Venture Capital and Clean Technology:
Opportunities and Difficulties[1]

April 8, 2011

Available: http://brie.berkeley.edu/publications/working_papers.html

Andrew Hargadon[2] and Martin Kenney[3]

[1] We thank William Miller, Donald Patton, Henry Rowen, and Rolf Wüstenhagen for valuable comments on earlier versions, with the usual disclaimer that they bear no responsibility for the arguments and conclusions drawn.

[2] Graduate School of Management University of California at Davis.
[3] Department of Human and Community Development University of California at Davis

Abstract

In the last half-century, venture capitalists have financed many of the most important new U.S. technology-based firms and industries. Most recently, venture capital has been touted as a key investor and driver of a new clean technology future. This paper examines the characteristics of successful venture capital investing and the structure and dynamics of clean technology markets to predict whether venture capital is the best model for financing a clean technology transition. We identify the following three key characteristics of technologies and markets in which venture capital can be successfully invested. First, the firm's markets must be large and rapidly growing. Second, the firm's solutions must be scalable, with the particular characteristic that a firm's growth in revenue (and valuation) significantly outpaces the capital cost of achieving that growth. Third, there must be the potential for large andrapid payoff, as either a public stock offering or acquisition by another firm. In the U.S. clean technology market, with the exception of energy being a large market, in nearly all cases these characteristics do not hold. For these reasons, a venture capital model for funding clean technology innovation is unlikely to be successful and the imposition of venture capital goals on clean technology firms may even be harmful to their survival. The current Obama Administration's strategy of providing enormous loan guarantees to a few chosen venture capital-financed firms is misguided because it is likely to truncate the chaotic business model search that characterizes the formation of new industries.

Keywords: Clean technology, venture capital, innovation

1 Introduction

Recent events ranging from climate change science to energy pricing to geopolitical conflict have increased public calls for a revolution in the ways we produce and consume energy. As a result, policy makers are investing billions in pursuit of innovations in clean technology. The current administration has embraced the perspective that the commercialization of clean technology (low-carbon) innovation and increased hydrocarbon production are the best policies to address climate change, as President Obama has said, "In no area will innovation be more important than in the development of new technologies to produce, use, and save energy—which is why my administration has made an unprecedented commitment to developing a 21st century clean energy economy." This article considers whether venture capital can be the financial vehicle for funding and commercializing clean technology innovations and, particularly, whether investing public funds in venture capital-backed ventures will promote the commercialization of clean technology innovations.

The current global energy system is the outcome of a technological trajectory that is now more than one century old and is thoroughly integrated into our everyday lives. Energy systems are literally at the core of all political economies and conversely government actions at all levels are omnipresent within nearly every energy system.[4] With the accretion of decades of political, social and economic decisions, today many, if not most of the subsidies to the existing system are indirect, hidden and indeed, appear as part of a "natural order." For clean technology, the competition will be in an environment built by and upon these arrangements.

The prospect of investing (relatively) small sums on innovation in order to kick-start a clean technology revolution on the scale of semiconductors, computers, and the Internet is very attractive. The Obama administration has committed to a goal of reducing the carbon emissions of this energy infrastructure in 2050 to 83% of the 2005 levels. Lester (2009) calculates meeting this target would require annual expenditures of $250-500 billion, and entail adding roughly 120 gigawatts every year of new low-carbon energy supply. In 2008, by comparison, US developers installed 8.5 gigawatts of wind and 0.338 gigawatts of solar. Moreover, the greatest historical increase in installed energy supply occurred in 2001, with the addition of 67 gigawatts of new, mostly natural gas, energy capacity. The significant political challenges of achieving these targets with existing clean technologies and markets,

---

[4] From regulation to active involvement, including the overthrow of foreign governments, politics is vital to the sustenance of our energy system.

played out in the zero-sum arena of federal expenditures, makes the prospect of a self-financing clean technology revolution much more appealing, but not necessarily effective and, without a guiding policy framework, certainly less deliberate.

The venture capital model has recently been promoted as such a framework and means to direct federal support for clean technology spending, on the assumption that entrepreneurs and the visionary investors who identify and support them are best positioned to guide relatively small government investments in pursuit of clean technology commercialization that will quickly fuel their own revolution independent of further federal support and far more controversial policies such as initiating carbon taxes. Indeed, for the Obama Administration and the U.S. Department of Energy (DOE), venture capital financing has gained significant influence in federal clean technology innovation investments. This is illustrated by the appointment of David Silver, previously a venture capitalist and the Managing General Partner of Core Capital Partners, an early-stage venture capital firm, as the Executive Director of the Department of Energy Loan Guarantee Program (DOE 2009).

Because venture capitalists worked closely with economically transformative start-ups, it seems wise for the federal government to follow venture capital's lead in identifying and investing in new clean technology ventures. And they have, with large loan guarantees to VC-backed start-ups like electric car manufacturers Tesla ($365 mil.), Fisker ($528 mil.), and solar manufacturer Solyndra ($535 mil). These investments— loans to startups are the equivalent of equity-free investments—are being guided by former venture capitalists now working closely with, or for, the DOE, which has more than $50 billion in loan guarantee authority to advance nuclear, clean coal, advanced renewable and energy efficiency technologies.

Is a venture capital-guided model the right investment strategy for a clean technology revolution? This paper explores the conditions under which VCs are likely to be successful at spurring a clean technology revolution and reflects upon the wisdom and efficacy of current government policy initiatives aimed at encouraging and even funding venture investing in clean technology startups.

2 Venture Capital and Innovation

Public policy makers have long been fascinated by the role of venture capital in fostering innovation (Premus 1986 Federal Reserve System 1958). Of particular interest to policy makers is fostering those innovations that revolutionize industries, reshape national competitiveness, drive local economic development, and create new jobs. Not all innovations are capable of such impact. The scholarly literature has characterized innovations by their ability to either strengthen or displace current practices: evolutionary versus revolutionary, continuous versus discontinuous, and incremental versus radical. Revolutionary innovations, by displacing old economic institutions, allow new ones to rise in their place. Revolutionary innovations are "as a rule, embodied, ... in new firms which generally do not arise out of the old ones but start producing beside them (Schumpeter, 1934: 66)." Venture capital, by having identified and invested in small, technology-based firms at the start of recent revolutions in information technology and biotech, thus presents an appealing policy tool for fostering a desired clean technology revolution.

Entrepreneurial new ventures have typically been credited with bringing such revolutionary technologies to market (Schumpeter, 1934; Baumol, 2010), making the fostering of such ventures an attractive policy objective. Such new firms may succeed where established firms cannot since they are able to embrace and organize around emerging technologies. This is because they are unencumbered by the sunken investments, entrenched interests, and preconceived structures and biases of established energy firms and government regulators (Hockerts and Wüstenhagen 2009). Further, a recent study has shown that "nearly all net job creation in the United States has occurred in firms less than five years old," and these from a very small percentage of high-growth, or what might be described as "Schumpeterian" ventures (Stangler and Litan, 2009; Stangler and Kedrosky, 2010: 2). And by establishing leadership in emerging technological fields and reshaping industries and market, these new ventures are also creating new platforms for national competitiveness.

In pursuing clean-technology revolutions, venture capital offers a convenient proxy and legitimating agent for identifying and supporting such private economic activity. Public policy most easily invests in the pursuit of incremental innovations, where political support from established interests strengthens such investments. More difficult is public policy support for revolutionary technologies, as they threaten established interests and any nascent interests are too early and ill-formed to yet have a voice. This presents the policy challenge of establishing policies that support tomorrow's interests at the expense of today's. Because venture capitalists can, indeed, even seek to invest in such revolutionary new ventures, it is hoped they will perform a critical function—alongside entrepreneurs—in Schumpeterian creative destruction in and around clean technology.

In the last twenty years, policy makers have increasingly considered venture capital firms as allies in achieving public policy goals including regional economic development and, most recently, global climate change. Venture capitalists have funded firms such as Amgen, Applied Materials, Apple, Biogen, Cisco, eBay, Federal Express, Genentech, Google, Intel, Netscape, MCI, Oracle, PayPal, Skype, Southwest Airlines, Sun Microsystems, Yahoo!, and so many more firms that have created new industries or dramatically altered existing ones. The implicit belief is that VC financing can discover and fund private sector solutions to a range of societal problems, and in particular, that VCs are best equipped to find, fund, and advise clean technology startups that will transform our existing hydrocarbon-based system.

As background, venture capital emerged as an investment practice in the aftermath of World War II, investing in startups and new ventures with the expectation that some subset of these companies will go public or be acquired for a significant multiple on their original investment. By investing carefully and actively supporting the management of new ventures, early VCs believed they could generate outsize returns (Hsu and Kenney 2005). The goal of these funds is to achieve returns on the order of 20% or more per year over an approximately 10-year period (Zider1998). Because historically, only about a third of VC-backed companies will go public; another third are acquired by larger firms (often with little return on equity); the remaining firms typically go out of business (NVCA, 2009). As a result, the performance of venture capitalists depends upon large payouts from a small set of the ventures they invest in. Thus, in order to cover the majority of ventures in a VC's portfolio that return little to no return on their investments, any single venture must have the potential, and strategic focus, of achieving returns in excess of 50% per annum. Due the enormous returns from the most successful VC firms, today, venture capital is considered a distinct asset class, within which wealthy individuals and institutional investors, as limited partners, commit substantial tranches of money to funds managed by professional venture capitalists. In effect, this can be seen as institutions with the longest-term perspectives committing small percentages of their assets to funding the Schumpeterian growth of the U.S. economy.

There are several reasons put forth to explain venture capital's outsized effect in the Schumpeterian process: First, venture capitalists commit significant tranches of capital to firms with few assets other than their founders and their business plans. They do this in return for partial ownership and without having the goal of ultimately dispossessing the entrepreneur of their idea and firm. This entails significant risk and is an investment strategy that banks or other financial intermediaries are not organized to undertake.

Second, because of the great risk involved, the venture capitalists undertake an extensive due diligence process through which they decide which firms to invest in (Florida and Kenney 1988; Gompers and Lerner 2001; Kaplan and Stromberg 2004; Sapienza et al. 1996; Zacharias and Meyer 2000). In an earlier paper, it was estimated that venture capitalists approximately 160 hours to conducting their due diligence before making an investment decision (Tyebjee and Bruno, 1984). In the due diligence process, VCs intensively investigate the technology, the potential market, the entrepreneurs, and their business plan. Firms are attractive investments when they have a defensible solution, protected by intellectual property, network lock-in effects or some other ability to occupy and defend a new market more rapidly than potential competitors (which are often small firms funded by yet other VCs).[5] The diligence process itself is iterative, forcing the entrepreneurs to sharpen various aspects of their business plan and the VCs to develop an understanding of the potential market. During this process, both the VCs and entrepreneurs develop a collective vision of how the firm should evolve (Burg and Kenney 2000). The decision to invest is accompanied by various benchmarks the portfolio firm is expected to reach prior to receiving new tranches of capital. In effect, a step-by-step plan is prepared even with the knowledge that the incipient market will require the fledgling firm to adjust its plan as their business develops (Gompers 1995).

Third, after the investment is made, since it is equity, the venture capitalist(s) become partners in the venture. They are not passive investors; instead venture capitalists are expected to commit significant time to each portfolio firm by serving on its board of directors, making introductions, helping craft overall strategy, assisting in the recruitment of members of the management team, and monitoring the growth of the firm (Florida and Kenney 1988; Gorman and Sahlman, 1989; Gompers and Lerner 1995). Because seasoned venture capitalists have been involved in a number of startups, they can provide valuable advice on avoiding the myriad pitfalls a rapidly growing firm can experience.

---

[5] Because the tipping point of new markets is preceded by a smaller but still tangible development of the market, venture capitalists base their investment decisions on the quantifiable presence of initial or potential customers, for example, early Google users were not customers for advertising because the advertising model was not yet in place. The reason it appears that VC-funded firms create new markets is because VCs must invest in the incipient stages of market, just prior to its rapid growth, as both new ventures and their venture capitalists succeed when they are positioned to exploit a market's rapid growth to fuel their own.

Finally, as seasoned advisors for early stage ventures, VCs are savvy regarding the raising of subsequent funds that their portfolio firms will require to continue growing. In the biotechnology industry, because of the long development cycles the VCs helped their portfolio firms find and negotiate contracts with large pharmaceutical firms as partners and also pioneered the usage of the now-defunct R&D Limited Partnerships (Kenney 1986). Veteran VCs have experienced a number of stock market cycles and can advise their firms regarding propitious opportunities to make a public offering (Lerner and Gompers 1999). VCs also are constantly scouting for potential acquirers of their portfolio firms and so assist with this alternative exit strategy.

Past success is not always an accurate predictor of future success, and thus venture capital's role in fostering innovation in industries such as semiconductors, information technology, and biotech may not accurately predict its success in other markets where we desire similar revolutions.[6] For this reason alone we should exercise caution. Not all revolutionary technologies have been advanced by new "Schumpeterian" ventures, and not all successful "Schumpeterian" ventures were backed by venture capital. Yet, as Kedrosky (2009: 1) argues, the venture capital industry "has become conflated with entrepreneurship in the popular imagination as well as in policy circles, with the result being a widespread and incorrect belief that venture capital is a necessary and sufficient condition in driving growth entrepreneurship." How appropriate is the venture capital model at effecting Schumpeterian in current energy system?

[6] While most of the greatest venture capital successes have been in the information and communication technology and biomedical fields, VCs will invest in other sectors ripe for significant change. The well-known delivery firm, Federal Express, received VC funding, as have a number of airlines such as Southwest Airlines and the now defunct People Express. The San Francisco microbrewery Gordon Biersch received VC financing, as did Mrs. Fields' Cookies. All of these investments led to IPOs; however VCs have not remained continuing sources of capital for the airline package delivery, airlines, microbreweries, or cookie producers. Entrepreneurship is possible in these and many other industries, but generally there are few transformative opportunities. Put simply, VCs are not biased against particular sectors; rather they invest in firms that have great potential—potential that is as much due to distinct market conditions as technological developments.

3 Market and Technology Conditions for Successful Venture Capital Investing

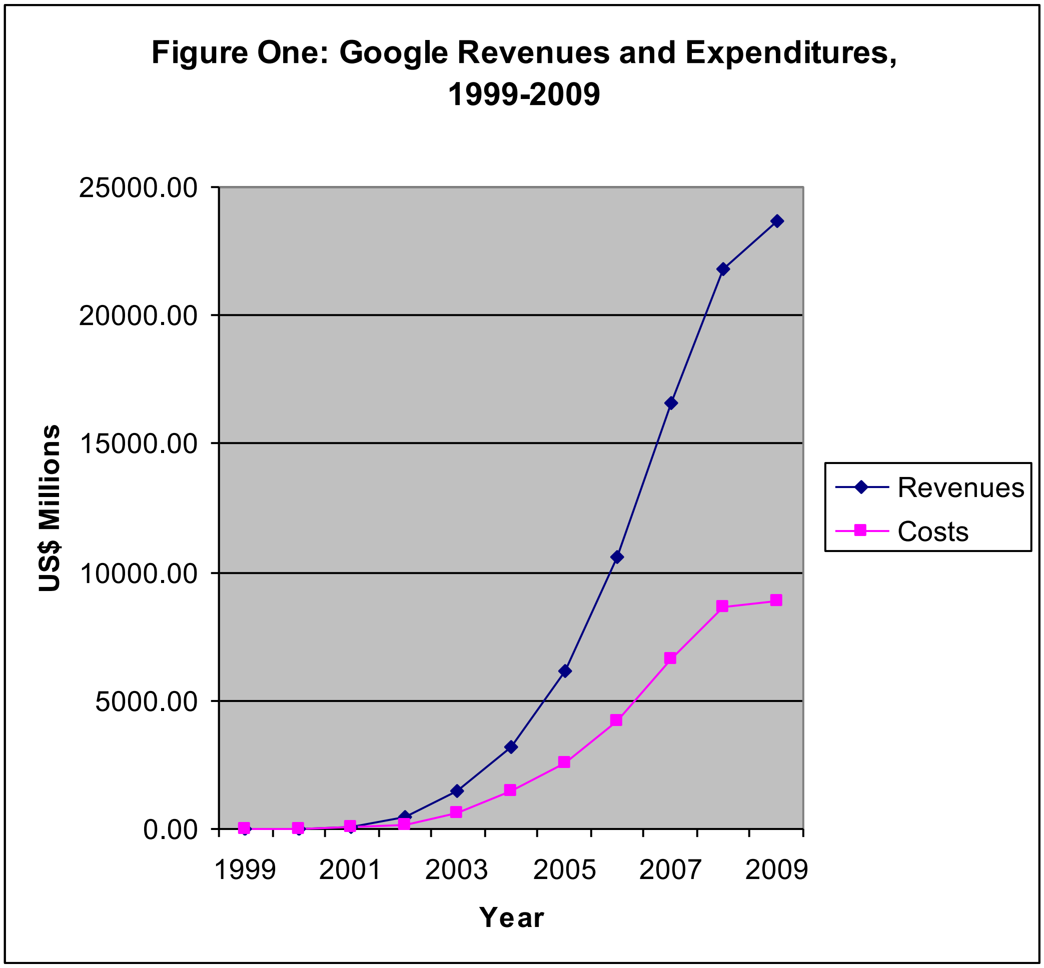
Economic and technical aspects of particular markets, in addition to differences among individual venture capitalists, determine the success of both venture capital investment and of their portfolio companies. In some markets, entrepreneurship can create enormous successes, while in others entrepreneurs cannot build firms capable of creating enormous value rapidly. Successful firms and sectors for VC investing can be reduced to three criteria—rapidly growing markets, scalable technologies and ventures, and large and rapid pay-offs. By extension, if these criteria are not sufficiently satisfied, then the sector is unlikely to be transformed through VC financial support. It is valuable, then, to examine each of these criteria separately to understand how they affect venture capital's role in innovation.

3.1 Large and Rapidly Growing Markets

The rate of a market's growth, which changes over time, affects venture investing. While venture capital is often linked to ventures that gave rise to new markets and industries, VC-backed companies did not, in a strict sense, create those new markets. The growth of a market is typically represented as the S-curve of adoption, with a leading edge that can last for decades before a rapid rise in the arrival of new customers (the tipping point) that signaling the beginning of a radical growth phase. In one study that looked at which firms developed the most important innovations of the 20th century, new firms contributed almost half of the innovations. These contributions, however, were greatest in immature industries (Acs and Audretsch, 1988). To illustrate, the very first microcomputer firms established in the mid 1970s by hobbyists were not funded by venture capitalists (Freiberger and Swaine 1984). VC funding of microcomputer firms began with January 1978, when a consortium of venture capitalists invested in Apple Computer (Apple 1980). As a generalization, Lerner (2009: 60) concludes, venture capital has had "relatively little impact on those [industries] dominated by mature companies… venture investors' mission is to capitalize on revolutionary changes in an industry, and the well-developed sectors often have a relatively low propensity for radical innovation."

New ventures entering a market in or just before its rapid growth phase can grow rapidly by attracting newly arriving customers (rather than wresting existing customers from incumbent technologies and competitors). The markets for Netscape, Yahoo!, Excite, and Amazon, for example, depended on the rapid migration of new users to the technology platform which supported them: the Internet. The early Internet, however, had been in use for over 30 years by a small population of academics and hobbyists prior to the mass market growth began in 1993 and 1994. **Figure One**, for example, shows Google's revenues from roughly its inception in 1999 through 2003 and its public offering (Google 1994). Its market (in terms of users, hosts, and domains) was growing extremely rapidly and Google's revenues were growing with it. Similarly, applications that run on the social networking platform Facebook quickly emerged into a billion dollar market. Playdom, one game maker for this platform, was purchased by the Disney Corporation for $763 million (Barnes and Miller 2010) and another, Zynga, has been more recently valued at over $5 billion. The multiplex nature and the richness of the Internet as a platform have provided new ventures and their venture capital investors with wave after wave of opportunities. So, as new users/consumers discovered the Internet, they also discovered new uses, in what some have termed "user-led" innovation (von Hippel 1988; 2001), and these early user-innovators transformed their use into new businesses—a dramatic example of what Schumpeter termed the opening of "New Economic Spaces."[7]

[7] For a discussion of this unfolding in the early Internet business, see Kenney (2003). The growth of the Internet market is particularly interesting because it grew in two ways: First, when the market did tip, the number of users grew rapidly. This was important because of the sheer number of potential customers. But this growth in users was only the base. The second more powerful growth was in the number of uses of the Internet. This is better understood by the growth in the number of Internet hosts, the number of hours that these users are online, and the seemingly endless variety of new uses that have been invented.



Such moments may occur in existing markets when customers embrace a new technology that rapidly obsolesces existing ones—if the discontinuity is large enough, rapid enough, or legally protected such that the incumbents cannot react. This situation can arise for a number of reasons. For example, the pharmaceutical and medical device industries regularly experience the introduction and rapid adoption of novel therapeutics.[8] Another example is when governments deregulate an industry. For example, VCs financed MCI, which began by competing against AT&T in the long-distance phone market that was being deregulated. In this case, MCI entered selected long-distance markets by purchasing lower-cost superior

[8] In most other markets, such change occurs infrequently. For example, automation sparked radical growth and re-organization of the cigarette market in the late 1880's, but remarkably little has changed in this industry during the past century. The U.S. steel industry experienced significant transformations in the 1850's with the introduction of the Bessemer steel process and again in the 1980's with the rapid diffusion of mini-mills, but otherwise has been quite stable.

foreign equipment, building microwave towers, and discounting transmission costs to large-volume corporate customers. AT&T, for a litany of reasons, was unable to respond effectively and MCI experienced enormous success (Baumol and Ordover 1985; Cantelon 1993).

Without a rapidly growing market, it is extremely difficult for new ventures to grow at a pace that justifies valuations that would support returns to venture capital investors. The return on VC investments depends on the market value of a new company (via IPO or acquisition) and, in new ventures, such valuations are typically multiples of revenues (rather than earnings) that reflect the anticipation of continued growth. For this reason, VC investments have concentrated in particular industries or industry sub-segments undergoing rapid transformation, growth, or experiencing massive discontinuities. These sectors naturally change over time. For example, from 1975 through approximately 1985 new firms such as Apple, Compaq, Commodore, Osborne, and many others developing personal computers were of great interest and attracted much venture capital funding. From 1995 onward Internet firms received an avalanche of investment, but within this larger business space different aspects received investment including browsers, portals, e-commerce, etc. Some sectors are hot for a few years and then become cool. In semiconductors during the 1960s and 1970s, VCs were willing to invest in startups that planned to design, manufacture, and market semiconductors. After 1980, it became too expensive for a startup to build fabrication facilities so VCs began investing in so-called "fabless" firms that only intended to design and market semiconductors, manufacturing would be contracted out. Since the late 1990s, VCs funded firms that only design particular semiconductor functions and market this as intellectual property to other firms, e.g., Rambus and Tensilica. Ultimately, the success of venture capital is predicated upon having investment opportunities with large enough potential returns to compensate for the risks.

3.2 Scalability

Without rapid turnover in customers either through new arrivals (a growing market), rapid technological obsolescence (a churning market), or radical change in market structure, there is little likelihood of rapid growth in customers or consumption. However, the ability of a new venture and its underlying production technologies to scale *as fast as* this market growth is also critical. In other words, new ventures must be able to provision a rapidly growing market without a correspondingly rapid need for capital investment and this scalability is a function of both the venture and the technical and market conditions. For example, in IT and life sciences, there is enormous value-added in product definition and testing; production and marketing is far more costly, so nearly always these small firms sell production and marketing rights to large pharmaceutical firms. Software, along with internet services, are far better situated to increase production of goods and services without a corresponding increase in capital assets. The online retailer Amazon.com illustrates how financial capital can enable a company to scale with a rapidly growing market. Amazon.com's growth tracked the growth of internet users and, as importantly, internet shoppers. Venture capital was critical to enabling that growth. Venture capitalist Tom Alberg, who's Madrona Venture Group invested $100,000 in Amazon in 1995, explained: "The revolution in thinking was everybody saying you have a great opportunity to grow quickly here, money is available, so let's take advantage of it and use that money to grow quickly even if we lose money [initially]."[9]

Unless a company can become the dominant player by scaling faster than competitors, there is little advantage to investing significant venture capital in them. In such markets as Information and Communications Technology (ICT) and biomedical, the returns on equity are relatively decoupled from returns on assets.

[9] YouTube, on the other hand, used considerable venture investment, which bought it market share and shaped the structure of the industry, and had not yet identified a business model to make it profitable (nevertheless, it was bought for $1.65B by Google which, as will be noted, meets the third criteria for venture investing). And of course, such thinking also led to the loss of billions of investors' capital as many other firms embarked on the same venture capital-fueled path and were far less successful.

In other words, the value of a company (and its growth) is exponentially larger than its capital requirements to achieve that growth. For example, in 1996 venture capitalists funded a telecom equipment startup, Juniper Networks. In 1999, after receiving several more rounds of financing, the company went public and within its first day was worth $5 billion and, within nine months, $50 billion. The original investors received profits of over 10,000%. In part, this was a function of the business opportunity, but it was also a function of the Dot.com Bubble equity markets. Nowhere is this scalability, and susceptibility to hype, more pronounced than in Internet companies, where a successful venture can go from 10,000 visiting customers to 10 million within a few months by adding additional servers at a relatively low cost. This scalability—discussed previously—is a dominant feature of the ICT sector and is also reflected in their performance on the public markets.

Scalability, like market growth, is thus a critical factor in the success of venture capital investing because it reflects an emerging venture's ability to grow rapidly—dramatically increasing the value of earlier investments in those ventures. Similarly, not all technologies (or the platforms they inhabit) are mature enough to scale rapidly without experiencing quality issues nor do all technologies necessarily experience decreasing costs as they scale, making early investors dependent for growth on subsequent funding rounds (and thus less able to maintain a favorable stake in the company as it grows).

3.3 Large and Rapid Payoffs

Because of the risk associated with the new ventures in which VCs invest, "winning bets" must pay 10-20 times their investments in order to earn an adequate return *and* cover the fund's losses in other companies. For example, of the firms that venture capital invested in between 1991 and 2000, 14% had an initial public offering, which typically produces significant returns on equity investments, while 33% were acquired (typically these were not for appreciable returns, though in the 1998-1999 period there were enormously profitable acquisitions as established firms felt they had to buy there way into the new Internet industry and newly public firms used their overvalued stock to buy even newer startups). The remaining 53% either failed outright (18%) or remained privately held and quietly failed (35%), essentially losing the venture investment. For this reason, the 14% of VC-backed ventures that did go public provided nearly all of the returns on equity for a given venture fund (and some funds experienced returns on investments of greater than 100% per annum compounded). Considering a venture fund's typical life of 10 years, such winning bets must pay off, or liquidate, within 5-7 years of the initial investment. Obviously, this payoff structure drives venture capital's initial criteria for selecting and managing new ventures: only those with the potential for rapid growth and large payoffs are attractive investment candidates.

While VCs are ostensibly agnostic to the sector within which they invest, there is a path-dependence as they continue and even increase investing in sectors within which they or their competitor VC firms have experienced success. In fields in which investment returns are too low, there is a marked tendency to decrease investment. For example, there is no longer any VC investment in hard disk drive, superconductors, or personal computer firms. What is necessary to initiate or continue the flow of investment is the tangible proof of an ability to earn an out-size return (i.e., there must be successful exits) or significant interest on behalf of their own limited partner investors. When there are successful exits, what can ensue is an avalanche of VC investments in firms having similar characteristics and veritable investment manias develop—as long as there are successful exits the investment continues and investment only stops when the exits wane—but as with all manias the reduction can be abrupt.

Gompers et al. (2008) has argued the critical importance of stock euphorias in particular market sectors, in which frenzied investor have "irrational" interest in stock offerings by new startups, are extremely important. In these periods, stock prices are often bid up to exorbitant levels, allowing VC investors to sell their equity holdings for substantial capital gains. For example, in late 2010 social networking-related Internet companies experienced dizzying rises in valuation: game maker

Zynga is currently worth more than $5 billion; Twitter is worth roughly $4 billion; in December 2010 Groupon declined a $6 billion offer by Google (after being valued at $1.35 billion 8 months earlier, and only having launched in 2008);and in January 2011 Goldman Sachs was arranging a private placement outside normal IPO channels for the six year-old Facebook valuing it at $50 billion. Investment euphoria increases the number of successful offerings and even weak portfolio firms can be listed or are purchased by existing firms because investors are so eager (Helewege and Liang 2004).

In sum, these three characteristics—market growth, scalability, and rapid payoffs—determine whether VCs can successfully fund innovations in a particular sector and with particular technologies. Absent these conditions, it is highly unlikely if not impossible for venture capital *as an asset class* to perform well. Because venture capital uses these criteria to select and manage companies, it is also highly unlikely that VC-backed start-ups, designed and managed by the needs of their investors, can succeed in markets without these criteria. Driving high–growth strategies in low-growth markets; rapidly scaling when the cost of growth outpaces the resulting equity value; or attempting to exit quickly in sectors where valuations recognize low-growth and low scalability—the beneficial effects of venture capital noted earlier may potentially be reversed!

4 Venture Capital Investment in Clean Tech

Innovation in clean technologies pose challenges that may be fundamentally different from those VC-backed startups are best suited to overcome. In the developed world, the types of clean technology innovations being supported by federal backing of VC-backed "Schumpterian ventures" must penetrate existing markets and displace incumbent energy systems that are characterized by four critical features: scale, large capital costs, long lifecycles, and heavy regulation. First, the sheer scale of technological change required to fuel a true transformation—in terms of new capital stock installed—is beyond both the ability of emerging ventures and emerging technologies to address. Second, the value of the existing global energy *supply* system (power plants, transmission lines, drilling rigs, pipelines, refineries, coal mines, etc.) is estimated to be approximately $12 trillion, with a typical asset turnover time of 30-40 years. The global energy *demand* system, including cars and trucks, planes, buildings, appliances, and industrial equipment, represents an even greater amount, though with turnovers ranging from 5-7 years for appliances to 80 or more for buildings (Holdren 2006: 6). Third, heavy regulations—both structure energy markets at the municipal, state, federal and international levels, and subsidize incumbent technologies and institutions This constrains the emergence not only of new technologies but also the new business models best able to exploit them. Given these characteristics, how well does a venture capital-driven model of Schumpeterian innovation fit with aspirations for a clean technology revolution? Consider the aforementioned market and technology criteria under which typical VC-backed ventures succeed.

4.1 Clean Technology Market Growth

The belief that there will be a rapid and widespread transformation of existing markets within developed countries is the attraction of clean technologies to venture investors. Interestingly, since World War Two, with the exception of the biomedical fields, outside the ICT industries, such transformational growth has been the exception rather than the rule. Almost by definition, for the markets most in need of low-carbon innovations, incumbent energy systems are already large, embedded, and heavily regulated. Additionally, they have low growth rates. Growth in the global energy market, for example, has been essentially flat for the last decade (0.14%). Of that growth, new wind and solar (PV) technologies contributed just 0.23% and 0.01%, respectively. And while 2008 saw 3% growth, this is far less than the double-digit growth of the "hot" portions of information technology markets.

To make significant inroads in these markets, clean technology ventures must displace entrenched competitors for existing customers with a relatively undifferentiated product—watts of electricity or joules of power. The long lifecycles of existing energy systems limits the number of customers turning over in a given year; the high capital costs of energy systems limits the risk-tolerance of those customers; and the shared infrastructure and economies of scale enjoyed by existing systems makes it extremely difficult for new technologies to compete on cost. Simply put, while the markets in which clean technology ventures hope to compete is large on an absolute scale, the *relative* arrival of new customers (or churn of old customers) willing to adopt does not provide opportunities for the rapid growth and diffusion of emerging technologies nor provide exponential revenue growth for the new ventures promoting them.[10]

In short, while the markets for clean technology are already extremely large, the churn—the rate at which customers switch from or retire their existing capital stock of energy (supply or demand) and to the offerings of new and smaller companies—is small.

4.2 Scalability in Clean Technology Markets

To displace the existing scale of incumbent systems on which markets currently depend, emerging clean technologies must be able to scale in terms of both capacity and quality. Even if a new technology does have the potential to scale in this way, the costs of achieving this scale in clean technologies rarely reflect the same ratios of investment to growth as historically seen in IT and in biotech. Energy supply technologies, such as solar, wind, or biofuels, find that investments in R&D, while equivalent to similar investments in IT and biotech, are considerably smaller than the investments needed to scale those technologies. For example, Russ Landon, a managing director at the investment bank Canaccord Adams in Boston, compared clean technology startups to IT start-ups: "the capital requirements for energy start-ups are huge." $25 million may develop a new biofuel production process, but an

---

[10] It is this arrival of new customers that makes it possible for clean technologies and clean technology firms to be more successful in rapidly growing developing nations that have far less fixed investments. Not surprisingly, rapidly growing China has received significant clean technology VC investment, aiding to the development of a number of firms.

additional $250 million is needed to create a production plant (and each new plant requires equivalent asset investments).

With clean technologies like wind, solar, or biofuels, scaling production, distribution, and installation often runs to ten times the costs of initially developing the technology, but most importantly continues to grow relatively linearly with the revenue growth of the company. In terms of pools of money, even the largest venture capital funds are relatively small (less than $1 billion per fund and, say, $3.5 billion under management). Even with syndication, opportunities requiring over $500 million are rarely attractive as the potential losses are too great. It is for this reason that VCs stopped investing in firms intending to manufacture semiconductors or build state-of-the-art data centers—the capital investment was just too high. Not only is the risk high, but the investment is lumpy, in that it is impossible to stage the investment. The investment decision is all or nothing.

Moreover, at the scale of capital stock turnover desired for a clean technology revolution, any low-carbon technologies intended to displace existing infrastructure in the near term will initially have no time to develop beyond current levels of reliability and performance, nor to establish new supply chains to produce and service them. Achieving even a fraction of the production volumes needed for additional low-carbon technology capacity requires large-scale construction or reallocation of manufacturing capacity. Moreover, the energy sector is heavily regulated, as both a commodity and a service, and is central to the provision of other goods and services, and as such, new technologies must meet very stringent cost, quality, and reliability expectations before they can enter and scale rapidly to serve the mass market. Indeed, both purchasing and financing decisions demand performance histories of not only the technologies under consideration but also the companies supplying those technologies and guaranteeing their performance.

4.3 Rapid, Large Payouts in Clean Technology Markets

Given the relatively slow transformation of clean technology markets and the expense of scaling up after initial technology development, it is difficult to envision more than a very few clean technology companies generating the growth in revenues, market share, or equity value that would justify VC investing. On the other hand, the mania associated with clean technology may spur short-term profits to venture investors from the IPOs of their startups. For example, A123 Batteries, a VC-backed company, went public in September 2009 priced at $13/share, with investors at that price suffering an immediate dilution of $8.37 per share. After the 180 day lock-up period, when insiders were able to sell the stock immediately began to drop. In January2011, A123 was trading at $10 per share. A123 proved to be a marginal investment for the VCs and a bad investment for the public. Similarly, the electric car manufacturer Tesla went public in June 2010 at $17 per share and by December was valued at $30 per share placing the value for Tesla of roughly 20 times their annual revenues. The multiple can be attributed to either its expected growth in revenue and profits, or mania. Considering existing automotive companies are typically valued at less than a single year's revenues (Ford Motor Company is trading at 33% of revenue while Honda is at 59%), it is unlikely that Tesla's valuation is based on its prospects of becoming the next Ford or Honda. Tesla's IPO raised $226 million, which does not cover the $365 million they owe creditors in DOE-backed loans. They have delivered a total of approximately 1,000 cars a year since introducing its Roadster. Moreover, they are a long way from profitable and, indeed, are pinning their real growth not on the 6-figure Roadster currently available but on the mass-market sedan due in 2012 and similar to the already available Nissan Leaf and Chevrolet Volt.

How long this financial market mania for clean technology continues is unclear. Pinning the hopes of a clean technology revolution on a few companies, and pushing them grow fast and exit early, will not transform the market. As Bob Metcalfe, a partner at Polaris Venture Partners in Waltham says, "Energy investing is ill-suited to venture capital." Regardless of the social benefits, absent sufficient financial returns, private investors such as pension funds and endowments will be compelled to discontinue advancing money to the VCs, unless their investments are driven by political goals—a very dangerous motivation for the pension fund endowment beneficiaries. And in the meantime, internet companies like Twitter (now worth roughly $4 billion), game maker Zynga (now worth more than $5 billion), and Groupon (which just refused a $6 billion offer by Google) continue to reach significant values within several years of inception.

In summary, the market conditions and technological constraints of clean technology typically fall short of meeting the criteria for successful venture capital investing. Some subsectors within clean technology appear to have several but not all of the criteria, many at the intersection between energy and information and communication technology sectors (broadly referred to as the "smart grid"). Yet existing companies like GE, Cisco, IBM, Oracle, General Electric, Honeywell, Hewlett-Packard, Siemens, and others are already targeting these markets, making it difficult for new startups to develop a unique offering, scale it independent of these established companies, and exit successfully. Perhaps more dangerous to the objective of fostering a clean technology revolution is that venture capital investment shapes the strategies of these "Schumpterian ventures." Pursuing a venture capital model for identifying and investing in new ventures is inappropriate in those markets and with those technologies that are not currently experiencing the rapid arrival of new customers, not working with scalable technologies and ventures, and providing large and rapid payoffs to early investors. Perhaps worse, driving companies to scale rapidly when the underlying technologies for production and use are not fully developed can be catastrophic in markets, like energy, where performance (and reputation) is critical. Finally, pushing companies to provide significant investor returns on the venture capital funding timelines may not only distort the venture's strategic decisions, it may also, by generating a wave of underperforming investments, lead other investors (including the federal government) away from this category altogether.

5 Discussion

This paper has identified a set of structural causes, stemming from market conditions and technology characteristics that explain both the success and limitations of venture capital investing. These causes suggest venture capital is an ill-suited investment vehicle—let alone policy framework—for fostering a clean technology revolution. Yet, venture capital investing remains active within clean technology. To avoid a panglossian justification for the presence of venture capital in clean technology, and an attendant rational for billions in federal subsidies and loan guarantees to VC-backed companies, we consider several reasons for this continued presence.

First, recent interest by large institutional investors (e.g., California's pension fund manager, CalPERS) in social investing has led to significant assets being invested in venture capital funds specifically for investing in clean technology. Despite the fact that there has not yet been a clean technology Google, Yahoo!, or Cisco, institutional investors have been eager to invest in clean technology VC partnerships. From 2006 through the first quarter of 2009, there was a rush among U.S. and European VCs to raise clean technology funds. Many U.S. public pension funds and charitable endowments for moral, ethical, and public relations reasons wanted to invest in the "socially desirable" clean technology funds, despite only a limited number of exits. Because venture capital funds are typically ten-year commitments, specific institutional investment strategies will continue to drive investment activity regardless of fit. Moreover, while venture capital fund managers are incented by overall fund performance, they also receive management fees which are essentially unaffected by fund performance. For funds approaching $250 - $500 million, the management fees alone provide considerable income and thus serve as an incentive to launch and manage sector-specific funds regardless of prospects for the fund's ultimate performance.

Second, the significant federal subsidies flowing into VC-backed investments are distorting the capital markets by multiplying a venture capital fund's investments in companies (shielding them from inherent risk) and by confounding technical with political competition for capital. A 2009 survey of global VCs 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 (2009: 8) opined that this increase could be due to "an increase in government/political support for clean technology and VCs are looking more to government participation in both investments and incentives." The primary direct government subsidy for VC-backed clean technology firms is a loan guarantee, often for building manufacturing facilities. For investors such government loans are desirable because they do not dilute the entrepreneur or investors' equity, and have no provision for the government to share in the rewards of success. Ira Ehrenpreis of Technology Partners put this very succinctly: "When I add up the dollars we have received from non-dilutive government funds in the first decade: less than $5 million. In the last two or three years, we have received almost a $1 billion across almost a dozen portfolio companies (Cohen 2010)." If the firm fails, the loans will not be repaid, while if the firm succeeds the government will capture none of the gains.

Additionally, massive government subsidies to individual firms confounds the necessary market competition which selects superior entrepreneurs and technologies with political competition for the allocation of subsidies and guarantees.[11] Today's VCs have entered the political realm by lobbying for government clean technology subsidies and regulations, appointing former politicians such as Albert Gore and Tony Blair as partners, and funding political campaigns. For example, venture capitalists actively invested in ethanol-related

[11] Massive loan guarantees also create arbitrage opportunities for the VCs. The loans make it far easier for the recipient firm to make an initial public stock offering, after which the VCs can exit the investment with their capital gains. For the VC investors, the ultimate fate of the firm is unimportant, as the losses fall upon later investors and the government. This micro-level tilting of the market in favor of specific competitors and mitigating the risk for specific entrepreneurs and their backers is a public investment policy of choosing the potential winners prior to any competitive tests winnowing ineffective technologies, inferior business models, or bad management. For the startup and its venture backers, this places a premium on effective government relations, not technology and market development.

ventures lobbied the federal government for increased ethanol mandates. Kleiner Perkins Caufield & Byers (KPCB) invested in Altra Inc., the now nearly bankrupt firm, which was meant to become a major producer of ethanol. To further their investment, KPCB partners testified to the U.S. Congress in favor of mandating greater ethanol usage (Denniston 2007).

The willingness of the government to provide large subsidies to specific firms has made it a critical part of the clean technology ecosystem and venture capitalists have recognized this. Jason Matlof, a partner at Battery Ventures, stated, "There is so much at stake here that there's an enormous need for entrepreneurs to get close with policy makers. There are billions just for R&D. It's a lot of money" (Mullaney 2009).[12] In 2010, as the stock market mania for clean technology firms waned, Stephan Dolezalek of VantagePoint Venture Partners summarized the current situation very well: "We learned is that we had to be as good as the defense contracting firms at understanding the flow of dollars from government. If government was going to hand out money, we had to figure out how to get our fair share." The dangers of enticing clean technology firms into the defense industry mindset, where price is no object for superior performance, has a long history of not working well in the more price-conscious consumer sector.

Such political competition for favorable support might have little impact on the market acceptance of competing technologies, but for the considerable capital requirements of emerging technologies. The size of government subsidies and loan guarantees (see **Table One**) ensures that firms not receiving them have little prospect of competing with firms receiving such massive and low-cost government support. To illustrate, two electric car firms, Fisker Motors and Tesla Motors,

[12] In a recent report, the Center for Public Integrity noted the rise in venture capital lobbying, advising us to "watch the venture capitalists that have money riding on new technology try to gain advantage in a game that so far has been deftly controlled by the old machine." In addition to lobbying, witness also the rising role of venture capitalists moving into positions within the Department of Energy and advising on the department's investment strategies.

received nearly $1 billion in loan guarantees to establish their own manufacturing plants. The newly publicly traded battery producer A123 received a $249 million matching grant from the Department of Energy to build a production facility;[13] BrightSource, a developer, builder, owner, and operator of large-scale solar energy projects, received a $1.37 billion loan guarantee; and California solar energy firms, Solyndra and Miasole, received $535 million and $102 million respectively, to assist their growth. Such subsidies effectively preclude other ventures, possible technological trajectories, and business models from emerging from their shadows. **Table One** illustrates the size of subsidies. Ehrenpreis stated this very well, it is this "kind of support that has catalyzed a number of companies to get that next level (Cohen 2010)." Of course, other car and battery startups not as successful garnering such large subsidies are in a very disadvantaged position.

Table One about here

These startups, despite receiving such enormous subsidies, still must compete against the established carmakers such as, Ford, General Motors, Honda, Hyundai, Nissan, and Toyota) and with their partners established battery makers such as Hitachi, Matsushita, Samsung, Sanyo (recently acquired by Matsushita for its battery expertise), Siemens, and Toshiba. Moreover, these large firms many of them foreign are likely to be able to acquire the assets of these government-funded startups should they fail. To illustrate, Toyota and Matsushita have already invested significant sums in Tesla Motors. This phenomenon is likely to continue as, even with the enormous government subsidies, these smaller firms have none of the complementary assets such as dealership networks, brand consciousness, etc. that the existing auto makers already have.

The final concern about such government subsidies is that it can create a dependence upon continuing support, which in the energy and environmental sector is notoriously fickle. Pat Eilers, of the private equity group, Madison Dearborn

[13] Of course, all of these were dwarfed by the Obama Administration's award of $8.3 billion in loan guarantees to build two nuclear power plants in Georgia.

Partners, put it well: “I [have] spent an equivalent amount of time in Washington, DC trying to work on policy that gives us long-term certainty (Cohen 2010).” The concern about long-term certainty is particularly important for venture investing, because political changes can dramatically alter in government subsidization patterns. This phenomenon can be seen in Europe where governments are changing the grid feed-in tariffs that encouraged massive investment in France, Germany, and Spain on solar and wind farms (see, for example, Macalister, 2010; Euroactiv.com 2010). The creation of clean technology firms dependent upon continuing government subsidy has a history going back to the alternative energy boom during the 1974 and 1979 Oil Crises, and when government support was withdrawn nearly all of these firms collapsed (Kenney 2010).

A second question raised from this consideration is: what other policy models exist for fueling a clean technology revolution? A valid question—considering that that across the ten years from 1997-2007, only a small subset (16%) of the startups that were on the list of the Inc. 500 list of the fastest-growing private companies in the United States were backed by venture capital companies (a period that includes the peak of the dot-com bubble) (Kedrosky, 2009). This suggests that venture capital may not be a necessary element of “Schumpterian ventures” and that other policy models might be as appropriate. A worthy discussion of these other policy options is not within the province of this paper, but to note some of them.

For example, one central policy model for spurring innovation has been government investments in basic research, under the assumption that the new knowledge generated within university and national research laboratories will trickle down into industrial and market use (Bush, 1945). R&D investment is relatively inexpensive, does not determine winners, and the results can provide opportunities for entrepreneurs to launch small firms. A second policy model has been employing subsidies and price incentives to shape the relative consumption of particular goods and services, and enable the profitable introduction of other competing, but currently more expensive, goods. This policy option accepts as given the technical and market infrastructure and advantages of existing firms, which may be appropriate for the current market and technology conditions of clean technology. Consider GE's recently described strategy of focusing on what CEO Jeffrey Immelt described as "heavyweight products that take patience and piles of cash to develop, weigh tons and last for years—next-generation jet engines, power turbines, locomotives, nuclear plants, water-treatment systems, medical-imaging equipment, solar panels and windmills." Of the eight big-ticket items in his list, six are central technologies of the clean technology landscape. Indeed, Immelt noted that the cost of a typical solar-panel plant is, at around $70 million, more than twice the total investment in Google in the six years before it went public in 2004.

A third policy has been using the enormous purchasing power of the federal government, and particularly the Defense Department, not to develop emerging technologies but rather to produce them and, in the process, drive the maturation of emerging industries. For example, during the early days of the electronics industry modest government defense contracts to small technology-intensive firms enabled them to establish operations to prove their technology and stabilize production processes. This last policy option has considerable promise as the clean technology innovations required under current market conditions will likely already be in the later stages of deployment, where "much of the most important cost-reducing innovation work typically occurs (Lister 2009, p 35)." Indeed, the most likely source of innovations providing these cost reductions will emerge from complementary innovations in the supply chain that enables production, service, and performance of existing technologies. Hence, and counter-intuitively, a production and consumption-driven policy, rather than one focusing on wholly new technologies and companies, may be more appropriate for fostering a clean technology revolution.

6 Conclusion

The promise of venture capital as the motive financial force for Schumpeterian creative destruction is seductive. However, it can be misleading without understanding the structural and market conditions in which venture capital investing has traditionally brought increased innovation and positive returns. Because industries differ in terms of their market conditions, maturity, and technology trajectories, not every industry will provide the same economics and responses to venture capital investing.

Given the political economic changes expected to result from global warming and the possibility that peak oil has been reached, there are ample opportunities for innovation and entrepreneurship in clean tech. Though this essay has been skeptical about the general suitability of VC investing in clean tech, there will be opportunities for entrepreneurs. Many clean technology businesses can and should 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. Moreover, there is every reason to believe that the desire to decrease carbon emissions will offer many opportunities to existing small and medium-sized firms with strong technical abilities. Finally, many large existing multinationals such as General Electric, Siemens, Hitachi, Toshiba, and others will leverage their competences to produce clean technology solutions.

Governments have an important role to play in assisting entrepreneurship in clean technology. However, the government might be better served by removing subsidies to existing energy technologies and unnecessary regulatory barriers locking-in existing technologies. Investing in individual companies will not transform these established markets, and may even hinder the process. Better to invest—through open technology platforms and enabling policies—in collective action that prepares nascent markets, like microgrids, to grow and transform. Massive government capital investments dwarfing anything that any private sector investor would invest in single firms or technologies will alter the competitive ecosystem—and not for the better. Such policies necessarily create non-market incentives to increase investment in lobbying for large government loans or grants diverting firms from private sector customers and market-based learning to focus upon the government as the customer.

Work Cited

Acs, Zoltan J. and David B. Audretsch. 1988. "Innovation in Large and Small Firms: An Empirical Analysis." *American Economic Review* 78(4): 678–690.

7 Apple Computer Inc. 1980. U.S. Securities and Exchange Commission Filing S1/A. Cupertino, CA: Apple Computer Inc.

Barnes, B. and C. Cain Miller 2010 "Disney Buys Playdom in $763 Million Deal, Becoming Hollywood Leader in Social Games" New York Times (July 27, 2010) http://www.nytimes.com/2010/07/28/technology/28disney.html?src=busln (accessed January 18, 2011).

Baumol, William J. and Ordover, Janusz A. 1985. " Use of Antitrust to Subvert Competition." *Journal of Law and Economics*, 28, (2): 247-265.

Baumol, William J. 2010. The microtheory of innovative entrepreneurship. Princeton: Princeton University Press.

Burg, U. von and Kenney, M. 2000."There at the Beginning: Venture Capital and the Creation of the Local Area Networking Industry." *Research Policy*29 (9):1135-1155.

Bush, Vannevar. 1945. *Science, the endless frontier: a report to the President.* Washington, D. C.: Govt. Print. Off.

Cantelon, Philip L. 1993. *The History of MCI : 1968-1988, The Early Years*. Washington, DC: MCI Communications Corporation.

Cohen, Yoni. 2010. "The Lessons Veteran Investors Have Learned." Greentechmedia.com (October 8, 2010) http://www.greentechmedia.com/articles/read/the-lessons-veteran-investors-have-learned/ (accessed January 18, 2011).

Deloitte. 2009. Global Trends in Venture Capital: 2009 Global Report http://www.deloitte.com/dtt/cda/doc/content/us_tmt_2009vcreport_060809.pdf (accessed January 18, 2011).

Denniston, John. 2007. Testimony of John Denniston, Partner Kleiner Perkins Caufield & Byers Before the Senate Energy and Natural Resources Committee March 7, 2007.

Department of Energy (DOE). 2009. "DOE Announces New Executive Director of Loan Guarantee Program." http://www.lgprogram.energy.gov/press/PR-Silver.pdf (accessed January 18, 2011).

Euractiv.com. 2010. “Germany, France cut support for solar power.” (January 21) http://www.euractiv.com/en/energy/germany-france-cut-support-solar-power/article-189131 (accessed January 18, 2011).

Federal Reserve System. 1958. *Financing Small Business* A Report to the Committees on Banking and Currency and the Select Committees on Small Business, United States Congress (April 11)

Florida, R. and M. Kenney. 1988. "Venture Capital and High Technology Entrepreneurship." *Journal of Business Venturing* 3 (4):301-19.

Freiberger, Paul and Michael Swaine.1984. *Fire in the Valley: The Making of the Personal Computer* Berkeley, CA: Osborne/McGraw-Hill.

Gompers, P.A. (1995). “Optimal Investment, Monitoring, and the Staging of Venture Capital,” *Journal of Finance* 50: 1461-1489.

Gompers, P. A. and Lerner, J. 2001. *The Money of Invention* Cambridge: Harvard Business School Press.

Gompers, P. and Lerner, J. 1999. *The Venture Capital Cycle*, MIT Press, Cambridge, MA.

Gompers, Paul, Anna Kovner, Josh Lerner, and David Scharfstein.2008.“Venture capital investment cycles: The impact of public markets,” *Journal of Financial Economics* 87, (1): 1-23.

Gorman, Michael & Sahlman, William A., 1989. "What do venture capitalists do?," *Journal of Business Venturing* 4(4): 231-248.

Helwege, Jean and Liang, Nellie. 2004. “Initial Public Offerings in Hot and Cold Markets.” *Journal of Financial and Quantitative Analysis* 39 (3): 541-569

Hockerts, K. and Wüstenhagen, R. 2010. “Greening Goliaths versus Emerging Davids – Theorizing about the Role of Incumbents and New Entrants in Sustainable Entrepreneurship.” *Journal of Business Venturing*. 25, (5): 481-492.

Holdren, John P. 2006. "The Energy Innovation Imperative: Addressing Oil Dependence, Climate Change, and Other 21st Century Energy Challenges". *Innovations: Technology, Governance, Globalization*. 1 (2): 3-23.

Hsu, D. and Kenney, M. 2005. “Organizing Venture Capital: The Rise and Demise of American Research & Development Corporation, 1946-1973.”*Industrial and Corporate Change* 14: 579-616.

Kaplan, S. N. and P. Strömberg. 2004."Characteristics, Contracts, and Actions: Evidence from Venture Capitalist Analyses." *Journal of Finance* 59 (5): 2177-2210.

Kedrosky, P., 2009. "Right-Sizing The U.S. Venture Capital Industry." *Kauffman Foundation Research Series: Firm Formation and Economic Growth.*

Kenney, M. 2003. "The Growth and Development of the Internet in the United States." B. Kogut (Ed.) *The Global Internet Economy* (Cambridge: MIT Press): 69-108.

Kenney, M. 2010. "Venture Capital Investment in the Greentech Industries: A Provocative Essay." Berkeley Roundtable on the International Economy Working Paper #185.

KPCB. 2008. "Kleiner Perkins Caufield& Byers Launches Green Growth Fund." May 1. http://www.kpcb.com/news/articles/2008_05_00.html (accessed July 10, 2009). (accessed January 18, 2011).
Lerner, Josh. 2009. *Boulevard of Broken Dreams* (Princeton: Princeton University Press)

Lester, R. K. 2009. "America's Energy Innovation Problem." MIT-IPC-Energy Innovation Working Paper 09-007.

Macalister, T. 2010. "Uncertainty Over Spanish Economy Hits Green Energy Firms' Ambitions to Float." *Guardian* (13 May 2010) http://www.guardian.co.uk/business/2010/may/13/renewables-float-spain-economic-uncertainty. (accessed January 18, 2011).

Mullaney, Tim 2009. "Lobbyists Are First Winners in Obama's Clean-Technology Push" *Bloomberg News* (accessed 3/25/2009).

Premus, R., 1986. *Venture Capital and Innovation: Study prepared for the Joint Economic Committee of the U.S. Congress*, US Government Printing Office, Washington, DC.

Sapienza, H., S. Manigart, and W. Vermeir. 1996, "Venture capitalist governance and value added in four countries" Journal of Business Venturing 11, 439-469.

Schumpeter, J. A. 1934. *The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle*. Cambridge: Harvard University Press.

Stangler, D. and Kedrosky, P., 2010. "Neutralism and Entrepreneurship: The Structural Dynamics of Startups, Young Firms, and Job Creation*." Kauffman Foundation Research Series: Firm Formation and Economic Growth.*

Stangler, D. and Litan, R. E., 2009. “Where Will the Jobs Come from?” Kauffman Foundation Research Series: Firm Formation and Economic Growth.

Tyebjee, Tyzoon T. and Bruno, Albert V. 1984. “A Model of Venture Capitalist Investment Activity. *Management Science* 30: 1051-1066.

Von Hippel, E. 1988.*The Sources of Innovation* Oxford University Press, Oxford/New York.

Von Hippel, E. 2001. Innovation by user communities: learning from open-source software, *Sloan Management Review***42** (2001) (4), pp. 82–86.

Zacharias, A. L. & Meyer, G. D. 2000. The potential of actuarial decision models: Can they improve the venture capital investment decision? *Journal of Business Venturing*, 15: 323-346.

Zider, Bob. 1998. "How Venture Capital Works." *Harvard Business Review* vol. 76, no. 6 (Nov.-Dec.): pp. 131-139.