The Influence of Uncertainty on Venture Capital Investments in Renewable Energy Technology: an exploratory study

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Abstract

The rate at which the climate is changing due to the exploitation of fossil fuel suggests that there is great emergency to speed up the development, commercialization, and diffusion of renewable energy technologies. Firms based on new technology (NTBFs) are widely recognized as propulsive in bringing new technologies to the market. Intriguingly, recurring studies report on severe difficulties experienced by NTBFs as regards getting access to sufficient growth capital. The traditional capital market's failure to provide finance has made venture capital a sine qua non of innovation in such firms. Being a lever of innovation and thus central to the issue of climate change, better understanding of what influences venture capital investments in renewable energy technologies is crucial. Equity investing is an uncertain undertaking. This thesis aims at investigating what sources of uncertainty are relevant in relation to investments in renewable energy technologies. Telephone interviews were conducted with nine Swedish venture capital firms. It was found that technological uncertainty, market adoption/consumer uncertainty, competitive uncertainty and political, or regulatory, uncertainty were influential. Based on these results this thesis offers a discussion of implications for venture capital firms, technology developers and other actors in the innovation system. The discussion centers on the importance of networking.

Key words: venture capital, renewable energy technology, uncertainty
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1. Introduction

The rate at which the climate is changing due to the exploitation of fossil fuel suggests that there is great emergency to speed up the development, commercialization, and diffusion of renewable energy technologies. Policy makers around the world are becoming increasingly occupied with the shaping of strategies aiming to support a transition towards sustainable production and consumption of energy. One example of an action initiative is ETAP\(^1\) (Environmental Technologies Action Plan) (COM, 2004), launched by the European Commision in 2004. The goal of the plan is to promote research, development, and commercialization of renewable energy technologies, i.e. to mobilize funds, to help drive demand and improve market conditions for such technologies. In short; to speed up the generation, adoption and diffusion of renewable energy innovations.

Innovation and technological change is often associated with entrepreneurship and the start up of new firms. While linking innovation with novelty as regards the life of an organization is common equalizing innovation with novel firms is fallacious. Innovation has rather become a prerequisite to competitiveness and is carried out on a continuous basis within large organizations and established enterprises (Baumol, 2002). Nonetheless, start-ups based on new technology (NTBFs) are widely recognized as propulsive in bringing new technologies to the market (Rickne, 2000; Storey and Tether, 1998). Intriguingly, recurring studies report on severe difficulties experienced by start-ups as regards getting access to sufficient growth capital (Eurobarometer, 2005; Sjögren and Zackrisson, 2005; Westhead and Storey, 1997). The traditional capital market’s failure to provide (loan and debt) finance (Berger and Udell, 1998) has made venture capital a sine qua non of innovation in such firms (Hellman and Puri, 2000; Locket et al., 2002; Mason and Harrison, 2004).

\(^1\) http://ec.europa.eu/environment/etap/index_en.htm
Venture capital is provided by firms whose predominant mission is to finance the founding or early growth of new companies that do not yet have access to the public securities markets or to institutional lenders (Gupta and Sapienza, 1992, p. 394). Venture capital has indeed proved to be a key ingredient to the costly process during which a promising invention are transformed to a successful innovation (Bygrave and Timmons, 1986; Florida and Kenney, 1988; Kortum and Lerner, 2000; von Burg and Kenney, 2000). Semiconductors, disk drive, information technology and bio-technology are all industries where venture capital has played a crucial role in eventual success stories. The present age is also replete with evidence of successful initial public offerings of venture capital-backed renewable energy technology firms. Cases in point are Metabolix, Suntech Power, Q-Cells, and Suzlon Energy from USA, China, Germany, and India respectively. Given the importance of venture capital to technological development, firms who invest equity may affect the trajectory of this development (Florida and Kenney, 1988). Thus, from a sustainability point of view, it is highly important that there is a viable venture capital market interested in investing in renewable energy technologies. A prerequisite for a transition to a sustainable production and consumption of energy is a well functioning venture capital market potent in providing renewable energy technology start-ups with equity during needy times. To date, however, venture capital is in general under-utilized as a means of small business finance (Harding, 2000).

\textit{Mosaic} is a metaphor frequently used in the public debate about renewable energy technology. At the stage of development of which the industry is at, there is a variety of product or equipment designs with potential to serve the same or closely related ends. Venture capital firms, with expertise in evaluating business opportunities and nascent ventures, are in the position to nurture a range of viable renewable energy technologies. However, investments in burgeoning industries are uncertain undertakings. In fact, it has been argued
that uncertainty is the major barrier for the breakthrough of renewable energy technologies (Foxon et al. 2005; Jacobsson and Bergek, 2004; Kemp et al., 1998; Meijer, et al., 2007a, b).

According to Dosi (1988, p. 222) innovation; the process whereby technologies are developed and commercialized, is fraught with "fundamental element[s] of uncertainty."

Uncertainty may regard the technological outcome of the innovation process, the state of the environment in which the innovation will be embedded, or how environmental changes will affect the prospect of the innovation and how to respond to such changes (Afuah and Utterback, 1997; Meijer et al., 2006; Milliken, 1987). While some uncertainties may be resolved through R & D, learning, and interaction between users and producers, others unfold as the process evolves (Kline and Rosenberg, 1986; Lundvall, 1992). As a result of these aggregate uncertainties long development processes is an innovation comme il faut. This holds true when it comes to emerging technologies in general (van Merkerk and van Lente, 2005) and to emerging renewable energy technologies in particular (Jacobsson and Johnson, 2000; Venetsanos et al., 2002). An illustrative example is the development of hydrogen fuel cell cars. Work by Quadflieg (1988), Ross (2006), and Nygaard (2008) give us informed evidence of an innovation process spanning over decades and pervaded by uncertainties. The prospect to liquidate investments in fuel cell technology in any given time horizon is hence very uncertain.

Since finance is an intrinsic part of the innovation process it is to be expected that the uncertainty affecting innovation will have corresponding influence on venture capital firms propensity to invest in renewable energy technologies. The Swedish Energy Agency (SEA) reports that although Sweden has a mature venture capital market, few investments are made in renewable energy technologies, especially in the so crucial early stages of development. For example, as little as 0.5% of the Swedish venture capital is being invested in the domain
of cleantech (Energimyndigheten, 2007).² According to SEA the aversion results from lacking industry specific competence on behalf of venture capital firms. Hence, due to insufficient knowledge, renewable energy technology investments are deemed to complex and to risky (Energimyndigheten, 2006). On the basis of this reasoning, and due to the significance of venture capital to innovation activities in NTBFs and the avert behaviour of venture capital firm regarding the renewable energy industry this thesis seeks to enhance our understanding of the relation between uncertainty and venture capital investments. To achieve this end I pose the following research question:

RQ: What is the influence of uncertainty on venture capital investment in emerging renewable energy technologies?

This thesis investigates the case of Swedish venture capital firms. By answering this research question it addresses gaps in our current knowledge about the influence of uncertainty on venture capital investment in emerging renewable energy technologies.

1.1 Risk and uncertainty

There is an extensive literature on the concept of uncertainty instructively reviewed by Meijer and colleagues (2005). What becomes evident in their work is that despite (or due to) the collective effort put into a conceptualization of the concept, “there is a lack of consensus about the definition, classification and operationalization of uncertainty” (Meijer et al., 2005, p. 7). This thesis adopts its definition from Walker and colleagues (2003). Uncertainty is thus “any deviation from the unachievable ideal of completely deterministic knowledge of the

² Clean tech is defined by Clean Edge (a research and publishing firm) as a diverse range of products, services, and processes that harness renewable materials and energy sources, dramatically reduce the use of natural resources, and cut or eliminate emissions and wastes (see http://www.cleanedge.com). Hence, the concept is wide enough to include any technology with potential to enhance sustainability and regards not only technologies associated with renewable energy.
relevant systemâ€”(Walker et al., 2003). Our understanding of uncertainty in relation to emerging renewable energy technologies are only beginning to be formed. Several recent studies (Foxon et al. 2005; Jacobsson and Bergek, 2004; Meijer, et al., 2007a; b; Venetsanos et al., 2002) have offered informed insights into for example the perception and impact of uncertainty on entrepreneurs, governments and intermediary organisations. However, there is (to my knowledge) no work investigating uncertainty in relation to emerging renewable energy technologies from an investorâ€™s point of view. This thesis seeks to start pouring into this hole in our understanding.

Acknowledging the prevalence of uncertainty in innovation processes it is intriguing how poorly worked out the concept is in the corporate investment literature. Finance and strategic management scholars have studied corporate investment in great depth. Their focus on value-adding investment decisions has beaconed into the impact of uncertainty on the decision to invest and, subsequently, on the outcome of an investment. However, in much of the literature, uncertainty is dropped in favour of another concept; risk. Risk denotes any deviation from an expected result, whether plus or minus. Nonetheless, in much of the literature, risk is associated with loss rather than unexpectedly high returns (March and Shapira, 1987). For the purpose of this thesis, a non-financial definition of risk and uncertainty is adopted. The former is thus defined as the probability distribution of returns given the potential outcomes from a decision while the latter denotes future states in which we are unable to predict a distribution of returns due to lack of information (Leggio 2004, pp. 633) Hence, risk is quantifiable ex ante while uncertainty is a truly qualitative measure of the future (Knight, 1921). The concepts are interrelated and overlap and there is no universal agreement regarding the delineation between the two. There is for example no obvious mechanism that can transfer uncertainty into risk nor does one leave out the other but

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3 Typically through discounted cash flows or accounting number analysis.
4 See LeRoy and Singell (1987) for an instructive discussion.
the two may co-exist in a given scenario. Even when the probability of the occurrence of events have been envisaged through the use of risk assessment methods there is residual uncertainty as regards the future, which, per definition, is impossible to fully predict. While the concepts are closely related, there are major differences as regards the behaviour of firms when facing situations characterised by risk and uncertainty respectively. Ruhnka and Young (1991, p. 118) suggest that venture capitalist investors are attempting to identify the various potential outcomes for the new venture and to assign probabilities to those outcomes, in order to transform the uncertainties involved into an aggregate reward-to-risk estimate for that prospect. Due to expected minimum portfolio target rate of return this transformation ought to be of greatest concern to venture capital firms. Courtney, Kirkland, and Vigerie (1997) argue that managers use different analytical methods to assess different levels of uncertainty and risk. Following Courtney and colleagues (1997), Alessandri (2003) found that when uncertainty is low and risk is dominant, managers employ quantitative techniques. Conversely, when uncertainty is high, they stretch their efforts to include qualitative techniques to assess the situation at hand (typically scenario planning or real option analysis). Where uncertainty and risk co-existed, uncertainty seemed to have dominant effect upon the choice of evaluation method. Alessandri's findings suggest that methods offered by traditional risk assessment are not sufficient to deal with high levels of uncertainty (Alessandri et al., 2004).

1.2 Uncertainty in venture capital investments

Investing venture capital is a truly uncertain activity (Zacharakis and Meyer, 2000). The aggregate uncertainty stems from a range of sources. For example Manigart et al. (1997) argue that a lack of track record of the company, uncertainty regarding the degree of novelty

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5 Keeney and Punjabi (1996) and Seppä and Laamanen (2001) offer an instructive discussion on the topic of the applicability and use of conventional, quantitative valuation techniques in venture capital investment in early stage ventures.
of products, eventual markets and the limited availability of public information due to non-presence on stock markets are factors that make evaluation of new ventures a time consuming and difficult task. While uncertainty can be mapped and assessed qualitatively, its affect on the outcome of investment is hard to foresee. As goes for its financial implications they are inherently difficult to quantify ex ante (Gompers and Lerner, 2001a). For example Muzyka and colleagues (1996) found that venture capital firm managers make trade-offs regarding financial aspects and "softer" assets. They argue that venture capital firms prefer to select an opportunity that offers a good management team and reasonable financial and product-market characteristics, even if the opportunity does not meet the overall fund and deal requirements. It appears, quite logically, that without the correct management team and a reasonable idea, good financials are generally meaningless because they will never be achieved (Muzyka et al., 1996, p. 274). The quote captures the inherent uncertainty in the future liquidity prospects of any venture while instead stressing the role of qualitative aspects, such as good management. Referring to the dominance of uncertainty over risk when the two exist jointly it can be argued that uncertainty is dominant in the domain of venture capital investments and it can thus be expected that venture capital firms make extensive use of qualitative methods to evaluate new ventures. This view is supported in the venture capital literature. Venture capital firms spend extensive time and effort on the screening and evaluation of new ventures (Carter and van Auken, 1994; Kaplan and Strömberg, 2001). While methods used include quantitative techniques (to assess the risk/return ratio) there is ample evidence of widespread use of qualitative evaluation. Prior work argue that venture capital firms base their investment decision on the analysis of for example market attractiveness, product differentiation, managerial capabilities, external threat resistance, cash-out potential etc. (Tyebjee and Bruno, 1984; MacMillan et al., 1985; 1987; Fried and Hisrich, 1991; Muzyka et al., 1996; Zacharakis

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6 A subsequent contract can be structured so as to minimize loss, for example through staged capital infusion, close monitoring etc. (Sahlman, 1990; Fiet 1995)
and Meyer, 1998). Shepherd (1999), and colleagues (Shepherd et al., 2000), found that venture capital firms evaluate factors such as industry related competence, competitive rivalry, timing of entry, educational capability, lead time and the stability of key success factors. Shepherd concludes that venture capital firms consider the level of uncertainty and the ability of the management team to minimize and/or deal with changes in the external environment in their assessment of new venture survival (Shepherd, 1999, p. 629). The number of factors assessed by venture capital firms has spurred research into the very process by which venture capital firms make investment decisions. It has been argued that there is a heavy reliance on informal techniques such as heuristics or rules of thumb (Baron, 1998; Gompers et al., 1998; Khan, 1987; Zacharakis and Meyer, 2000).

This thesis was inspired by Dimov and Murray (2008): "We have some understanding of how investors accommodate risk but we remain much less informed on how they manage decisions given the very high level of uncertainty involved with new science, emerging technologies, and their innovative consequences (p. 148). This thesis seeks to explore this uncharted territory by investigating what sources of uncertainty venture capital firms perceive as regards emerging renewable energy technologies and what the influence of these uncertainties is on their attitudes towards investing in such technologies. By drawing upon several theoretical perspectives it seeks to add to our present knowledge of the relation between uncertainty and venture capital investment.

1.3 Structure of the thesis

The rest of this thesis is organized as follows. In section 2 I introduce the field of technology in focus; renewable energy technologies. I offer a definition and a short historical review before I move on to discuss the current renewable energy sector and its characteristics. In

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7 Key success factors represent the requirements for success within a particular industry. When the industry environment changes, so do the success factors, exerting pressure on ventures to update and innovate their products and their organisations.
section 3 I review relevant venture capital literature and again offer a definition. Subsection 3.1 offers a short investigation of venture capital investments in renewable energy technologies. Section 2 and 3 should be seen as a backdrop against which to read the remainder of the thesis. Section 4 with subsections provides a thorough review of the uncertainty concept in relation to renewable energy technologies. The methodology in use is discussed in section 5 while a description of the sample is offered in subsection 5.1. The results are presented and discussed in section 6. Following the presentation of the results, section 7 elaborates upon some implications of the presented results. Finally, section 8 draws some conclusions as to what has been found and what would be interesting future research inquiries.

2. Renewable energy technology

In this thesis, renewable energy is defined as "a flow of energy that is not exhausted by being used" (Sørensen, 1991a, p. 386, original italics). Hence, renewable energy technologies are means by which such flows are converted into applicable devices. The sun is the king provider of renewable energy flows. Apart from being a direct supplier through radiation the sun is also causing the wind to blow and plants to grow, and is as such a prerequisite to wave, wind, and bio energy. Other examples of sources of renewable energy include for example hydrogen and geothermal activity. Technologies to convert flows generated by these sources form a heterogeneous industry consisting of numerous sub-industries with widely differing characteristics (Johnson, 1999). Still, however diverse the set of technologies, they all serve the purpose of counteracting global warming, reducing the ecological foot print and enhancing sustainability. Due to the common denominator as regards purpose, I will treat the renewable energy technology industry as one.

8 For example photovoltaics, flat-plate, and mirrors can be used in different ways to produce electricity; passive solar heating designs can be used to cool and heat buildings.
The practise of converting renewable energy flows into power is age-old and has been undertaken in various forms (Sørensen, 1991b). Even the large scale industrial production of renewable energy has a long history. A case in point is ethanol where the first larger production unit was built in 1909 in Skutskär, Sweden.

Although history is replete with evidence of potent inventions, the share of renewable energy technologies in global energy supply matched against that of fossil fuel remains of David versus Goliath proportions. While combustible biomass composed 10% of the world's total energy supply in 2005, hydro and other renewables reached a 2.2 and 0.5% respectively (IEA, 2007). However slow the adoption process of renewable energy technologies (Jacobsson and Lauber, 2006; Kemp and Volpi, 2008), their share of the global energy supply is growing according to IEA (2007). Rising oil prices and an expected shortfall of affordable fossil fuel (Aleklett, 2006; Aleklett and Campbell, 2003) may catalyst the adoption and diffusion of renewable energy technologies. A growing demand for renewable and affordable energy will most likely generate an increase in the perception and construction of business opportunities (Cohen and Winn, 2007; Dean and McMullen, 2007). Entrepreneurial endeavours may subsequently result in the start up of new NTBFs and hence an increased demand for venture capital.

The RET industry is experiencing dramatic times. Sagar and Holdren (2002) point to a number of factors that have altered the conditions for energy sector:

- Deregulation and restructuring of energy markets in industrial countries
- Energy sector privatization in many developing countries, resulting in...
- An increase in market access for and interest by multinational corporations
- A dramatic rise in the use of and demand for natural gas
- A global wave of mergers and acquisitions.
A growing recognition of challenges facing the energy sector

The dynamic development of industries has been studied in great depth by scholars adhering to the Schumpeterian research tradition (Malerba, 2006). The evolution of industries is often described as a process moving through different stages. The course starts off in a fluid or formative phase, followed by a growth phase and finally, a mature phase (Abernathy and Utterback, 1978; Bergek et al. 2005; Klepper, 1997). The time it takes for an industry to evolve can range from just a few years to many decades (Klepper and Graddy, 1990). Entrepreneurs endeavoured into new industrial fields experience a range of difficulties stemming from the nascent state of their technologies (Aldrich and Fiol, 1994). The formative phase is characterised by the existence of entrepreneurial experimentation, a variety of competing technological designs, small markets, many entrants and uncertainty as regards technology, market, and regulations (Jacobsson and Lauber, 2006). While the RET industry in many aspects comports with the description of the formative phase it also possible to position it in the growth phase. Significant for this stage of development is the ramping up of production through for example economies of scale. According to Bergek and colleagues (2005) a prerequisite to enter the growth phase is the formation of a mass market. Further, they argue that it is normally not self-evident which applications that will generate 'mass markets' so a 'breadth in entrepreneurial experiments' must be kept up (p. 17). In this view there is no clear-cut transition as to when an industry moves from the formative phase to the growth ditto. An either-or positioning of the RET industry does not fit the analytical scope of this thesis. The heterogeneity of the industry implies great variance as to what stage its different sub-industries and their respective actors have reached. However, it is instructive to speak of the RET industry as still being in its emergent, early years, as opposed to stabile and

9 Often pictured as an S-curve.
mature. This thesis will center on investments in firms in their early stage of development. Such young firms are most likely to encounter difficulties in retrieving finance (Murray and Lott, 1995; Murray and Marriott, 1998; Locket et al., 2002; Mason and Harrison, 2004; Storey and Tether, 1996; Kortum and Lerner, 2000). Venture capital, a source of capital for young firms, is being presented in the following section.

3. Venture capital

Venture capital is a specific form of industrial finance where funds raised from outside investors are invested by corporate managers in ventures at various stages of their development. The existence of a well-working venture capital market has proved to be a lever of thriving innovative endeavours (Bygrave and Timmons, 1986; Kortum and Lerner, 2000). In this thesis, venture capital investment is defined as “an activity by which corporate investors provide long-term equity finance, supported by business skills, to unquoted companies with the potential to grow rapidly” (Mason and Harrison, 1995, p. 153). Hence, there are two fundamental aspects of venture capital investments; equity finance and non-financial aid. As regards equity finance venture capital firms typically provide money during a limited period of time. Capital is normally infused in sequences as the venture grows, in general during a period of between five and ten years (Gompers and Lerner, 2001a;b; Neher, 1999). The investment is usually liquidated through initial public offering or trade sale.

The second aspect of venture capital investment is hands-on involvement in funded ventures. Business skills are provided with the aim of improving the risk/return ratio (Gupta and Sapienza, 1992; Kaplan and Strömberg, 2000). While common in use, research results on what value (if any) non-financial assistance adds diverge (see for example Sapienza, 1992; Steier and Greenwood, 1995).
The venture capital industry is heterogeneous. Classifications are made on the basis of what stage of a venture's development firms prefer to invest in (Robinson, 1987). Early stage investors are referred to as *classic venture capital*, while later stage investments or management buy-outs are undertaken by *merchant* venture capital funds (Landström, 2007). Other demarcations regard industry preferences; hi-tech-low-tech, and geographic scope (Bygrave, 1988; Sapienza and Gupta, 1992; Sorenson and Stuart, 2001).

Venture capital investments are typically undertaken in an uncertain environment where asymmetric information (such as problems associated with moral hazard, adverse selection, and principal-agent issues (Akerlof, 1970)), is abound (Chan, 1983; Amit et al., 1990; Chan et al., 1990; Sahlman 1990; Amit et al., 1998). As a result, venture capital firms use a range of precautionary measures to mitigate the risks emanating from these circumstances (Fiet, 1995). Strategies to minimize risks are executed throughout the investment cycle, instructively described by Tyebjee and Bruno (1984) as a multistage process consisting of (1) deal origination, (2) deal screening, (3) deal evaluation, (4) deal structuring, and (5) post-investment activities. Central aspects of venture capital investments such as the sequencing of capital infusion and hands-on interest in funded ventures are strategies designed and applied when the investment contract is being structured and implemented and are perfect examples of risk and uncertainty minimizing strategies.

The Swedish venture capital industry has been thoroughly analysed by Karaömerlioglu and Jacobsson (1999). They investigated the industry with respect to size, diversity and competence. On the aspect of size, they found that the Swedish venture capital industry is growing rapidly and is among the four largest in OECD when compared to the size of population. Many new entrants and more specialization among firms led the authors to conclude that the industry is steadily becoming more diverse. Following from further specialization, it will also accumulate more sector-specific competence, which however may
take some time. Karaömerlioglu and Jacobsson ascribe the evolution of the Swedish venture capital industry to structural and institutional change. For recent numbers on the development of the industry I refer to the homepage of the Swedish Private Equity & Venture Capital Association (henceforth SVCA). In the following section I will touch upon venture capital investments in renewable energy technologies.

3.1 Venture capital investments in renewable energy technologies

Venture capital investments in emerging renewable energy technologies are an under-researched area. While our knowledge of investments in NTBFs holds high standard (see for example Murray and Lott, 1995; Murray and Marriott, 1998; Locket et al., 2002; Mason and Harrison, 2004; Storey and Tether, 1996; Kortum and Lerner, 2000), there are, to my knowledge, only two papers dealing with venture capital investments in emerging renewable energy technologies on an academic level; Moore and Wüstenhagen (2004) and Wüstenhagen and Teppo (2006). Both are exploratory in character.

Moore and Wüstenhagen (2004) argue that the increasing, albeit still rather small, interest on behalf of the venture capital community in renewable energy technologies can be traced to essentially three factors. First, the deregulation of power markets. Second, environmental pressures, and third, security needs (Moore and Wüstenhagen, 2004). They further suggest that the typical energy venture capitalist by and large follows the same investment model as other, generalist venture capital firms. They start of by examining the financial, economic, politic, and social conditions surrounding the venture, they establish objectives, allocate assets to the planned investment and subsequently, if the venture passes through the stage of detailed due diligence, they structure the contract and monitor the performance of the venture (Moore and Wüstenhagen, 2004).
There are a number of reports on the investment activities among Swedish venture capital firms. SVCA produces useful quarterly and annual reports on the subject. Renewable energy technologies, here denoted as a subcategory of the wider concept clean tech\textsuperscript{10}, are portrayed positively in these reports. A steady increase in both number and size of investments are discernable as well as positive attitudes among venture capitalists participating in the investigations on which the reports are based (see for example SVCA, 2006; 2007). However, Energimyndigheten, the Swedish Energy Agency, reports on severe uncertainties hampering venture capital investments in the renewable energy sector (Energimyndigheten 2006). A theoretical investigation of the uncertainty concept is offered in next section, where after my own empirical investigation of the influence of uncertainty on venture capital investments in renewable energy technologies follows.

4. Theoretical framework

4.1 Uncertainty and its sources: the case of renewable energy technology

Uncertainty denotes the degree to which the outcome of an event cannot be predicted. There is an ongoing debate about the conceptualization of the term, instructively reviewed by Meijer and colleagues (2005). Since there is pervasive uncertainty about what kind of definition this debate will eventually render, this thesis adopts a satisfying explanation of the concept. Uncertainty is hence œany deviation from the unachievable ideal of completely deterministic knowledge of the relevant systemō (Walker et al., 2003). Uncertainty is highly contextual and may be perceived differently depending on spatial and temporal conditions as well as on what actors are concerned (Milliken, 1987). In the following analysis venture capital firms form the actors and emerging renewable energy technologies the œsystemō about which varying degrees of knowledge can be held.

\textsuperscript{10} See footnote 2 for a definition of clean tech.
Bygrave (1988, p. 139) argues that "all industries have a degree of uncertainty. But some industries face more uncertainty than others." It has furthermore been argued that uncertainty hampers the development and diffusion of renewable energy technologies in general (Foxon et al. 2005; Jacobsson and Bergek, 2004; Kemp et al., 1998; Meijer, et al., 2007a; b; Venetsanos et al., 2002) and it has also been proposed that uncertainty in particular blocks venture capital investment in such technologies (Energimyndigheten, 2006; Jacobsson and Bergek, 2004). In the following section I will de-black box uncertainty in relation to renewable energy technologies.

A source of uncertainty is a domain of the surrounding environment which an actor is uncertain about (Milliken, 1987). All sectors differ when it comes to what parts of the environment the uncertainty is emanating from. Wüstenhagen and Teppo (2006) put forth three factors that might distinguish the energy sector from other sectors targeted by venture capital firms.

- the perceived risk (market adoption risk, exit risk, technology risk, people risk, and regulatory risk) of investment in energy technologies
- the perceived returns in energy VC investments
- in an evolutionary perspective, the maturity of energy as a VC investment sector (Wüstenhagen and Teppo, 2006, p. 63)

The above factors can be addressed by a taxonomy in which uncertainty about domains important to new renewable energy technologies are investigated. The following taxonomy relies heavily on work by Meijer and colleagues (2005; 2007a; 2007b), Teppo and Wüstenhagen (2006) and Jacobsson and Bergek (2004).
4.1.1 Technological uncertainty

Uncertainty concerning the technological prospect is abound in any innovation process and has been dealt with in an extensive literature. Typical uncertainties regard R&D costs (Mullins and Sutherland, 1998) and eventual performance. Putting uncertainties afflicting innovation processes in general aside, Teppo and Wüstenhagen argues that capital intensity and long lead times are particular uncertainties in the development of renewable energy technologies (2006). The time it takes to get a product to the market (if there is one) may be positively correlated with the complexity of the technology in question. While uncertainties in some domains may be technology-specific, other beset the entire industry of renewable energy technologies. An example of the latter is how the renewable energy technologies fit the current energy infrastructure (Meijer et al., 2007a; b).

Technological uncertainty may severely afflict the investee-investor relation due to asymmetric information problems such as moral hazard and principal-agent issues. The technology developer may withhold information regarding for example time, cost, and alternative search paths. Technological uncertainty may therefore be a prime reason to why there is a trend among venture capital firms to reject early stage deals in favour of ones in later stages (Dimov and Murray, 2006). Some authors even argue that there cannot be an efficient allocation of venture capital to NTBFs, the technological uncertainty being too high (Branscomb and Auerswald, 2002).

4.1.2 Market adoption/consumer uncertainty

One major source of uncertainty pertains to the demand and preferences of various customer groups. The deregulation of many western energy markets have resulted in fragmentation and complex segmentation. The situation is described by Teppo and Wüstenhagen (2006, p. 69): "It is still unclear who will be promising customer segments and what is the best way of
addressing them. Successful market penetration of these technologies, such as fuel cells and other technologies for small-scale combined heat and power generation (micro-CHP), depends on things like that customers must be allowed to connect them to the grid, that interconnection standards exist and that customers are able to sell excess electricity to the grid operator at attractive prices. The development of the size of energy demand and of different customer segments’ expectations regarding quality, price, appropriate distribution channels, and other characteristics of energy technologies therefore all pose uncertainties regarding the future prospects of emerging renewable energy technologies. Additional issues may have ethic dimensions, arisen in the light of the current climate concerns.

The market adoption of emerging renewable energy technologies is also affected by the present energy infrastructure, for example because of sunk investment. Further, in the case of energy technologies, thresholds in the number of sold and used applications are important determinants of the realization of advantages due to complimentarity effects (Bergek et al., 2004; Kemp et al., 1998).

As an example, Meijer and colleagues (2007b) recently reported on how concerned actors perceived uncertainties regarding the growth of a market for micro-CHP. It was found that technology developers did not think of a prospective market as a problem, seeing its development more as a matter of time. Conversely, potential adopters, government and intermediary organizations, saw the development of a market as an uncertain process. As regards venture capital investors, diverging views on market potentials may enhance difficulties in the assessment of ventures. These in turn may be augmented by problems of asymmetric information vis à vis the actors mentioned above.
4.1.3 Competitive uncertainty

Competitive uncertainty concerns the characteristics and actions of competitors and what impact they will have on the competitive position of the firm (Meijer et al., 2005; 2007b). The possibility of reaping first mover advantages suggests close monitoring of competitors. Adding the range of energy technologies with potential to serve the same or close related ends, keeping track of the entry of new firms as well as of moves made by incumbents is an important task for any renewable energy technology developer. According to industry life cycle analysis, emerging renewable energy technologies have to cope with market control by established players (Afuah and Utterback, 1978; Klepper, 1997) and ambiguous and/or opposing behaviour of such players may constitute a source of uncertainty for new entrants (Johnson, 1999). One example is the diversification of oil companies into renewable energies. A case in point is BP who recently signed a contract with Associated British Food and DuPont with the intention of growing wheat for ethanol production.

Jacobsson and Bergek (2004) highlight the positive side of competition in the renewable energy domain. They argue that firm entry/activity can create new knowledge, supply resources, develop different types of designs and stimulate market formation. However, the overall advantage of many entrants into a field is the potential of jointly working to legitimize new technology. This can be achieved for example through the mobilization of organizational power in market networks (Nygaard, 2008). A delayed or non-achieved legitimization may enhance uncertainty, scare new entrants off and guide search for business opportunities into other directions (Jacobsson and Bergek, 2004).

4.1.4 Regulatory uncertainty

It is widely recognized that the emergence of new technology is heavily influenced by the political climate and governmental regulations (van de Ven, 1999; 1993). Policies may affect
the rate, timing and substance of new technologies (Marcus, 1981). At best, governmental policies induce the development of new technologies. However, while the use of policy instruments can stimulate innovation and give rise to positive feedback loops, it may also constitute an element of uncertainty and thus act as a blocking mechanism (Bergek et al., 2004). An example of such uncertainty is how current policies may be influenced by external factors such as for example price fluctuations. Clarity and stringency in the area of jurisdiction, regulation of end markets, subsidies, and regulative power allocation may have positive effects on the development of renewable energy technologies whereas conversely, fuzziness may give rise to uncertainty and hamper the development of technologies and markets (Kemp et al., 1998). Meijer and colleagues (2007a) found that in the case of biomass gasification utilities, uncertainty about licensing procedures and emission regulations caused great concerns for technology developers as well as adopters. A second source of uncertainty was the financial policy instruments for renewable energy in general.

Whereas the workings of individual policies must be clear, there is also a need to align the entire policy apparatus to fit developing technologies and markets (Jacobsson and Bergek, 2004). Policies that remain aligned to present energy technologies (i.e. fossil fuel) may make investors reluctant to pursue alternatives. An important note here concerns the current debate on climate change, a phenomenon overtly induced by an extensive use of fossil fuel, and the subsequent need for low-impact energy sources. Increased coherence between rhetoric and actual behaviour on behalf of governments is crucial for the reduction of uncertainties pertaining to renewable energy technologies. Furthermore, Teppo and Wüstenhagen (2006, p. 73) found that venture capitalists consider future government subsidies hard to predict, and that "market liberalisation of the electricity sector has somewhat stalled in several countries, making it challenging for new entrants to compete with the former monopolists." The authors
conclude that investors usually dislike uncertainties related to regulation because they are difficult or impossible to influence (ibid.).

4.1.5 Resource uncertainty

Resource uncertainty refers to ambiguity about the availability, quality and price of for example raw material, financial or human resources (Meijer et al., 2005). As has been argued earlier, the development of renewable energy technologies is a long and capital intensive process and it is fair to expect difficulties in how to best allocate financial resources (Mullins and Sutherland, 1998). The problem is central to the investee-investor contract and can be handled for example through sequential infusions of capital. When it comes to raw material, the situation is particularly pressing for those technology developers who use resources which they have to compete over with others over. A case in point is ethanol where an ethical dilemma has arisen regarding whether to use for example corn as fuel or as food. There may therefore be a positive correlation between strong dependency on resources such as raw material and high resource uncertainty11. Further the problem of resource uncertainty may be even more complex; for example solar cell technology developers are not dependent on coveted resources for their supply of energy but may experience resource uncertainty in relation to silicon, a raw material common in such technologies.

4.1.6 Supplier uncertainty

An area related to uncertainty about resources is uncertainty related to suppliers. Doubts may be experienced regarding the actions of supplier firms, the timing of delivery, quality and price of supplies (Meijer et al., 2005). Supplier uncertainty also covers relations with partner firms. Joint ventures can for example pose problems of information asymmetry. Again, heavy

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11 A problem acutely experienced by fossil fuel producers.
reliance on partners or suppliers may be positively correlated with high levels of uncertainty. Venture capital investors may experience enhanced uncertainty if such reliance and concomitant asymmetry abounds.

5. Methodology

As stated in the introduction, this thesis aims at adding to our current knowledge of the influence of uncertainty on venture capital investment in renewable energy technology. Hence, the object of study is uncertainty and venture capital investments in emerging renewable energy technologies, whereas the relational glue linking the two is ‘influence’ As was made clear in the theoretical framework, uncertainty is a wide-spanning concept not easily captured and an analysis thereof may take off in unexpected directions. In the introductory section I discussed the conceptual difference between risk and uncertainty. It was stated that risk is specific, quantifiable ex ante and measured along known parameters whereas uncertainty is a truly qualitative measure of the future. Since this thesis wants to capture dimensions other than the pure financial ones risk was dropped in favour of uncertainty. By using the latter concept I believed that the respondents would be more liable to think outside the box of well-known risk estimation tools. Hence, ‘influence’in this regard does not denote estimations of return ratio or any other quantitative impact on investment decisions. Rather, the concept of ‘influence’constitutes in this thesis an attitudinal measure, producing results meant to be interpreted as an indicator of the venture capital industry’s attitudes towards the renewable energy technology sector. Uncertainty and how it influences venture capital firms is thus truly qualitative measures. An investigation thereof requires a correspondingly qualitative method. Interviews were chosen as the method to investigate the influence of uncertainty on renewable energy technology investments. Interviews were believed to best capture complexities in ideas about causes and effects of different types of
uncertainty. The interviews were conducted by telephone. The reason for not choosing face-to-face interviews was that many of the venture capital actors in the sample worked in places distant from where I was situated while working on this thesis. The interviews lasted for between ten up to forty minutes. The set-up was semi-structured, allowing for the interviewees to elaborate on their answers. The concept of uncertainty was introduced in the beginning of the interviews in order to steer the interviewees away from talking about conventional risks. Hints were given as to what areas of uncertainty were intended (technological, competitive, regulatory etc.). Notes were taken, compiled, and arranged immediately after the end of the interview, but no tape-recording took place. Notes were I kept a pre-arranged sheet (with categories following the presented taxonomy) ready during the interview on which I could note key words as well as longer statements. Quotes were rewritten literally. All quotes are translated from Swedish to English by me and I should therefore be held responsible for any misinterpretation of the interview subjects. Interviewing the venture capitalists in face-to-face sessions would perhaps have offered a more thorough understanding of their attitudes towards the renewable energy technology sector, allowing for more in-depth discussions and follow-up questions. It would certainly have left me with a lot more material to work with. However, due to monetary constraints, vacations (not pertaining to the author) and time available this was not possible. Another central factor in the choice of interview medium is that the interviewees are busy persons, not easy to get hold of in the first place. Considering that many of them would not have had time to meet I found telephone interview to be a fruitful way to access them at all.

The selection of venture capital firms was made from a public listing on the website of the Swedish Private Equity & Venture Capital Association (henceforth SVCA). SVCA is an organization gathering a majority of the Swedish venture capital firm population. Twenty venture capital firms were found (as of 2008-05-09) under the sector preference heading
The listing was considered to give a fair coverage of the population of venture capital firms interested in investing in renewable energy technologies. An email was sent to the twenty listed firms asking them to participate in a telephone interview. Twelve firms responded to this email. From these twelve responses followed subsequently nine interviews. Hence, three venture capital firms declined participation. All of them stated in their email responses that the sector was too risky and that they therefore did not invest in it. This while still being listed under the sector heading on the aforementioned website. As regards the non response rate, I consider it being of secondary importance as far as the scope of this thesis is concerned. The exploratory and qualitative inquiry implies that some primer conclusions can be drawn from the data at hand. A full response rate may have added further weight to those, but the omission of eleven or so interviewees' thoughts is not subverting the data that were actually collected nor the conclusions that were derived from the interpretation of them. In the section that follows I will make a few remarks on the sample of interviewed venture capital firms.

5.1 Sample

Table 1 gives an overview of the venture capital firms that participated in the interviews. The set of firms have some things in common and differ in some respects. Firm D and I are related to big parent companies. These firms are thus expected to invest in technologies that could benefit the performance of their respective parent company. While similar in prioritising investments in technology useful to the parent company, the two firms differ in scope; firm D is only concerned with energy and clean tech whereas firm I have a wider interest. Interviews with these firms centred on for them relevant technologies but some remarks were given concerning the sector at large. Firm A has specialized in renewable energy investments and does not invest in other sectors. This may make representatives from firm A more informed
about the particularities of the renewable energy technology sector. Firm A together with the aforementioned firm D are distinguished from the other by their sole interest in energy and clean tech. Firm E has a regional scope in its investment strategy and is also somewhat different as regards the ownership structure. The firm is a foundation established by a big company active in the same region. Board members and accountants are appointed by the government, making it a semi-public institution. Firm H is also regional in its investment scope and is first and foremost interested in financing seed and start-up firms. Remaining firms (B, C, F, and G) are more or less traditional venture capital firms with a wide investment scope.

I will also make a few remarks concerning differences and similarities in fund size, number of investments, employees etc. This information was collected from SVCA’s webpage and was (at the time of the preparation of this thesis) not complete. I will therefore only offer some descriptive comments based on the information at hand.

The size of the capital funds managed by the firms in the sample varies a lot. Firm B comes out strongest with 28008 M SEK while D, E and H have smaller pools of capital. Following the variation in fund size, the minimum and maximum amounts per investments also differ remarkably. Firms A, C, H, and I are prepared to invest 1 M SEK in a venture whereas firms F and G has minimum set to 20 M SEK and 15 M SEK respectively. As concerns the upper limits per investment firm B stands out with 500 M SEK compared to the majority of firms in the sample with an upper limit ranging between 10-20 M SEK. Firm E has the biggest portfolio in the sample with 327 active investments. Firm B comes out second with 59 while firm A has 3 and firm F 8. While second regarding number of current investments firm B is number one when it comes to number of employees. With a staff body of around 100 persons it is biggest by far, the rest of the firms in the sample all employ less than 20 people (with a saving clause for firm F on which no information was collected).
All firms are interested in early stage financing (start-up and to some extent also seed). Five of the firms regard start-up financing as their number one priority while four place start-up financing second to expansions ditto.
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<tr>
<td>Capital managed</td>
<td>Not available</td>
<td>28008 M SEK</td>
<td>N.a.</td>
<td>500 M SEK</td>
<td>500 M SEK</td>
<td>1000 M SEK</td>
<td>2500 M SEK</td>
<td>180 M SEK</td>
<td>825 M SEK</td>
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<td>Min per investment</td>
<td>1 M SEK</td>
<td>10 M SEK</td>
<td>1 M SEK</td>
<td>N.a.</td>
<td>0,5 M SEK</td>
<td>20 M SEK</td>
<td>15 M SEK</td>
<td>1 M SEK</td>
<td>1 M SEK</td>
</tr>
<tr>
<td>Max per investment</td>
<td>10 M SEK</td>
<td>500 M SEK</td>
<td>10 M SEK</td>
<td>N.a.</td>
<td>20 M SEK</td>
<td>80 M SEK</td>
<td>80 M SEK</td>
<td>8 M SEK</td>
<td>N.a.</td>
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<tr>
<td>Invested capital</td>
<td>20 M SEK</td>
<td>5811 M SEK</td>
<td>N.a.</td>
<td>N.a.</td>
<td>541 M SEK</td>
<td>N.a.</td>
<td>1850 M SEK</td>
<td>100 M SEK</td>
<td>265 M SEK</td>
</tr>
<tr>
<td>Current investments</td>
<td>3</td>
<td>59</td>
<td>N.a.</td>
<td>N.a.</td>
<td>327</td>
<td>8</td>
<td>43</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>Amount per investment</td>
<td>1-10 M SEK</td>
<td>10-500 M SEK</td>
<td>3 M SEK</td>
<td>N.a.</td>
<td>2-10 M SEK</td>
<td>N.a.</td>
<td>15-80 M SEK</td>
<td>5 M SEK</td>
<td>5-50 M SEK</td>
</tr>
<tr>
<td>Number of employees</td>
<td>3</td>
<td>100</td>
<td>4</td>
<td>4</td>
<td>15</td>
<td>N.a.</td>
<td>20</td>
<td>3</td>
<td>8</td>
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<tr>
<td>Prioritized financing stage</td>
<td>Start-up (1), expansion (1), seed (2), buy-out (1), replacement capital (3)</td>
<td>Start-up (1), expansion (1), buy-out (1), seed (3), replacement capital (3)</td>
<td>Start-up (1), expansion (4), replacement capital (5)</td>
<td>Expansion (1), start-up (2)</td>
<td>Expansion (1), start-up (2), Seed (3)</td>
<td>Start-up (1), expansion (1), seed (2), replacement capital (4), buyout (5)</td>
<td>Expansion (1), start-up (2), buyout (3)</td>
<td>Seed (1), start-up (2)</td>
<td>Seed (1), start-up (1), expansion (1), replacement capital (4), buyout (5)</td>
</tr>
<tr>
<td>Industry preference</td>
<td>Energy and clean tech</td>
<td>Telecommunication (hardware), internet technology, communication (other), IT (hardware, software, services), electronics, semiconductors, biotechnology, healthcare, medicine technique, pharmaceuticals, energy, clean tech, industrial automation, manufacturing</td>
<td>Telecommunication (hardware), internet technology, communication (other), IT (hardware, software, services), electronics, semiconductors, bio technology, medicine technique, energy, clean tech, industrial products and services, industrial automation, manufacturing</td>
<td>Energy and clean tech</td>
<td>Telecommunication (hardware), internet technology, communication (other), IT (hardware, software, services), electronics, semiconductors, energy, clean tech, industrial products and services, industrial automation, manufacturing, services</td>
<td>Telecommunication (hardware), internet technology, communication (other), IT (hardware, software, services), electronics, semiconductors, bio technology, medicine technique, pharmaceuticals, energy, clean tech, industrial products and services, other services</td>
<td>Telecommunication (hardware), internet technology, communication (other), IT (hardware, software, services), electronics, semiconductors, energy, clean tech, industrial products and services, other services</td>
<td>Telecommunication (hardware), internet technology, communication (other), IT (hardware, software, services), electronics, semiconductors, bio technology, healthcare, medicine technique, pharmaceuticals, energy, clean tech, industrial products and services, other services</td>
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</tbody>
</table>
6. Presentation and discussion of results

In what follows I will present and discuss the results of the interview investigation.

6.1 Technological uncertainty

A consistent pattern emerged from the data regarding technological uncertainty in the development of new renewable energy technologies. A distinction was made between early and later stage projects and the two were further ascribed different levels of uncertainty where early stage projects were recognized as more uncertain than later stage ditto. In the case of early stage projects the main sources of technological uncertainty referred to were the time consuming R&D-process. When analysing the data it was clear that there were a lot of concerns about the managerial capabilities to transfer an idea to an innovation. This was emphasized in relation to early stage projects and newly started NTBFs. One interviewee put it succinctly: the innovation risk is high in these companies. Not having a product ready is a rule rather than an exception. There is a big difference between walking the laboratory in clogs and building a firm. One interviewee voiced the belief that renewable energy technology firms where no different in this respect from firms active in other industries. However, the predominant opinion in the data was that renewable energy technology companies are particularly problem ridden during the innovation process.

In recent years, renewable energy technologies have become central to agendas in various domains (political, technological, and environmental). One interviewee expressed concern about the possibility that this hype combined with plenteous investment opportunities would sugarcoat the technological potential in the industry and entice investors to back bloated deals: when on fairs, there are everything from scientists, mature electro-mechanical firms active in other industries, high-tech firms with no idea of when they will have a ready
product to mature wind power firms ready to project big wind farms. The range is immense!

When everybody is going in, I am getting worried.

6.2 Market adoption/consumer uncertainty

The overall pattern in the data concerning market adoption/consumer uncertainty was that the adoption rate is closely related to market structures designed and controlled by state regulations. Interviewees expressed, often with resilience, that regulations hamper the adoption of various technologies. “Firms are sitting on the lap of the state,” it is an imperfect buyer, market, it is a complicated market, the superior risk is that normal market forces are not at work here are typical quotations representing opinions throughout the data. In accordance with the perceptions of Meyer and colleagues (2007b) micro CHP-entrepreneurs, the venture capitalists in the present sample did not regard the development of a market as an uncertain process as concerns customer preferences. On the contrary, it was stated that the market is experiencing strong growth in its various segments: “we do not see any risk that the market for renewable energy technologies will disappear,” “we do not see any impending risks on the customer side. Big applications are bought by the state and power producing companies and smaller ones by property owners and municipalities.” One interviewee, representing the specialized renewable energy technology firm, deviated and raised concerns about the numbers of buyers, meaning they are too few at present. Another interviewee also expressed doubts about the ability of customers to distinguish between technologies. On the whole, the data point at clear linkages between market adoption and consumer uncertainty and regulation.
6.3 Competitive uncertainty

Data was consistent when it came to awareness of the causes and consequences of competitive uncertainty. This kind of uncertainty stems from ambivalence regarding characteristics of competitors, their actions and what impact they will have on the competitive position of the firm. Being an actor in a competitive market implies more or less of constraints due to regulations. Thus, competitive uncertainty is closely related to the regulatory framework. There was consensus among the interviewees about the extraordinarity of the renewable energy technology market in this sense. Statements such as “this market is not being governed by normal market forces” and “others control the market” were common. Several interviewees expressed resignation about the possibility to get engaged in the electricity market. Monopolistic or oligopolistic tendencies in the ownership of for example distribution nets where referred to as causing high barriers to entry.

One interviewee deviated somewhat in raising concerns about the rushing of fools into an industry which in fact is age-old: “it worries me a lot when everybody is going in. This is about materials and energy; it is an old sector which suddenly has been given a “clean tech” label.” Yet another interviewee (representing the firm specialized in renewable energy technologies) repelled the latter view by welcoming more competitors into the field; “as goes for competitiveness, there are not much, this is a fast growing market. It is a sad that not more people are in there, it would speed up a transition towards a sustainable energy use.” All in all, the message given by the data on competitive uncertainty was that it is closely related to rules regulating the competitive environment.

6.4 Regulatory uncertainty

Political or regulatory uncertainty was found to be the largest source of ambiguity and hesitation regarding the prospect of investments in renewable energy technologies.
Uncertainty related to the reliability of current policy and objectives of future ditto was a central theme in the majority of the conducted interviews. Ideas about such uncertainty were expressed against the backdrop of a wait-and-see attitude colored by equal pieces of resentment and indifference. As answers related to competitive uncertainty also indicated, interviewees frequently referred to the energy sector as one not being guided by normal market forces but rather by political ones. The overriding attitude towards this was one of scepticism. It was expressed poignantly enough in one of the interviews: “sitting on the lap of the market is ok while sitting on the lap of the state is not.” Reasons given to this scepticism were minor variations on a common theme related to rules, regulations, and the long-sightedness and predictability of the policy apparatus. Quotes in point are: “politics are constantly changing,” “there is a lack of reliable aiming points among politicians,” “when it comes to politics and its influence, it can either make or break investments; what is needed is stability and long-sightedness,” “there have to be clear visions on behalf of the politicians — what do they want?” “debating the climate is trendy at present, but what happens when it fades? It is going to be a bumpy road ahead,” “no politicians can disregard renewable technology today, but there is an open sea between rhetoric and action.” Consensus prevailed in the data on how stable regulations and clear policies could facilitate investment and hence ignite a positive development in a sector somewhat unprogressive. Answers related to the potential ascribed to a stable regulatory framework can be represented by the following quote: “EU directives, rules and other regulations that simplify analytical undertakings would benefit this sector greatly.” The findings related to the ease or difficulty with which analyses can be undertaken are much in line with the conclusions of Teppo and Wüstenhagen (2006). They argue that market liberalisation in western economies has not (as of yet) provided a benign environment as regards the entry of new firms into the renewable energy sector. Rather, they find the situation to be a rather complex hank of policies and regulations.
What should the role of the state be then, if the interviewed venture capitalists could decide? Ideas pointed in somewhat different directions. There were those who strongly doubted the state to be capable of adding any value to the workings of the renewable energy sector and the energy sector in general. These interviewees expressed opinions such as: "we would like as little interference by the state as possible," "we don't believe in regulations," "about political involvement and regulations, we want as little as possible of it." Others saw the state as a useful actor capable of shouldering the role of an enabler of commercialization of new technology and the start-up of new firms: "the authorities have to be involved. With the help of potent rules and regulations they can facilitate the entry of new actors," "we need a system helping investments, private companies will never go down the innovation path if there is no profit within reach," "there has to be a public system pointing out the direction as concerns what areas are worth investing in and there has to be money on behalf of this system to invest where commercial forces fail." Interesting enough, only one firm representative was of the opinion that venture capitalists themselves should try to impact policies, rules and regulations. I.e. *not* resting passively on the lap of the state but shaping the seat. This particular interviewee was explicit about the need for a lobby organization to speak on behalf of the venture capital industry. However, it was made clear that the venture capital firm in question was not itself involved in any such activities. The interviewee did not develop the idea further and one can clearly see difficulties in such an endeavour due to the heterogeneity as regards the venture capital industry (size, portfolio characteristics and particular preferences etc.). The remaining eight interviewees did not mention any ideas about how to influence the lap on which they rest. However, for the record, they were not asked to do so.
6.5 Resource uncertainty

The data was somewhat ambiguous regarding resource uncertainty. A scan minority (four) of the interviewed venture capitalists considered the supply of raw material to be subject to special uncertainty. None of them had experienced any difficulties in this respect but expressed doubts about the reliability of access to cheap and abundant production inputs. Three interviewees mentioned ethical aspects and controversies regarding the supplanting of for example production of corn for bio fuel at the expense of food production. One interviewee (representing the firm specialized in renewable energy technologies) was explicit about the unwillingness to invest in technologies that consume finite resources or resources with equivocal impact on the environment. Hence, the company in case invested in solar technologies but was hesitant about thin film technology (heavy metals are required to manufacture thin film). The inconsistencies in the data about resource uncertainty should not give rise to too far reaching conclusions. The default may be due to greater concerns with other types of uncertainties.

6.6 Supplier uncertainty

There was no evidence of any supplier uncertainty based on the collected data. If any conclusion is to be drawn from this it would be that supplier uncertainty is no bigger in the renewable energy industry than in other industries.

Put together these results render some implications for our knowledge about the role of uncertainty in relation to venture capital investments in renewable energy technologies. In what follows I will discuss the results, conclude this thesis and give some pointers as to what could be future inquiries into the subject.
7. Implications of results

The findings presented in this thesis show the attitudinal significance of uncertainty related to investments in renewable energy technologies on behalf of actors in the venture capital firm population. The sector specific uncertainties earlier presented in taxonomy guided the understanding of the answers given by the interviewees. With an exception for supplier uncertainty, the different forms of uncertainty occupied all venture capital firm representatives in the sample to various extents. This was not surprising. As argued in the theoretical framework the venture capital investor-investee relation is generally fraught with elements of uncertainty due to for example asymmetric information. Further, as regards the renewable energy technology industry, there are additional uncertainties enhancing investment complexity.

Indeed, uncertainty is a natural as well as inevitable ingredient in equity investing. However, it is highly important not to settle with uncertainty as being something ipso facto and ever present but to keep track of different kinds of uncertainties and not bunch them together arbitrarily. The theoretical framework and the presentation of the results made it possible to separate between for example competitive and political uncertainty. Uncertainties may differ in cause, effect as well as in potential remedies. Nonetheless, various forms of uncertainty may be deeply intertwined, have common origins and may be thwarted using the same means.

One of the main messages coming from the data was that the uncertainties pertaining to the renewable energy technology industry are of such kind that the venture capital firms themselves are not able to control or influence them to any greater extent. Except for technological uncertainty, it was argued that actors with keys to tap or close off sources of uncertainty were others than those involved in the contractual arrangement; i.e. politicians and others with power to steer the shaping and workings of laws and regulations. Since political
and regulatory uncertainty were held as very important these findings suggest that we look in
directions other than at the investor-investee relationship in isolation in order to understand
what influences venture capital investments in renewable energy technologies. The financing
of innovative start-ups and early stage ventures and the uncertainties pertaining to such
endeavours must be seen in a wider context. For example, institutional aspects and social
settings must be investigated. An unfolding of the cover and blankets (de-black boxing) in
which such investments are embedded may give rise to new knowledge about venture capital
investments in general and in particular about renewable energy technology investments.

As regards a broader take on venture capital investments, several studies have been
executed in order to elicit how institutional particularities affect such investments. However,
to my knowledge, these studies have mostly been comparative in kind (see for example
Zacharakis et al., 2007; Wright et al., 2004) and undertaken on a rather abstract level. What I
will argue is that the findings presented in this thesis suggest that we take an actor centred
grab on the relation between venture capital investments and renewable energy technology. I
will further argue that the results presented in this thesis suggest that there is a need for a new
lens through which to view venture capital investment in renewable energy technology. One
that allows us to see the interrelations between various kinds of uncertainties and the role of
multiple actors, not only the role of the investor and the investee.

The discussion is organized as follows. First, a short passage in which I comment on the use
of an investigation based on qualitative estimations. Second and last, a system analysis in
which I argue for the potential in using such a perspective on venture capital investments in
renewable energy technology.
7.1 Investigating qualitative judgement

Investing in nascent ventures is an uncertain undertaking and sources of uncertainty may not be possible to influence by the investor or the investee alone. However, when discussing the influence of uncertainty on venture capital investments it is important to again emphasize (see introduction) the need to distinguish between uncertainty and risk. In the beginning of this thesis uncertainty was referred to as "future states in which we are unable to predict a distribution of returns due to lack of information" (Leggio 2004, p. 633), while risk was described as the "probability distribution of returns given the potential outcomes from a decision" (ibid.). Uncertainty was labelled a qualitative factor while risk was denoted quantitative. It was suggested that managers use different analytical methods to assess different levels of uncertainty. Studies were referred to showing that when uncertainty is high managers stretch their analytical efforts to include qualitative techniques to assess new ventures or arisen situation (Alessandri, 2003). Traditionally, venture capital research has dealt with quantitative strategies to minimize risk, for example co-investing, staging of investments etc. Such measures, i.e. risk-reduction strategies have been investigated in great depth by for example Fiet (1995) and Shepherd with colleagues (2000). As much as risk and uncertainty exist side by side, both quantitative and qualitative measures are important to scrutinize. However, since uncertainty’s influence on venture capital investment is under-researched it may be fruitful for both the research and the practitioner community to dwell upon that topic.

Before starting to discuss the results obtained from the interviews it is important to make a distinction between attitudes towards investments and actual investments. Following the process whereby venture capital firms make their investment decisions (Tyebjee and Bruno, 1984), an initial screening of a deal may contain an analysis of both qualitative and quantitative factors. However, it is, due to time constraints likely that an initial screening will
consist of mostly qualitative analysis while the share of quantitative analysis will increase further down the line, closer to the signing of an actual investment contract. Initial screenings may be guided by heuristics (Zacharakis and Meyer, 2000) and such an analysis may therefore not be as thoroughly elaborate as one conducted later on in the investment process. In some cases, decisions based on heuristics lead to a ‘herding’ phenomenon (Gompers et al. 1998). In such cases venture capital firms invest in the sectors which are most popular among other equity investors. This is what ultimately happened during the dot.com boom and bust (Valliere and Peterson, 2004). However, heuristics is not bad per definition as concerns the outcome of a decision (i.e. eventual venture success or failure) (Baron, 1998). Since the investigation presented in this thesis asked venture capital firms to discuss their attitudes to the renewable energy sector in general and not particular or potential deals, it may further be expected that they applied qualitative rules of thumb; heuristics during the interviews. This assumption does not imply that the results are skewed in terms of reliability, but that they can be expected to be supplemented by quantitative measures later on in the investment decision process.

High levels of uncertainty may result in the dismissal of renewable energy technology as an attractive sector to invest in. It is therefore important to consider and discuss strategies to reduce the influence of uncertainty on the attitudes of venture capital firms. Such a discussion follows in the next section.

7.2 Innovation system analysis

Uncertainty and control are something of antagonists. Uncertainty implies a lack of control over important variables affecting performance. A central theme in the data was that the control over the renewable energy sector were believed to be in the hands of others than the
venture capital firms and maybe more important; in hands other than those of the technology developers. Firms were believed to have little impact on the market on which they are active. This was considered as a problem. Uncertainty related to the success of a venture was thus in part ascribed to other actors.

A handy way to involve multiple actors in an analysis of the development of new technology and ditto new firms is to use tools from the innovation system theory framework. The justification for such an analysis is that an innovation process is both an individual and a collective act. Jacobsson and Bergek (2004, p. 817) argue that "the determinants of this process are not only found within individual firms; firms are embedded in innovation systems that guide, aid and constrain the individual actors within them." Treating venture capital investors (and renewable energy technology developers) as actors in a larger system may help us to understand what affects their attitudes towards the industry in point. It allows us to look at the behaviour of other actors in the system and subsequently at the causality interlinking such behaviour with investments in renewable energy technology.

There are several different innovation system approaches. For the purpose of this thesis; to investigate how uncertainty influences investments in a certain technology, I find the technology specific innovation system approach to be best suited. A technological system is defined as "network(s) of agents interacting in a specific technology area under a particular institutional infrastructure for the purpose of generating, diffusing, and utilizing technology." (Carlsson and Stankiewicz, 1991, p. 21). A technological system contains many dimensions and various elements. Bergek and Jacobson separate between three main ones:

- *actors* (and their competences), for example firms, users, suppliers, politicians, non-commercial organizations, and investors
• *networks* of actors; acting as transfers of knowledge and may be used to influence both market and institutional set-up

• *institutions* stipulates norms and regulations, heavily influential on how actors interact (Edquist and Johnson, 1997)

The performance of a technological system can be measured by looking at how well a range of functions are being served. System functions are being served by actors, individually and through networks under institutional auspice. A technological system is functional when it (following Johnson, 1998):

• creates and diffuses *new* knowledge

• guides search for new knowledge

• supplies resources

• creates positive externalities

• forms markets

Uncertainty may arise when actors fail to fulfil any of these functions. If the creation of new knowledge comes to a halt, perhaps due to a lack of guidance in which direction to search, uncertainty will be abound regarding the future development of technology and therefore hamper investments in the sector in point. In fact, all of the above functions are intertwined and changes in one of them may lead to subsequent changes in others (Bergek and Jacobsson, 2004). When the venture capitalists in the sample refer to political uncertainty or technological uncertainty it must be understood as a system’s failure due to the unfulfillement of functions by actors such as for example customers, policy makers and intermediary organisations. Under-achievement on behalf of any actor in the system may trigger a vicious
circle (for example if investors fail to provide sufficient resources, or if the regulatory framework is conservative and retrogressive, the creation and diffusion of new knowledge (for example new technology) may come to a halt and markets may stagnate in their infancy. On the other hand, actors fulfilment of functions may give rise to a positive development in which cumulative causation creates a virtuous circle. Hence, actors and their actions are deeply intertwined. With this interconnectedness in mind, it is easy to see both reasons for the experienced powerlessness and feeling of lapsitting on behalf of the venture capital firms but also potential to jointly initiate a positive development involving more actors in the system.

Venture capital investors are ultimately interested in building new, successful organisations. But, as was argued in the interviews such an endeavour is fraught with uncertainty. Further, uncertainty has been ascribed to actors others than those involved in the contractual arrangement between an investor and an investee. An innovation system style network approach to venture capital investment would look beyond any single investment in emphasiz[ing] the threads of continuity linking actions across a field of action that includes individuals, organizations, and environments as a totality (Dubini and Aldrich, 1991, p. 306). The basic idea in all network theory is that economic actions must be analysed in terms of an expression of social relations. Concerning the building of new firms, there is a large literature in entrepreneurship research on the importance of networking with various actors. For example Stuart and colleagues (1999) mean that building a new company is a social process...entrepreneurs must access financial and social capital and other types of resources via business relationships with parties outside of the boundaries of their organizations (p. 315). The importance of ties to a diverse set of actors has indeed been investigated (see for example Auha (2000)). However, while entrepreneurship research recognizes extended networks as central to entrepreneurial success, in venture capital research, attention has nearly
exclusively been directed to internal networks between venture capital firms and other equity investors or service providers (such as for example patent lawyers). Syndicated investments are a way to spread risk and to draw on each others’ resources in order to best benefit the venture in case. Syndication networks facilitate the sharing of information and contacts and may be seen as formal or informal reciprocal relations (Bygrave, 1988). The access to other firms’ resources may, as Stuart and Sorenson (2001) argue, make syndication networking an efficient way to expand the spatial and sectoral boundaries of investment for any venture capital firm. What is more, as argued by Hochberg and colleagues (2007), well-networked venture capital firms and their portfolio companies enjoy better performance. However, in this thesis, we are interested not in factors affecting a particular deal (i.e. not in risk and related risk-reduction strategies), but factors influencing attitudes towards investing in any firm in a particular sector; namely that of renewable energy technology. I argue that by networking not only with co-investors and service providers, venture capital firms can contribute to a reduction of the uncertainty besetting the renewables sector. By interacting and networking with actors throughout the innovation system (as referred to above) venture capital firms could contribute to a legitimization of the renewable energy technology sector. Jacobsson and Bergek have touched upon the subject of the possibility to form advocacy coalitions to support the forming of a stronger renewable energy technology market (Jacobsson and Bergek, 2004). However, in their analysis, financiers are not in focus. In my opinion it is highly important to involve investors in the forming of networks and/or advocacy coalitions because without sufficient financial resources, there will be no new start-ups, no firm growth, and thus no enlargement of the sector. Actors with an interest in boosting the renewables sector ought to be concerned with getting a proper relational mix in any network together to work for such a boost. Lechner and colleagues (2006) emphasize (again in relation to firm development and entrepreneurs) the importance of maintaining several different relations in
ditto different networks. They suggest that networking should be a proactive task of entrepreneurs and that strategic network building over time is an important factor for the development of the entrepreneurial firm. Supposedly, this also goes for those who help firms to develop; i.e. venture capital firms. With all the different forms of uncertainty related to the development of renewable energy technologies in mind, networking ought to be central to all actors in the sector, not only investors and entrepreneurial firms. Further, as there was such a strong consensus among the interviewees on the lack of control over the market on behalf of themselves and their investees, both investors and firms should be aware of the potential benefits in networking with actors who are controlling rules and regulations. As goes for politicians aiming at a sustainable society this should be of no less concern.

8. Conclusion and summary

This thesis has explored the influence of uncertainty on venture capital investments in renewable energy technologies. It was argued in the introductory section that too much uncertainty may hamper investments in such technologies and subsequently delay a mitigation of global warming. It was thus considered important to understand what kind of uncertainty influences venture capital firms in their evaluation of new ventures. This based on the centrality and importance of these firms' willingness to invest in renewable energy technologies, given the equity need of NTBFs. In this light I posed the following research question:

What is the influence of uncertainty on venture capital investment in emerging renewable energy technologies?
An empirical investigation was conducted through which nine Swedish venture capital firm representatives were asked to discuss different kinds of uncertainties. What was learnt from the data, and what is offered as an answer to the research question, was that regulatory uncertainty, technological uncertainty, competitive uncertainty, and market adoption/consumer uncertainty were all important influences. Regulatory uncertainty was considered the backdrop of the other sources of uncertainty. Based on the results, I discussed the importance of putting the investor-investee relation in a wider context. An innovation system analysis was offered in order to include multiple actors, for example policy makers and intermediary organizations.
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