

Handbook of Research on Energy Entrepreneurship

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1 INTRODUCTION

In the first decade of the twenty-first century there has been increasing awareness of environmental issues and recognition that these are now global in scope. This has occurred for many reasons and is perhaps best epitomized in the global warming discussion. The dramatic rise of China and India, in particular, reoriented the debate about the sustainability of the current trajectory of fossil-fuel usage and environmental degradation. Quite simply, if the economic growth of China, initially, and then India were to follow the historical trajectory of fossil-fuel energy usage and resource consumption that Japan, Taiwan, and Korea followed, the environmental impacts would be nothing short of monumental.

This chapter does not propose to debate the need for 'green technologies' or the merits of particular technologies. It accepts that the current trajectory of the fossil-fuel-based energy system is not sustainable, environmentally or ethically. Evaluating the merits of particular energy generation or environmental technologies is beyond the scope of this chapter and, perhaps, at this early stage unknowable. Rather, the chapter addresses the question of whether venture capital (VC) in its current organizational form offers significant promise for funding the commercialization of what we shall term 'greentech'. To presage the following discussion, this chapter is skeptical about the possibility that VC investment can become an important component of the financing of greentech. This is mainly because the investment criteria for successful venture investing are unlikely to be met by most green technologies. This is a contrarian perspective as the promise of VC financing for greentech and the potential of greentech as a new field of venture investing has already received an enormous amount of interest and hype in the global press and from elements of the venture community. In the academic literature, interest in VC investing in various green technologies has increased (O' Rourke and Parker, 2006; Wüstenhagen and Teppo, 2006; Bürer and Wüstenhagen, 2009; Wüstenhagen et al., 2009). Despite these pioneering efforts, understanding of greentech VC investment is still limited.

From a public policy perspective there are reasons to support private VC investment over other more direct corporate subsidy programs. Market-oriented economists would argue that private VC investment is desirable because it eliminates the need for public decision making on which technology or firms should receive funding. This limits the role of government in decision making and trying to 'pick' winners – a problem that has received significant attention in the energy and industrial policy literature (Pack and Westphal, 1986; Helm, 2002). This position is in particular strongly held in Anglo-Saxon market-centered nations such as the US and the UK. For the market-oriented

economists, the market in the form of VC or other investors will discover, fund, monitor, and assist their greentech portfolio firms. Proponents of this model in general would confine governmental involvement to funding research and ensuring that markets operate transparently and in a non-discriminatory fashion.

An entirely different group of observers argue that independent VC investing in greentech should be encouraged because it is not subject to the sunk costs, entrenched interests, and biases of established energy firms and government regulators (Hockerts and Wüstenhagen, 2009). For them, venture capitalists, with their willingness to support new technical solutions and/or business models, offer hope for change. These advocates observe that in their investment policies independent venture capitalists are not influenced by legacy costs and decisions and thus can finance firms whose success would portend the creative destruction of incumbents. Their goal is that VC-supported entrepreneurship should prove sufficiently disruptive so as to transform the economic environment.

The analysis in this chapter focuses exclusively upon dedicated VC limited partnerships, the dominant form of formal venture investing globally. Excluded from direct examination are corporate VC operations¹ and angel investors, both of which have different processes, logics, and goals from professional venture investors.

Understanding the potential for building a successful VC practice in greentech investing begins with a description of the VC life cycle and the economics of the industries within which venture capitalists have typically invested (Section 2). Section 3 considers the question of whether greentech is a single industry or a variety of industries. This is important because successful VC investing (Section 4) is predicated upon developing deep knowledge of the evolutionary trajectories of technologies and markets. The decision to invest in new sectors is largely determined by the possibility that the investments will provide sufficiently large returns. A tentative answer to questions about returns can be given by examining previous returns (Section 5). Because the historical record may provide insight into the trajectory of this greentech investment boom, Section 6 briefly describes the VC response to the 1973–80 oil crisis period, during which there was a wave of VC investment in the greentech of that time, that is, alternative energy. The conclusion questions the possibility that greentech will prove to be a lasting investment interest for venture capitalists, and suggests that the current investment boom may be an unsustainable bubble.

2 THE VC LIFE CYCLE AND THE OPERATION OF THE TYPICAL VC FIRM

From 2006 through the first quarter of 2009, there has been a rush by US and European venture capitalists to raise greentech funds. Continuation, rather than episodic VC involvement in greentech investing, will require that the candidate greentech-recipient firms eventually, if not initially, develop the characteristics of successful VC portfolio firms in terms of rates of growth and desirability to post-VC investors. The investments must offer sufficient returns to allow venture capitalists to raise more money for future investments (Gompers and Lerner, 1999). In other words, greentech must allow each stage in the cycle to be completed or VC investment in greentech will end. Most

importantly, regardless of the social benefits – which may have attracted the VC fund's initial investors – without sufficient financial success to justify the investment, investors such as pension funds and endowments will discontinue advancing money to the venture capitalists, although governments may invest in VC funds even if the investments are failures as a part of a larger social goal, such as supporting greentech firms. To be sustainable, private greentech investing must be sufficiently profitable to justify continuing funding, and only profitability can ignite a self-reinforcing entrepreneurial dynamic capable of making a difference in the trajectory of global warming and environmental pollution.

The basis of the VC industry is to invest in firms early in their life cycle and then to sell these investments to others later in the life cycle – hopefully with capital gains. This chapter deals only with the VC limited partnerships, though the field of investing in small firms includes private individuals or groups (often termed 'angel' investors), corporate venture capitalists, and, less frequently, various government agencies. Today's VC firms generally raise investment capital through partnerships with institutional investors and wealthy individuals who, as limited partners, commit their capital for 10 years. For the limited partners, the attraction is the promise of returns significantly greater than could be achieved with conventional investments. Diversification has also been mentioned as a benefit from investing.² The venture capitalists are the general partners responsible for the investment decisions.

The economic interests of the general partners explain their behavior. The venture capitalists receive an annual management fee of between 2 and 3 percent of the capital managed and a share of any profits (usually 20–30 percent) after the initial capital committed by the limited partners is returned. Prior to the 1980s, average VC fund size was below \$100 million. With a 2 percent management fee, a VC firm managing a \$100 million fund took in \$2 million to pay salaries and expenses. If a VC firm had two active funds, then the income was \$4 million per year. If there were five partners and each managed approximately \$40 million in 8–10 portfolio firms, then each partner's share of the management fee was \$800,000 minus expenses. In the 1990s the size of the funds mushroomed, and by the mid-1990s it was not unusual for firms to raise \$500 million to \$1 billion funds. Even if management fee percentages were not raised – and in some cases they were – the management fees grew to between \$10 and \$20 million per fund. If the venture capitalists managed two funds, the income was \$20–40 million per year, and each individual's share was \$8,000,000 minus expenses. Even if the number of partners tripled and each now managed \$125 million, the individual partner's share of the management fee was \$2.5 million minus expenses. The new economics meant that each partner received a handsome salary for 10 years (the life of each individual fund), whether the investments were successful or not. Today, a venture capitalists can become wealthy without even generating a good return for the limited partners. Thus the simple act of raising a large fund is a guarantee of a significant income for 10 years. In effect, if the limited partners want venture capitalists to manage a targeted fund, the question of its long-term investment potential is of little importance to the venture capitalists. Note the difficulty that the limited partners may create for themselves: they might be making a long-term largely irrevocable decision to invest in what could be the latest technological fad – a dangerous investment strategy.

3 GREENTECH VERSUS TRADITIONAL VC-FINANCED INDUSTRIES

Prior to discussing the limited research on VC investing in greentech, it should be noted that in terms of venture investing, there is no definitive definition of greentech. At this time it appears to be an amalgam of a number of industries. If this is so, then consider the obstacles to a sustained program of VC investment. First, venture capitalists will find it difficult to specialize and deeply understand the business space. This suggests that a community of investors may not coalesce, thus limiting an ongoing flow of capital from increasingly experienced investors. This contributes to what may become a second obstacle. Many of the industries in which venture capitalists have been most successful are characterized by firms opening what Joseph Schumpeter termed 'new economic spaces' within which there is a swarming of new firms. This also plays to the venture capitalists' strength, which is the ability to peer just over the horizon to see what the next step in the technology/business evolution might be and to create a firm to occupy the space before incumbents or adjacent existing firms can react (von Burg and Kenney, 2000). The development of the internet space illustrates this. Early browsers such as Netscape allowed more people to discover the fledgling web. This increasing viewership made it possible for market software to build websites. The increase in websites and viewers allowed new entrants to begin online sales, that is, Amazon, eBay, Expedia, Etrade and so on. The growth of the web made it possible to have portals such as Yahoo!, Lycos, and Excite, as well as search engines, for example, Google. After this came webscraping, wikis, blogs, and a myriad of other economic activities (Kenney, 2003). It is these burgeoning technology/economic spaces that create the investment frenzies and the outsize returns for the venture capitalists. Are there greentech technologies or market developments that will allow venture capitalists to invest in the creation of a myriad of firms, thereby sparking the formation of a new ecosystem? To illustrate, in biotechnology, which after information technology (IT) has been the most important area of VC investing, there have been a sufficient number of successes to permit the creation, survival, and reproduction of biotechnology specialist VC firms and an ecosystem of support organizations.

In the case of biotechnology, a number of authors have noted that it was the availability of VC that allowed an industry consisting of entrepreneurial firms to be established outside the pharmaceutical industry (Kenney, 1986; Pisano, 2006). The attraction of biotechnology has been the development of new and superior drugs that could demand premium prices in the market. Despite a relative paucity of commercial success, biotechnology firms have offered sufficiently high returns to their VC investors. Will greentech produce venture investing successes such as Genentech and Amgen? What is the likelihood that greentech will produce firms such as Intel, Cisco, Google, and Oracle? For the venture capitalists to have a long-term interest in greentech, it must perform as well as biotechnology. If a sufficient number of such successful investments are not made, then VC investment in greentech is likely to decline precipitously, stranding portfolio firms as the hype ends.

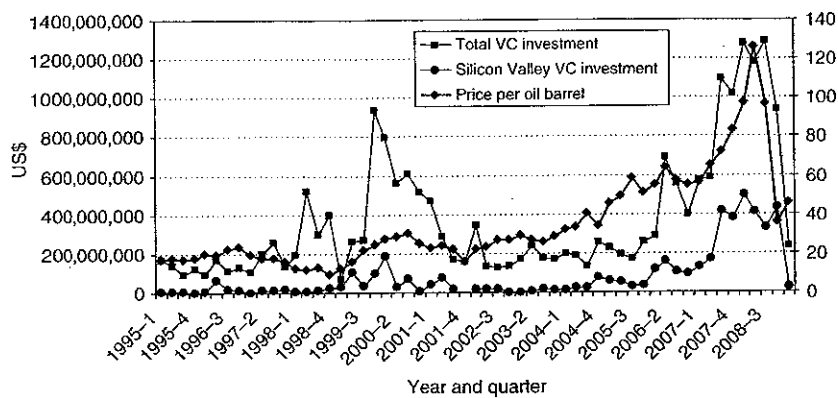
Venture capitalists have also invested in other industries outside of the IT and biomedical fields. In fact, they are agnostic regarding industrial areas. So, for example, the well-known firm Federal Express received VC funding, as have a number of airlines such as the now defunct People Express. The San Francisco brewery Gordon Biersch,

which has expanded rapidly, was also the beneficiary of VC financing. All of these were successful investments leading to important initial public offerings (IPOs), however venture capitalists did not become significant sources of capital for the package delivery, airline, or microbrewery industries. This is not because entrepreneurship is impossible in these industries, but because there is a relative paucity of the types of opportunities that venture capitalists are comfortable funding. Put simply, venture capitalists are not biased against particular industries; rather they invest in opportunities that are appropriate to their organizational goals.

There has been comparatively little research on VC investment patterns by industry. What industry-level research exists has been concentrated on biotechnology and the information technologies (on the internet, see Kenney, 2003; Zook, 2005; on biotechnology, see Powell et al., 2002; Baum and Silverman, 2004; on data communications equipment, see von Burg and Kenney, 2000). As a comparatively recent phenomenon, greentech VC investing has received little attention in the scholarly press, but enormous attention in the popular press. The major exception is the important paper by Wüstenhagen and Teppo (2006) examining the available evidence regarding VC investing in greentech firms. Of the four greentech firms they examined that went public on the NASDAQ in 1999 to 2000, one is no longer listed, two are penny stocks (trading under \$1), and one was delisted. In the case of three of these firms, the venture capitalists made adequate returns – a situation that is expected if they can make a public offering. The fourth firm Plug Power, which had the best return (not at the time of IPO, but at the end of the share lock-up expiration date), was not VC financed; rather it was a spin-off joint venture. These three successful VC-backed IPOs show that greentech firms can be successful, but does not provide sufficient evidence of the return to total VC investment in the industry. Consider the most successful US solar photovoltaic firm, First Solar, which was founded in 1984. In 1999 it was sold to the Walton family (heirs to the Wal-Mart fortune). The stock was sold to the public in 2006, seven years later – a comparatively long time to IPO.

Greentech (formerly alternative energy/environment) has a long history of attracting investors with only limited returns. As Figure 11.1 indicates, from 1995 to 2000, far more capital was invested in the industrial/energy category than was returned in the initial public stock offerings. Unfortunately, we do not have data on the number of mergers that occurred. What this suggests is that more capital was invested in the industrial/energy category than was returned through exits – not a sustainable situation. The industrial/energy category in terms of investment roughly tracked the collapse in total VC investment, suggesting that it did not perform differently from other VC investing in the aftermath of the internet bubble.

Energy-focused VC funds in the European context may offer more attractive returns (Wüstenhagen and Teppo, 2006). This may be because either European venture capitalists require a lower hurdle rate to measure an acceptable return or European entrepreneurs are superior. Also, because European stock markets such as the London AIM have less rigid criteria and require less documentation for exits, smaller firms can be listed allowing venture capitalists to recoup their investments. From an American perspective, there has not yet been a greentech Google, Yahoo!, or Cisco that yields 100 times the original investment and thereby offsets the many unsuccessful VC investments made. To return to First Solar, it had a market capitalization of approximately \$12 billion in 2009.



Source: Compiled by author from PricewaterhouseCoopers Moneytree and US Energy Information Agency.

Figure 11.1 Total VC investment and VC investment in Silicon Valley in the industrial energy sector and per barrel crude oil price by quarter, 1995-Q1 2009

Despite its success, its value is one order of magnitude smaller than Google, which in 2009 had a market capitalization of \$134 billion. In terms of the larger picture, are there many more First Solar level of successes in photovoltaics? In IT there may be another Google. For example, since 2005 there has been YouTube (after 18 months purchased for \$1 billion), Facebook (recent valuations suggest it is worth \$6 billion), and Twitter (recent valuations suggest it may be worth \$1 billion or more). Are the potential returns similar for greentech start-ups?

It may be possible that the returns are not as large, but the other question is will they be sufficient? This is more difficult to answer, as it is contingent upon the relative receptivity of public markets to greentech firms, government action, price of alternatives, and the quality of the firms and managers involved. This section has suggested that thus far opportunities as large and lucrative as those in IT have not been created in greentech. Whether there will be sufficiently large returns to justify investment from VC firms operating under the current Silicon Valley model is not yet knowable. It is also uncertain that the VC model can be reshaped to justify lower returns, and how that might be done.

4 GREENTECH AND VENTURE CAPITAL

How do VC economic dynamics apply to greentech? An illustration from recent fund raising may clarify the problematic nature of the current VC environment. Many greentech advocates were excited when in May 2008 one of the elite VC firms Kleiner Perkins Caufield & Byers (KPCB) announced that it had raised a \$500 million Green Growth investment fund (KPCB, 2008). As Figure 11.1 demonstrates, KPCB was fortunate as the fund was subscribed at the exact peak of the 2008 oil price bubble and the greentech/alternative energy fever. Regardless of the fate of the fund, as far as returns are

concerned, KPCB will reap significant benefits as it collects its 2.5 percent annual management fee or \$12.5 million per year no matter what the returns are to investors.

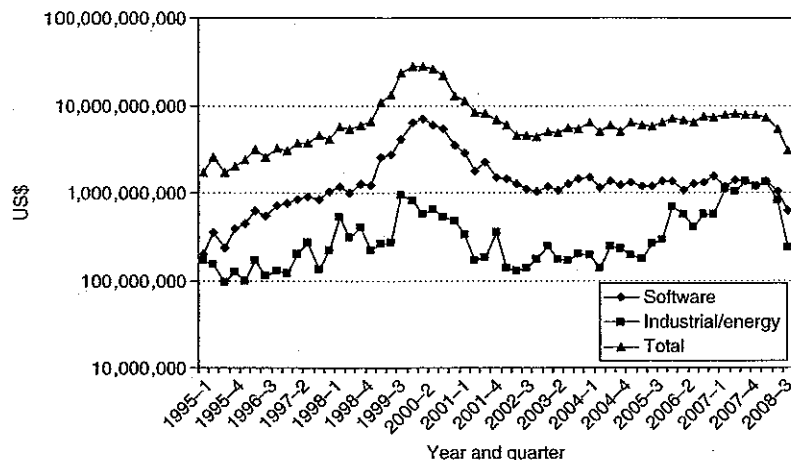
While venture capitalists are typically agnostic to the industry they invest in, there is a path-dependent component of the practice because they continue and even increase investing in industries where they experience success. In fields in which investment returns are low, there is a marked tendency to throttle back investment, for example, few any longer invest in nanotech firms (and this field was hot less than five years ago). There is a recognition of the importance of path dependence for VC investing in greentech. For example, Wüstenhagen and Teppo (2006) find that VC investment in greentech requires knowledge and experience, but what they overlook is that path dependence requires the building of routines that buttress a path that can only come from the positive reinforcement of previous successes that legitimize the investment field (see von Burg and Kenney, 2000). What is necessary to continue the flow of investment is the tangible possibility of a significant return. It is for this reason that many have called venture investors 'lemmings', as they chase after the newest 'hot' industry or investment idea. As long as there are successful exits the investment will continue – they only stop investing in the field after experiencing a sufficient number of failures.

The difficulties with greentech investments are well described by Scott Carter, partner at Sequoia Capital:

There's going to be a massive amount of money lost in Cleantech over the next few years although Obama's presidency will probably give it new life for a while. But that doesn't mean we're not fans of Cleantech and alternative energy. We've been actively investing for three years, but we have one golden rule, which is investing where low capital expenditures are required. That means a big part of the market is a lot less appealing to Sequoia Capital. We view innovation in Cleantech as we do in other technology sectors. If you have great entrepreneurs who are incredibly frugal, who really focus on delivering a product that solves an immediate need, and you apply those principles to Cleantech, then you're going to make money. (Ernst and Young, 2009: 12)

Carter understands that there is already overinvestment in the sector, which is, of course, dangerous. He goes further in stating that short-term success will be due to government intervention – hardly a strong incentive for public markets or larger firms to acquire a VC-funded greentech firm, particularly if the direction government mandation is unclear or erratic. Carter then states the obvious that many segments of greentech are not interesting to elite Silicon Valley venture capitalists. There is a possibility that these capital-intensive sectors will be interesting to less sophisticated venture capitalists, or to those that have a lower investment hurdle rate; only time will tell.

Given that greentech is an enormous and amorphous category, there will undoubtedly be investment opportunities for venture capitalists. Most likely, these opportunities will resemble those that have some of the characteristics of current VC investment areas. In cases where there might be the construction of new infrastructures, there may be significant investment opportunities in providing components or software. For example, though somewhat ill-defined, the roll-out of a 'smart' electrical grid could offer significant opportunities for the establishment of new software firms and possibly firms creating communications devices to transmit data through the grid itself. Although most of the focus has been on energy generation, there may be significant opportunities



Source: PricewaterhouseCoopers Moneytree.

Figure 11.2 Total, software, and industrial energy VC investment in the US by quarter, 1995-Q1, 2009

in energy efficiency fields where new materials could create significant cost savings in products produced in great numbers. For example, new technologies may create more efficient lighting systems and the volume of such a consumer product is sufficiently large to be able to generate a good return. Finally, there may be superior materials able to receive intellectual property protection that could eliminate serious environmental hazards. Many of these innovations would not be as highly tied to the energy generation paradigm that drives greentech investment thinking every time fossil-fuel energy prices rise.

The pattern of VC investing in the industrial/energy category for the last 14 years, as Figure 11.1 showed, is highly correlated with the price of oil. Of course, there is a similar correlation in the interest of public stock markets in industrial-energy firms. The implication for VC investors is that when they make investments predicated upon a high cost of energy, if energy prices fall, so will the value of their portfolio firm. In cases in which their investments are capital intensive, the loss in market value will be immediate, unless some other variable such as government interventions, legal requirements, or subsidies, can overcome the market decision. It is also important to note that when energy prices fall, the hype surrounding greentech firms also falls, thereby discouraging potential follow-on investors including public markets, potential corporate investors, and other venture capitalists. As Figure 11.2 shows, since 1995 there have been two significant bursts of VC investment in the industrial/energy category, 1999–2001 and 2006–09. Each of these was followed by a precipitous investment collapse. The figure also shows that industrial/energy VC investment has roughly tracked the overall VC market and software except in mid-2005, when it expanded rapidly while software and total VC remained stagnant. This also captures the increasing concern about global warming highlighted in Albert Gore’s movie ‘An Inconvenient Truth’ and the apparent spiral in energy costs attributed to the rise of China and India. Thus, some in the VC community have been led to believe

that these two factors created a powerful market discontinuity that could be filled by VC. Former Vice President Gore was invited to join one of the most elite VC firms in the world, KPCB, as a special limited partner.

In the last 15 years there have been two spikes in VC investment in the industrial/energy category. In the first case, from 1999 to 2001 there seems to have been an acceptable return on the investment for the promoters and venture capitalists based upon calculations from the greentech IPOs, but public investors who bought these stocks and held them have experienced terrible returns (Wüstenhagen and Teppo, 2006) – a recipe for creating public investors skeptical of greentech promises. The second spike of VC investment began in late 2005 and has declined precipitously due to the stock market crash that began in 2008. The decline is not surprising when one considers that greentech IPOs globally have collapsed (Milunovich, 2009). Even worse is the number of large secondary offerings undertaken as troubled firms were forced to raise capital. Whether this is the result of declining greentech opportunities or larger market forces is unclear at the moment.

5 HISTORICAL PARALLELS?

Energy costs have had an important influence on greentech investment. There are parallels with the increase in oil prices experienced in 2007–08. In the 10 years beginning in 1973 there were, in quick succession, two oil crises due to the 1973 Arab–Israeli War when the Arab world imposed an oil embargo, and then in 1980 when the Shah of Iran was overthrown. Oil prices spiked massively, prompting a belief that global peak oil was imminent and an argument about the necessity of developing alternative energy sources (for example, Akins, 1973; Tanzer, 1974). Today, as then, the question often raised was who should make the investments in alternative energy? Although the data are spotty, when oil prices spiked in the 1970s and early 1980s a number of venture capitalists, believing in the peak oil hypothesis, invested in energy production and alternative energy resources.³ Figure 11.1 indicated that in the 1980s, VC investment in the industrial/energy category spiked. However, by the late 1980s VC investment in that category dropped dramatically. One aspect of this was the drop in fossil-fuel energy prices, but there are other insights that can be taken from this experience.

A simple economic interpretation of the collapse of VC investing in the industrial/energy category may be too facile. A more detailed explanation is the fact that these types of investments may not suit VC-based investment. In a fascinating article, Raghu Garud and Peter Karnøe (2003) compare Danish and US models for entering the wind turbine industry, providing insight into why the US largely failed, while Denmark successfully built a globally competitive industry. An important obstacle to US success was that the US wind turbine industry adopted a high-technology aerospace development model in the late 1970s and early 1980s, in search for technical breakthroughs – exactly the type of firms that venture capitalists seek to fund. Ultimately, this strategy proved to be inferior to the more collaborative and initially low-technology model adopted by the Danes. The Danish experience applies to the current alternative energy investment boom. Much of the equipment to be produced will require investments in manufacturing, which benefits from incremental improvements and in some cases large capital

investments. Such firms often exhibit relatively slow growth (5–15 percent per annum) as opposed to the most successful VC-funded firms that grow at 50–100 percent per annum. This slower growth is not as attractive for VC investors. As Garud and Karnøe so effectively describe, the Danish success was a relatively slow evolutionary process where improvements came gradually and in increments too small to justify VC investing. With the wind turbine industry, a cluster of dedicated suppliers formed to supply the turbine assemblers. But these firms were relatively small and often were existing firms operated by skilled craftsmen who simply repurposed their knowledge of material forming for the growth of the wind turbine industry. By contrast, in Silicon Valley a cluster around the rapidly growing semiconductor industry consisting of semiconductor equipment, design software, and materials suppliers also formed, but these were usually *de novo* firms. Their growth was rapid and profitability was high, therefore justifying VC investment.

If most greentech technologies and industries evolve incrementally with few industry-changing breakthroughs, there may not be the same types of investment opportunities that have been seen in the information technologies and university-born human pharmaceuticals. To illustrate the different industry dynamics, the efficiency of wind turbines in converting wind to electricity, or solar photovoltaics in converting sunlight to electricity, have experienced improvements at 1–2 percent per year. Moreover, they are bounded at 100 percent efficiency. In contrast, the electronics industries driven by Moore's law experience operational improvement of approximately 100 percent in 18 months, and there is no obvious upper limit. The point is not to deny that economically significant improvement occurs in greentech, but rather to observe that they have proceeded rather slowly. A slow pace of incremental improvement may not provide sufficient competitive advantage for a new entrant to overwhelm incumbents.

Market growth is also important. As the success of hybrid and electric vehicles demonstrates, the greentech market is expanding rapidly – though this is a relative measure. However, to access these growing markets the greentech start-up must displace incumbents with a similar, though possibly inferior, product. To provide an example, a number of electric automobile firms have been funded by wealthy individuals and venture capitalists. The task for these firms is to unseat existing competitors such as Honda, Nissan, and Toyota, all of which also have significant alternative energy research programs that can be combined with complementary assets such as dealer and supplier networks, capital, and strong manufacturing expertise. Attacking such firms head-on is a risky business strategy. The historical lesson has been that VC investment has been most successful when there are no incumbents or the incumbents have an entirely different business model, hence Netflix, which delivers videos through the mail, outflanked video stores that required customers to travel to the store.

Green technologies have significant commercial promise particularly if governments mandate their usage. For the VC investor, though, the obstacles to successful investment are daunting. A high level of manufacturing expertise may be required and the amount of capital investment can be too large. A common solution to this problem for VC-backed electronics firms has been to outsource manufacturing. In cases where the product is entirely new and there is little manufacturing expertise, the establishment of in-house production and an active program of incremental improvement might be necessary – but this consumes capital.

6 WAITING FOR GODOT OR GOVERNMENT SUBSIDIES?

There is a long history of argument from alternative energy and greentech supporters stating that since they internalize costs of pollution externalized by fossil fuels they deserve extra-market compensation.⁴ Again, this is something that this chapter acknowledges but will not dwell upon. Greentech investing is and will continue to be more difficult than IT and even biotechnology due to the dependence of success on non-market factors. Whereas venture capitalists are comfortable dealing with market, technology, and personnel risks, government policy poses another risk for greentech (for another perspective see Bürer and Wüstenhagen, 2008, 2009). In this realm the venture capitalists and their small firms may be competing in lobbying against corporate giants that have more capital and stronger connections to lawmakers. Investing in lobbying is expensive and unproductive for a smaller firm.

For a VC investor – whose firms are ‘burning’ cash – waiting for the government mandation of certain standards or technologies or the appearance of subsidies is dangerous. For example, in 2006 Vinod Khosla, a former Kleiner Perkins partner began ‘financing a California ballot initiative to fund alternative energy initiatives through tax hikes on oil companies’ (Associated Press, 2006). Although defeated, it was perhaps the first time venture capitalists had proposed that the public begin subsidizing the firms in which they invested. Today, many venture capitalists are hoping that President Barack Obama’s stimulus will improve the prospects for their portfolio firms. This suggests that venture capitalists have doubts about the financial viability of greentech. In effect, greentech investments may not be able to succeed in the market within which they find themselves, but rather must wait for an outside source to change their market.

For advocates of greentech, there is another concern, namely that government regulation will choose winners, commercialization models, or lock-out better alternatives. The US government decision, in large part driven by lobbyists from factory agriculture and large multinationals, to mandate the use of ethanol may be moving the US in the wrong direction environmentally. Another case is the recent decision to provide \$500 million in loans to the partially VC-financed, Silicon Valley electric car maker, Tesla Motors, whose sole product is an all-electric sports car. The point is not to critique the bad policy decisions. This discussion recognizes that VC investors will not choose the ‘right’ or beneficial technologies. For example, KPCB has invested in Altra Inc., which is California’s biggest producer of ethanol. KPCB has also testified to the US Congress in favor of mandating greater ethanol usage. Ultimately, venture capitalists are agnostic regarding technologies. Their primary purpose is, as it should be, the capturing of outsize returns that justifies their investment practice – a purpose that can be traced back to the pioneers of the VC industry such as American Research and Development (Hsu and Kenney, 2005). Government incentives meant to encourage VC investment in greentech must be structured to discourage rent-seeking behavior, not to mandate inflexible solutions, and incentivize ‘desirable’ investment.

There clearly is a role for the state in encouraging greentech investment, but the test is in the conceptualization and execution of involvement. In the US context, those advocating government regulations and incentives for greentech investment may be disappointed in the outcome, which will be shaped by lobbyists for the existing industries. An alternative history would suggest that VC might operate most efficiently in situations

where governments made sound macro-level economic decisions such as, for example, a carbon tax, and allowed venture capitalists to sort out what they could effectively support. If VC could not operate in such a climate, then it is likely that other financing mechanisms could be substitutes. Angel investors could be substitutes because many are willing to accept higher risks and receive lower returns. In the case of potentially very profitable smaller projects, particularly in the efficiency area, whose potential returns do not justify the attention of full-time venture capitalists, angel investors could provide the necessary funds. Finally, it may be that the greentech field will require entirely new funding mechanisms.

7 DISCUSSION

Given the political economic changes expected to result from global warming and the putative possibility that peak oil has been reached, there should be ample opportunities for innovation and entrepreneurship in greentech. Although this chapter has been skeptical about the general suitability of VC investing in greentech among US venture capitalists, there is a distinct possibility that there will be interest and opportunities. It is emphatically not a statement that greentech lacks economic potential, is unnecessary, or even that there may not be a few good deals in the general greentech area. Many greentech businesses can grow using self-financing and investments from friends and family. The Danish wind turbine industry is a classic case of such growth. For these firms, there is no need for VC. Greentech will offer many opportunities to existing small and medium-sized firms with strong technical abilities. In many sectors, European and Japanese *'mittelstand'* firms will have ample opportunity to use their existing knowledge to develop more environmentally friendly products. They will draw upon their existing competences, as did the Danish metal-working firms that were early entrants into the wind turbine industry. Finally, one would expect a number of large existing multinationals such as Siemens, Hitachi, Toshiba, Sanyo, and others to be able to leverage their competences to produce greentech solutions.

If there is a problem with VC investing in greentech, it is not that value cannot be created in the industry; rather it is because VC is not organized and structured to support most of the opportunities to create value. As we stated, there will be opportunities providing the returns required by VC and which could benefit from VC. Also, it is unlikely that these will create sectors that allow the powerful feedback loops that occurred in IT and biomedical technologies. This most recent spike in greentech investing is exhibiting the same trajectory as previous spikes. The collapse of global equity markets and the drop in energy prices has halted the flow of greentech IPOs. There is little evidence that trade sales of greentech firms promise to be lucrative.

The current retreat of VC investment is not the first. There have been at least two previous alternative energy/environment VC investment bubbles. The first one in the early 1980s had a few successful exits, but when the oil crisis subsided, investment collapsed. The next significant greentech bubble was during the internet bubble of the late 1990s. Wüstenhagen and Teppo (2006) identified four greentech firms that benefited from the wild valuations of the period and went public experiencing excellent returns for investors. However, like so many firms of this period, within three years they had lost nearly

all of their value. Significantly, there were few other greentech IPOs as the VC industry drew back after the excesses of the internet era. But in contrast to greentech firms, some of the internet bubble firms, such as Amazon, eBay, and Yahoo! survived and changed our world. Each of the previous greentech investment surges has proven to be a bubble that, when popped, left little in the way of a new industry or excellent firms that could form the basis for the next surge of interest in greentech.

This brings us to the contemporary wave of greentech venture investing, which has been the largest ever. It is impossible to be certain that VC investing in greentech will continue, or even if the investments already made will survive the suddenly far harsher economic environment of the global economic downturn. Our doubts do not concern the importance of greentech, but whether VC can provide the financial backing necessary to develop new products and services. There may be some green technologies to which the VC model may be well adapted. Often these are related to industries with a tradition of VC investing such as the development of software to manage energy usage, creating energy conscious websites, providing lower-energy consumption electronic components and equipment, and data center management protocols. There also may be interesting opportunities in technology-intensive, energy-efficiency products and a myriad of other areas. Often such firms may not have the potential to grow sufficiently large for an IPO, but may make excellent candidates for trade sales.

One area of substantial entrepreneurial opportunity is in the provision of environmentally friendly products to the giant energy economies of China and India. In China, demand for greentech products is driven by the national government which understands the dimension of the nation's problems. Also, in these nations technical and manufacturing labor costs are sufficiently low that small VC investments could yield large returns. It may be that the most interesting opportunities for VC investment would occur in industries and applications regarding improved efficiency and producing the same products at far less cost, even though these are less glamorous than fuel cells, photovoltaics, electric cars, and biomass conversion.

VC investors in greentech will need to identify business opportunities that are not at risk from proximate incumbents and entrepreneurs able to wisely utilize the high-powered capital they invest. The challenge of finding potential market opportunities of sufficient size to provide significant growth and exit opportunities may prove more difficult than many believe. The hype that drove greentech capital raising and investing from 2006 to mid-2008 is being replaced by the sobering problem of finding firms that can reasonably and rapidly become self-supporting, as constant infusions of VC support are no longer possible due to the changing market for exits.

This admittedly skeptical perspective on greentech for VC investment is not shared by many. For example, a 2009 survey of global venture capitalists concluded that 'a majority of venture capitalists (79 percent) anticipate stable levels of investment across all industry sectors with the exception of the clean technology sector where 63 percent of venture capitalists expect to increase their investments over the next three years' (Deloitte, 2009: 7) Deloitte (p. 8) opined that this increase could be due to 'an increase in government/political support for Greentech and [venture capitalists] are looking more to government participation in both investments and incentives'. Dependence upon government support to make investment decisions financially successful is a dangerous strategy.

Greentech investment has been closely correlated with the price of energy and it is uncertain if this linkage will end. Given the highly volatile history of energy prices, investing in greentech can be treacherous if the VC investor's timing is less than ideal, because when the investment matures it may be difficult to sell the company due to a weak stock market. Expecting VC to play a central role in the commercialization of greentech is unlikely to yield the results that environmental advocates hope. There is a distinct possibility that well-meaning pension funds and endowments seeking to 'change the world' with their beneficiaries' funds may lose their investment in VC firms and not have contributed to environmental improvement. Previous efforts to use VC investing for economic development or other well-meaning causes have often resulted in punishing losses with little advancement of the *cause de jour*.

NOTES

- * I acknowledge the useful comments and suggestions from William Miller, Donald Patton, Henry Rowen and Rolf Wüstenhagen.
1. Teppo and Wüstenhagen (2009) find that many corporate venturers, particularly the energy companies that began operations between 1999 and 2002 had discontinued their operations. They attribute this to a clash between the ventures capitalists and their parent firm's organizational cultures. An observation that is undoubtedly true, but has also been true in the case of nearly every CV operation over the last 40 years. The sole exception to this is Intel Ventures, which is approximately 20 years old and still active.
 2. This chapter is not the place to discuss the notion that 'diversification' is, in and of itself, a good investment idea. Were that to be so, buying lottery tickets would be an investment strategy. The available data on VC returns show that it is the top quartile that make the outsize returns, the remainder do not perform as well as the S&P Index (Kaplan and Schoar, 2005). According to Teresa Barger (2002), from 1980 to 1995 an investor who could not have got into the top 25 percent of the VC funds, would have had a 1.9 percent compound annual rate of return in investing in an index fund of listed equities. What this suggests is that if an investor cannot get into a top-tier firm, diversification will only lead to underperformance. This is the mistake that so many make when they allocate x percent to VC investing. Performance is not improved by an abstract median percentage return, but rather by the returns of specific funds. If one cannot enter these funds and since there is little turnover in the investors in the top quartile funds, then investment performance will be poor (see, among others, Kaplan and Schoar, 2005).
 3. This chapter takes no position on whether global peak oil has been reached.
 4. It is an undisputed fact that fossil-fuel energy in the US has been and continues to be the beneficiary of massive government subsidies.

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