen sind für alle Mitarbeiter verfügbar.</p>
<p>... möchten wir bei allen Führungskräften einen einheitlichen Führungsstil durchsetzen.</p>	<p>..überlassen wir es jeder Führungskraft, einen eigenen Führungsstil zu wählen.</p>
<p>..hat bei Entscheidungen immer der direkte Vorgesetzte das letzte Wort.</p>	<p>..hat bei Entscheidungen stets diejenige Person das letzte Wort, die über das beste Expertenwissen verfügt. Dabei kann auch der Dienstweg übergangen werden.</p>
<p>..halten wir auch bei Veränderungen im Geschäftsumfeld an bewährten Führungsprinzipien fest.</p>	<p>..passen wir bewährte Führungsprinzipien ohne grosse Bedenken an, wenn sich das Geschäftsumfeld verändert.</p>
<p>..legen wir Wert darauf, dass jeder Mitarbeiter sich stets an die vorgegebenen Arbeitsschritte hält.</p>	<p>..legen wir Wert darauf, dass die Arbeit, ohne Rücksicht auf vorgegebene Arbeitsschritte, möglichst gut erledigt wird.</p>
<p>..kontrollieren wir die meisten Abläufe sehr genau mittels detaillierter Kontroll- und Informationssysteme.</p>	<p>..kontrollieren wir die Abläufe kaum. Unser gutes Betriebsklima stellt sicher, dass die Arbeit erledigt wird.</p>
<p>..haben wir die Aufgaben jedes Mitarbeiters detailliert beschrieben und legen Wert darauf, dass sich jeder Mitarbeiter stets eng an diese Beschreibung hält.</p>	<p>..legt jeder Mitarbeiter aufgrund seiner Persönlichkeit und den Anforderungen der Situation selbst fest, welche Aufgaben nötig sind.</p>

Weiter

Fragen zu Ihrer Person

In diesem Fragenblock möchte wir Ihnen einige Fragen zu Ihrem persönlichen Hintergrund stellen.

1. Position im Unternehmen

a) Welche der folgenden Rollen trifft auf Ihre momentane Position im Unternehmen zu? *(Mehrere Antworten möglich)*

- Gründer
 Geschäftsführer
 andere:
 Präsident des Verwaltungsrates
 Haupteigentümer

- | | Ja | Nein |
|---|-----------------------|-----------------------|
| b) Haben Sie bereits einmal mitgeholfen, ein Unternehmen zu gründen? | <input type="radio"/> | <input type="radio"/> |
| c) Haben Sie Ihre momentane Position durch Nachfolge innerhalb Ihrer Familie erlangt? | <input type="radio"/> | <input type="radio"/> |

2. Erfahrung

a) Seit wievielen Jahren sind Sie bereits beruflich aktiv?

wieviele Jahre davon...

b)...in Ihrer momentanen Firma?

c)...in Ihrer momentanen Branche?

d)...in Ihrer momentanen Position?

e)...als Selbstständiger?

3. Ausbildung

Bitte kreuzen Sie die höchste Ausbildung an, welche Sie bisher absolviert haben:

- Obligatorische Schule
 Matura / Berufsmatura
 Fachhochschule
 Abgeschlossene Berufsausbildung
 Höhere Berufsausbildung / Höhere Fachschule
 Universität / ETH

4. Netzwerke im Berufsleben

Welche der folgenden Netzwerke nutzen Sie aktiv in Ihrem Berufsleben?*(Mehrere Antworten möglich)*

- Berufsvereinigung / Fachverband
 Ehemaligenvereinigung von Schule / Universität
 Politische Vereinigungen
 Arbeitgeberverband / Gewerbeverband
 Soziale Gruppen (enge Freunde / Familie)

Weiter

Produkte und Branche

Die folgenden Fragen beziehen sich auf das Produktesortiment Ihres Unternehmens im Allgemeinen und mit Bezug zum Energiesektor. Die Angaben in diesem Bereich benötigen wir insbesondere auch für Ihren persönlichen Feedback-Bericht.

1. Sortiment

a) Wie viele unterschiedliche Produkte umfasst das Angebot Ihrer Unternehmung?

- ein einziges Produkt
- mehr als ein Produkt

b) Wie wichtig sind die von Ihnen angebotenen Produkte für Ihre Kunden, um die folgenden Ziele zu erreichen?

	nicht relevant						sehr wichtig
...den gesamten Energieverbrauch zu reduzieren	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
...Energie effizienter zu nutzen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
...die Menge nicht genutzter Energie zu reduzieren	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
...den Anteil erneuerbarer Energie am Energieverbrauch zu erhöhen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
...Energie aus Nebenprodukten oder Abwärme zu gewinnen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
...den CO2-Ausstoss zu senken	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
...die gesetzlichen Anforderungen im Energiebereich besser zu erfüllen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
...die Anforderungen betreffend Deklarationen besser zu erfüllen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
...den eigenen Energieverbrauch besser zu überwachen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. Produkte für den Energiesektor

Die folgenden Fragen beziehen sich auf Ihre Produkte mit Bezug zum Energiesektor*

(* Der Energiesektor umfasst Produkte und Technologien, welche die nachhaltige Generierung, Speicherung, Übertragung sowie den effizienten Verbrauch von Energie ermöglichen. Beim Verbrauch von Energie sind sowohl industrielle Prozesse wie auch Verbraucher in den Bereichen Haushalt, Gebäude und Mobilität eingeschlossen).

a) Mit welchem Produkt mit Bezug zum Energiesektor* haben Sie 2010 den grössten Umsatz erzielt?

(bitte geben Sie eine kurze Beschreibung des Produktes ab)

b) Welchen Anteil haben Produkte des Energiesektors am gesamten Umsatz Ihres Unternehmens? ca. %

	stark verkleinert		nicht verändert		stark vergrößert
c) Dieser Anteil hat sich in den letzten 3 Jahren...	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Weiter

Entwicklung neuer Produkte

Für die nächsten Fragen möchten wir Sie nun bitten, sich an das letzte Mal zu erinnern als Sie in Ihrem Unternehmen ein neues Produkt entwickelt oder eines Ihrer bestehenden Produkte grundlegend verändert haben.

1. Aussagen zur Produktentwicklung (1/ 2)

Sie sehen unten einige Aussagen von verschiedenen Unternehmern. Die Unternehmer beschreiben dabei, wie sie zu Beginn der Entwicklung eines neuen Produktes vorgegangen sind. In dem Antwortfeld rechts können Sie angeben, wie gut diese Aussagen mit Ihrer eigenen Herangehensweise übereinstimmen:

	trifft überhaupt nicht zu							trifft vollständig zu
"Wir haben bereits frühzeitig Marktstudien und Konkurrenzanalysen durchgeführt"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Wir hatten von Anfang an eine klare Vision davon, was wir erreichen wollten."	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Wir haben die Produktion und Vermarktung von Anfang an eingeplant."	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	trifft überhaupt nicht zu							trifft vollständig zu
"Wir haben verschiedene langfristige Chancen am Markt analysiert und diejenige ausgewählt, von der wir uns die grössten Erträge erhofft haben"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Wir haben eine Strategie entwickelt, wie wir die Fähigkeiten unseres Unternehmens optimal nutzen können"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Wir haben eine Geschäftsstrategie (z.B. einen Business Plan) ausgearbeitet"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Um die Erreichung unserer Ziele sicherzustellen, haben wir Kontrollprozesse eingeführt"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	trifft überhaupt nicht zu							trifft vollständig zu
"Wir haben darauf geachtet, nicht mehr Geld einzusetzen als wir uns erlauben konnten zu verlieren"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Wir haben darauf geachtet, nicht mehr Geld zu riskieren als wir im schlimmsten Fall bereit waren, mit unserer ursprünglichen Idee zu verlieren"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
"Wir haben darauf geachtet, nicht soviel Geld zu riskieren, dass die Firma im Fall eines Fehlschlages in ernsthafte finanzielle Schwierigkeiten geraten könnte"	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Weiter

2. Aussagen zur Produktentwicklung (2/ 2)

<p>"Wir haben mit unterschiedlichen Produkten und Geschäftsmodellen experimentiert"</p> <p>"Das Produkt, so wie wir es jetzt anbieten, ist im Kern genauso wie wir es in unserem ersten Konzept festgehalten hatten"</p> <p>"Wir haben einige verschiedene Ansätzen ausprobiert, bis wir ein funktionierendes Geschäftsmodell fanden"</p> <p>"Das Produkt, so wie wir es jetzt anbieten, ist wesentlich anders als wir es uns ganz zu Beginn vorgestellt hatten"</p>	<p>trifft überhaupt nicht zu</p> <p>● ● ● ● ● ● ●</p>	<p>trifft vollständig zu</p> <p>●</p>
<p>"Wir haben unsere Geschäftsidee angepasst, wenn sich neue Möglichkeiten ergeben haben"</p> <p>"Wir haben unsere Vorgehensweise den verfügbaren Ressourcen angepasst"</p> <p>"Wir waren flexibel und haben Gelegenheiten wahrgenommen wenn sie sich ergeben haben"</p>	<p>trifft überhaupt nicht zu</p> <p>● ● ● ● ● ● ●</p>	<p>trifft vollständig zu</p> <p>●</p>
<p>"Wir haben alles vermieden, was unsere Flexibilität oder Anpassungsfähigkeit eingeschränkt hätte"</p> <p>"Um die Unsicherheit zu reduzieren, haben wir möglichst viele Vereinbarungen mit Kunden, Lieferanten und anderen Organisationen oder Personen getroffen."</p> <p>"Wann immer es möglich war, haben wir verbindliche Vereinbarungen mit Kunden und Lieferanten geschlossen"</p>	<p>trifft überhaupt nicht zu</p> <p>● ● ● ● ● ● ●</p>	<p>trifft vollständig zu</p> <p>●</p>

Weiter

Finanzierung und Subventionen

Im Energiebereich wurden in den letzten Jahren einige neue staatliche Förderinstrumente eingeführt, von welchen jedes Unternehmen unterschiedlich profitiert. Mit den folgenden Fragen möchten wir herausfinden, wie die Bedeutung dieser Instrumente für Ihr Unternehmen ist und welche Präferenzen Sie allgemein bei der Finanzierung Ihrer Tätigkeiten haben.

1. Subventionen für Ihr Unternehmen

Stellen Sie sich vor, **Sie** würden per sofort keine der folgenden staatlichen Beihilfen mehr erhalten.

Wie hoch schätzen Sie den Anteil **Ihres** Umsatzes, den Sie dann nicht mehr erwirtschaften könnten?

	< 5%	5-10%	10-25%	25-50%	50-75%	75-90%	90-100%
a)... direkte Beihilfen (<i>jede Art von direktem Geldtransfer von einer offiziellen Stelle</i>)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b)... indirekte Beihilfen (<i>jede Art von nicht-finanzieller Unterstützung, wie etwa Exportgarantien, Zugang zu Marktforschung, vergünstigte Weiterbildung, etc.</i>)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
c)...jede Art von Beihilfen durch das Bundesamt für Energie (BFE)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

2. Subventionen für Kunden

Stellen Sie sich vor, **Ihre Kunden** würden per sofort keine der folgenden staatlichen Beihilfen mehr erhalten.

Wie hoch schätzen Sie den Anteil **Ihres** Umsatzes, den Sie dann nicht mehr erwirtschaften könnten?

	< 5%	5-10%	10-25%	25-50%	50-75%	75-90%	90-100%
a)...Kostendeckende Einspeisevergütung (KEV)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
b)...Beiträge aus dem Gebäudesanierungsprogramm	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3. Finanzierungsstrategie

a) Welche der folgenden Finanzierungsquellen nutzt Ihr Unternehmen?(*mehrere Antworten möglich*)

- | | |
|--|--|
| <input type="checkbox"/> Bankkredite | <input type="checkbox"/> Venture Capital (Wagniskapital) |
| <input type="checkbox"/> Lieferantenkredite | <input type="checkbox"/> Leasing |
| <input type="checkbox"/> Kredite von staatlichen Stellen | <input type="checkbox"/> staatliche Fördermittel (nicht rückzahlbar) |

b) Wie hoch ist der Anteil der Kredite an der gesamten Bilanzsumme?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
	0%	1-25%	25-50%	50-75%	75-100%	
c) Wie schwierig ist es für Ihr Unternehmen, die Finanzierung besonders riskanter Projekte sicherzustellen?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
	sehr einfach					sehr schwierig

[Weiter](#)

Peter Hürzeler

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Education

- 10/08 - 09/12 **University of St. Gallen (HSG)**
Doctoral programme at the Institute of Technology Management, Chair for Innovation Management, Prof. Dr. Oliver Gassmann
- 08/06 - 12/06 **University of Toronto, Rotman School of Management**
MBA programme
- 10/05 - 05/07 **University of St. Gallen (HSG)**
M.A. in Information, Media and Technology Management (IMT)
- 10/02 - 07/05 **University of St. Gallen (HSG)**
B.A. in Business Administration
- 10/97 - 12/01 **Gymnasium, MuttENZ BL**
Matura

Professional experience

- 10/08 - 05/12 **University of St.Gallen**
Institute of Technology Management
- 02/08 - 09/08 **The Innovation Society Ltd.**
- 07/07 - 12/07 **Novartis Pharma Development**