

Venture Capital and Cleantech:

The Wrong Model for Clean Energy Innovation

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Abstract

Venture capital (VC) firms spent over \$25 billion funding clean energy technology (cleantech) start-ups from 2006 to 2011 and lost over half their money; as a result, funding has dried up in the cleantech sector. In this article, we present the most comprehensive account to date of the cleantech VC boom and bust, aggregating hundreds of investments to calculate the risk/return profile of cleantech, compared with those of medical and software technology investments. The results are stark—cleantech offered VCs a dismal risk/return profile, dragged down by companies developing new materials, chemistries, or processes that never achieved manufacturing scale. We conclude that the VC model is broken for the cleantech sector, which suffers especially from a dearth of large corporations willing to invest in innovation. Fortunately, new public and private capital may be on the way after announcements made at the 2015 Paris Climate Change Summit. If a new and more diverse set of actors avoids the mistakes of the cleantech VC boom and bust, then they may be able to support a new generation of cleantech companies.

Introduction

Beginning in 2006, Silicon Valley venture capital (VC) firms bet heavily that the energy sector was ripe for disruption. That year, clean energy technology (cleantech) start-up companies attracted \$1.75 billion in VC investment, dwarfing the hundreds of millions of dollars raised in previous years.¹ Rising fossil fuel prices and recent legislation enhanced the investment case for cleantech. And growing consumer awareness about climate change—sparked in part by Al Gore’s 2006 movie “An Inconvenient Truth”—suggested a sizable market for solar panels, batteries, and biofuels. Although cleantech companies hardly resembled the software investments that dominated their portfolios, VCs could point to the success of start-ups in the semiconductor and biomedical sectors as evidence that cleantech start-ups might also turn scientific breakthroughs into commercial profits.

But just five years later as 2011 came to a close, the cleantech sector was in shambles. Shares of public cleantech firms traded at steep discounts to the market peak in 2008, and almost all of the 150 renewable energy start-ups founded in

Over the course of the carnage, VC investors had plowed \$25 billion into the cleantech sector and lost over half of it

Silicon Valley over the past decade had shut down or were on their last legs. Solyndra, a high-flying start-up manufacturing cylindrical solar tubes, had received \$500 million in federal loan guarantees but filed for bankruptcy and sparked campaign controversy in the 2012 U.S. Presidential election.² Falling natural gas prices from the fracking revolution and a glut of cheap Chinese solar panel exports had undercut the competitiveness of U.S. energy start-ups.^{3,4} And the credit crunch from the financial crisis made it tougher to raise enough capital to achieve the manufacturing scale necessary to compete in a commodity market.⁵

Over the course of the carnage, VC investors had plowed \$25 billion into the cleantech sector and lost over half of it. In 2008, VC cleantech investments exceeded \$5 billion. By 2013 funding had dropped to \$2 billion (Figure 1) and has remained roughly constant since. As a result of the lack of capital, only 24 cleantech companies were founded in 2013, compared with 75 companies in 2007.

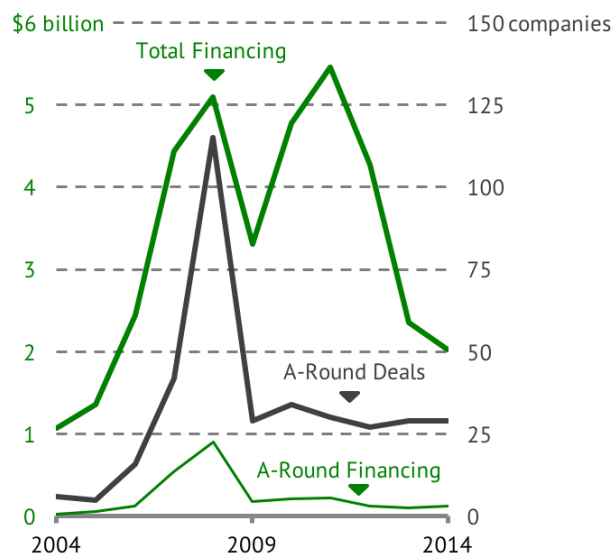
What went wrong? And where should the cleantech sector go from here? To answer these questions, we used publicly available data to compile the performance of every medical technology, software technology, and cleantech company that received its first round, or “A-Round,” of VC funding from 2006 to 2011. We found that betting on cleantech start-ups simply does not make sense for VCs, who require a profile of risk and return from their investments that is better found in other sectors. In particular, cleantech companies developing new materials, hardware, chemicals, or processes were poorly suited for VC investment because they required significant capital, had long development timelines, were uncompetitive in commodity markets, and were unable to attract corporate acquirers.⁶ As a result, they were more likely to fail, and even those that did not fail returned limited capital to investors. By contrast, cleantech companies developing software solutions were a better bet, consistent with the superior performance of the software

sector. As a result, VCs have since reduced the total capital they allocate to cleantech, and within the sector they have shifted investments from hardware and materials to software.⁷

But the VC model does not need to be the only model for supporting innovative cleantech companies. Instead, other investors without the time or capital constraints of VCs may be better suited to scale up cleantech start-ups and realize returns in the longer-term. Corporations could also boost prospects for commercializing new technologies by strategically investing in or acquiring cleantech start-ups, as happens in the biomedical sector. To entice these private sector actors to invest in cleantech, the government must share some of the risk of commercializing innovation. For example, policymakers should boost funding for research and development (R&D). The government should also partner with the private sector to fund joint research with industry and to support projects that demonstrate new technologies at scale.

Figure 1. Boom and bust in cleantech venture capital

VC investment in early-stage companies declined after the 2008 peak, financing shifted towards late stage rounds, and the number of A-round investments has remained relatively constant at



Two announcements made recently at the 2015 Paris Climate Change Conference could jumpstart a recovery in funding for cleantech innovation. Led by Bill Gates, a group of wealthy investors known as the Breakthrough Energy Coalition have pledged funding for early-stage cleantech companies. Their investments will complement a concurrent effort by twenty countries around the world who have signed on to the Mission Innovation pledge to double public R&D funding to \$30 billion by 2020.⁸ Guided by the lessons learned from the cleantech VC boom and bust, policymakers should capitalize on the momentum of recent announcements to develop a more functional ecosystem for cleantech innovation.

Silicon Valley Meets Cleantech

John Doerr, a partner at the prominent Silicon Valley VC firm Kleiner Perkins, announced in a 2007 TED talk that, “Green technologies—going green—is bigger than the Internet. It could be the biggest economic opportunity of the 21st century.”⁹ At the time, many of his colleagues agreed that cleantech represented a massive market opportunity and that the VC model was ideal for capturing it.

That model relies on high-risk investments in early-stage companies in exchange for ownership stakes that may deliver high returns in the future.¹⁰ The start-ups rely on VC funding to bridge the “valley of death” when their technology is too advanced for public R&D funding but not yet commercially viable.¹¹

Typically, VC funds are structured as 10-year partnerships, where outside investors (the limited partners, or LPs) provide capital to the VC fund (run by the general partners, or GPs) to make investments on their behalf.¹² A fund will usually invest in a portfolio of ten to twenty start-ups over the first five years and harvest the returns in the remaining five years. Those returns materialize when a portfolio company is acquired by another firm or when it issues shares on a public market through an initial public offering (IPO)—these events are known as “exits.” VC funds may invest at multiple stages of a company’s development, starting with early “seed” rounds, typically \$1 million or less, continuing through subsequent rounds (named “A”, “B”, etc.) typically on the order of \$10 million, and culminating in late-stage growth rounds that can raise \$10–\$100 million or more. But if a company cannot exit within three to five years of raising a major funding round, the VC is likely to write off the investment and withhold further funding.

When VC funds make ten to twenty investments, they expect that most investments will fail, a few may break even, and one or two might succeed wildly, justifying investments across the portfolio. From the LP perspective, these one or two successes must be sufficient to make up for the investments in all of the failed companies, in addition to returning a premium for the length and illiquidity of the investment. The venture capital fund (run by GPs) typically is entitled to keep 20 percent of the proceeds of a sale, but only after the invested capital has been returned to LPs. This all means that VCs look to invest in start-ups that can quickly achieve scale to address a high-growth market and provide large payoffs (ten to one hundred times the invested capital) within a short time frame.¹³

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Cleantech start-ups fit this mold in the eyes of the VCs who fueled the investment boom from 2006 to 2008. Rising fossil fuel prices supported the investment thesis that clean energy would be a high-growth market. Between 2002 and 2008, rising natural gas prices drove up U.S. electricity prices by 38 percent, and from 1998 to 2008, gasoline prices approximately quadrupled. Financial analysts predicted the price of oil would continue rising (e.g., Goldman Sachs forecasted an equilibrium price of \$200 per barrel).^{14,15,16}

On top of this, policymakers in the United States and abroad offered incentives for clean energy adoption. In 2005, Congress enacted tax credits to incentivize solar, wind, and other renewable energy sources.¹⁷ And from 2009 to 2011, President Obama’s stimulus legislation delivered over \$100 billion to support clean energy through grants, loans, and tax incentives.¹⁸ Public policy abroad also supported the creation of markets for clean energy—Germany in particular offered generous incentives for renewable energy throughout the 2000s.¹⁹

Finally, VCs were emboldened by the hype around, and stock market valuations of, early cleantech entrants. In 2004, Elon Musk invested in Tesla Motors, an electric car maker, and joined its board to great fanfare. In late 2005, three solar companies went public at valuations above \$100 million (Q-Cells, SunPower, and Suntech) followed by a billion-dollar initial public offering by U.S. company First Solar in late 2006.²⁰ Venture capital investors responded by hiring cleantech experts, forming sector-specific funds, and deploying considerable capital to the sector.

A Losing Combination: High Risk and Low Returns

But if cleantech investments had in fact fit the VC investment model, they should have swiftly met VC risk and return requirements—at least ten percent of cleantech startups should have succeeded in a big way, such that their returns alone justified investments across the portfolio. To determine whether this was the case, we adopted the perspective of A-round VC investors—whose decisions are a bellwether for investor attitudes toward a sector—and judged whether their bets from 2006 to 2011 paid off or flopped. Then we compared cleantech start-up performance against that of two other technology sectors that have attracted considerable VC investment: medical technology and software technology (see Box). We found that across all rounds of funding, start-ups in the three sectors received similar amounts of funding at similar points in a company’s lifecycle (Figure 5 in the Appendix). Since VCs were investing similarly across the three sectors, they presumably expected similar performance across the board.

Unfortunately, cleantech start-ups—indistinguishable from companies in the other two sectors in terms of fundraising—clearly stood out as the poorest performers in retrospect. First, cleantech companies were much riskier bets than counterparts in the other two sectors. From 2008 onwards, the cleantech sector had the lowest proportion of companies to at least break even, from the perspective of A-round investors. And more than 90 percent of cleantech companies funded after 2007 ultimately failed to return just the initial capital invested (Figure 2a).

More than 90 percent of cleantech companies funded after 2007 ultimately failed to return just the initial capital

Second, cleantech investments yielded substantially lower returns compared to medical or software technologies (Figure 2b). After 2007, cleantech investments delivered internal rates of return (IRR) much lower than those offered by the other sectors. Cleantech companies funded in 2010 appear to deliver handsome returns—an IRR of 45%—but that result is skewed by a single company: Nest Labs. Acquired by Google for \$3.2 billion in 2014, Nest sells a sleek thermostat that intelligently regulates indoor temperature to save consumers money. Nest could easily have been reclassified as a software company, which would have plunged the return for cleantech companies in 2010 to negative 23% (Figure 2c).

It is worth noting that the returns to A-round investors across all sectors is not particularly impressive. Other studies have demonstrated a wide performance gap between the best VCs and all the rest.²¹ Might cleantech look more appealing to those exceptional investors? Unfortunately, no. A portfolio comprising the 10 software technology companies with the largest exits would return 11.6 times an A-round investor’s capital, compared with an 8.6x return for cleantech and 4.2x for medical technology (Figure 2d). And because the actual dollar value of the exits for the best medical technology start-ups was higher than that of the best cleantech start-ups, the VCs making the investment decisions would have made 20% less from cleantech, even if their limited partners (the investors who fund the VCs) made more. In short, even clairvoyant VCs would have preferred the other two sectors to cleantech.

How We Classified and Evaluated Start-up Companies

1. We used publicly available data to identify start-ups funded between 2006 and 2011 in three different technology sectors:

- **Cleantech** companies are those that develop technologies for energy generation, energy storage, advanced fuels, energy efficiency, energy software, and energy software appliances, as well as those that deploy or finance clean energy technologies.
- **Software technology** companies include those that commercialize mobile applications, enterprise software, e-commerce, games, and social media (but not clean energy software).
- **Medical technology** companies include those focused on biotechnology and pharmaceuticals

2. We evaluated the risk and return of each company:

For all companies receiving A-round funding in a given year and technology sector, we calculated:

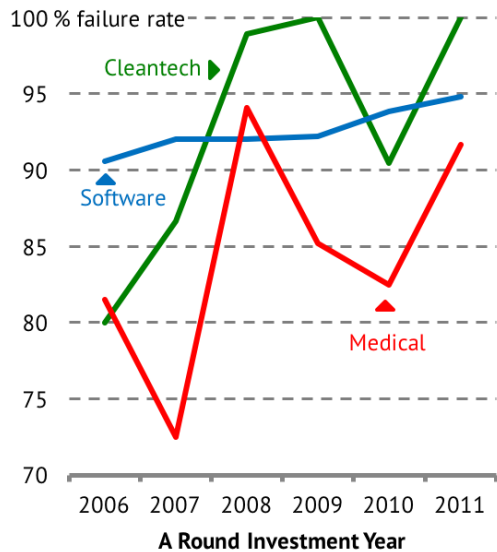
- **Risk:** the proportion of companies that failed to return at least as much capital to the A-round investors as those investors originally put in.
- **Return:** the average internal rate of return (IRR)—a metric commonly used by VCs. Returns can be realized through exits (acquisitions or IPOs).
- **Uncertainty bounds:** There was unavoidable uncertainty in our dataset, because many companies do not report certain parameters. Around each datapoint of risk and return, we added an uncertainty range that is more likely than not to contain the actual value, considering:
 - **Fundraising:** For some companies, the amount of capital raised in one or more fundraising rounds was missing. In some cases, we could fill in the data from other publicly available information, like news articles, press releases, SEC filings, etc. Otherwise, we approximated the funding as the median funding level of all companies in the relevant technology sector that did disclose their funding and set our uncertainty bounds at the 25th and 75th percentile levels.
 - **Exit value:** In some cases, a company was acquired for an undisclosed exit value. This is often an indicator that the exit was not successful from the point of view of the investor; investors tend to advertise lucrative payouts. For these companies, we approximated their exit value as the amount that would just enable A-round investors to break even, and we set our uncertainty bounds to return a 0x to 2x multiple to the A-round investors.
 - **Ownership stake:** The fractional ownership of the company by the A-round investors at time of exit was not available in the dataset. We used well-known examples to approximate the stake at 12%, and we set our uncertainty bounds at an 8% to 16% stake in the company.
 - **Residual unknowns:** Some of the companies in our dataset are still in existence and cannot be classified as failures or successes. To minimize data exclusions, we assumed that any company that has not received a further round of funding or achieved an exit within three years will not provide a return to A-round investors. This is reasonable because 80 percent of companies in our dataset that did return at least the capital invested in the A-round had gone no more than three years without funding. Any remaining company that has received funding in the last three years is excluded from our results because the outcome is unknown.

Figure 2. Risk and reward for cleantech investors compared to software and medical technologies

The risk and return profile of all reported A-round investments in cleantech, medical technologies, and software technologies, shown by year of A-round 2006-2011.

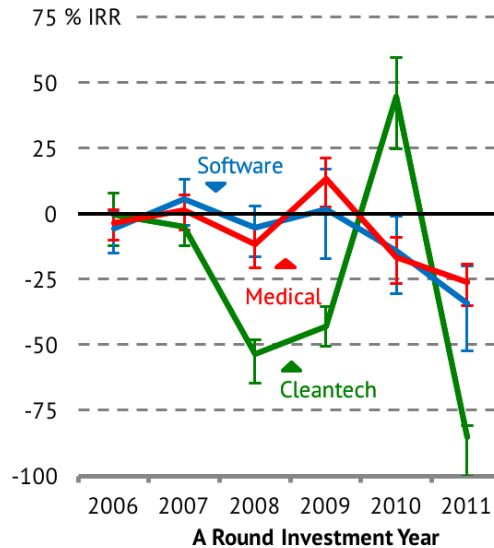
a) Cleantech companies were more likely to fail...

After 2007, over 90% of cleantech investments failed to return capital to investors.



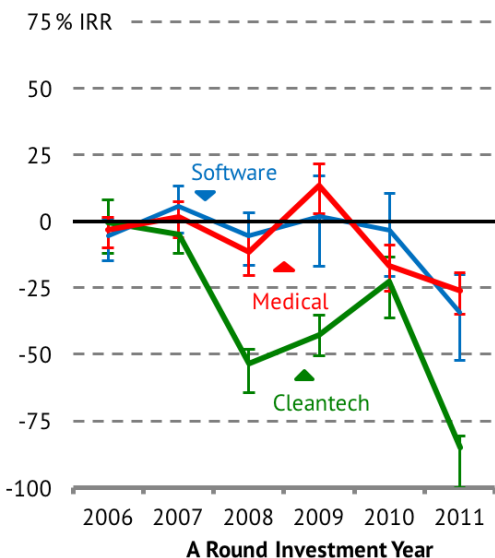
b) ...and yielded lower returns.

After 2006, cleantech investments underperformed the other sectors, with the exception of 2010, the year of Nest's A-Round.



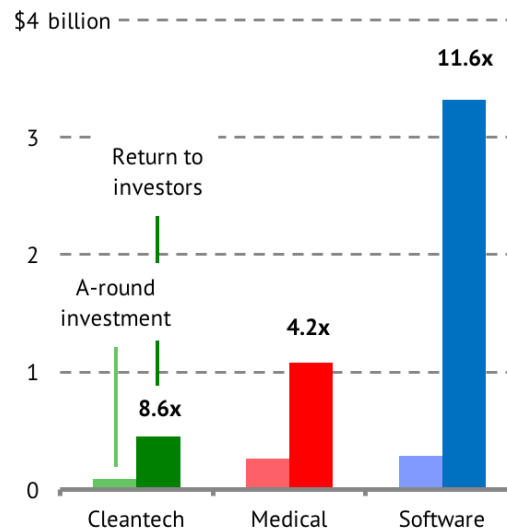
c) Without Nest, cleantech IRR plunges.

Reclassifying Nest as a software company brings the 2010 cleantech IRR down from almost 50% to -25%, and puts that cleantech under the other two sectors after 2006.



d) The clairvoyant investor would choose software

An investor who could pick the perfect portfolio of the ten biggest exits in each sector would choose to invest in software technology.



What Went Wrong?

There are many candidate explanations for why cleantech start-ups flopped and VCs pulled out from the sector. Changing economic conditions certainly played a role, including the financial crisis and credit crunch in 2008, the resultant decline in oil and natural gas prices, and a glut in solar panel manufacturing capacity in China that caused the price of panels to plunge. But digging deeper into the types of cleantech companies that received VC funding and how each type performed, it is clear that most companies failed for reasons independent of external economic trends.

The biggest money loser for VCs was the segment of cleantech companies commercializing fundamentally new materials and processes

Cleantech start-ups fall into five categories (Figure 3a), among which there are huge disparities in performance:

- **Companies developing new materials, processes, or chemicals**—for solar, biofuel, battery, lighting, and other applications—**returned only a sixth of the invested capital.**
- **Hardware integration companies**, which commercialized novel ways to integrate existing hardware components, performed even more poorly, **returning only 5 cents on the dollar.**
- **Cleantech software companies**—like Nest, which dramatically boosted the aggregate return of cleantech companies funded in 2010, and Opower, which analyzes energy use data and helps utilities apply peer pressure on customers to compete with neighbors on efficiency—**returned about three and a half times the capital that A-round VCs invested.** This makes sense, since these cleantech companies could also be classified under the software sector, where strong returns are more common.
- **Deployment finance companies**, which sought investor capital to construct large projects like solar farms based on proven technology, **also performed poorly, returning only a quarter of the invested capital.**
- **Other companies** that fell into none of the categories above—including energy efficiency consultants and waste processing services—**returned only a fifth of the invested capital.**

The biggest money loser for VCs was the segment of cleantech companies commercializing fundamentally new materials and processes, losing A-round investors over \$600 million. For example, in solar photovoltaics, companies like Nanosolar, Solyndra, and Miasole tried to commercialize an alternative to silicon known as “CIGS” (a thin film composed of Copper Indium Gallium Selenide that promised flexibility, light weight, and cheap processing) but struggled to match the scale of production of conventional silicon solar panels, which leveraged tried-and-true manufacturing techniques from the semiconductor industry.²²

In biofuels, our results may actually paint a rosier picture than the reality, because several high-profile biofuels companies have gone public, returned capital to their investors, and then failed to live up to market expectations. Amyris, which designs synthetic microbes to convert Brazilian sugarcane into renewable

diesel fuel, first offered shares at over \$17 apiece that now trade at less than a tenth of that value. And Kior, which invented a proprietary catalyst to convert waste (“cellulosic”) biomass into a biofuel that could substitute for gasoline and diesel, went public in 2011 but filed for bankruptcy in 2014.²³

And companies attempting to follow in the footsteps of Tesla by integrating existing hardware in new ways wiped out \$500 million of early-stage capital. This category included companies like Better Place, which raised nearly \$1 billion to build electric vehicles and create a network of electric vehicle charging stations but went bankrupt.²⁴

From 2010 onward, VCs sharply reduced Series A funding for new companies and transitioned remaining cleantech investments to focus heavily on software

Cleantech companies commercializing innovative science and engineering were especially unsuited to the VC investment model for four reasons. First, they were illiquid, tying up capital for longer than the 3-5 year time horizon preferred by VCs, because working out the kinks in new

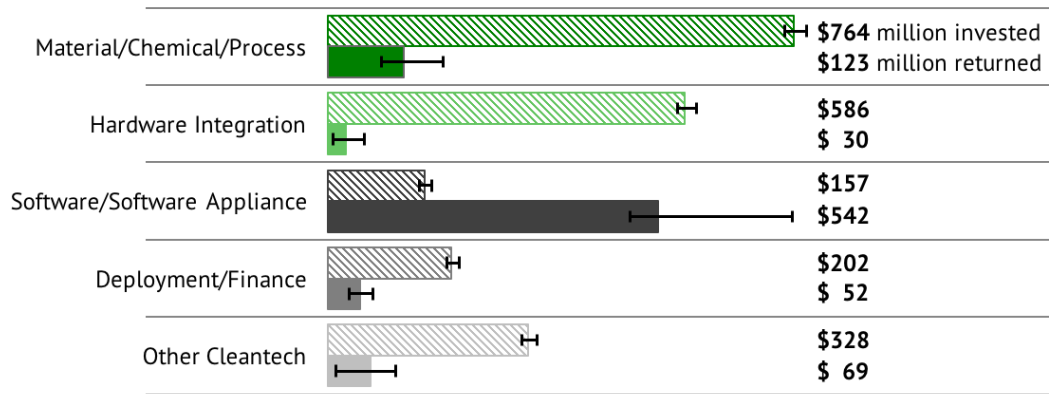
science is time consuming.²⁵ Second, they were expensive to scale, often raising hundreds of millions of dollars to build factories, even while the fundamental technology was still being developed.²⁶ Third, there was little room for error because these companies competed in commodity markets with razor-thin margins—against cheap silicon solar panels or abundant oil and gas—making it difficult to invest in R&D while also operating a lean manufacturing operation.²⁷ Finally, the likely acquirers—utilities and industrial giants—were unlikely to acquire risky start-ups and averse to paying a premium for future growth prospects when they did invest.^{28,29} For most cleantech start-ups, this meant that the sale price couldn’t offer the outsized returns investors needed. These factors conspired to cost VC investors hundreds of millions of dollars before learning whether their cleantech bets had a chance of success—an order of magnitude greater than the equivalent software experiment.

From 2010 onward, as VCs cottoned on to the difficulties facing their early investments, they sharply reduced Series A funding for new companies and transitioned any remaining cleantech investments to focus heavily on software and deployment finance at the expense of hardware and physical sciences (Figure 3b). Some hardware companies that managed to raise money ahead of the decline shifted focus from hardware to software. For example, Bridgelux, a lighting company, recently sold the remaining hardware portion of its LED business to China Electronics Corporation in order to focus on the software-enabled, connected lighting.³⁰

Difficulties in scaling lab science to factory production help explain why cleantech companies underperformed companies in the software sector. But medical technology companies also often involve groundbreaking innovation, are capital equipment intense, and require production at scale—some other factor is needed to explain the gap between medical technology and cleantech start-up performance.

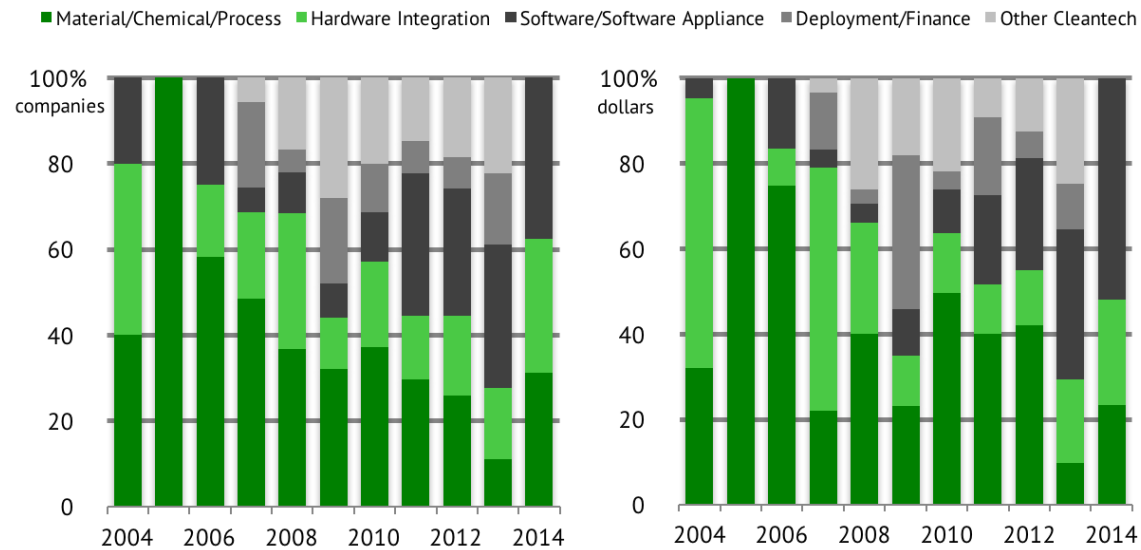
Figure 3. Within cleantech, underperforming hardware led to increased software investment
a) Materials and hardware start-ups did not return capital to A-round VC investors

Companies commercializing new materials, chemicals, manufacturing processes, and hardware dragged down the entire cleantech sector. Only companies commercializing software and software appliances returned capital to investors.



b) A-Round VC Investors have slowed funding for materials and hardware companies

The poor performance of materials, chemicals, and processes companies and the strong performance of “cleanweb” and software appliance companies have driven investors to lower funding for companies commercializing breakthrough science.

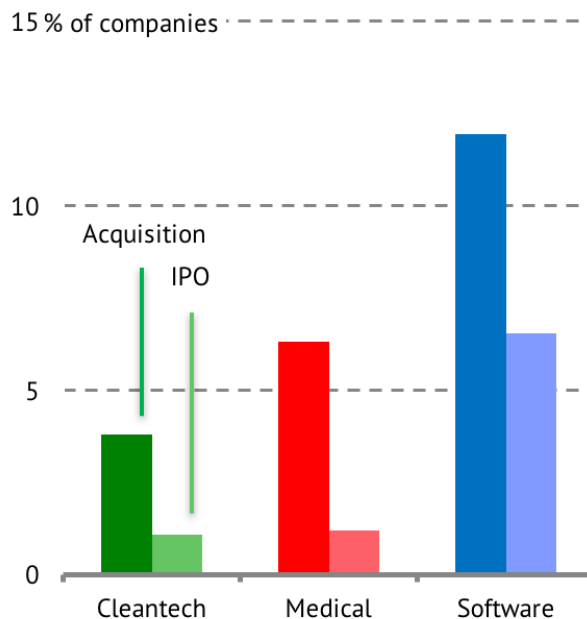


Looking at the nature of exits from the two sectors offers a clue (Figure 4). Fewer than 4 percent of cleantech companies were acquired under favorable terms. By contrast, 6 percent of medical technology start-ups exited through acquisition, offering a route to returning VC capital before a company had fully achieved scale. For example, large pharmaceutical firms would acquire start-ups developing drugs that had passed important milestones in regulatory testing, but had not yet received a green light. But instead of requiring years of further development and VC funding, these companies would return capital to investors and then enjoy the scale and customer pipeline of a large company as they refined their product.

The dearth of large companies willing to acquire cleantech start-ups stranded companies with promising technologies that had run up against the capital and time horizon constraints of VCs. Over the past decade, major energy companies divested much of their clean energy portfolios—Shell announced it would not invest in wind and solar in 2009, and BP left the solar industry in 2011.³¹³² Without a viable acquisition pathway and facing a long grind to achieve the bottom line performance necessary to enter public markets, cleantech companies outlived the patience of VC investors unwilling to lock up their funds’ capital for a decade or tolerate massive capital outlays to scale up production.

Figure 4. No exit for cleantech

Cleantech companies saw fewer exits overall, and fewer acquisitions compared to other sectors.



Beyond the VC Model for Cleantech

One lesson that entrepreneurs may take away from this story is that cleantech companies need to adapt to fit the constraints of VCs. Perhaps any cleantech company ought to be a software company in disguise, and new materials and processes are hopeless money losers.

That lesson is wrong and could be a disastrous impediment to the development of much-needed clean technologies to upend the world’s energy systems—a transformation that software alone cannot accomplish. The correct lesson is that cleantech clearly does not fit the risk, return, or time profiles of traditional venture capital investors. And as a result, the sector requires a more diverse set of actors and innovation models.

Bill Gates and his fellow billionaires have already pledged to provide more “patient capital” for risky cleantech ventures pursuing fundamental science breakthroughs—that is, they will invest early, provide substantial capital, and tolerate long delays before potential returns. And if Congress agrees to double present appropriations of roughly \$6 billion of funding for cleantech R&D—which the Obama administration signed up to in Paris—that money could fund alternatives to VC funding.

Demonstrating first-of-a-kind products and building factories to churn out units at scale will require further infusions of capital

Still, demonstrating first-of-a-kind products and building factories to churn out units at scale will require further infusions of capital. That money could come from institutional investors like pension funds, sovereign wealth funds, and family offices, which are set up to wait for decades to realize returns but are often inexperienced technology investors. Some of these investors are already testing the waters of cleantech investing. In June 2015, the White House announced that multiple networks of institutional investors and charitable foundations around the world had collectively pledged \$4 billion toward scaling up innovative cleantech companies and technologies.³³ More of these investors may enter the cleantech sector if they perceive viable routes for a company to return invested capital, like strategic investments and acquisitions by established companies who offer start-ups a route to scale-up and market access. There are signs that firms are increasingly willing do so—for example, in May 2016, two global oil companies announced technology partnerships with smaller cleantech firms.^{34,35}

Public policymakers can support increased involvement of these actors in supporting cleantech companies by lowering the risk of cleantech investments. First, they should increase support to start-ups and private investors to provide an alternative to VC funding. The Department of Energy can do this by increasing funding for the Small Business Innovation Research and Small Business Investment Company programs and supporting the expansion of private and non-profit cleantech incubators and accelerators. Congress can also increase funding to ARPA-E, the energy analogue to the Defense Advanced Research Projects Agency (DARPA, which was largely responsible for funding early work on the Internet and autonomous vehicles).³⁶ Second, to encourage corporations to participate in cleantech innovation, the federal government should incentivize regional partnerships between large corporations, startups, and incubators and offer favorable technology transfer terms from the national laboratories. Similarly, the government should continue to develop a national manufacturing program by continuing to fund the National Network of Manufacturing Institutes that start-ups and large companies alike can access to improve manufacturing techniques en route to new technology commercialization. Third, the federal government should further expand access to federal research institutes through programs like the Department of Energy’s Small Business Vouchers. Moreover, the Department of Energy should support entrepreneurship at the national laboratories—its programs providing innovators access to shared lab resources at Lawrence Berkeley and Argonne National Laboratories are models that can be replicated across the country.

Indeed, if cleantech entrepreneurs can use shared resources from federally funded research centers, university labs, private research institutes, or incubators, they can avoid the VC countdown clock to exit. And the rise and fall of hundreds of start-ups might have an upside if a new generation of public and private support avoids the missteps of the cleantech VC boom and bust.

Appendix: Full Methodology

We compiled a database of all early-stage venture capital investments in cleantech as well as in two other technology sectors. Previous studies have discussed the changes in the amount of early-stage cleantech investment during the period of increased investment and just after the retrenchment began.^{37,38} In order to report the performance of those investments, we have selected A-Round investments that occurred in 2006–2011, which corresponds to the significant rise and fall in early-stage financing. This data enabled us to compare the risk and return profiles of cleantech investments against those of other sectors. Moreover, we used the database to isolate commonalities among companies that underperformed as VC investments and to identify factors that drove success in other sectors but not in cleantech.

We evaluate the performance of cleantech venture capital investment over the life of the investment as of January 2015, starting with the A-round financing event, and concluding when the invested company either closes or returns capital to the investors. Previous analyses of non-sector-specific venture investment have evaluated the performance of investment funds using proprietary data provided by investors in the funds.^{39,40,41,42} This study addresses the need for transparent analysis based on publicly available data. Because cleantech investments were made by both sector-targeted funds and generalist funds, we use individual financing events and track the returns to investors.

Sector Analysis

We compare the performance of cleantech investments to that of software and medical technology investments. Software companies include those producing enterprise and consumer focused software, web applications, mobile applications, and social media. Medical technology companies include those commercializing pharmaceuticals and medical devices.

We placed each cleantech company into one of five categories based on the core innovation it commercialized through VC funding:

- Materials, chemicals, or manufacturing processes
- Hardware integration
- Software or software appliances
- Finance and deployment
- Other products or services, including recycling, consulting, and energy efficiency audits

Examples of companies developing new materials, chemicals, or manufacturing processes include those developing new collector materials for solar photovoltaics, such as copper-indium-gallium-selenide, or cathode materials for lithium-ion batteries, such as nickel-manganese-cobalt-oxide. The category also includes biofuels companies creating fossil-fuel replacements from plant matter. New processes for creating existing compounds are also included, such as using algae to create ethanol. Hardware integrators combine off-the-shelf components in novel ways. One such company, Better Place, hoped to assemble electric cars and electric vehicle charging stations. Cleantech software companies, like OPower, and

software appliances, like Nest, apply advances in computing power to energy management or energy efficiency. We distinguish hardware from software appliances, where significant value is added by software, even if a tangible product is sold. Companies that finance and deploy clean energy technologies may include those that directly install or provide loans for installations of new technology, including solar panels and energy storage systems. Other companies, those that did not fit into the previous categories, typically offered materials recycling services, recycling infrastructure, energy audits, or energy efficiency consulting programs.

Table 1: Financing events in the data set. The table shows the number of companies in the data set in each technology sector, as well as the breakdown of companies with disclosed A-round financing events. Each subsequent row reports the number of “live” companies remaining after we filtered the data set, first to limit our scope to companies that received A-round financing events between 2006–2011, then to companies whose exit outcome is known or reasonably guessed. The details of this filtering process are described in Section 3.2.

	Cleantech	Software	Medical
All Companies	1611	25635	4174
All A-Rounds	365	6033	982
A-Round 2006-2011	266	3064	523
Included in Set	185	2169	260

Venture Capital Investment Data

The deal-by-deal financing data discussed in this study was obtained from CrunchBase, aggregate cleantech financing data from Bloomberg New Energy Finance, market capitalization data from NASDAQ, and S&P 500 data from the Federal Reserve Bank in St. Louis and Yahoo! Finance. In some cases, when financing data was not available in the data set, additional data was gathered from public sources including news articles, press releases, and disclosures to financial regulators. In order to evaluate the cleantech financing boom that peaked in 2008 and subsequent bust, we evaluate financing rounds that occurred from 2006 to 2011 and exits through the end of 2014. A summary of the available data and how it was filtered for this analysis is shown in Table I.

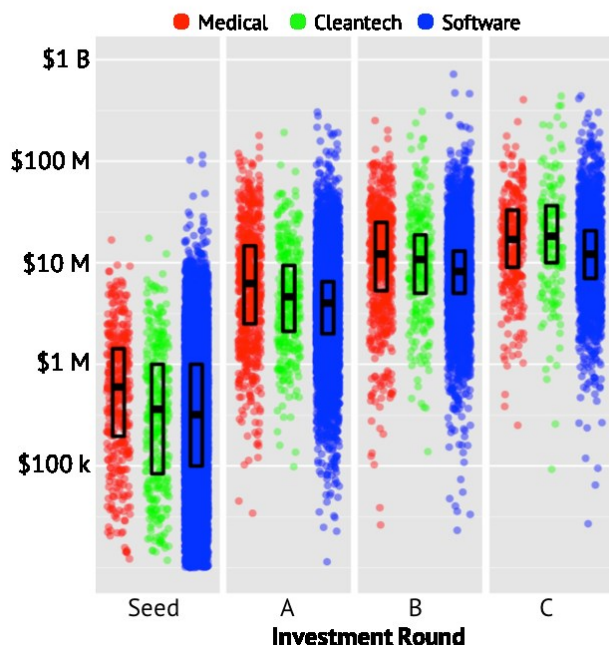
The details of financing events and exits are sometimes unavailable in non-proprietary data sources. Occasionally, the amounts invested in early funding rounds are not public. We find that undisclosed fundraising events are more common in earlier financing rounds, were more common in earlier funding years and have become less frequent, and that these trends are consistent across sectors. As seen in Table I, across the three sectors, approximately 23% of companies had disclosed A-rounds. The distribution of B-rounds (not shown) was slightly more variable: 11% of cleantech companies had disclosed B-rounds, compared to 9% of software companies and 15% of biotech companies. Among the companies in the data set that raised A-rounds, 33% went on to raise a disclosed B-round. Approximately half of the companies that raised B-rounds did not have disclosed A rounds. When an A-round financing event was disclosed but

the amount of money raised in the round was not available, we approximated the funding by using the median level of all disclosed A-round funding events in that sector, and we set uncertainty bounds at the first and third quartile. We found that venture capitalists treated cleantech deals much like medical or software technology investments. Per company, investors deployed similar amounts of capital in each round across the three sectors and made investments at similar times in a company’s life cycle. (Figure 5)

Figure 5. Investment behavior was similar across Medical, Cleantech, and Software

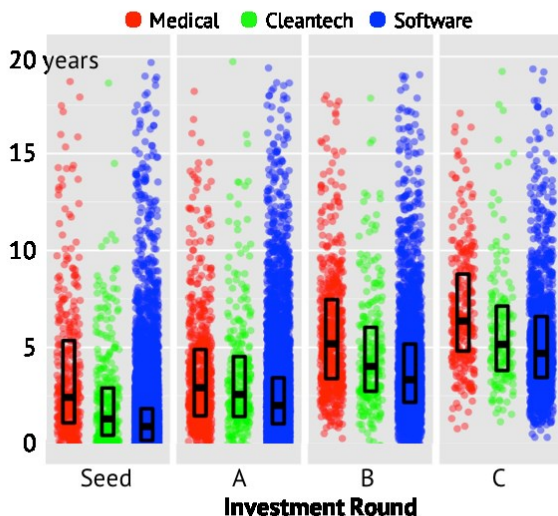
a) Investors deployed similar dollar amounts into companies in all three sectors...

The amount invested in early financing rounds for companies in the data set. Boxes show median, 2nd quintile, and 4th quintile.



b) ...and at similar life-cycle stages.

Elapsed time (in years) from founding of company to close of investment round. Boxes show median, 2nd quintile, and 4th quintile.



Acquisition prices are also not always available, because there is no disclosure requirement unless the acquisition is material to a publicly traded acquirer’s business. Undisclosed exits are often an indication that an investment did not return capital to investors. For these companies, we estimate on average that the exit returned the invested capital to investors, yielding a 1x multiple, and we set our uncertainty bounds at 0x and 2x. Companies that closed or declared bankruptcy are categorized as having failed, and are recorded as having an exit value of \$0.0. To separate companies that “succeeded” from companies that “failed,” we use a very conservative metric, classifying “successful” companies as those who returned more capital to A-round investors than what they originally invested. Because VC investors have a higher threshold for success, this classification will conservatively classify more companies as successes, making any result supporting the hypothesized higher failure rate of cleantech companies more credible.

Our data shows that ninety percent of companies that received venture capital investment during this period neither exited nor closed. Their status as successes or failures can be difficult to categorize. Some of

these companies may be growing steadily and may raise new funds. Other companies may yet exit. Still others will continue to operate for many years without exiting. Companies in this last category are considered failures from the perspective of the investors, who expect a large exit within three to five years. Investors refer to them as the “living dead” or “zombie” companies.^{43,44,45,46} Among these companies that have not exited or closed, we separate them into “dead” companies, and “live” companies. Over 80% of the companies that either exit or raise a new round of funding do so within three years of their previous funding round. Therefore, companies that received venture capital investment in the past three years are categorized as “live” companies, and are excluded from the data set, since their fate cannot yet be determined. It is likely that on average, “live” software and medical technology companies would fare approximately as well as companies who received investment earlier and whose fate has been determined. It is possible that because the cleantech sector is newer, recent investments may perform better than the initial cohort of investments. This may be true in particular if current live companies have adapted to changing conditions after the first wave of failures. For instance, they may have different business models or they may have access to support services of local governments, incubators, and accelerators that were not available to the first cohort.

Those companies that have neither exited nor raised new funds in the past three years are considered “dead” and we record them as having an exit value of \$0. The number of companies remaining in each sector—those that had disclosed fundraising rounds between 2006 and 2011 and are not “live” companies can be found in Table 1.

Limiting the data set to the 2006-2011 time period excludes some notable successful cleantech exits. For instance, Tesla Motors, an electric vehicle manufacturer, raised a \$7.5 million A-round in 2004 and a \$13 million B-round in 2005. The company exited in 2010 with a market value of \$1.6 billion. A-round investors with a 12% stake would have seen the value of their investment rise to \$192 million on the day of the IPO, for an estimated multiple of 26×. Analysis of the IPO filing shows that Elon Musk’s \$6.5 million A-round investment was diluted to a 13.8% stake in the company at IPO, giving him a 34× return on that investment at the time.^{47,48} Nevertheless, this study’s time window includes a large majority of the cleantech companies that received initial funding over the last decade, so results from this period are broadly representative of the cleantech boom and bust.

Assessment of Risk and Return in Venture Capital Portfolios

When comparing the performance of investments we average the investments in each category in each year in an effort to reduce the effect of the well-known high variability in venture capital returns.⁴⁹ An individual VC investor will often make only one or two investments per year; therefore we aggregate all the deals in a given sector in a given year to measure the investor’s expected outcomes. Table III shows the cleantech investments of 2006 to illustrate our methodology. This approach includes both the best and worst outcomes for investors. Other studies have shown that the best outcomes for venture capital accrue to the top quintile of funds.⁵⁰ Therefore, we have also compared performance for only the best investments in each sector.

We evaluate the risk of investment in each of the three sectors by comparing the historical failure rates (Figure 6). For each investment year, we calculate the fraction of companies that failed to reach a successful exit. For instance, in 2006, two of ten cleantech A-round investments returned at least the invested capital to investors (see Table 2). This is recorded as an 80% chance of failure for A-round cleantech investments in that year. Recall that the venture capital investor typically expects an 80%–90% failure rate in early rounds.

Table 2: Cleantech A-round investments in the year 2006. The outcome, distribution, IRR, and cash-on-cash multiple for each investment and for the yearly portfolio of investments are shown. All dollar values are reported in millions.

Investment			Exit				
Date	V _{PIC}	Outcome	Date	V _{exit}	Distribution	IRR	Multiple
01/18/06	\$2.9						
07/01/06	\$25.0	Closed					
07/31/06	\$15.0	Bankruptcy					
08/01/06	\$2.9	Acq. - Undisc	12/01/10	\$23.8	\$2.9	0%	1.00
09/18/06	\$4.0						
10/12/06	\$20.0	IPO	04/21/14	\$687.7	\$82.5	21%	4.13
10/16/06	\$7.0	Acq. - Undisc	10/08/10	\$58.3	\$7.0	0%	1.00
11/1/06	\$5.2	Closed					
11/1/06	\$8.0						
11/10/06	\$0.6	Acquired	04/15/11	\$17.0	\$2.0	34%	3.61
		Failure Rate					
Portfolio	\$90.5	80%		\$786.8	\$94.4	0.6%	1.04

Risks that investors take must be matched by returns from successful investments. There are many ways to evaluate the return of an investment. Because we are interested in comparing the performance across the three sectors, we report the internal rate of return (IRR) and a cash-on-cash multiple (CoC). These metrics are compared for two hypothetical investments in Table 3.

The returns to investors depend upon the amount invested (the paid-in-capital) V_{PIC}, the total enterprise value at the time of exit V_{exit}, the ownership stake at exit f_{stake}, and the elapsed time until returns are realized t. For companies that are acquired, the exit value is simply the sale price. For companies that exit through an IPO, the total exit value used here is the market capitalization based on the price at which the initial shares are offered. It is important to note that there is often a “lockup” period during which early investors and founders cannot liquidate their position (realize a return). This period often lasts 180 days after the IPO. During this period, the publicly traded stock may appreciate or depreciate.

The returns distributed to investors depend upon the number of shares they own at the time of exit. This fractional ownership stake depends on the terms of the original financing deal, as well as subsequent

investments. The stake an investor takes during a fundraising event varies with each deal, and this stake is usually diluted when new shares are issued in subsequent fundraising rounds. Though there are no fixed ranges, when a company exits an A-round investor may own 5–50% of the company (though <15% is typical). Because the exact ownership stakes are often not disclosed until a company files for an IPO, our calculations model the returns assuming an estimated stake of 12%, with our error bounds set at 8% and 16%. This central value and associated uncertainty bounds were derived from numerous publicly disclosed investments in startups across the three sectors. The effects of ownership stake on IRR and multiple can be seen in Table 3.

Table 3: Example investments and returns. The distribution, IRR, and cash-on-cash multiple for an investment of \$10 million and a \$200 million exit are shown as a function of the ownership stake at exit. All dollar values are reported in millions.

Investment		Exit		8% Stake			12% Stake			16% Stake		
Date	V _{PIC}	Date	V _{exit}	Dist.	IRR	CoC	Dist.	IRR	CoC	Dist.	IRR	CoC
	(\$)		(\$)	(\$)	(%)		(\$)	(%)		(\$)	(%)	
01/01/08	\$10	01/01/11	\$200	\$16	16.9	1.6	\$24	33.9	2.4	\$32	47.3	3.2
01/01/08	\$10	01/01/13	\$200	\$16	9.8	1.6	\$24	19.1	2.4	\$32	26.2	3.2

In our analysis, we discount for time from the perspective of the limited partners. In this paper we consider the investment returns exclusive of fees collected by the VC fund. These fees are often structured as an annual operation fee of 2% of the committed capital, which may decrease towards the end of the 10-year life of the fund, and 20% of the proceeds of all earnings after the limited partners paid-in-capital has been returned. See, for instance, Ref. 33. The LP typically does not pay in capital until the investment is made. Therefore, the time of the investment is the time between the funding event and the exit. Table II evaluates the returns from two hypothetical investments that are identical except for the amount of time between investment and exit. As discussed below, time will affect IRR but not the cash-on-cash multiple.

Internal rate of return

The IRR for a given investment accounts for the time elapsed (t) between the investment and the exit. IRR is the value of the discount rate r at which the net present value of an investment equals zero. IRR can be used by an investor to compare investment alternatives, and indeed is often reported by venture capital funds.⁵¹ In general, a higher IRR indicates a better investment, though we note that there are many caveats to using IRR as the only measure of performance and that it may not always lead to a straightforward comparison.⁵²

For a single investment the IRR, R, is given by the expression:

$$R = \left(\frac{V_{\text{exit}} f_{\text{stake}}}{V_{\text{PIC}}} \right)^{1/t} - 1 \tag{1}$$

For a portfolio of n investments, R is given by the solution to the equation

$$0 = \sum_n \frac{V_{\text{exit}}^n f_{\text{stake}}^n}{(1 + R)^{t^n}} - \sum_n V_{\text{PIC}}^n \tag{2}$$

Cash-on-cash multiple

The cash-on-cash multiple (mCoC) provides a way to compare investments without considering the time of the investment. This metric is also often used by venture capital funds when they report their performance. The multiple is determined according to the expression

$$m_{\text{CoC}} = \frac{V_{\text{exit}}}{V_{\text{PIC}}} f_{\text{stake}} \tag{3}$$

For a portfolio of n investments, the total cash-on-cash return MCoC is determined by a sum of the capital distributed divided by the capital invested, according to

$$M_{\text{CoC}} = \frac{\sum_n V_{\text{exit}}^n f_{\text{stake}}^n}{\sum_n V_{\text{PIC}}^n} \tag{4}$$

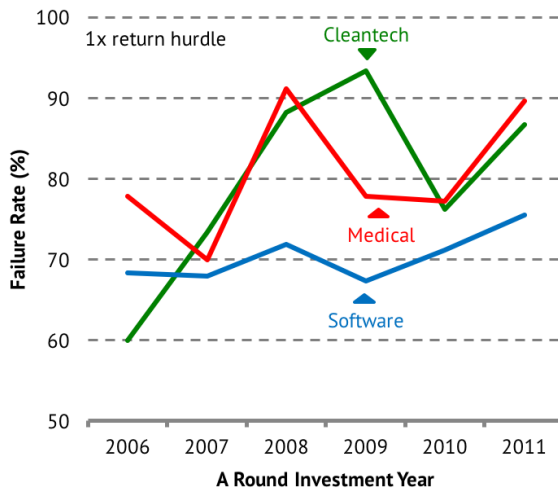
Expected multiple for successes

We also evaluate each investment year according to the expected return multiple on successful investments, which is identical to the cash-on-cash computation, but summed across only successful investments.

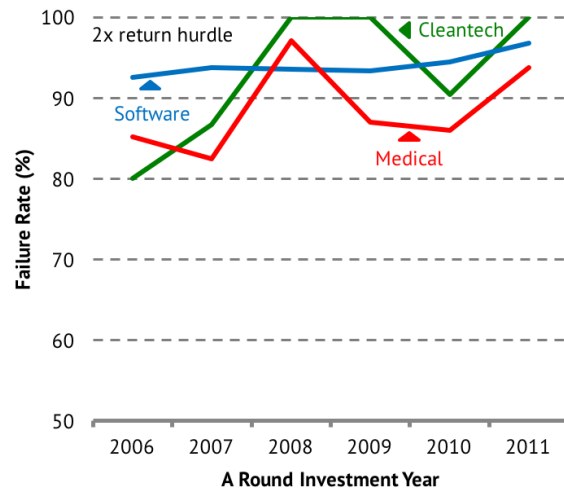
Figure 6. Cleantech investments were riskier than investments in software and medical technologies.

The failure rate of all reported A-round investments in cleantech, medical technologies, and software technologies, shown by year of A-round 2006-2011.

a) Portion of investments that failed to return the original invested capital.



b) Portion of investments that failed to at least double invested capital.



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