

2 Emergence of Cleantech as an Investment Category – Media Attention and Venture Capital Investment

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Abstract:

This paper investigates the emergence of the category “clean technology investing” in the field of venture capital (VC). Building on industry evolution and life-cycle literature it extends the understanding of drivers for VC growth. It takes industry and public policy forces into account. The case of cleantech investing is examined using a multitude of datasets and methods including a quantitative and qualitative content analysis. A software-based analysis of press publications combined with investment data shows clean technology media and investment emergence patterns. These patterns follow evolutionary life-cycle patterns. The paper conjectures on factors that influence observed patterns in each stage.

2.1 Introduction

Sustainability and cleantech are commonplace words today relative to two decades ago. Renewable energy, energy efficiency and alternative transportation technologies which are part of the cleantech vernacular originate from inventions from the 1980s and 1990s and were developed to become household knowledge and important business sectors (Pernick & Wilder, 2007). The term cleantech was created by the investment community and is widely regarded as a major investment category or even asset class (Caprotti, 2012; O'Rourke, 2009; Pernick & Wilder, 2007). The cleantech industry encompasses companies that focus on green and sustainable technologies with product, process or service offerings decreasing the amount of greenhouse gas emissions. Newly introduced technologies such as cleantech require significant work to establish their positioning within society. This development is carried heavily by small, innovative, and entrepreneurial ventures (Hockerts & Wüstenhagen, 2010a), which commonly lack the resources that are needed for rapid growth. Venture capitalists have developed a strong reputation for funding promising technology companies. For this reason, entrepreneurial firms are commonly financed by venture capitalists (VCs) who provide the requisite capital. VCs provide funding that is not generally available through traditional financial institutions, and have been found to be one of the major drivers of innovation and technology commercialization (Da Rin et al., 2011; Samila & Sorenson, 2010a). They are especially important during early

stages of an industry. For example, von Burg and Kenney (2000) describes the emergence of the local area network (LAN) industry and the support provided through VC. According to their work, not only did the VCs supply capital for the companies but also assisted in strategic planning and were influential over the adoption of a dominant design. Dodgson et al. (2008) similarly highlighted the role and importance of VC in the evolution of the national as well as sectoral innovation system (NIS/SIS) in Taiwan's biotech industry. Despite these studies, there is limited research that shows how new technology classes are financed over time by the VC community.

This article explores the evolution of the cleantech category for venture capital investment from early industry emergence to a decline in investment. While cleantech as a new industry and its corresponding investment category has been reviewed in recent research, a comprehensive analysis of the category's investment evolution has not been done (Randjelovic et al., 2003; Ghosh & Nanda, 2010; Kenney, 2011b; Marcus et al., 2013; Cumming, Henriques, & Sadorsky, 2013). This paper seeks to explain when an investment category within venture capital emerges and the factors associated with its evolution. It leverages longitudinal data including press articles mentioning "venture capital" from Lexis Nexis to analyze the emergence of the cleantech VC category (Da Rin, Hellmann, and Puri 2011; Wright, Pruthi, and Lockett 2005). These articles are analyzed alongside investment data from Thomson One Banker to identify key milestones of investment class emergence and to understand how investment patterns align with or deviate with media attention given to emerging technology classes. Cleantech terminology within media data is used to identify investment stages and the technologies, that dominated the stages of industry development (Hoffman, 1999; Kennedy, 2005; Navis & Glynn, 2010).

By analyzing the historical emergence of the cleantech VC category, this paper shows patterns relevant for emerging investments within the VC industry. Moreover, there is a gap in academic literature showing historical patterns of VC investments (Da Rin, Hellmann, and Puri 2011; Wright, Pruthi, and Lockett 2005). This study adds to the different streams of literature and addresses calls for further research by (1) Gompers and Lerner (2001) who asked for additional research on the interlink between the growth of the VC industry and the respective funded high-tech companies; (2) Wüstenhagen and Teppo (Wüstenhagen & Teppo, 2006) who requested more work on the emergence of market sectors within VC especially with a focus on cleantech; and (3) Avnimelech et al. (2004) who see opportunities to transfer their life cycle model to different areas of application.

The main research question of this paper is:

How does an investment category within venture capital emerge?

The paper proceeds as follows. It begins with a theoretical background on venture capital evolution and life cycle. It then describes the data and research methods used, followed by results of the analysis from the media database matched with the investment data. It concludes with a discussion on the emergence and evolution of the cleantech venture capital category, the paper's limitations and several suggestions for future research.

2.2 Theory

2.2.1 Venture Capital Evolution

VCs play essential roles in funding the commercialization of new technologies. Thus, the emergence of a VC investment category is important for technological innovation and business formation (Florida & Kenney, 1988a, 1988b; Lerner, 2002; Oakey, 2003; Samila & Sorenson, 2010a; Timmons & Bygrave, 1986). Despite this importance, there has been “little research ...[on] the industrial organization of the VC industry and its evolution over time.” (Da Rin et al., 2011, p. 100). The creation of markets is typically described as an evolutionary development in a systemic environment (Hekkert et al., 2007; Nelson & Winter, 1982). Karaomerlioglu and Jacobsson (2000, p. 77) argue that “a VC industry evolves as a function of the institutional set-up in the economy”.

In national contexts, government policy influences evolutionary development of VC investment classes and the overall VC industry (Lerner, 2009; S. White, Gao, & Zhang, 2005). White et al. (2005) confirms the importance of governments creating a macroeconomic environment that supports a national venture capital industry. A VC industry also requires a sufficiently active entrepreneurial community for investments as well as open capital markets for exiting investments (Da Rin, Nicodano, & Sembenelli, 2006a; Jeng & Wells, 2000; Kenney, 2011a).

In contrast to the institutionalized VC markets in the USA, Israel and Taiwan, research on VC market growth in the German, European, Hong Kong, and Swedish VC markets (Becker & Hellmann, 2003; Bottazzi & Da Rin, 2002; Chu & Hisrich, 2001; Karaomerlioglu & Jacobsson, 2000) and Asian markets (Dossani & Kenney, 2002; Kenney, Han, & Tanaka, 2004) shows that internal and external forces drive the VC market evolution. Industry level research has examined several aspects of general VC historic development or its development in certain countries and regions. It reveals

cyclicality in the investment process, the level of funding, as well as the returns on subsequent investments (Bygrave, Fast, Khoylian, Vincent, & William, 1989; Gompers & Lerner, 2001). For example, Murray (1995) concludes that by the mid of the 1990s the VC industry as a whole had reached a maturity stage as described in Porter's (1980) model of industry maturity. To ensure a future path for the industry, investments into new industries or categories is necessary (Badino, Hu, & Hung, 2006). For this reason, VC investments follow a life-cycle process, where investments begin, grow and decline over time.

2.2.2 Venture Capital Life Cycle

Kenney (2011a) compares the development of VC to the emergence of an organizational ecology. Thus, the growth of VC as an institution can be compared to an evolutionary process and the analysis of its creation requires a systemic perspective. Building on emergence and industry formation literature (e.g. Abernathy & Utterback, 1978; Klepper, 1996, 1997; Franco Malerba & Orsenigo, 1996) Avnimelech, Kenney, and Teubal (2004) suggest that high-tech industries in the USA and Israel co-evolve with adjoining VC-markets. The authors build a life cycle model reflecting the emergence and evolution of these VC industries and describe it "as a cumulative, self-reinforcing process with a distinctive profile of emergence" (Avnimelech & Teubal, 2006, p. 1494). Moreover, Avnimelech et al. (2004) observed that the evolutionary processes were different. While the US VC emergence was market led, the Israeli VC emergence was policy driven. Lerner (2002) who believes external forces drive the cyclicality of VC markets urges policymakers to accelerate the cycles within the VC market by supporting trending technology classes in order to limit overinvestment in peak periods of the VC market which he calls overshooting. Overshooting makes investments inefficient and leads to disappointing returns and a countering effect of underinvestment in subsequent periods. However, due to the limited longitudinal research on the VC industry, the market indicators that determine when overshooting occurs is not well known. As Dodgson et al. (2008) suggest about research opportunities on evolution within innovation systems and the key constituents therein, there is an opportunity to explore innovation investment systems and forces within venture capital. The innovation system that is explored below is that of clean technology.

2.2.3 Cleantech Venture Capital

The cleantech investment category broadly includes investments in companies mitigating and adapting to climate change and encompasses several industry sectors. Research on venture capital in the cleantech space or some of its niches is rare. Prior research on the category depicts the characteristics and advantages but also challenges associated with cleantech and the VC industry. The following section overviews the scholarly work that involves the category and which played a significant role in shaping the discourse on cleantech investments.

Early work on VC and clean technologies opens the field by considering why so little capital had been invested in the sector and foresees a difficult future for the category (Diefendorf, 2000). Randjelovic, O'Rourke, and Orsato (2003) firstly mention the emergence of the cleantech category previously referred to as "environment-related VC" or "green VC". They define the investment category and show characteristics, processes and mechanisms as well as drivers and barriers in the field. They predicted that the category - then mostly supported through the idea of socially responsible investments (SRI) and an added ecological orientation - would become more mainstream in the future. "Continuing affirmation of the existence and importance of the sector has resulted in the acceptance of, and support for, the sector by established multinationals as well as governments." (Caprotti, 2012, p. 382). However, early levels of support, related technologies experience difficulties obtaining financing in this category due to policy preferences of investors in this field.

Wüstenhagen and Teppo (2006) revisit the emergence of the cleantech sector and looked at the perceived risk and expected return characteristics while also clarifying the path dependencies occurring within VC developments. They specifically call for research addressing "how new market sectors for VC investment emerge" (Wüstenhagen & Teppo, 2006, p. 81). O'Rourke (2009) examines the first decade (from 1995 to 2006) of the emergence of cleantech as an investment category. She describes the institutional processes of the emergence and creates a classification system for the category. Furthermore, she examines the investors which are active in the field and looks at their strategies. Caprotti (2012) analyses the development of the cleantech sector from a geographers standpoint over the period from 2000 to 2010. His work describes the sector through discursive logics as a socio-technical sector defined by a networks of actors. Three topics are core to the discourse: cleantech as a response to climate change, as a market opportunity and as a technological revolution.

Cleantech as a response to climate change. The social and ecological need for investments in renewable energies and clean technologies is stressed in a report for the

International Conference for Renewable Energies 2004. It emphasizes the role of VC to supply risk capital but foresees limited return possibilities in the highly risky sector (Sonntag-O'Brien & Usher, 2004).

Cleantech as a market opportunity. The few exit opportunities make it hard for investors to justify significant investments in risky clean energy technologies. Characteristics of path dependency are detected within the cleantech VC sector influencing investments in renewable energy and energy efficiency companies according to prevailing initial conditions (Marcus, Ellis, Malen, Drori, & Sened, 2011). A further work looks at the potential and limitations of VC for the clean energy sector. The authors analyze trends and draw the path to legitimization of the category. They raise several research questions for future scholars to pursue, one of them to research along the historical evolution of the category in a multisectoral way (Marcus et al., 2013). Bürer (2008) adds a policy angle on investment decisions and risk management practices within the clean energy private equity and VC sector. She explains the supportive nature of market-pull policies in favor of technology-push options and emphasizes the general importance of government actions to create market opportunity within this investment category.

Cleantech as a technological revolution. Ghosh and Nanda (2010) research on the role of VC for the commercialization of clean energy technologies. They focus on the problem of innovations associated with too much technology risk and at the same time requiring too much funding until maturity. Cleantech ventures are hard to fund and face the so called "Valley of Death". Establishing commercial viability for innovations already vetted and tested is difficult.

Kenney (2011b) is one sceptic concerning VC within the cleantech sector due to the lack of fit between traditional VC investment criteria and the characteristics of cleantech innovations. He suggests that in its current state, investments in cleantech would produce an unsustainable bubble. In contrast he advocates for investments in clean technologies that are more closely adapted to the traditional VC model and typical investment industries. For example, he suggests that investments in energy and efficiency software as well as smaller scale efficiency equipment are potential innovation paths. Another work that examines the fit of cleantech and VC considers the regulatory support mechanisms for the cleantech industry and criticizes the missing boundary conditions for a VC financed transformation through cleantech. Clean technology and in particular energy markets are generally large, however, they are not growing rapidly in most developed markets. The scalability of the highly capital intensive cleantech innovations due to production plants or material based processes is limited in comparison to many of the software based or biotech business models. Some

exceptions might be technologies at the intersection between energy and the information technologies (Hargadon & Kenney, 2012). Otherwise, these conditions make it hard to find evidence for large and rapid value creation in cleantech markets. Therefore, in order to understand how new investment categories emerge, it is necessary to examine investment patterns in light of policy and market forces that hold the potential to influence investment decisions.

2.3 Research methodology & data

2.3.1 Data

This paper combines methodological approaches and datasets to provide a comprehensive picture of the historical emergence of VC investment in an emerging technology class. At the core is a database consisting of press publications from several major international newspapers which were compiled from January 1st 1995 to December 31st 2011. All articles from the selected newspapers during that time frame that mentioned the term “Venture Capital” were downloaded. The source of this data is Lexis Nexis which compiles international press. Within Lexis-Nexis, we chose the subset of “Major World Newspapers”, which comprises 79 international newspapers in English language. This selection of articles makes it possible to analyze the development of the VC industry on a global level. In total there are 84,259 articles mentioning “Venture Capital” in the whole data set. The 17 years, which are observed, are divided into 68 quarters for the analysis. The lowest number of articles per quarter was published in the first quarter of 1995 with only 491 articles including “Venture Capital” appearing in major newspapers. The highest number of articles appeared in the second quarter of 2000 at 3097 articles.

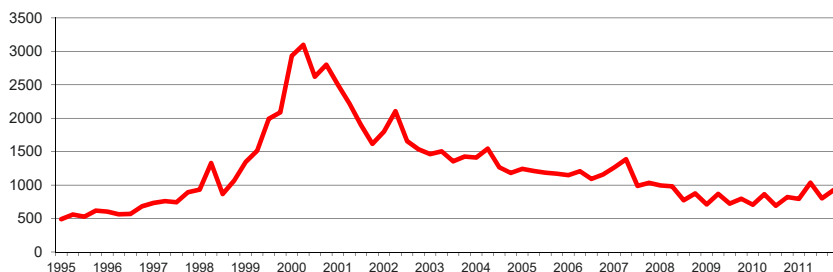


Figure 2 – Historical development of articles containing the term “Venture Capital”

The data resulting from the analysis of the media discourse is matched with investment data from the Thomson One Banker database of private equity investments. The investment data used is from the years 1995 until 2013. These data on total and subsector VC investments are from all global VC markets and include all investments from seed to late stage investments. Additionally, a comprehensive search for resources on the cleantech industry, (e.g. reports, policy papers and web media) was undertaken. These data have been thoroughly analyzed and used to confirm the findings of the other streams of research.

2.3.2 Method

This paper uses a quantitative content analysis of press articles to analyze and describe the case of the historical emergence and evolution of the cleantech investment category. Similar methods have found increasing prominence in organizational research recently (e.g. Phillips, Lawrence, & Hardy, 2004; Ventresca & Mohr, 2002; Wuthnow, 1989). For example, research on the historic shifting composition of actors and frames in corporate environmentalism (Hoffman, 1999) and the construction of market categories in the computer workstation market (Kennedy, 2005). McGrath (1998) used media patterns to analyze technology s-curves and technology cycles within the electric vehicle battery industry. Furthermore, the evolution of the U.S. satellite radio was researched over sixteen years based on a multitude of data sources including a large sample of newspaper articles. Within the textual documents changing thematic frames explained the differentiation in three different phases – emergence, commercialization, and early growth (Navis & Glynn, 2010). A further category emergence paper looks at the market for modern Indian art. A discourse analysis of diverse textual documents including newspaper articles shows the growing legitimization of the market category through a shared rhetoric (Khaire & Wadhvani, 2010).

The advantages of computer aided content analysis are in the depth of the assessment of a broad sample of textual documents (e.g. newspaper articles, excerpts). Additionally supporting is the independence from databases, which, especially in the field of VC investments, usually present a restricting factor in regard to data quality and availability. Resulting, quantitative content analysis enables a more detailed industry analysis than the assessment of classical venture databases (Berelson, 1952; Elo & Kyngäs, 2007; R. P. Weber, 1990). WordStat 6.0 by Provalis Research is a content analysis and text mining software for unstructured textual documents. It is used to analyze the created database based on a predefined dictionary, which is a

collection of words, structured in several different subgroups. The software counts the words according to the structure defined in the dictionary (Krippendorff, 2012; Neuendorf, 2002).

As a foundation for structuring the cleantech sector dictionary, the taxonomy developed by the Cleantech Group² was used. The Cleantech Group is one of the leading market intelligence companies in the field of clean technologies and is widely seen as influential over the establishment of the term “cleantech”. The Cleantech Group’s definition of the sector spans 13 categories encompassing several different industries and technologies. We built the dictionary according to these categories, and introduced two additional overview categories to observe general word groups related to “cleantech” and “ecology”. These 15 different categories were applied to the quarterly structured articles from the 17 years from 1995 to 2011. The analyses permit us to give attention to included themes and technologies throughout the research period. Below, the relative importance of the cleantech category in entirety is contrasted to all VC mentioned. Specific sub-categories are reported in comparison to the cleantech category.

A description of the early years of the cleantech industry is found in O’Rourke (2009). Her analysis shows the important linkage of cleantech to the VC sector and defines it as a venture category. The analysis reports that 74% percent of all articles mentioning “cleantech” include mention of “venture capital”. The analysis used in our study differs from O’Rourke (2009) - by looking at all articles mentioning “venture capital” and the terms associated with cleantech. “Greentech [Cleantech] VC investing has received little attention in the scholarly press, but enormous attention in the popular press” (Kenney, 2011b, p. 218). This paper modifies Venture Capital Life Cycle Model so far only used in a national context (Avnimelech et al., 2004; Avnimelech & Teubal, 2006).

To understand the detailed analysis of investment data this paper builds on the quantitative content analysis of a dataset of 84,259 articles reporting on “venture capital”. Applying the assembled cleantech dictionary allows for fine-grained analysis of trending categories and themes at certain points in time. In order to investigate emergence it is necessary to have data predating emergence; for investment categories this implies the need to cover a time not observed by traditional financial databases or added to them post hoc (Woolley, 2011).

2 <http://www.cleantech.com/>

2.4 Results and discussion

2.4.1 The cleantech venture capital life cycle

The VC industry has experienced several booms and busts throughout its history. This pattern is of the form and character of a classical business cycle. The cycle whereby a new industry emerges with successful startups and good returns for VC funds to an industry with more funds being raised and bigger volumes leading to high competition for investments and high valuations and finally to the burst of the VC bubble. Despite its re-occurrence, industry and as well academia are often surprised each time the bubble bursts (Block & Sandner, 2009; Lerner, 2002; Mason, 2009). This pattern has appeared with changing amplitude in several countries, industries and investment stages (Lerner, 2002). The cyclicity and high volatility of the general VC market as well as the cleantech VC market can be observed in Figure 3. The Dotcom boom and crash of the late 1990s and early 2000s was an exceptionally high peak. The total VC market grew from \$ 2.3 billion in the first quarter of 1995 to a peak of \$ 43.7 billion in the second quarter 2000 just to drop to \$ 9.1 billion less than three years later (Q1/2003).

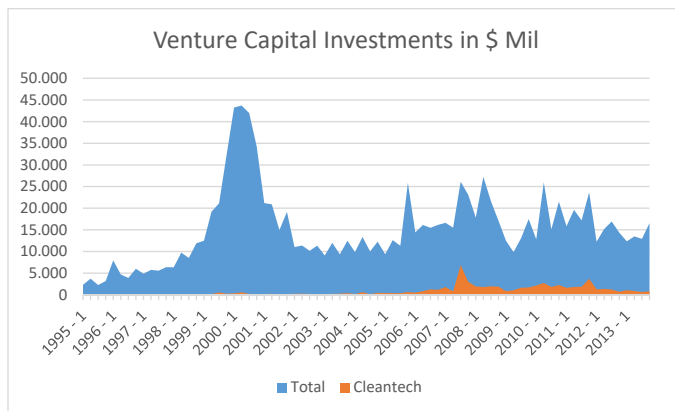


Figure 3 – Venture capital investments - total and cleantech from 1995 to 2013

The global media attention is aligned to the deals and investments as its pattern mirrors investment deals and it is highly correlated with the investments (see Table 2). While our data are not structured to inform us whether media or VC drives the conversation, it is clear that VC backed deals bring awareness of new technologies to mainstream

media. This indicates that this media data can be used as a proxy for VC investment patterns.

	All Article	All Deal	All Invest	CT Article	CT Deal	CT Invest
All Article	1					
All Deal	0,78104389	1				
All Invest	0,6699168	0,91317293	1			
CT Article	-0,14846649	0,30272177	0,35815285	1		
CT Deal	-0,29431883	0,24240478	0,31221119	0,89394843	1	
CT Invest	-0,24197175	0,18057498	0,3423279	0,68266914	0,78225744	1

Table 2 – Correlation of VC general and CT – articles vs. investments

Figures 4 and 5 show the progression of total deals in the VC industry relative to the development of the total articles published on VC in the international newspapers, and the cleantech deals relative to the cleantech articles published in international newspapers. These charts suggest that media give less attention to VCs, except for when a new technology is being backed.

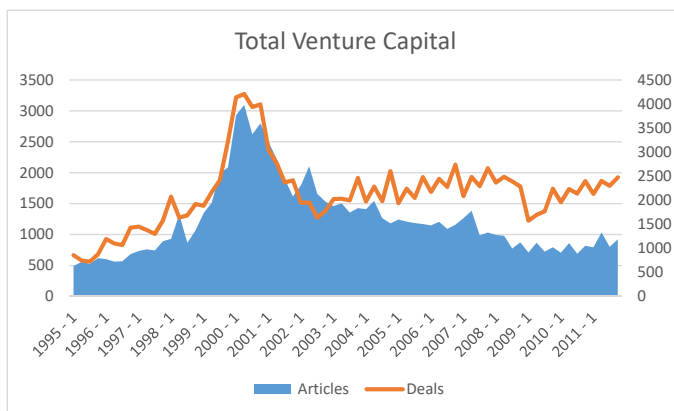


Figure 4 – Total venture capital articles and deals from 1995 to 2011

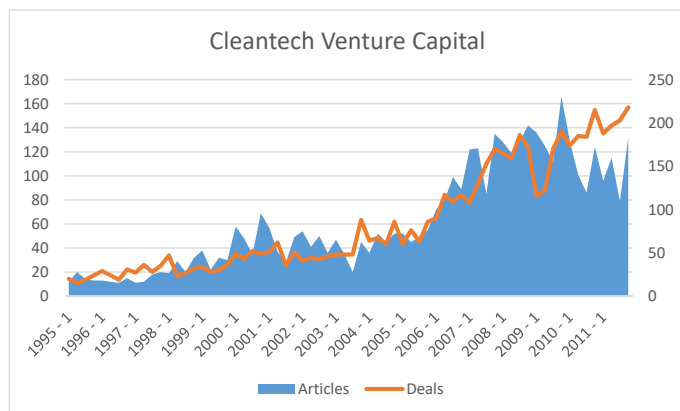


Figure 5 – Cleantech venture capital articles and deals from 1995 to 2011

From these general patterns of media on VC, we drill down further to understand the pattern of investments being made within the cleantech sector. Figure 6 displays the results of the quantitative content analysis. Applying the cleantech dictionary to the media database³, we see that media attention differed across quarters and/or years, permitting us to determine the relative importance of various technologies in different time periods, which we have organized into life cycle stages.

3 The “Air” theme as part of the taxonomy has proved to include too many articles not properly fitting the categorization so this theme has been left out for the analysis.

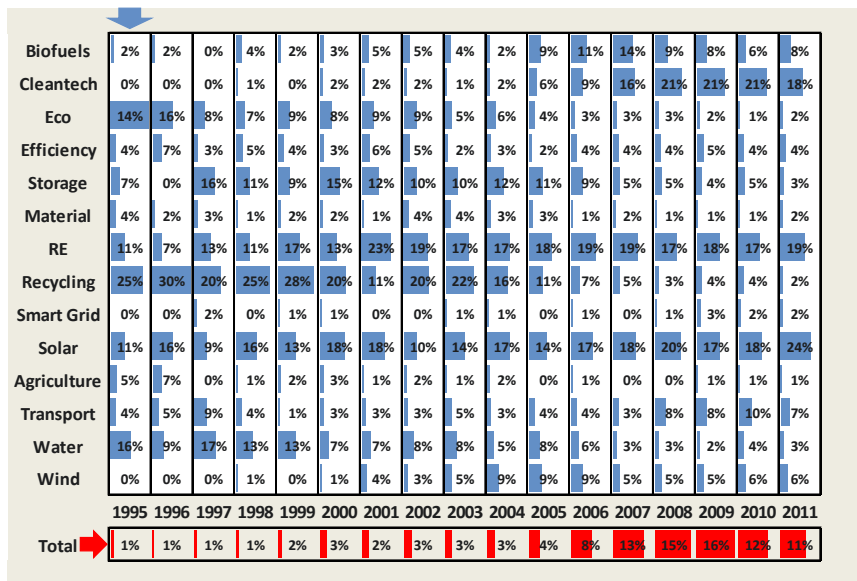


Figure 6 – Dictionary application – sector importance in venture capital articles

2.4.2 Early Investment Stage

In 1995, less than 1.5% of the \$11.4 billion VC deals went to cleantech companies (78 deals, \$168 million). Media attention, by comparison, is slightly higher at 2.7% discourse on cleantech related issues. By 1998, the VC market grew to \$36.5 billion (7317 deals), however, the share of cleantech investments fell to .7%, or \$269 million invested in 163 deals, and media attention dropped to 2.4%. Recycling is the dominant category in the media in this phase. It is one of the categories usually connected with environmentalism. The amount of articles within the relevant cleantech frame mentioning this theme fluctuates between 20 and 30%. Other themes mentioned more often are water, between 9 and 17%, ecology, with 14 and 16% in 1995 and 1996 followed by a drop to never surpass 9% again and solar, varying between 9 and 16%.

In this stage, recycling is the dominant category in the media. It is one of the categories commonly connected with environmentalism. The volume of articles relevant mentioning this theme fluctuates between 20 and 30%. Other themes mentioned more often are water, between 9 and 17%, ecology, with 14 and 16% in

1995 and 1996 followed by a drop to never surpass 9% again and solar, varying between 9 and 16%. These themes reflect VC investments in cleantech companies that are responding to climate change. The late 1980s and early 1990s introduced a growing fear of environmental pollution and recognition of the finiteness of natural resources, and heightened consciousness concerning the use of resources and sustainable consumption. The growing importance of these topics, combined with the emergence of green parties lead to political initiatives for more sustainability. Several countries introduced different policies protecting the nature and supporting the environment. The topic of climate change lead to the decision to limit carbon emissions at the United Nations conference in Kyoto 1997. These social and political trends were supported through the investment into more research on sustainable technologies at universities and corporations. As a result, startups and SME started to recognize opportunities in the cleantech context as well, which fostered the continued investments in cleantech.

2.4.3 Commitment Stage

In 2000 the VC market reaches its peak year with 16,279 deals at a volume of \$163.2 billion. Approximately 0.8% of the total deal volume went to 193 cleantech deals, totalling \$1.2 billion. This investment represents a significant rise in absolute terms and as well as in average deal size. Media attention hovers around 1.8% of cleantech articles. After the Dotcom crash, the total VC market drops to \$ 42.9 billion invested in 8516 deals in 2003. However, Cleantech investments drop not nearly as much with \$916 million invested in 232 deals. This investment represented 2.1% of all money invested and an increase relative to other years. The media attention for cleantech rose to 2.6% as well.

Recycling remains an important media topic. Water and Ecology lose their importance while solar as a media topic increases to 18% as it wins economic importance at the same time. During this phase wind is mentioned significantly more often starting in 2001 but still only reaches maximal 5% of the attention in 2003. Energy storage especially fuel cells are an important topic of the early 2000s which shows through higher media attention of around 10 to 15%. Attention towards other renewables raises to around 20% or higher.

These investments reflect increasing commitment to cleantech. In the earliest years of the commitment stage the VC market reached levels never seen before in terms of money invested and average valuations. The positive environment for VC investments promoted growth in nearly every part of the industry. Cleantech deals were happening

more frequently even though they were not yet called cleantech or even grouped into a category. Well regarded VCs like Venrock Associates, 3i Group and Draper Fisher Jurvetson made their initial investments in what would later be categorized as cleantech in 2001/2002. Early dedicated funds like the SAM Private Equity Energy Fund closed in 2000, while SAIL Capital Partners closed their first fund in 2002. At the same time technological breakthroughs happen in the renewable energy and fuel cell industry which steer attention towards the possibilities in the category. Entrepreneurial activity is also rising with startups that become role models for getting funded in that period. Tesla Motors for example, which was incorporated in July 2003 was later financed with several hundred million dollars of VC money before it went public. These facts demonstrate that cleantech had become viewed as a clear market opportunity.

2.4.4 Institutionalization Stage

By 2004, VC has slightly recovered with 8,840 deals at a volume of \$45.5 billion. Nearly 3% of the total deal volume was spent on 277 cleantech deals, totaling \$1.3 billion. Media attention to cleantech articles rises to 3.4 %. In 2007, when cleantech had its peak year the global VC industry invested \$ 81.3 billion in 9,525 deals and within the cleantech category it invested \$ 12.4 billion in 561 deals which is 15.3% of the whole market. Media attention towards cleantech was also high at 10%.

In 2005 the cleantech category was growing immensely in media attention. The relative importance for all cleantech associated articles jumps from 2% in 2004 to 9% in 2005. Mainstream media incorporated the terminology relatively late. From the mid-1990's more specialized media reported on the category frequently. Therefore, the category had reached some legitimacy even outside of the VC industry by 2005 (O'Rourke, 2009). In the institutionalization stage the relative importance of recycling disappears. Media attention drops to 11% in 2005 followed by a steady decline down to 2 to 4% until the end time period. This drastic shift away from technologies focused on addressing climate change to other technology categories shows the closeness of the category to market driven businesses as discussed by Caprotti (2012). Wind, Solar and other Renewable Energy Sources reached their maximal importance during the institutionalization stage. Wind peaks at 9% from 2004 to 2006, solar fluctuates between 14 and 20%, and other renewables stay at 17 to 19%. Additionally there is a brief increase in attention towards biofuels, which appear more heavily in 2005 with 9% of the attention and rises to 14% in 2007.

The cleantech VC category is firmly established in the institutionalization stage. With the burst of the Dotcom bubble, mainstream VC investors sought new investment areas. Combined with the attacks on the World Trade Center in New York City, there was increased interest in reducing dependence on oil-based technologies. Another major turning point for cleantech investment was California's Green Wave initiative. Beginning in early 2004 the treasurer of California mandated CalPERS and CalSTRS to invest into environmental conscious assets. The first \$500 million tranche was earmarked for PE/VC investments to develop clean technologies. This public effort spearheaded the widespread acceptance of the category and influenced many of the developments of the category. There was a clear shift towards cleantech for technological revolution.

These factors motivated VC investors to consider industries which, by mid-2004 were labeled as cleantech, as a suitable investment field. As a result, cleantech VC investments category expanded rapidly. With dedicated funds, mandates arise from pension funds or corporate investors and big multi fund investors seeking to raise new fund vehicles targeted at the cleantech market. KPCB for example launched their Green Growth fund in early 2008. The support for cleantech is changing drastically as well. For example, in 2004 Germany's "Renewable Energy Sources Act" drove installations of RE technologies. The solar energy market grew immensely during this time, even though it has not been economically viable without public support. This rise in demand led to more and more company formations in the RE and solar fields worldwide.

Relevance as an investment category creates a VC and entrepreneurial network co-evolution process. The popularity of cleantech across investment participants, from institutional investors over VC funds to start-ups fosters a growing market. A general understanding of industry participants and technologies exists (Caprotti, 2012; O'Rourke, 2009). Market information/ support providers like the Cleantech Group, Clean Edge, and New Energy Finance gain importance and provide databases, reports and organize conferences and fairs to promote the industry (see O'Rourke, 2009 for a detailed analysis on cleantech service providers). High growth attracts general VCs without prior experience in asset heavy industries like cleantech start entering the category and results in new and less skilled VC managers raising funds. The abundance of capital spread across companies, and leads to increased competition, high valuations and skepticism about the long term viability of funded companies. This later stage introduces overshooting (Lerner, 2002).

2.4.5 Overshooting Stage

The volume of the VC market dropped drastically after Q4/2008. In 2009 the VCs invested only \$ 53 billion in 7,279 deals. Within the cleantech category less than half of the prior year's total - \$ 5.2 billion was invested in 598 deals. At this level, the average deal size plummeted by more than 60% compared to the peak year 2007. Nevertheless media attention for cleantech reached its peak in 2009 with a share of 17.4%. However, largely due to press regarding bankruptcies of cleantech firms and the failure of stimulus programs like the DOE-LGP.

In late 2008 and early 2009 media use of the term Cleantech reached its peak. 21% of all articles of the cleantech frame mention that specific topic. Further dominant topics in media are Other RE and Solar with 18 and 17% of the attention. For the first time the topic Smart Grid gains some relevant attention and reaches 3% of media discourse. This announces the change towards less asset heavy investment categories within the cleantech category. The transportation topic which has some more attention as well is supporting this trend but has some link to the stimulus packages for large VC financed companies like Tesla Motors or Fisker Automotive.

The burst of the US housing bubble and the loss of trust in many financial institutions led to the beginning of a global recession. The confidence in the markets had to be supported by heavy government actions to save the financial system, especially US banks and insurance companies. On September 15, 2008, the bankruptcy of Lehman Brothers was announced and the financial crisis became apparent. This recession hit the VC markets as well.

Governments around the world introduced stimulus programs to support recovery most often with a focus on green growth, examples include the ARPA-E in the USA and the Green New Deal Package in Korea (UNEP, 2009). These initiatives strengthened the cleantech category. Concurrently, policymakers started several initiatives to "de-risk" capital markets through new regulation like Basel III or Solvency II⁴. Over time these policies decreased allocations towards riskier assets like cleantech VC.

4 Basel III and Solvency II are comprehensive reform measures to strengthen the regulation, supervision and risk management of banks or respectively insurance companies. Core initiatives include increasing capital & liquidity requirements and higher risk discipline in investments.

2.4.6 Stabilization Stage

Following overshooting, the cleantech VC category consolidated and restructured. Investment volumes regained \$2 billion in Q1/2010: New company formations like Nest Labs, a developer and manufacturer of smart thermostats which was founded in 2010, financed by major VCs and sold to Google in early 2014 for \$ 3.2 billion in cash. Tesla Motors the manufacturer of electric cars founded in 2003 went public in Q2/2010. Exits and IPOs restored confidence in the category. Even struggling companies like Fisker Automotive another car manufacturer or A123 a battery manufacturer who went into bankruptcy in 2013 were saved and are still active under new ownership.

The overall VC industry recovered in 2010 and 2011 to reach \$ 76.3 billion invested in 9,307 deals. The cleantech category reached almost \$ 9 billion invested in 806 deals for a share at 11.7%. Still in the following years the total VC market consolidated and lost some ground. In 2013 just \$ 55.3 billion were invested in 512 deals with \$ 3.4 billion invested in 512 cleantech deals. This reflects a change in the investment category to technologies that are both less expensive to bring to maturity and less asset heavy.

Technologies such as transportation and smart grid received increased media attention beginning in late 2009. Wind and Solar which had reached widespread market adoption are still of very high importance in media discourse. Nonetheless investors are hesitant to invest in asset intensive companies and focus on less capital intensive companies with a software or consumer focused market (Hargadon & Kenney, 2012; Kenney, 2011b). In general newly founded startups in this stage are market driven rather than policy dependent. Thus, markets with reliable market-pull regulation may benefit from new company foundations, as policies align with the VC approach better than technology push policies (Mary Jean Bürer & Wüstenhagen, 2009).

We summarize each of these life cycle stages in a comprehensive manner in Table 3. The structure stems from previous work (Avnimelech et al., 2004; Avnimelech & Teubal, 2006) and has been refined for the category emergence analysis.

Hightech VC categories		Cleantech VC category
		<i>Length of pre-emergence and emergence phases-8 years</i>
		<i>VC emergence - first policy led now market led</i>
Background Conditions Phase	<ul style="list-style-type: none"> • Market need • Political initiatives • Creation of industry R&D/innovation capabilities in university labs and corporates • Startups and SME recognize opportunities 	<ul style="list-style-type: none"> • Fear of environmental pollution and finiteness of natural resources • Political initiatives for more sustainability • Creation of cleantech R&D/innovation capabilities in university labs and corporates • Startups and SME recognize opportunities in cleantech context
Pre-Emergence Phase	<ul style="list-style-type: none"> • Technological breakthroughs/revolution • Growth of VC in general and first investments in category area by general funds • Increasing numbers of startups excess demand for VC investments 	<ul style="list-style-type: none"> • Solar energy, wind energy and energy efficiency technologies enter the market • First investments in cleantech by general funds • Innovators start cleantech companies and are looking for funding
Emergence Phase	<ul style="list-style-type: none"> • High rate of growth of VC and founding activity • VC-SU co-evolution process; strong collective and onset of cumulative process • Increased competition and overshooting • Entry of less skilled VC managers/firms and startup companies 	<ul style="list-style-type: none"> • First dedicated cleantech funds start operations • Support environment through databases (Cleantech Group/New Energy Finance) and specialized service firms grows • High competition and therefore high valuations for top deals • Several new and established VC firms open clean/green/sustainable fund
Crisis Phase	<ul style="list-style-type: none"> • A deep crisis that may be caused by a one or combination of factors including stock market downturn causing an inability to have IPO (sometimes termed “overshooting,” • Negative government actions, more general economic downturn, etc. • Exit of VC funds and closure of SUs, while SUs suffer liquidity problems <p>General loss of confidence in the industry</p>	<ul style="list-style-type: none"> • Financial crisis started by US housing bubble & Lehman Brothers bankruptcy • Governments "de-risk" capital markets through new regulation • Unfavorable returns lead to drying fundraising conditions especially in the young cleantech field
Consolidation Phase	<ul style="list-style-type: none"> • The VC industry restructures with the help of collective institutions • New institutions (formal and informal) emerge • New government policies are implemented 	<ul style="list-style-type: none"> • New growth in less policy driven markets • Market pull for technologies and following investments - less asset heavy and faster to maturity • Returning confidence through first exits

Table 3 – Description of life cycle phases

2.5 Conclusion

This research aimed to understand VC investment patterns in an emerging technology sector. We examined the emerging cleantech sector and considered the evolutionary influences in the early and expansion stages of the life cycle of the adjoining investment category. The results clearly reflect that VC investment patterns occurred in stages, beginning with early investments and proceeding through commitment and institutionalization stages where the technology class becomes more accepted. Investments during these times align with broader societal trends in this whether the technology responded to climate change, represented a clear market opportunity in the sector and then finally those that represented a technological revolution for the category. They illustrate that investments begin slow and at small amounts, perhaps to provide low-cost learning opportunities to the involved VCs, and then increase in amount and volume over time. Also observed was an overshooting stage where VC investors investments capped out and began to slow, and finally a stabilization stage where investments were diverted into specific types of investments in order to capture value in VC investments. Overall, these results strongly support the work of Caprotti (2012) and Ghosh and Nanda (2010).

This paper provides insights into the evolution of cleantech financing. The joint analysis of press publications and investment data highlights understanding of historical turning points in the sector. A variety of factors such as policy changes, political shifts in direction, investment programs and global trends or phenomena likely underlie these investment patterns and influence market growth and public perception. Deeper knowledge of these factors would enhance understanding of emerging investment categories. The understanding can support in the construction of public measures or supporting frameworks to foster innovation and job creation in desired industries. This paper contributes to different streams of literature, first on the historical emergence of VC investments and second, on the role of VCs in industry development. Additionally we advance the literature on cleantech and sustainable VC (Caprotti, 2012; O'Rourke, 2009; Pernick & Wilder, 2007). Finally, we make a methodological contribution by showing the usefulness of media data as a proxy for VC investments.

The approach used in this paper is one of the few examples of a conceptualized framework for the historical analysis of a VC market (Avnimelech et al., 2004; Avnimelech & Teubal, 2006). It transferred a life cycle model from the national to an industry level and introduced methodology to interpret the changing themes within the VC industry. The VC life cycle model aims to understand the establishment of the cleantech VC category and its environment.. VCs changed the look of the category and

ultimately pushed the market towards a dominant design (von Burg & Kenney, 2000). By leveraging the growing environmentalism of the late 1980s and early 1990s and political initiative to support sustainability, VCs were able to help finance an emerging industry. Moreover, through market pull, for example through Germany's renewable energy feed-in-tariff and on the other hand, and direct investment support like California's Green Wave initiative, the cleantech category was poised for investment. However, the policy driven support led to an immense growth and "overshooting" (Lerner, 2002) which in addition to the financial crisis reversed the momentum the industry had been experiencing.

Our results call for thoughtful use of policy instruments in emerging industry contexts as too much policy stimulation can saturate the market. A consistent and reliable regulatory environment that encourages technology-push policies in earlier stages and market-pull policies in later stages with a relatively free acting and without overshooting the financial system would contribute to sustainable industries that not only provide impressive returns for investors but also contributes to sustainable economic growth and job creation. While we believe the combined analysis of the emerging VC investment category for clean tech emergence should transfer to other industries and investment category contexts, we encourage research that validates this assumption. The quantitative content analysis can be biased based on the dictionary development and depends upon predefined textual information (Hsieh & Shannon, 2005). Therefore, testing our findings through different quantitative analysis could enrich the overall contribution and strengthen knowledge transferability.

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