On Creating Cleantech Confluences

Best Practices and Partnerships to Mobilize Multiple Sources of Private Capital into Early-Stage Clean Technologies

by

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B.S.E. Civil Engineering
Loyola Marymount University, 2014

SUBMITTED TO THE INSTITUTE OF DATA, SYSTEMS, AND SOCIETY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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Abstract

During the 2015 Paris Climate Change Conference, world climate scientists and policymakers agreed that global temperatures must not exceed a two degree Celsius increase above pre-industrial levels within the next 30 years. It is estimated that this will require investments of $40 trillion or $1.3 trillion per year in new and mature clean technologies. Currently, only about $0.3 trillion of investment goes to clean technology a year and the majority of that funding goes to mature, proven technologies. There is an investment gap in clean technologies, and the gap is especially pronounced for new and unproven technologies that are necessary to bring down costs of the entire system, and produce quicker breakthroughs in CO_2 mitigation. The gap is partly due to the large losses sustained by venture capitalists—one of the greatest source of early-stage capital—who invested heavily in clean technology companies in the years leading up to the 2008 recession. After the market crashed, federal and state governments ended up being among the few remaining supporters of these technology companies because of their public benefits. However, in order to stay below 2 degree Celsius warming, venture capitalists and other private venture investors must be engaged to invest in the clean technology sector again. Public sector funds are not sufficient. In a sector that has produced few winners while receiving substantial government support, the challenge could not be greater.

To address this challenge, we ask three questions of three key actors: How can entrepreneurs attract private investment and scale up pass the Valley of Death? How can venture capitalists build the ability and confidence to invest in the cleantech sector again? How can policymakers address the failure modes that may still exist if investors and entrepreneurs follow best practices? To explore this issue, we conducted interviews, reviewed literature, compiled data from online sources, and compiled information from conferences and workshops. Our findings reveal a “Cleantech Confluence”, or a preliminary set of best practices and partnerships. When simultaneously implemented, the Confluence can mobilize multiple sources of private capital into early-stage clean technologies.

Thesis Supervisor: Jason Jay
Title: Senior Lecturer, MIT Sloan School of Management

Biography

Sergio's journey began in Boise, Idaho where he was born and raised by parents who emigrated from Argentina to the US and it seemed that he was always involved in sports starting to play soccer by age three. By the time Sergio was a teenager, he was traveling around the country playing in competitive regional and national tournaments and even played against the national team of Iraq. Despite changes in life and family situations, soccer remained a constant.

Inspired in part by his mother who worked at an environmental engineering firm, Sergio began taking engineering and environmental science classes in high school, but the decision to pursue this field at the university level did not come about until a high school field trip to a local wastewater treatment plant. He was shocked to see the "treated" water flow back into the Boise river still containing harmful pharmaceuticals, pesticides, and other toxic chemicals.

Sergio turned down athletic scholarships and entered Loyola Marymount University to study Environmental Engineering, and with the high hopes of playing division one soccer. Unfortunately his dreams of eventually becoming a pro soccer player were dashed when he was injured during the first week of tryouts. Even though his focus was turned to academics, his drive for fitness did not die. Inspired by the writings of Dr. Mercola, the health guru, and links between environmental health, fitness training and sports performance, he wrote a personal fitness book published online called *ProNature Fitness: Unlocking Radiant Health Through Smart Exercise*. Academically, Sergio excelled and won a fellowship with the EPA as well as a research internship in upstate New York. He topped off his college career with university wide awards and the Jerome K. Doolan Endowed Engineering Award—a tribute inscribed in the engineering halls of LMU.

By the end of his undergraduate study, he concluded that solutions to environmental problems were not just technological, but also financial and political, so TPP was a natural choice for graduate studies. Although he jokes that the decision hinged on the flip of a coin, it was really because he felt a stronger community vibe at MIT TPP than another similar program he was deciding between at similar school in the Bay Area. At TPP, Sergio gravitated towards the business and entrepreneurial part of environmental technology solutions, focusing on Sustainability-Oriented Innovation with the Sloan Sustainability Initiative. He chose the clean technology "Valley of Death" as the focus of his research with his dream remaining focused on sending better water back into the environment.

—As featured in the Winter 2016 TPP eNewsletter

Acknowledgements

It has been an incredible two year journey at MIT and a privilege to work with absolutely amazing people. I have come a long way from not even knowing that MIT was in Boston to where I am now. It took a leap of faith to jump across the country to a place I had never been and an institute I had never seen, but I knew it was right. I can say without question I am very glad I did. The experience has given me friends, mentors, and awareness that will stay with me forever. I am extremely grateful for having had the opportunity to live and learn within such a vibrant community.

First I want to thank Jason Jay for guiding and inspiring my sustainability-oriented direction at MIT. Everything was up in the air until I found you and the Sustainability Initiative. All your questions and revisions took time but they made me much stronger. I hope to represent the group, the work on SOI, and your style well.

Next I want to thank a few individuals that made key differences along the way: John Sterman for spending the time to talk about the infinite world of System Dynamics, and for bringing a young 20-some year old into an executive Business Dynamics conference; Bill Aulet for making Energy Ventures the pivotal course of my time at MIT, and for providing connections to all start entrepreneurs; David Miller for giving me the opportunity to see the inner workings of clean energy venture investing, and for helping orient my thesis questions and research; and Barb DeLaBarre and Ed Ballo for always being friendly faces—I likely would not have chosen MIT TPP if it were not for our helpful email exchanges in Spring 2014

I also want to thank all my interviewees for taking time out of their busy schedules to help me dig into the realm of clean technology. Without your insights I would have not been able to do this. Thank you Shervin Ghaemmaghami and the rest of MIT FC for being my sound on and off the soccer pitch, and thank you Sarah Kearney and Peter Davidson for the opportunity to be involved in the beginning of Aligned Intermediary.

Finally, I thank my family for their unending love and support. Muchisimas gracias.

Chapter 1: Introduction

Overview

The aim of this master's thesis is to further the conversation on how we might advance the clean technology[1] ("cleantech") sector from a multi-stakeholder perspective. Its goal is to find ways to advance the economic scale and impact of the sector.

Why cleantech? The sector direly needs simultaneous and collaborative action by its champions and enablers (i.e. entrepreneurs, intrapreneurs, investors, policymakers, incubators). These actors play a critical role in mitigating anthropogenic driven climate change and environmental pollution through radical new technologies. The economic, environmental, and security benefits of cleantech are imperative for long-term health and safety. However, cleantech companies face unique and difficult challenges to reaching scale that must be addressed. This master's thesis has consequently sought an array of solutions to help cleantech companies surpass the barriers and bottlenecks holding them back from scaling up. It has parsed several crosscutting themes in cleantech development and financing that serve to better equip cleantech champions and enablers with the knowledge they need to make more informed and confident decisions in their individual and collective capacities.

This thesis is by no means a full illustration of the cleantech ecosystem and its inner workings, or a complete practitioners guide for implementation. It is rather a sketch of how its primary champions and enablers make cleantech an effective tool for public and private benefit. This thesis should be viewed only as a preliminary proposal for how cleantech champions and enablers can simultaneously improve their own lot while improving the lot of the overarching cleantech ecosystem. It assumes that by maximizing the number of cleantech companies that successfully scale, the overall advancement of the sector can be maximized, and the largest proportion of sustainability benefits can be attained for people and the environment. This is what characterizes the cleantech confluence.

Climate and Pollution Impetus

Earth's climate is changing rapidly and entails serious consequences. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment reports that the period between 1983 and 2012 was likely the warmest 30 year period of the last 1,400 years in the Northern Hemisphere (Pachauri et al. 2014). They report that precipitation over mid-latitude land areas of the Northern Hemisphere have also been rising since

[1] Clean technologies include any sort of innovations that enhance resource productivity and reduce environmental pollution. They are defined here as any sustainability-oriented technologies encompassing energy generation, energy storage, energy efficiency, energy infrastructure, transportation, water, biofuels and materials, land and agriculture, carbon capture and sequestration, and waste that reduce greenhouse gas emissions.

1951, while global ocean surfaces rose 0.11° C per decade between 1971 and 2010[2]. The implications of these and many other changes in climate are potentially catastrophic for cities and communities worldwide[3].

The main question in the international scientific and policymaking community had been whether these climate changes are due to anthropogenic activity or natural climate variability. The question was answered in the 2007 IPCC Fourth Assessment when it concluded that climate change was *very likely*[4] due to anthropogenic emissions of greenhouse gasses (GHG) and not natural cycles (Solomon 2007). The report went further to state that in the absence of human activity, natural climate variability would have *likely*[5] induced a global cooling effect beginning in 1950. Since then, it has been corroborated that globally observed climate change should be attributed to anthropogenic activity and not natural variability (Rosenzweig et al. 2008); it is now well established that humans are most likely forcing climate change.

World leaders have responded by demanding drastic GHG mitigation. They selected a 2° C increase above pre-industrial levels as an upper limit to global warming (Accord 2009). This limit was consistent with early science indicating that anything above 1° C "may elicit rapid, unpredictable, and non-linear responses that could lead to extensive ecosystem damage (Rijsberman, Swart, and Stockholm Environment Institute 1990)." In order to have a *likely* chance of not exceeding this threshold, cumulative carbon emissions must not exceed 2,900 $GtCO_2$, or approximately 480 to 530 ppm of atmospheric CO_2 (Pachauri et al. 2014). We have already emitted a cumulative of 1,900 $GtCO_2$ since 2011, leaving a less than 1,000 $GtCO_2$ budget remaining. At the rate of 2015 annual carbon emissions[6], we are expected to reach 2° C warming earlier than 2045. It is therefore imperative to transition to a low-carbon energy economy as quickly as possible within the next 30 years—at least from the standpoint of climatic risk.

At the micro level and outside the scope of the carbon budget, anthropogenic GHG emissions also entail severe human and environmental health consequences. CO_2 and equivalent GHGs[7] are all classified as air pollutants[8], and have known human health impacts beyond heat stress. Asthma, cancer, and death have all been causally linked with other air pollutants released with CO_2 and GHG emissions (Jacobson 2008). For

[2] Based on medium to high confidence intervals of historically available climate data in Europe and North America.
[3] Primary consequences and concerns include large-scale biodiversity extinction, increased food insecurity, drought and water scarcity, severe storms, flooding, landslides, air and water pollution, sea level rise, heat stress, and global economic shocks.
[4] Greater than 90% likelihood of occurrence.
[5] Greater than 66% likelihood of occurrence.
[6] 36 $GtCO_2$.
[7] Other GHGs include water vapor, methane, nitrous oxide, surface ozone, chlorofluorocarbon and perfluorocarbon.
[8] On April 2, 2007, in Massachusetts v. EPA, 549 U.S. 497 (2007), the Supreme Court found that greenhouse gases are air pollutants covered by the Clean Air Act.

example, fine particular matter[9], which is commonly released from the same point sources of CO_2 and GHG, has maintained a strong causal link to mortality (Laden et al. 2006; Samet et al. 2000). Methyl mercury released in CO_2 and GHG emitting coal-fired power plants has had devastating effects through widespread water pollution (Pacyna et al. 2006). It is therefore critical to mitigate CO_2 and GHG emissions also for the sake of long-term sake of human and environmental health.

Economic activities in electricity production, industry, transportation, commercial and residential sectors, agriculture, and land use have all[10] continuously polluted the climate with CO_2 and equivalent GHG (Stern 2007; U.S. Environmental Protection Agency 2015). If emissions continue at current rates, climate stability and worldwide human and environmental health will be put at jeopardy. There is an urgent need for cleantech innovation and deployment at scale, as well as climate policy and social innovation (Mitchell 2012). However, world governments cannot finance cleantech innovation and deployment alone; capital markets[11] must be engaged in order for low-carbon and low-pollution economies to become a reality before it is too late.

Cleantech Financing Gaps

World governments have long attempted to leverage private investment into cleantech. Its social benefits have merited public financing across all stages of innovation and deployment. Public funds, however, remain inadequate and inappropriate to advance the cleantech sector indefinitely. The International Energy Agency (IEA) estimates that between 2010 and 2050, and spread across power, transport, buildings, and industry, the 2° C scenario (2DS) will cost approximately $140 trillion U.S. dollars (IEA 2012). This translates to *annual* costs ranging between $2 to $3 trillion, which is just short of the $4.5 trillion *total* assets U.S. federal reserve banks had in 2014[12]. Therefore not withstanding a carbon tax[13] and the amount of investment people would be willing to make to avoid it: only capital markets have the long-term ability to finance this sum. In

[9] Fine particular matter is classified into those with diameters larger than 2.5 micrometers and smaller than 10 micrometers (PM_{10}) and those with diameters that are 2.5 micrometers and smaller ($PM_{2.5}$). Most PM forms from reactions in the atmosphere when chemicals such as sulfur dioxides and nitrogen oxides are emitted from power plants, industries and automobiles burning fossil fuels.

[10] The EPA estimates that in 2013 the U.S. emitted 6.673 $GtCO_2$ equivalent into the atmosphere. Electricity production contributed 31% of the total, industry 21%, transportation 27%, commercial and residential 12%, agriculture 9%, and land use -13% (managed lands absorbed more CO_2 from the atmosphere than they emitted. This is not the case for all countries.). CO_2 comprised 82.5% of the total emissions, methane 9.5%, nitrous oxide 5.3%, and chlorofluorocarbons, perfluorocarbons and the rest 2.6%.

[11] Private markets for buying and selling equity and debt in cleantech companies and projects.

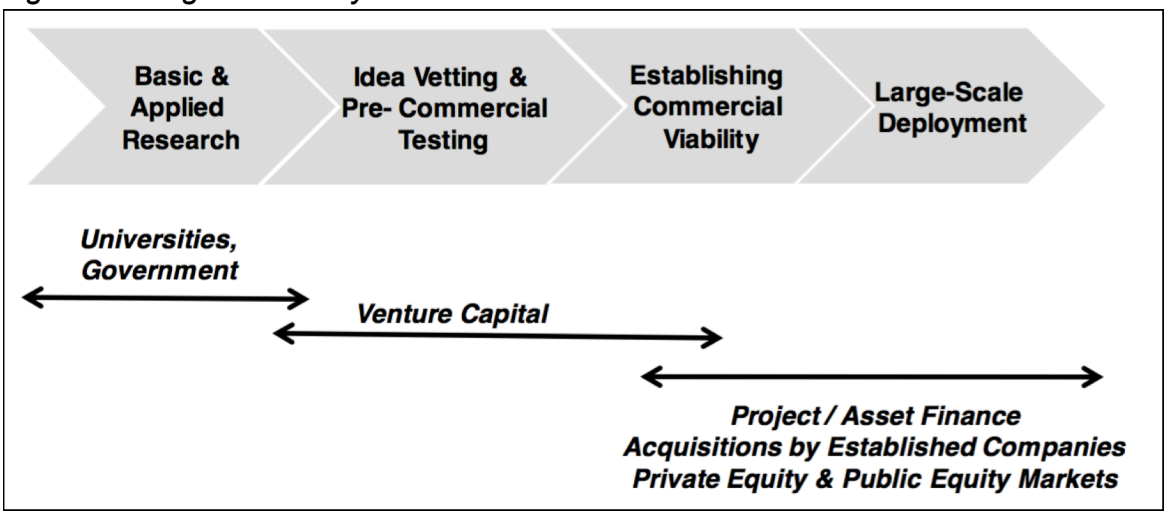
[12] Up to date information available at: https://research.stlouisfed.org/fred2/series/WALCL

[13] Climate Markets & Investment Association estimates that global carbon revenue in 2015 was $22 billion, and Resources for the Future estimates that even a $40 price on carbon in the U.S. would only produce $50 to $70 billion of annual revenue in 2011 dollars. Though a price on carbon could help partially finance the necessary investment in cleantech, implementation of the policy and determining how its revenues would be dispersed is highly contended.

2014, global assets under management (AUM) reached approximately $74 trillion, and the figure will continue to grow into the future (Shub et al. 2016). World governments must therefore leverage its allocation into cleantech in order to effectively finance the 2DS.

Mitigating climate change requires financing both cleantech innovation and deployment—across all stages shown in Figure 1. Many argue that radical new technologies are not needed for 2DS and that deploying a portfolio of existing technologies is sufficient to stabilize GHG emissions by 2050 (Pacala and Socolow 2004). Though deploying existing technologies is essential for large-scale emissions mitigation, early-stage innovation has been counter argued to be just essential to improve the technologies, bring down their costs, and deploy them on an even greater scale (Grubb 2004; Newell 2009). Some models show it will take radical breakthrough innovations in cleantech to significantly reduce mitigation costs for the 2DS to be accomplished (Bosetti et al. 2009), but while private investment in late-stage cleantech deployment has begun to gain traction, in early-stage innovation it has not, leaving a pronounced financing gap.

Figure 1: Stages and Players of Cleantech Investment



Source: (Ghosh and Nanda 2010)

According to Bloomberg New Energy Finance, international clean energy[14] investments reached a record $329 billion in 2015[15]. This was in spite of the fact that Brent crude prices dropped 67% to $37.28 and U.S. natural gas fell 48% on the Henry Hub Index to $2.31 per million British Thermal Units. Private markets have hence proven that they are investing in and deploying mature cleantech as nearly $200 of the $329 billion total

[14] Clean energy is a subset of cleantech, encompassing energy efficiency, generation, storage, and infrastructure. Cleantech and clean energy can be used interchangeably when speaking about the energy industry.
[15] Announcement available here: http://about.bnef.com/content/uploads/sites/4/2016/01/BNEF-2015-Annual-Investment-Numbers-FINAL.pdf

was set for utility-scale projects[16]. Plus, an additional $67.4 billion was spent on rooftop solar, which is another mature technology. While the total investment figure is still far below the estimated $1 trillion per annum needed for widespread transition to low-carbon economies (See Figure 2), it is expected to continue rising and surpass the long-term projections the U.S. Energy Information Administration (EIA) has historically underestimated (See Figure 3).

Figure 2: Current Versus Required Global Annual Investment in Clean Energy

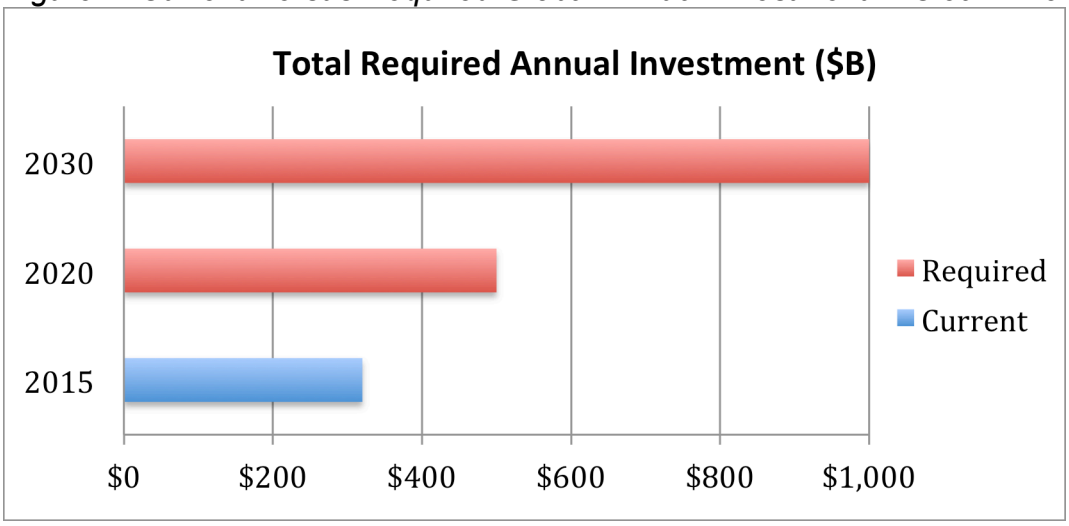
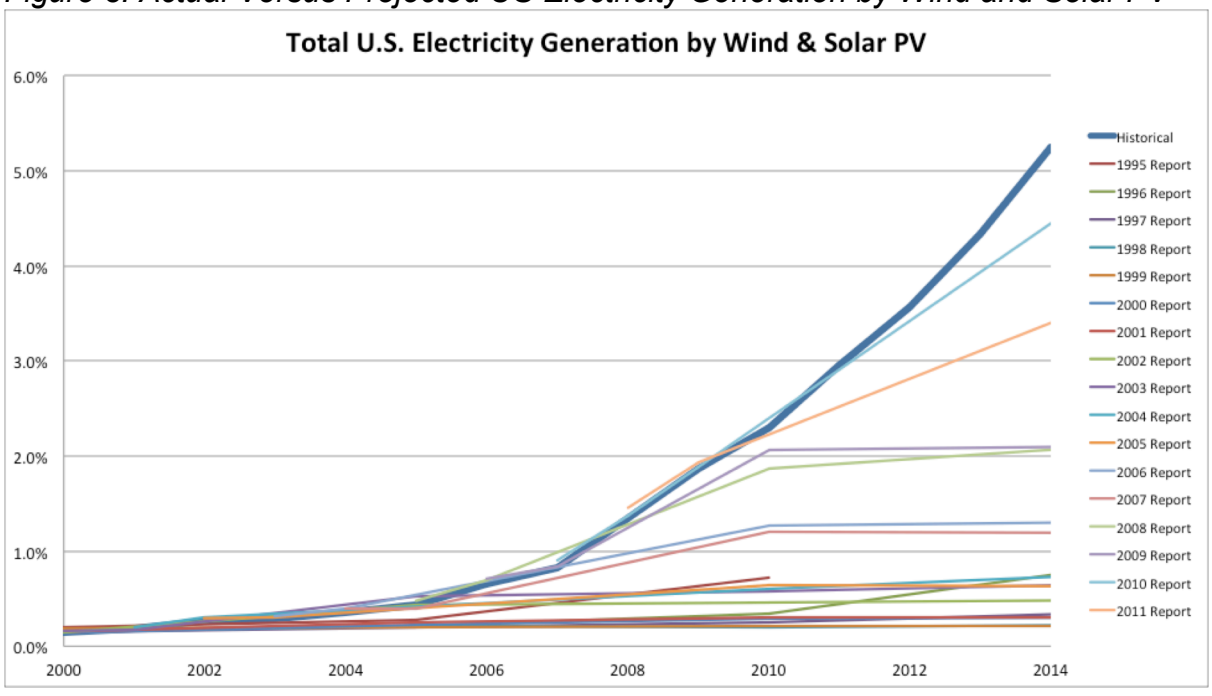


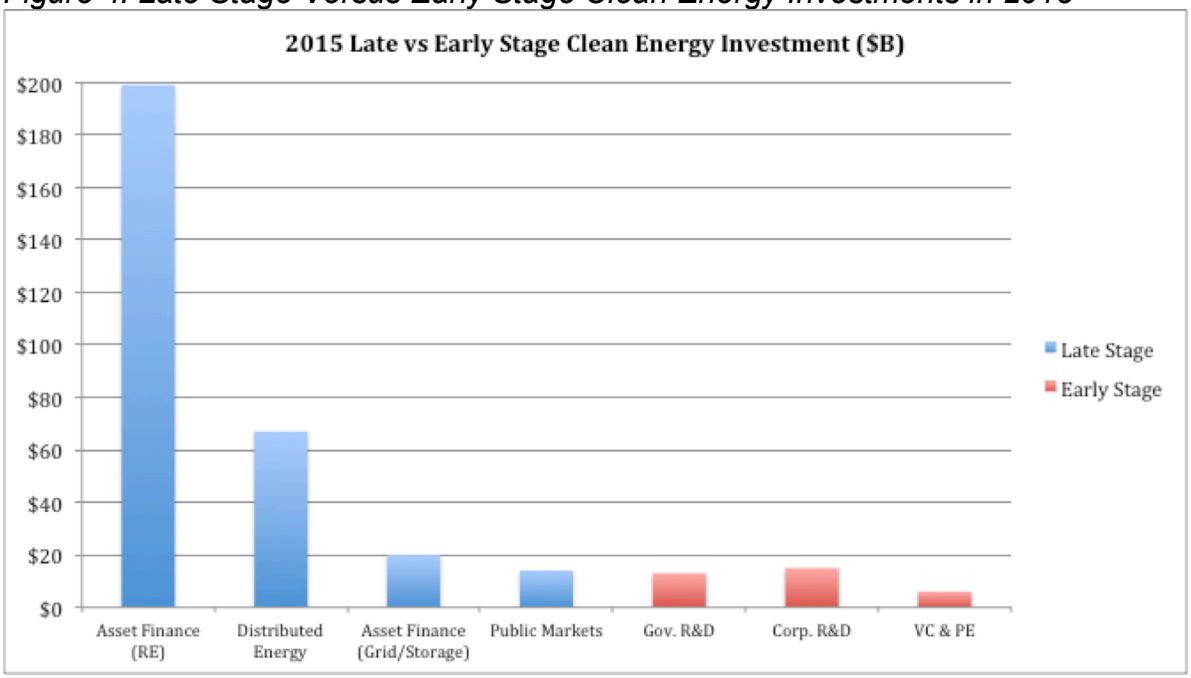
Figure 3: Actual Versus Projected US Electricity Generation by Wind and Solar PV



[16] Wind farms, solar parks, biomass and waste-to-energy plants, and small hydro-electric schemes

At the bottom of clean energy spending is that of venture capital, private equity[17], and government and corporate R&D. Bloomberg New Energy Finance shows that these groups only spent about $34 billion on early-stage clean energy companies and technologies (See Figure 4). This is far less than the estimated $2.6 trillion in cumulative investment required to advance early-stage cleantech for the 2DS by 2050 (Marangoni and Tavoni 2014), which comes out to approximately $75 billion necessary per annum (See Figure 5). With investment trends pushing away from riskier early-stage bets towards safer later-stage investments (Freed and Stevens 2011), and evidence of federal underinvestment in clean energy research, development, and overall funding (Jenkins et al. 2012), the gap has gained notorious prominence in the cleantech sector and has been dubbed as the cleantech "Valley of Death."

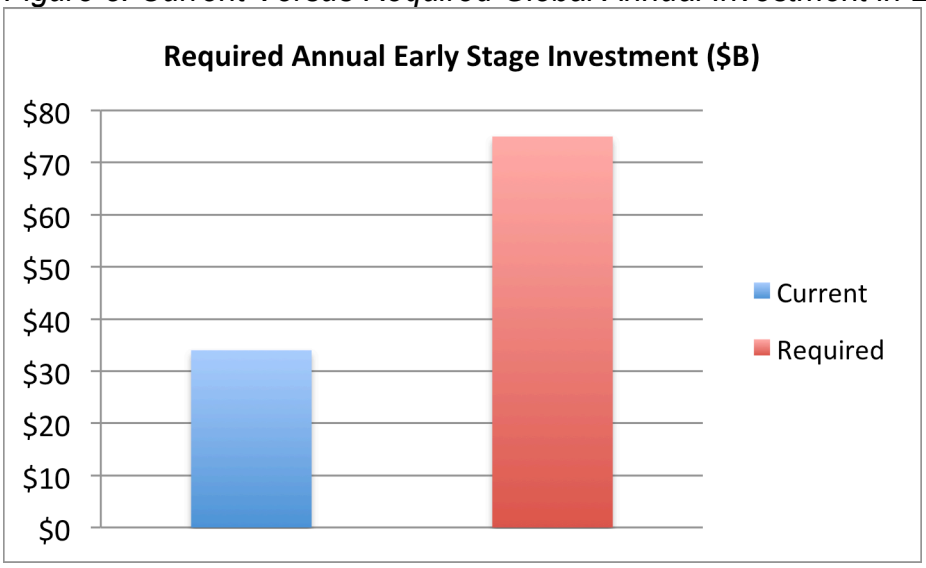
Figure 4: Late Stage Versus Early Stage Clean Energy Investments in 2015



Source: Clean Energy Investment Q4 2015 Factpack, Bloomberg New Energy Finance

[17] Private equity is technically for growth stage companies but included since it is distinctly different from late stage project financing.

Figure 5: Current Versus Required Global Annual Investment in Early Stage Cleantech



The Valley of Death

Most cleantech companies face several hurdles to innovating and scaling up that companies in information technologies[18] (IT) and biotechnology[19] ("biotech") do not (See Figure 6).

[18] Including consumer and enterprise software, Internet, mobile, cloud computing, telecommunication, and computer hardware companies.
[19] Pertaining to biotech companies with medicinal and pharmaceutical applications. Biotech has overlap with cleantech with regards to biofuels, in which case it faces the same commercialization hurdles as cleantech.(Holdren 2006)

Figure 6: Innovation Factors in Pharma, IT, and Energy

	PHARMACEUTICAL	SOFTWARE & IT	ENERGY
Time Required to Innovate	10-15 years	1-5 years	10-15 years
Capital Required to Innovate	Medium to High	Low to Medium	High
New Products Primarily Differentiated By	Function/Performance	Function/Performance	Cost
Actors Responsible for Innovation	Large Firms Reinvesting in R&D; Biotech startups, often VC & govt. funded; Govt. (NIH, NSF)	Dynamic Startups, often VC-funded; Large Firms Reinvesting in R&D	Various: Utilities, Oil & Gas Co.s, Power Tech Co.s, Startups, Govt.
Typical Industry Risk Tolerance	High	High	Low
Innovation Intensity	High	High	Low
Intellectual Property Rights	Strong	Modest	Modest

Source: (Jenkins and Mansur 2011)

First, cleantech has a unique need to be physically near its end markets. This is unlike many IT and biotech innovations because cleantech performance is tied directly to geographic location (Knight 2010). The implications of this are several fold. One is that individual clean technologies will not be able to reach the same global economies of scale that were attained by modern energy conglomerates. Cleantech end markets are decentralized and non-uniform, and different regions give rise to different cleantech clusters (Tierney 2011). Additionally, the geographic dependency of cleantech gives rise to different regulatory environments, which may or may not be favorable to private investors (Bürer and Wüstenhagen 2009). And lastly, because venture capitalists prefer to be close to their investment companies (Bernstein, Giroud, and Townsend 2015), the geographical dependency of cleantech places additional constraints on investment flow into the sector. These location and geography dependent factors make cleantech scale up notoriously difficult.

Second, cleantech companies sell commoditized products differentiated primarily by cost[20]. This is unlike the products that IT and biotech sell, which are differentiated primarily by function and performance. The implications of this are that new cleantech ventures must compete against conventional fossil fuels on a price basis rather than a unique value proposition. Oil and fossil fuel prices therefore become significant risks (Silla 2011) and unpredictable since they have historically been subsidized by hundreds of billions of dollars (Victor 2009). It is not until new technologies reach the status of U.S. residential solar energy, which has reached grid parity in several states[21], that it can compete effectively against fossil fuels. But either way it will still require substantial government support for other technologies to reach grid parity, which is a luxury not all clean technologies have been granted like residential solar (Goldberg 2001).

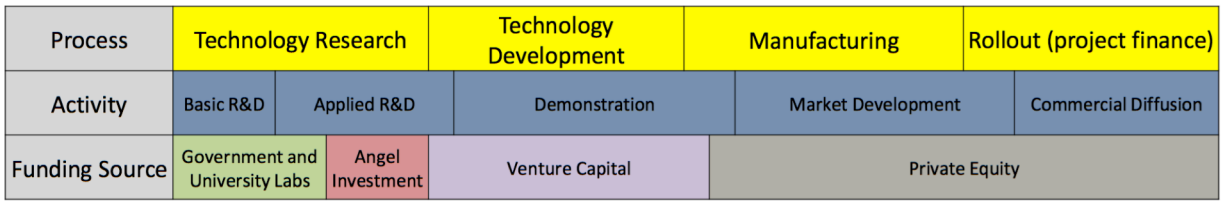
Third, the asset turnover and sales cycles in the energy industry are too long for new startup companies to grow. On the supply side, utilities are often the end customers for many cleantech ventures. They are highly regulated, risk-intolerant, bureaucratic, slow and have 30 to 40 year operating cycles before new infrastructure and supply sources are added (Holdren 2006). On the demand side, turnovers range from 5 to 7 years for appliances and up to 80 years for buildings. This makes sales and growth for many cleantech companies a long and difficult endeavor, and highly opposed to IT and biotech companies that can quickly innovate and use patents and complex software to capture and secure large markets.

Fourth, cleantech requires significant time and capital to innovate and scale up. Unlike IT, cleantech requires several forms of demonstration projects before commercialization can begin, and these demonstrations are large and capital-intensive (Bossink 2014). The demonstration projects require significant investment by private investors and do not always have public resources to assist in financing (Gallagher et al. 2011) (See Figure 7). Unlike biotech, which also requires capital-intensive demonstration projects in various phase trials, cleantech still requires significantly more capital if it reaches commercialization because of its final product manufacturing build-up. The upfront and fixed costs in cleantech are prohibitively large, and make market entry and scaling up extremely difficult for new companies that are competing against existing technologies by variable costs alone.

[20] Certain demand-side technologies in energy and water efficiency can be differentiated by performance, such as double pane windows, but on the supply-side they are differentiated by cost.

[21] The point at which the levelized cost of energy becomes equal between clean and traditional energy sources. According to GTM Research, 20 U.S. states have reached grid parity as of 2016.

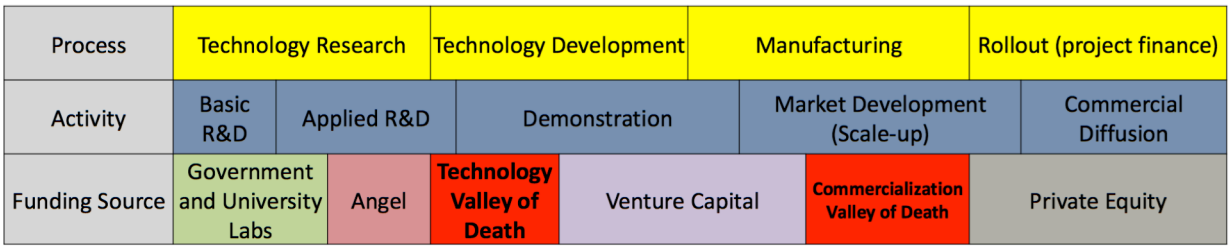
Figure 7: The Classic Investment Stage Progression for Cleantech Investing



Source: (Heap, Pless, and Aieta 2013)

Out of all the possible investors, venture capitalists (VC) are best poised to fund cleantech innovation and deployment yet are reluctant to invest because of the inherent and perceived: 1) capital-intensity, 2) market, technology, and regulatory risk, and 3) general ambiguity as a new sector for private equity investment (Wustenhagen and Teppo 2006). These factors lead to a widespread lack of private investor financing for early-stage cleantech companies, and give rise to the infamous Valley(s) of Death (See Figure 8).

Figure 8: Technological and Commercialization Valleys of Death



Source: (Heap, Pless, and Aieta 2013)

The technological and commercialization Valleys of Death shown in Figure 8 are referred to as "cash flow" Valleys of Death (Murphy and Edwards 2003). However, there is also a subtle "managerial" Valley of Death in early-stage cleantech. These companies need strong commercially oriented management teams to attract private investment (Salerno, Lambkin, and Minola 2009) as VCs and other early-stage investors frequently rank managerial capabilities as one of their top criteria for investment (Hall and Hofer 1993).

Most cutting-edge cleantech companies often have technical management teams that lack the business skills needed to manage energy/water production companies. On the flipside, sometimes these companies acquire professionals with deep business experience in running large energy companies and utilities, but they still do not know how to manage a cash-starved startup (Ghosh and Nanda 2010). Not even the VCs have the comprehensive expertise needed to build and operate a cleantech company since the sector is relatively new[22]. The result of these managerial deficits and lack of

[22] The cleantech sector first gathered attention after the 1970's oil crisis. It wasn't until the dawn of the 21st century that the sector began to receive billions of dollars of public and private investment.

operating expertise give rise to the non-financial and subtler managerial Valley of Death.

In sum, long time horizons, capital-heavy demonstrations and commercial products, volatile federal incentives, commodity markets, bureaucratic customers, and managerial deficits all contribute to the broadly defined cleantech Valley of Death. After the global economic recession in 2008, VCs and other investors that rushed to the sector found out that the cleantech sector is quite unlike IT and biotech sectors. The surge of private investment into cleantech that followed the dot-com bubble was precarious and premature, and unfortunately branded cleantech as an infamous sector of investment later on when the Valley of Death was quickly exposed. Only a handful of investors left the eminent crash cash flow positive as the majority sustained large losses and left the sector for good.

The Cleantech Crash

VCs have historically been the primary providers of risk capital to all risky, early-stage technology companies. Since their rise in the 1940's, they have transformed the process of innovation throughout the United States and throughout the world (Florida and Kenney 1988; Gompers and Lerner 2001). By providing equity funding to risky companies and unproven technologies, they have given rise to the likes of Apple, Google, Intel, Amazon, and Genentech amongst many others. Their impact has been so great that they have been responsible for financing a third of all publicly listed companies in the United States (Strebulaev and Gornall 2015). After the dot-com bubble, VCs turned their attention way from IT and toward cleantech (Migendt et al. 2014). They perceived the cleantech sector as large and growing, scalable for new entrants, and ready for large payoffs—the economic boundary conditions that VCs look for in a new potential investment sector (Hargadon and Kenney 2012)—so they all rushed in.

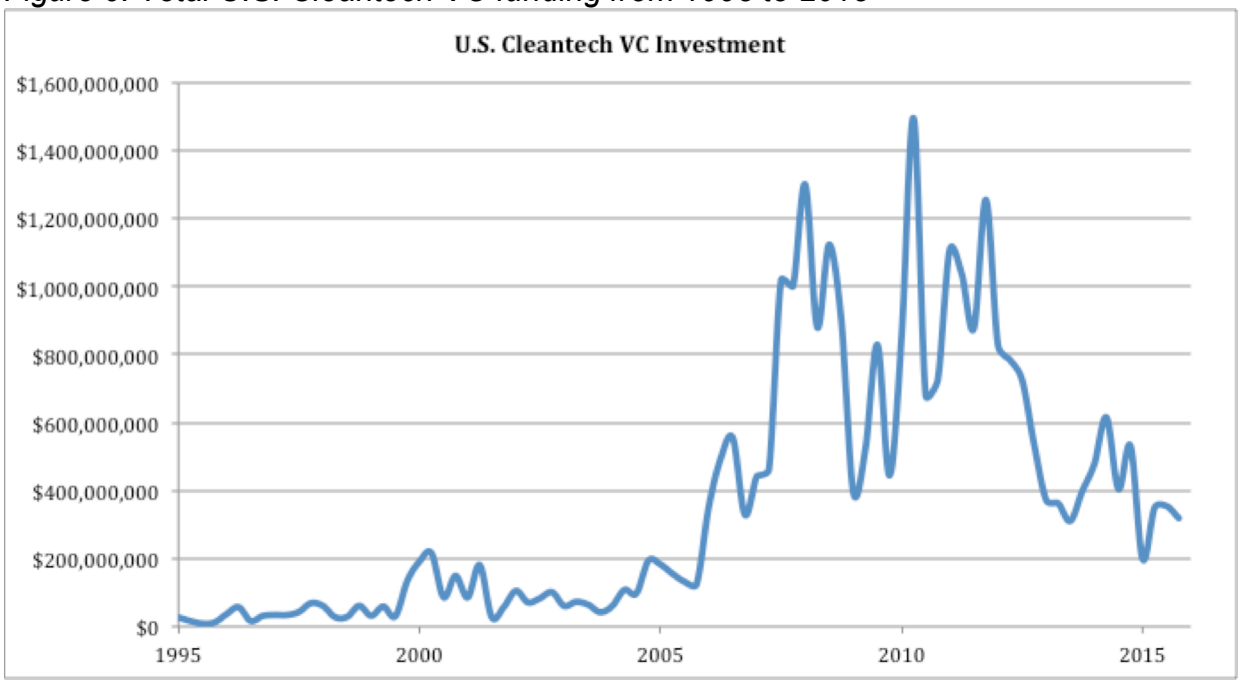
However, after turning to cleantech VCs sustained large losses. The Valley of Death and multiple micro- and macroeconomic factors crushed their investments. One major reason they failed was due to the large proportion of Silicon Valley VCs who were found as "tourists" investing "dumb capital" in the sector where they had no operational expertise (Rai et al. 2015). The VC limited partners (LP) were chasing cleantech because of social and political reasons, and had their high-prestige and IT-focused general partners (GP) pursue these opportunities with little to no sector experience (Marcus, Malen, and Ellis 2013). The GPs were all too happy to comply as their reputation in an emerging sector was at stake (Petkova et al. 2014). The result was billions of dollars lost in capital-intensive biofuel refineries, solar cell manufacturers, and alternative fuel automobiles. The bankruptcies of KiOR ($125 million in investment), Solyndra ($846 million in investment), Fisker Automotive ($942 million in investment), and Better Place ($775 million in investment) are a few examples of the resulting spectacular failures[23]. The burned reputations made resounding waves in the Silicon

[23] Information available here: https://www.crunchbase.com/#/home/index

Valley VC ecosystem and then the rest of the world, so further investment in the sector was discouraged everywhere.

Besides the blind VC rush, macroeconomic reasons leading VCs to sustain large losses was 1) the global recession hitting in late 2008, 2) the Chinese flooding the solar photovoltaic (PV) market, and 3) natural gas becoming cheap and abundant with the advent of fracking and horizontal drilling (Eilperin 2012). These and other factors led the $20 billion invested in U.S. cleantech between 2000 and 2013 to gross only 3.4% IRR for VCs[24]. Plus, of the 52 cleantech companies that did have an initial public offering (IPO) between 2000 and 2010, only reported a median IRR of 26% for their VC investors, which was a far cry from the 507% median IRR that IT companies returned to their VCs during the same time period (Bygrave et al. 2014). Since VCs did not attain the 25% IRR median annual return they need to sustain investment in a given sector, LPs retracted funds from cleantech investing (See Figure 9) and an eminent "crash"[25] ensued. VC had to redefine its approach to cleantech using its experience and expertise in IT and biotech.

Figure 9: Total U.S. Cleantech VC funding from 1995 to 2015



Source: Cleantech Sector Investments MoneyTree Report, Data from Thomson Reuters, PwC and National Venture Capital Association, 2015

[24] Information available here: http://www.cambridgeassociates.com/our-insights/research/clean-tech-company-performance-statistics-2015-q1/

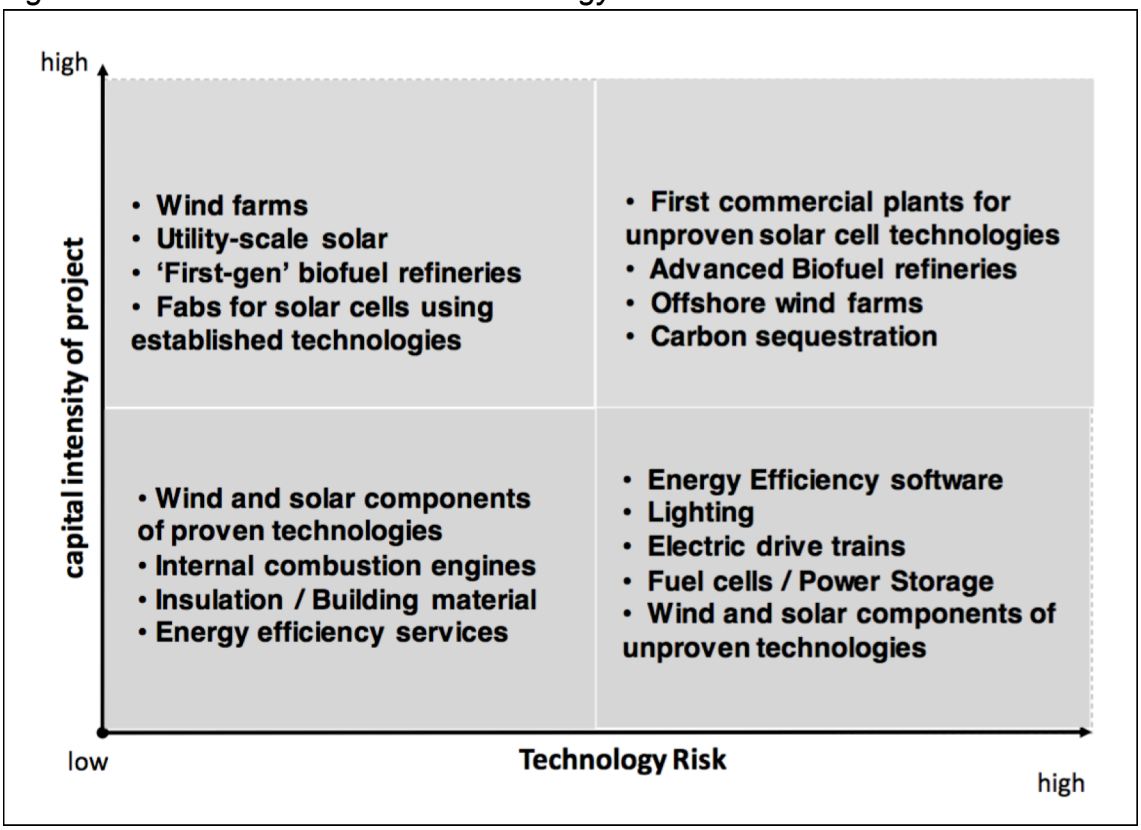
[25] The news show 60 Minutes aired a special program called "The Cleantech Crash" in January 2014, describing the descent of the sector during an interview with Silicon Valley investor Vinod Khosla. The video is available here: http://www.cbsnews.com/news/cleantech-crash-60-minutes/

Cleantech 2.0

After the crash, most generalist VCs pivoted back to IT and biotech. A few pure play cleantech VCs survived and kept to the sector, outperforming with the help of outliers like investments in Tesla Motors and Solar City[26], but a large portion of the others pivoted away from capital-intensive, hardware-based cleantech investments, depicted in the upper right-hand box of Figure 5. Early-stage entrepreneurs for these hardware-based cleantech companies had to turn to strategic investors, family offices, venture debt investors, government, and a few remaining cleantech specialist VCs to finance their technologies and scale up. Either way they still found financing insufficient (Taylor Wessing 2010).

Although generalist VC money disappeared for these hardware-based cleantech companies, it did not for all cleantech companies. Some money found its way to a new intersection between IT and sustainability that better fit generalist VC criteria in the bottom right-hand box of Figure 10. This area of investment has gained prominence amongst many VCs as the "cleanweb" subsector (See Figure 11), and has marked a resurgence of innovation and investment in the software side of cleantech.

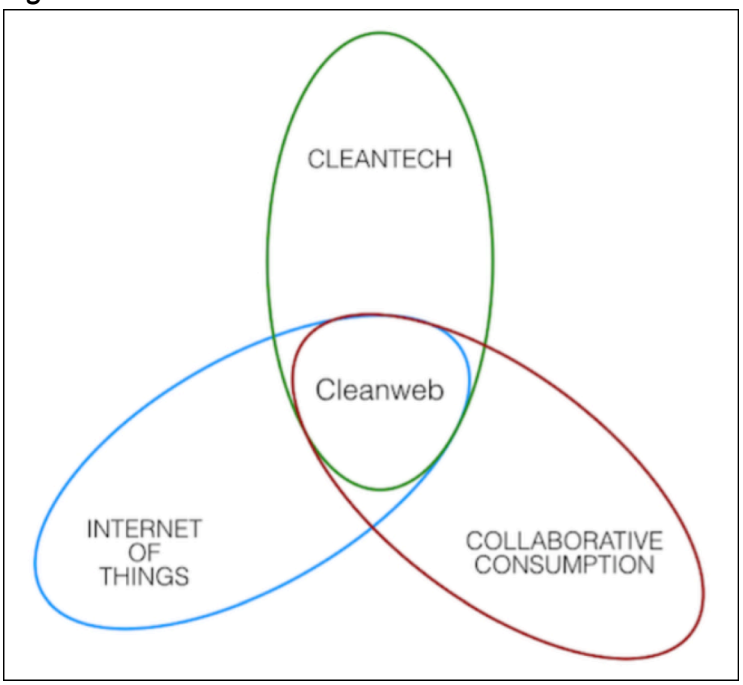
Figure 10: Subsectors Within Clean Energy



Source: (Ghosh and Nanda 2010)

[26] San Francisco VC firm DBL Partners was one of the few pure play cleantech VCs to outperform during the industry shakeout.

Figure 11: Cleanweb - The Intersection of Internet and Sustainability



Source: The Cleanweb Initiative

The Cleanweb Initiative defines cleanweb as, "a cleantech sub-category capitalizing on the potential of IT and network-based technologies and platforms (i.e. Internet, social media, mobile) to develop solutions that reduce the environmental burden associated with a given activity[27]." It usually encompasses "Smart Grid" solutions. High-profile examples include Uber, Opower, Climate Corporation, and Mosaic. These cleantech companies and others are following macro trends such as the "Internet of Things" and the "Collaborative Economy" or "Sharing Economy" to use new and existing data sources, and corresponding advanced analytics capabilities, to enhance resource productivity across all of cleantech. Cleanweb solutions are being applied to many crosscutting sectors like transportation and power with positive results. They are capital-light, less dependent on government incentives, and take advantage of core VC competencies in IT. They are proving a major renaissance in reshaping the sector into cleantech 2.0.

Although cleanweb companies are poised to create substantial economic and environmental impact, the original hardware-based cleantech companies remain underfunded and at the mercy of the Valley of Death. These radical cleantech ventures still must be funded in order to make the 2DS a reality. It is imperative to continue seeking sustainable financing solutions for these companies to scale up and successfully combat climate change and environmental pollution. Investors, management teams, and policymakers are all creating innovative solutions to help hardware-based and capital-intensive cleantech companies bridge the Valley of Death.

[27] Information available here: http://oriolpascual.com/tagged/cleanweb

On the financing side, efforts to bridge the Valley of Death include channeling new program- and mission-related investments from nonprofit foundations (Kearney, Seiger, and Berliner 2014); creating alternative "Social Stock Exchanges" for sustainability-oriented companies to raise additional financing (Ottinger and Bowie 2014); facilitating institutional investors to do direct cleantech investing with the help of novel intermediaries (Monk et al. 2015; Polzin et al. 2015); activating investment from accredited and non-accredited investors through crowdfunding platforms[28] (Chiang 2014; Bruton et al. 2015); and forming novel venture funding models with extended time horizons[29]. These efforts have all activated more private investment into early- and late-stage cleantech.

In terms of strategic management decisions, efforts to bridge the Valley of Death include joining combined incubator and prototyping spaces for decreased demonstration costs (Fullmer 2014); using various operational hedging strategies to secure financing and/or decrease upfront costs and capital-intensity (Erzurumlu, Tanrisever, and Joglekar 2010) (See Figure 12); employing market entry strategies that focus on making products that 1) compete on variables other than price, 2) serve higher-margin markets first, or 3) target emerging economies with few fixed investments in cleantech and growing demand and government support (Clay 2013); and engaging strategic partners, either through joint development or joint research partnerships, to decrease large upfront fixed costs, expand capabilities in research, distribution, and supply, and provide longer-term exit opportunities for financial investors (Fontes, Sousa, and Pimenta 2012).

[28] In late 2015, the U.S. Securities and Exchange Commission approved Title III of the JOBS Act. Non-accredited investors are now allowed to participate in equity crowdfunding alongside accredited investors in all types of early-stage companies, including cleantech.
[29] Two novel private investment entities with extended time horizons and greater risk tolerance include Breakthrough Energy Coalition and i(x) Investments.

Figure 12: Operational Hedging Strategies for Cleantech Companies

Company	Operational Hedge Type	Early Start-up Stage/Growth	Effect on the Financing Options	Product/ Process
Accuwater	Underproduction	Early Start-up	Increased availability of internal funds in case of an economic down turn.	Product
XYZ Solar	Window dressing	Early Start-up	Reduced financial distress and increased chances for second round VC funding.	Product
Evergreen Solar	Outsourcing	Early Start-up	Increased availability of internal funds in case of an economic down turn, and increased excess to debt financing.	Process
Scholt Energy	Insourcing	Growth	Reduced need for a margin account to hold forward contracts and increased availability of internal cash to invest in growth.	Product
ITC Holdings	Distribution flexibility	Growth	Increased chances of getting long-term government funding.	Process
Verenium	Decentralized production	Growth	Increased chances of getting long-term government funding.	Process
SolarReserve	Strategic alliance	Growth	Increased private financing from various fund investment groups.	Product/ Process
Emergya	Joint venturing	Growth	Reduced marginal cost of production. Secured long-term financing by the joint venture.	Process

Source: (Erzurumlu, Tanrisever, and Joglekar 2010)

Policymakers have also sought to address the Valley of Death by providing venture-backed cleantech companies with debt financing and grants for production and demonstration facilities (Harborne and Hendry 2009; Hendry, Harborne, and Brown 2010; Bürer and Wüstenhagen 2009); providing equity funding and grants for very early-stage technologies (Lerner 1996; Bonvillian and Atta 2011); subsidizing renewable energy generation with feed-in tariffs (Criscuolo and Menon 2015); pairing national lab expertise and equipment with early-stage incubators[30]; providing tax breaks and incentives for early-stage companies and investors (Wilson 2015); and promoting regional cleantech clusters that connect early-stage companies with local industry and academia, and accelerate change in entrenched energy regimes (Chapple et al. 2011; Horwitch and Mulloth 2010; McCauley and Stephens 2012; Porter and Kramer 2015). Policymakers have largely played the role of picking up what the private sector leaves off.

Summary

These public and private efforts are beginning to bring the sector back to resurgence, and into a cleantech 2.0 dominated by cleanweb applications. However, they are not

[30] See Cyclotron Road and their report: http://www.cyclotronroad.org/reports

enough for the 2DS or for long-term public and environmental prosperity. Following the issues above, the central question this thesis seeks to answer is: what best practices and partnerships successfully de-risk and lower the capital-intensity of radical new clean technology companies, and drive more private investment into their formation and growth? How can entrepreneurs attract private investment and scale up pass the Valley of Death? How can venture capitalists build the ability and confidence to invest in the cleantech sector again? How can policymakers address the failure modes that may still exist if entrepreneurs and investors follow best practices?

These are broad research questions being pursued by the MIT Sloan Sustainability Initiative through their research on Sustainability-Oriented Innovation (SOI). Answering the many layers of these questions should provide valuable insights to researchers, entrepreneurs, investors, and corporates involved in cleantech efforts. It should also provide policymakers additional guidance on how to better leverage private investment in spurring clean technology innovation and deployment, and correct the "…greatest example of market failure ever witnessed" (Andrew 2008) with a "policy-technology-finance-systems thinking" approach (Taneja 2016).

Chapter 2: Data and Methods

Overview

The objective of this thesis is to discover additional organizational and tactical approaches to de-risk early-stage and capital-intensive cleantech companies. It seeks to stimulate more private investment in the sector and form what is termed here as cleantech confluences. The research has hence focused on the early-stage cleantech landscape in the United States and has used a mix of research methods most appropriate to answer the primary thesis questions.

To briefly describe the overview of the research process: first, I conducted an in-depth literature review on current approaches. This is described in the introduction (See *Cleantech 2.0)*. Second, I conducted 28 semi-structured and informal interviews to rectify and find gaps in the current approaches with post-hoc reflections. Third, I followed up with forced ranking questions to distill investment preferences amongst investors. Fourth, I synthesized and triangulated the findings from the literature review, interviews, and forced rankings to arrive to a systemic understanding of the perceptions and decisions beheld in the sector. Fifth, I conducted a case study on XL Hybrids to demonstrate the findings in practice. Sixth, I used system dynamics to describe how individual behavior and system structures co-influence each other in the cleantech sector. From this information I gleaned how entrepreneurs, investors, and policymakers could positively impact the sector and create cleantech confluences.

Interviews

After reviewing academic and practitioner literature, I conducted 30-45 minute semi-structured interviews with venture capital investors, angel investors, corporate investors, governmental investors, family office investors, incubators/accelerators, and entrepreneurs. The interviewees were selected by availability and willingness to participate in the study. Their responses were voice recorded and/or transcribed depending on consent.

Semi-structured interviewing was selected as the method of choice because it allowed the elaboration of existing theories via a further analysis of stakeholder behaviors and decision-making in new cases (Eisenhardt 1989). This method was also selected because investors and entrepreneurs, like all of us, are decision-makers who act under bounded rationality (Simon 1955) and therefore do not have completely “objective” measures of risk-return. They often weigh risk and return, gains and losses, much differently than what rational decision making theory would suggest (Kahneman and Tversky 1979). This makes it critical to understand the unique perceptions, heuristics, and biases inherent in their decision-making process.

Ideally, the interviewees would have been selected across a range geographies and demographic backgrounds, and done all in-person (Eisenhardt and Graebner 2007). However, given the low availability and busyness of these professionals, they were

selected according to MIT affiliation and other close contacts, and the interviews were done predominantly through phone calls. All subjects were informed in advance that they would not be identified in the thesis. This was done for matters of privacy and to enhance their level of disclosure.

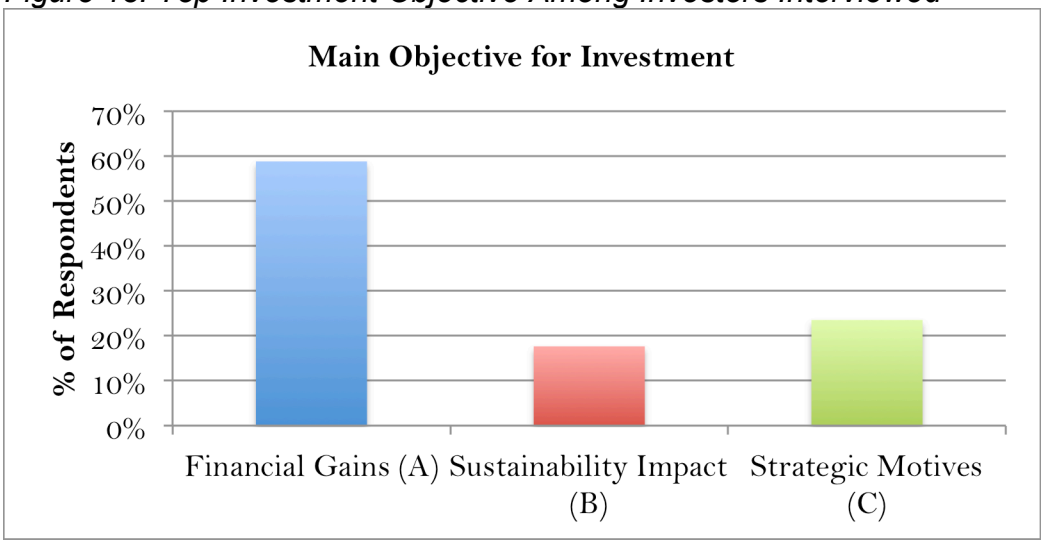
I began with nine semi-structured interviews following a risk-reward and prospective theory protocol that could be generalized (Harrison, List, and Towe 2007). Afterwards, I transitioned to semi-structured interviews that targeted other research questions once the risk-reward findings were solidified. These interviews were codified in research memos that stated 1) information already known, 2) information needed, 3) new information arising from the interview, and 4) new theories developing from the new information. Key insights and findings from all the interviews were compiled and used as a reference in designing following interviews. These and the original semi-structured interview protocols are listed in the appendix.

A small number of informal interviews and field observations were also used to augment the findings. These were done at conferences, workshops, and seminars on the topics of cleantech, startup companies, corporate venture capital, and innovation policy.

Forced Rankings

Forced rankings of investor preferences and risk evaluations were used to extract patterns of interlinked investment behaviors (Hazels and Sasse 2008). This allowed investment preferences to be compared on a relative basis between the interviewees. The forced rankings covered 1) primary motivations for investment, 2) primary determinants for investment, and 3) primary cleantech sectors of investment. They were sent to the interviewees after each interview. The number of respondents was N=17 and the sample primary motivations for investment is characterized in Figure 13. The complete ranking questionnaire is listed in the appendix.

Figure 13: Top Investment Objective Among Investors Interviewed



Data Analysis

All interview and forced ranking data was compiled and refined for synthesis according to (Strauss, Corbin, et al. 1990). The initial findings were grouped by actor (i.e. entrepreneur, venture capitalist, corporate investor, etc.) and according to common ideas, preferences, perceptions and decisions. Crosscutting themes were then identified and aggregated across all stakeholder groups. These themes were grouped together based off their common identification by at least two different actors. Next, they were distilled into best practices, partnerships and policies for investors, entrepreneurs, and policymakers.

An important caveat is that the best practices come from post-hoc analysis of what the interviewees thought caused success in early-stage cleantech financing and development. I did not do a systematic analysis of case successes and failures, and identify which practices are present in the former and not the latter. The practices are justifications of what the different actors thought worked best, and are adopting because others may also be adopting and make them appear legitimate. However, the findings are meant to be this way because the study is in part an exploration of what *perceived* practices would increase investor confidence to finance early-stage cleantech. These "soft" tactics are just as important as "hard" strategy tactics to increase investment in early-stage cleantech, as they operate in the realm of investor's bounded rationality.

Case Study

XL Hybrids was selected as the thesis case study because its story was able to refine and validate the findings from the data analysis (Eisenhardt 1989). The company was selected based off its 1) identification as a hardware-based, capital-intensive cleantech company, 2) strong investment track record to date, 3) utilization of public resources, 4) competitive ties to oil prices, 5) strong management team, and 6) close ties with MIT and willingness to interview. The case explores the XL Hybrids origin and growth story, and how it relates to a cleantech confluence in action. Information was collected through semi-structured interviews with management and board members, and through general Internet research.

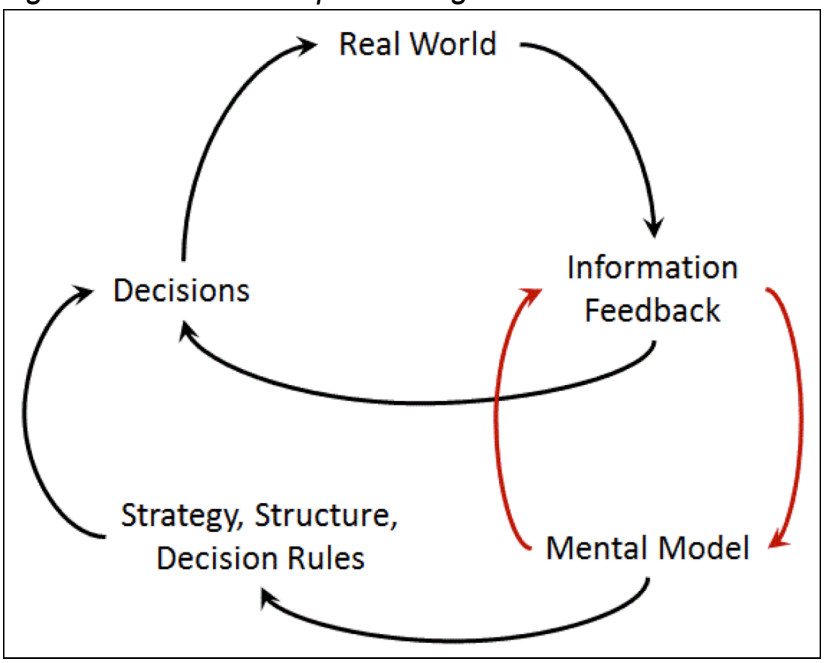
System Dynamics

The cleantech sector involves a diverse set of stakeholders making a complex set of decisions. The sector also intersects both public and private spheres, and has time horizons extending over decades. As such, systems dynamics (Forrester 1994) was used to describe how individual behavior and system structures co-influence each other in the sector. This is done with a multi-loop, decision-making and feedback system (See Figure 14). All system dynamics models were implemented using Vensim software.

Modeling with system dynamics is appropriate for this thesis because it can be informed by qualitative data gathered from interviews and field observations (Luna-Reyes and

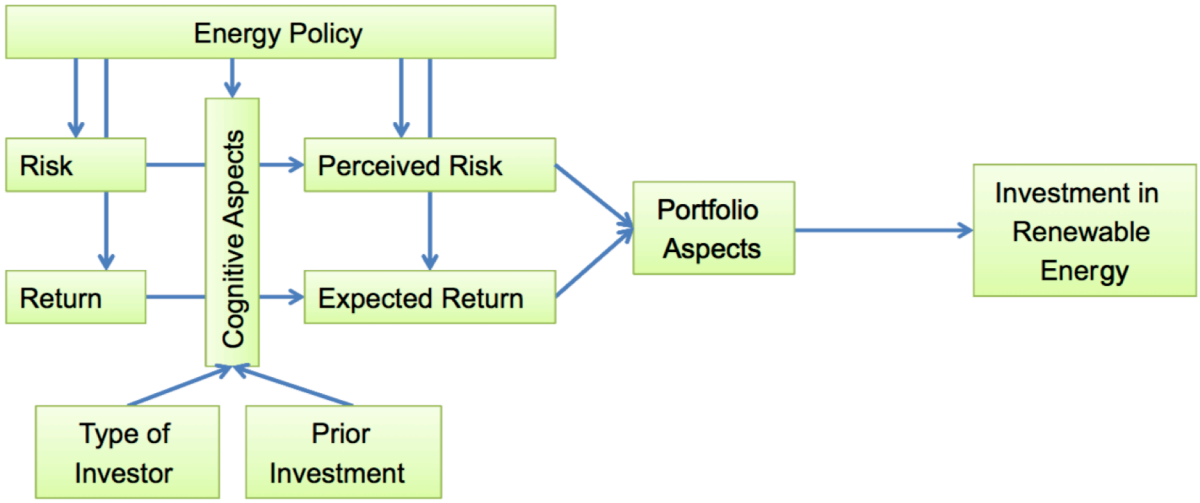
Andersen 2003). The information is not refined further into quantitative data and need not be given the complexity and multi-dimensionality of the topic (Coyle 2000). The intention is to build on the decision-making process outlined by (Wüstenhagen and Menichetti 2012) (See Figure 15) and expand its boundaries to include other early-stage cleantech stakeholders and strategic decisions. However, further system dynamics model quantification is a possibility.

Figure 14: Double-Loop Learning Feedback Process



Source: (Sterman 2000)

Figure 15: A Differentiated Model of Renewable Energy Policy and Investment



Source: (Wüstenhagen and Menichetti 2012)

Chapter 3: XL Hybrids Case Study

In 2007, Bill Aulet, senior lecturer and managing director of the MIT Martin Trust Center for Entrepreneurship, decided to launch a new entrepreneurship course. Aulet was puzzled as to why students in entrepreneurship were not starting energy startup companies. He saw a significant gap in his entrepreneurship curriculum and sought the help of faculty from the recently founded MIT Energy Initiative, and the Sloan School of Management. He quickly realized from his conversations that breaking into the energy sector was no quick or easy endeavor. Aulet had called the head of the alternative energy division at Citizens Energy, a Boston nonprofit, for advice on setting up the course. Aulet asked if the director would help lead a new energy focused entrepreneurship class, which he titled Energy Ventures. The alternative energy director of Citizens Energy, Tod Hynes, jumped on the opportunity and eventually began co-teaching the course in 2008. He is now President and Co-Founder of XL Hybrids, one of the most promising cleantech companies growing out of New England.

What follows is the story of XL Hybrids. It is an excellent example that illustrates how best practices, partnerships and policies by and between entrepreneurs, investors and policymakers together lead to the culmination of what is called here as a "Cleantech Confluence." We follow the journey of Hynes and XL Hybrids as it relates to the burgeoning Cleantech Confluence in New England. Since its incorporation in 2009, the company has gone on to raise approximately $20 million in follow-on investment from private and public investors, and has formed a number of strategic partnerships with large corporations and state and local governments. The work of Hynes and his management team exemplifies many of the best practices distilled from other cleantech entrepreneurs and investors. It is a prime example showing how hardware-based cleantech companies can scale under the conditions of a Cleantech Confluence.

Formation and Early Decisions

In August 2008 and before he started teaching at MIT, Hynes put in his notice to leave Citizens Energy and incorporated a holding company as a predecessor to XL Hybrids. He was determined to start a company that reduces oil consumption in the US. "[The country] has an oil problem," he said. "We're very dependent on oil: we rely on imports, and more than 95 percent of transportation fuel is oil[31]."

At the time, Hynes and Aulet had already started the MIT Clean Energy Prize. The inaugural competition began in spring 2008 and several teams competed for the prize. One venture was led by Justin Ashton, a MIT Sloan student who had interned with Citizens Energy in 2007. Ashton started his own company after competing in the Clean Energy Prize in 2008 and graduating from Sloan a few months later. Hynes was impressed with Ashton's attempt at starting a clean energy company and competing in the Clean Energy Prize, and after ongoing conversations he convinced Ashton to join

[31] http://www.tgdaily.com/sustainability-features/89726-driving-down-fuel-consumption-with-xl-hybrids

him in developing a competitor to oil. They formally incorporated XL Hybrids that July in 2009.

Seeking operational and supply chain expertise, Hynes asked Aulet for a third co-founder recommendation, and at the end of 2009 Aulet provided an introduction to Clay Siegert, a former MIT graduate with expertise in supply chains and energy startup experience. Siegert joined Hynes and Ashton as the third co-founder of XL Hybrids and the trio "…started work on the concept and prototypes of XL Hybrid's product… an easy-to-incorporate device that reduces vehicle fuel consumption by 20%[32]."

Hynes says that at first "[they] didn't necessarily plan on a hybrid[33]." The team had researched various plug-in and hydraulic options and looked into who would make great customers. The trio used their business and entrepreneurial backgrounds to assess both the technology and market opportunities in clean transportation.

Hynes, who graduated from MIT in 2002 with a bachelor in Management, had actually started a company that provided consulting and engineering services for distributed power generation by wind power, and had even competed in the former $50K competition (now know as the $100K) with a business plan that offered no upfront cost distributed fuel cell power through power purchase agreements (PPAs). He was well versed with understanding what economics would be most attractive and realized that the economics, logistics, and scalability of hybrid technology made it a more attractive option than all electric vehicles (EV) [34].

The team ran with the hybrid concept and found a garage in Somerville, Massachusetts where they could begin early trials with their proof-of-concept. They targeted customer segments that drove lots of miles per year and had low mileage vehicles. One promising segment was taxis and limos, so they experimented with the Ford Crown Victoria.

The Technology

The core system of XL Hybrids is a powertrain that includes, 1) an electric traction motor, 2) a lithium-ion battery, 3) advanced power converters, 4) other connecting components that attach to the powertrains of traditional vehicles, and 5) sensors and software that track the entire system. The electric powertrain augments vehicle power with electrical energy, thus reducing the amount of gas required per mile. The lithium-ion battery then recharges itself when the vehicles brake so valuable energy is not unnecessarily lost. Custom software reads each driver's braking habits to optimize the system during driving and provide valuable input for technology refinement. The operational data from entire fleets is then used to inform fleet managers of the best vehicles and routes for the hybrid technology, so the data is an equally valuable offering of the system.

[32] http://www.forbes.com/sites/petercohan/2013/09/25/xl-hybrids-growing-10-fold-by-cutting-fleet-fuel-consumption/#47c6180c66f9
[33] http://www.fastcompany.com/most-innovative-companies/2014/xl-hybrids
[34] Of course Elon Musk thought otherwise

However, by the end of 2009 the customized system was still too costly. Each individual part carried a hefty price when sourced at low volumes. Integration in their Somerville garage was also costly. Investor financing was needed to scale up production. Unfortunately, the world was in the middle of a global economic recession and venture capitalists (VC) were quickly pulling funds out of cleantech after sustaining big losses. It was not a good time to be a growing hardware-based cleantech company. Regardless of macroeconomic conditions, Hynes and the team pushed through and put together a clear plan around 1) what they wanted to do with investor financing, 2) who was their target customer, and 3) what was the specific technology architecture they wanted to test. The goal was to get enough funding to prove the technology architecture in the lab, and then out in field with potential customers. Hynes crafted a winning pitch.

Fundraising Through The Recession

According to the Bureau of Labor Statistics, in 2014 there were around 234,000 taxi and limo operators in the United States[35]. Hynes and the team initially thought they were an excellent beachhead market. Taxis and limos represented a billion-dollar market opportunity when they priced their hybrid system at $8,000 to $10,000 and assumed five year operating lives for the vehicles. The team therefore retrofitted several Crown Victoria town cars used often by typical taxi and limo fleets. The idea was to prove that the economics of a hybrid conversion were positive, and that the payback time would be within two years—assuming 1) the cars averaged less than 20 miles per gallon (MPG), 2) operators drove them over 60,000 miles a year, and 3) oil prices remained around $70 a barrel. Hynes and the team were confident that investors would jump onboard the lucrative market opportunity despite the economic recession.

Hynes stuck to the plans and pitched to multiple investors. It took almost a year but the XL Hybrids technology and market pitch finally resonated with a few investors. By the end of 2010 the team had raised a total of $1.8 million in convertible debt. The financing came from a consortium of angel investors and from the Massachusetts Green Energy Fund[36], and the team did not stop there.

In January 2011, the team signed a strategic licensing agreement with Ashwoods Automotive, a British hybrid system retrofitter, and raised another $2 million in financing. Investors were pleased to see the team working with proven technology. Hynes and the team used the Series A financing to relocate their headquarters to a 10,000 square foot facility in Brighton, Massachusetts. They began adapting the Ashwoods Automotive hybrid kits for American vehicle installations and hired several more technicians and salespeople. Eventually they actively searched for customers willing to pilot their product. Unfortunately, everything they initially thought and assumed was turned on its head.

[35] http://www.bls.gov/ooh/transportation-and-material-moving/taxi-drivers-and-chauffeurs.htm
[36] Launched by former Massachusetts Governor Mitt Romney in 2003 to spur innovation in energy. It was modeled as a government venture capital fund.

Pivots and Pilots

By the end of 2011 the team had come to several important realizations. One was that they had perceived the electric drivetrain industry to be far more advanced than what it actually was. They had planned to adapt the Ashwoods Automotive kits for the American market but the process ended up taking too long and costing too much. To the surprise of many, the team decided to end their strategic partnership with Ashwoods Automotive when they publicly announced: "Our role is to build the hybrid architecture from the ground up[37]." Hynes and the team brought all engineering in-house to ensure their product met 20% to 30% baseline efficiency improvements.

Another realization the team had was that taxis and limos were not the ideal beachhead market. The team acknowledged that the taxi and limo business-to-consumer (B2C) market was substantially bigger than business-to-business (B2B) markets like Fortune 500 commercial fleets, but they concluded that the latter B2B market was a better beachhead market. They had always had the class 2-6 van and truck market as a main market to tackle, but when they decided to bring more technology development in house they accelerated their entry in the class 2 van market instead. Federally mandated Corporate Average Fuel Economy (CAFÉ) standards and private investor demands for Corporate Social Responsibility (CSR) were pushing commercial fleets to adopt newer and more sustainable technology, and these external drivers plus the fact that commercial fleet managers made larger volume purchase orders made commercial fleets a much more attractive initial customer segment to target.

A third realization the team had was that the commercial fleet industry had established a two stage manufacturing capability, where the likes of General Motors (GM) and Ford would make basic vehicles and then a host of other companies, known as "upfitters," would add ancillary parts and do installations. They found that in reality, there was little need for them to do all the costly installations themselves. They therefore searched widely and diligently for upfitters who would potentially make excellent strategic partners.

Taking into account these three realizations, the team announced by the end of 2011 that they would be targeting GM vans used by corporate fleets, and by the beginning of 2012 the team rolled their pilot into an Environmental Protection Agency (EPA) certified testing facility. Soon after they began trials with "one of the biggest fleets in the world… a Fortune 50 brand that everyone knows[38]". The pilot took longer than expected but by mid 2012 the test results came in and their technology achieved a 21.2% reduction in fuel consumption for light-duty cargo vans[39].

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[37] http://www.xconomy.com/boston/2011/11/07/xl-hybrids-with-new-d-i-y-approach-gears-up-to-go-beyond-vehicle-retrofits/

[38] http://www.showtimesdaily.com/fleetsfuels/xl-hybrids-begins-fleet-trials

[39] http://www.greencarcongress.com/2012/06/xlh-20120625.html

The results gave the team much needed approval in the eyes of corporate fleet managers, and the technicalities gave important insights into how they needed to modify their product in order for it to be readily adopted by other corporate fleets. The team therefore hired Dr. Edward Lovelace in September 2012 as their full-time Chief Technology Officer to look into transferring the technology into different vehicular makes and models. Dr. Lovelace was previously an advisor of XL Hybrids in its early days and had a pedigree of four MIT degrees and a PhD in hybrid electric powertrains to make him the right person for the task. The team could then focus on driving costs down and hone in on making their pilot catalyze into a first customer order.

De-Risking and Speeding Sales Cycles

Corporate fleets are an attractive customer segment from the standpoint of their large purchase orders and high lifetime value. However, what Hynes and the team discovered was corporate fleets also had detrimentally long sales cycles. Talks with the Fortune 50 Company testing their pilot were progressing but sales were not. The team learned that the Fortune 50 Company's sales cycles were between two and three years, which would mean imminent death for their startup if they could not find a way to accelerate adoption. They had to quickly get their technology to market while simultaneously manage long sales cycles with potential customers in order to keep their company alive. They made critical engineering, supply chain, and marketing decisions to help them do so:

The engineering decision was to use an alternative off-the-shelf motor that required extensive integration. The decision added extra cost to the system and made integration lengthier, but it significantly accelerated their time to market with a minimum viable product. Ongoing operation and reliability are the highest priorities for corporate fleet managers so they designed the system that was not a central part of the powertrain and would not stop the vehicle if some part failed—a big decision factor for corporate fleet managers. XL Hybrids has maintained a 99.9+% vehicle availability in part because of the decision.

The supply chain decision was to sign an agreement with Johnson Controls to supply their lithium-ion battery packs. Just like the decision to use a proven motor, the decision to use proven battery technology also increased the customer's confidence in system reliability. Choosing the USA-based supplier amongst many other international options also gave XL Hybrids an important nod as a company supporting domestic production. This decision would also increase the likelihood of potential government support and prove helpful later on.

The marketing decision was to talk about sustainability side-benefits with the corporate fleet managers. Hynes and the team knew that although the fleet managers were making the purchasing decisions, the corporate sustainability teams and C-suite executive boards had tremendous influence over pushing for new sustainable solutions. They therefore talked about the potential for greenhouse gas (GHG) emission

reductions after they covered the system's operational reliability. This allowed for CSR initiatives to enter the decision-making process of the fleet managers.

These strategic moves all together hastened final sales decisions. In 2012, the pilot customer finally converted into a full system customer when they bought a unit. Six to nine months later in early 2013 the customer came back and ordered another 35 units, and the team put the 3rd generation "XL3" system on all of their new GM vans for the reminder of the year.

The team had successfully "got the clock ticking" in terms of data collection and preparing for next generation systems so by time the customer came back for another purchase, they would have a next generation system available at lower cost and easier installation. The team used the momentum to initiate conversations with other potential customers and understand how they make decisions. Hynes labeled this as "one of the most important processes[40]" of their early stages. They then turned their focus to cutting unit costs and improving margins.

Growth Stage: Pedal to the Metal

By 2013, XL Hybrids was ready for a fresh infusion of capital. Sales were beginning to ramp up and the team needed funds to manufacture more systems. Hynes went out with a new pitch this time and centered the story on reducing unit costs and increasing up production. It did not take long because by March he had successfully raised another $4 million in investment. Both new and existing investors contributed to the Series B round. The team was able to focus fully on cost reduction strategies.

At the beginning, the first few units Hynes and the team sold were old vehicle retrofits. They were priced at a loss in order to maintain a consistent value proposition at $70 to $100 per barrel of oil. Overall the system was well received by the initial corporate customers. The team knew the product was right and could eventually turn a profit once they drove down costs, so they employed new development strategies to expand their product offerings and attain higher volume purchase orders.

One immediate strategy was to "upfit" new vehicles rather than old ones. They could take advantage of existing infrastructure set in place by upfitters and avoid adding unnecessary costs to the product. The team decided to sign an agreement with The Knapheide Manufacturing Company to install and distribute their systems, whereby Knapheide would install the XL Hybrids systems through its existing ship-through process and combine purchasing, upfitting, delivery, and invoicing into one seamless process for corporate customers. That way the entire XL Hybrids system package plus installation would be available at one-stop shops, and all sorts of installation and shipping costs would be eliminated throughout the process.

[40] Personal interview. December 29th, 2015.

Another strategy was to use programs offered by the Massachusetts Clean Energy Center (MassCEC)[41]. The team was able to get customers to commit to buying the XL Hybrids system for new makes and models, but not the development expenses needed to create them in the first place. MassCEC stepped in with their inaugural InnovateMass to help cover these development expenses. The program provided $150,000 in funding and a matching $230,336 from several strategic partners to fund new vehicular makes and models demonstrations[42]. This support "got the clock ticking" on new types of commercial fleet hybrid systems so corporate customers would be more willing to purchase them after being proven out in the field.

A third strategy was to expand into international markets that had strong sustainability incentives to adopt clean technologies. By mid-2013, the team had begun pilots with Canadian Linen, a large rental and linen supply company that prided itself on being "clean[43]." The Canadian company was one of many in the northern country with especially strong CSR agendas, since the federal government and private sector heavily promote sustainability. The Canadians were impressed that the XL Hybrids system did not require any additional infrastructure or driver training, and did not require any changes to vehicle operations. It took only a few months after the pilot to secure their first international sale.

The combination of these strategies resulted in massive a 100-unit end of year order from corporate giant Coca-Cola and orders from other major fleets like FedEx, and $3 million in venture debt financing from WindSail Capital Group to fuel the sales. Coca-Cola's vice president of environment and sustainability, Bruce Karas, said the company was "attracted by the convenience of XL Hybrids technology, and ability help Coca-Cola meet its goal of reducing its carbon footprint by 25% by the end of the decade[44]." The corporate executive was bought in on the startup's system, and with a growing backlog of customer orders, sufficient collateral to cover a loan, and proven technologies being used in the system, the XL Hybrids team had also met the criteria of the rare and tremendously valuable early-stage debt financing of Windsail Capital. The new sales and non-dilutive debt financing fueled the management team's morale as much as it did company growth. It geared them up for tough years coming ahead.

[41] MassCEC is the state government backed clean technology node of Massachusetts
[42] Johnson Controls, Kiessling, and NatVans were the strategic partners and private investors providing the matching funding.
[43] http://www.canadianlinen.com/en/about-us/corporate-responsibility/
[44] https://www.bostonglobe.com/business/technology/2013/12/12/coca-cola-going-hybrid-with-boston-based-technology/h6ZF1zw3f9fB7eIkFVJwvJ/story.html

The Ultimate Cleantech Test: Selling When Oil Prices Drop

XL Hybrids did well through most of 2014:

- In January, Neal Isaacson, former Chief Financial Officer (CFO) of EnerNOC that took the software company public, was announced as the new CFO of the company.
- In March, the Department of Energy (DOE) announced new credits under the Energy Policy Act that expanded credit coverage to hybrid electric vehicles[45].
- In April, total customer miles reached one million—saving 160 metric tons of carbon dioxide (CO_2)[46], 18,000 gallons of gasoline, and 184 hours of driver productivity[47].
- In October, the California Air Resources Board (CARB) permitted XL Hybrids to perform certain aftermarket conversions of gasoline-powered vehicles in California, and allowed for sales in the auto-loving state for the first time[48].
- And in November, the City of Boston announced it would begin to retrofit its 160+ vehicle fleet with XL Hybrids technology under the Greenovate Boston program[49].

The issue, however, was that macroeconomic trends were shifting. Oil prices were dropping precipitously as it lost almost half its value between August and December 2014[50]. The team realized that a new economic landscape was on the horizon. It was one far worse than the recession that was threatening the viability of their business.

The team responded by offering special financing options through Priority One Financial Services[51]. The financing scheme was one Hynes new well. It allowed customers to retrofit current fleet vehicles and pay for the hybrid system over time, just like a PPA. It also allowed customers to refinance their existing vehicles, and order new vans and buses with pre-installed hybrid systems. The special financing made the system simpler and easier to acquire.

The team also took advantage of special tax credit financing to build a facility in Quincy, Illinois. The facility was strategically placed in the middle of the country where a significant number of upfitters and suppliers were located. Instead of shipping equipment to Boston and then shipping it out to upfitters like Knapheide in the Midwest, the team could receive inventory from suppliers nearby Quincy and immediately ship it

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[45] http://fleetnewsdaily.com/abcs-new-epact-alt-fuel-acquisition-credits/

[46] Equivalent to removing 70 vehicles from the road over six months

[47] http://www.businesswire.com/news/home/20140428005329/en/XL-Hybrids-Announces-Million-Customer-Miles-Achieved#.U2KGQ_ldWT8

[48] http://www.businesswire.com/news/home/20141014005100/en/XL-Hybrids-Receives-Industry's-First-Ever-Executive-Order#.VD1YUBawXmd

[49] http://www.businesswire.com/news/home/20141209005275/en/City-Boston-Boosts-Green-Initiatives-XL-Hybrids#.VIhYr4u-XjI

[50] http://www.macrotrends.net/1369/crude-oil-price-history-chart

[51] http://www.businesswire.com/news/home/20150112005193/en/XL-Hybrids-Introduces-Special-Financing-Speed-Customers#.VLQEXHuLmxU

out to other nearby upfitters—all within a few hours drive each way. The move saved significant costs in shipping and handling.

Lastly, the team realized they needed to broaden their market segments as much as possible. GM vans made up only 10% of their target market, while Ford and a few other makes and models comprised over 60%. They needed another round of investment to enter broader bands of commercial fleets because sales with existing customers were likely to slowdown. Hynes therefore went out to raise a Series C. It took some time but by August 2015 the team had raised an additional $10 million in venture funding. Peter O'Brien, a former Morgan Stanley banker, was convinced that XL Hybrid systems were economically attractive and easy to acquire for corporate customers. He led the round[52].

These three moves all helped maintain sales in spite of lower oil prices making the business environment more challenging. While it is true that XL Hybrid's value proposition went down and their customers expressed less urgency to purchase hybrid systems, Hynes and the team were still receiving healthy follow on orders regardless. Hynes explained at the time that, "the business has remained steady because many other companies still want to save money by cutting fuel consumption [to fight climate change]… It's taken decades but the technology and mindset toward clean energy has really changed[53]."

The team's corporate customers were taking much more into account than just spot prices and savings on operations expenditures: the customers were using oil prices averaged over the long-term and including brand reputation in their economic analyses. Although oil prices reached record lows at the beginning of 2016, XL Hybrids continued forward thanks in part to their compelling sustainability side-benefits. In January 2016 they received a $1 million follow on order and a few months later they received a $0.9 million order from a new customer—their largest initial order to date. It was clear their value proposition was still winning over customers regardless of the low oil prices.

Ultimately, Hynes and the team did very well fairing through the toughest test any cleantech company can go through. Time will tell how successful their company does in the long-term with the likes of Tesla Motors bring online full EVs in larger and cheaper quantities.

[52] http://blogs.wsj.com/venturecapital/2015/08/28/xl-hybrids-taps-10-5-million-to-convert-gas-guzzling-fleets/
[53] http://www.bostonglobe.com/business/2016/03/11/clean-energy-goes-mainstream/ae4QRHpWAj6Ld67iUbn6oO/story.html

XL Hybrids and the Cleantech Confluence

The story of XL Hybrids depicts multiple best practices, partnerships, and policies that advance hardware-based cleantech companies:

First, Hynes, Ashton, and Siegert did their part as tremendously persistent and resourceful entrepreneurs. Without their commercial orientation, well planned market entry strategies, and engineering, development and marketing decisions, they likely would not have scaled their business so quickly after a global economic recession.

Second, investors played a vital role in enabling XL Hybrids to gain traction. Angel investors, strategic investors, and debt-financing investors all pooled their capital and expertise to help advance the cleantech company to the next milestone.

Third, policymakers and government entities rounded out overall support by providing access to critical resources that investors and other private stakeholders could not. The InnovateMass early customer program enabled the company to expand into new makes and models, while the CARB executive order opened up the California market. These along with city government sales expanded the company's reach into new markets that it needed to succeed through low oil prices.

The combination of these best practices, partnerships and policies amongst the entrepreneurs, investors, and policymakers demonstrate a Cleantech Confluence in action. This Confluence is where hardware-based cleantech companies have the best chances of scaling up. XL Hybrids is a case example of the developing Cleantech Confluence in the New England region. The number of hardware-based cleantech companies growing in New England has been growing steadily, and the decision of General Electric to relocate their headquarters in Boston is testament to the region's burgeoning Confluence system.

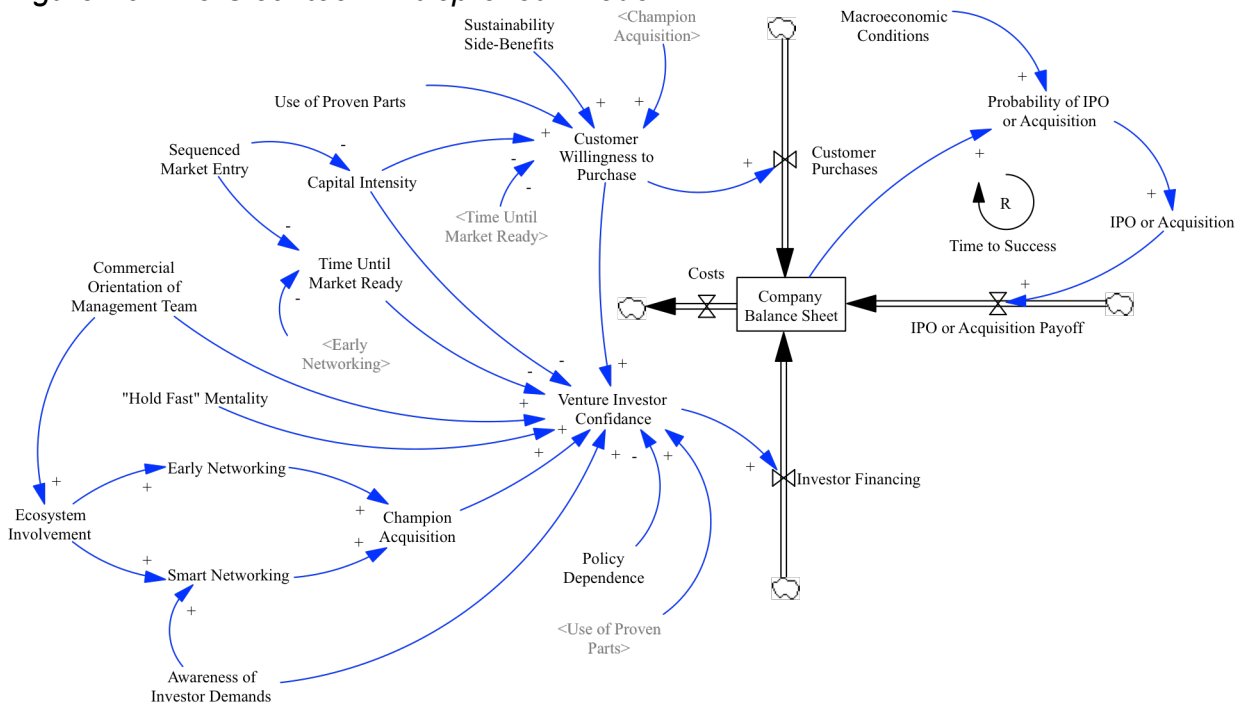
Chapter 4: Findings

Overview

My findings show multiple best practices and partnerships that increase private investment into early-stage cleantech companies. Broadly defined, they are either operational decisions to increase business survivability and growth, or tactics to increase investor confidence and willingness to invest. The findings are ordered according to those applicable to entrepreneurs, investors (venture capitalists) and policymakers. The entrepreneur and investor sections both include an overarching system dynamics model to formally depict the findings and how they interrelate. All sections and best practices include a case example or refer to the XL Hybrids case. Finally, the idea of the Cleantech Confluence is introduced to tie all three actors and their actions together.

Entrepreneurs

Figure 16: The Cleantech Entrepreneur Model



Commercial Orientation

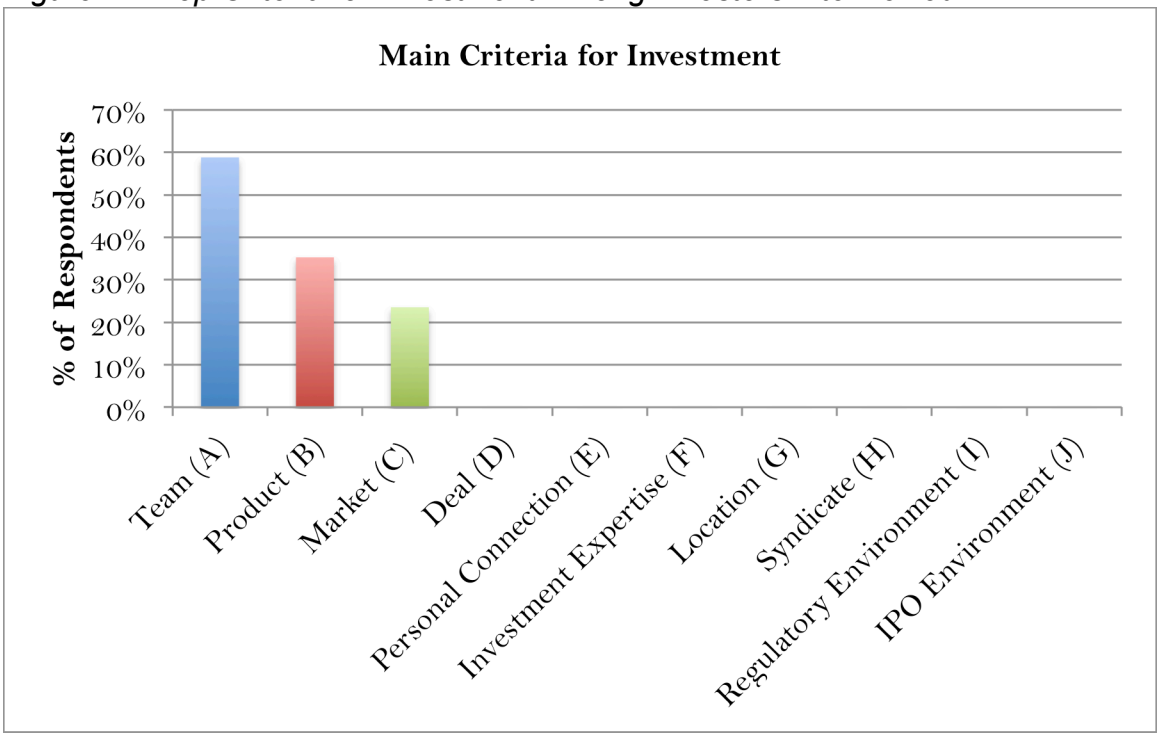
Ability to attract private investment and commercialize pass the Valley of Death is dependent on having a commercially oriented management team.

> *"I've walked away from a lot of investments with superstar CEOs who didn't know enough to bring in an experienced person who knew the customers or look after the nuts and bolts of growing a business while they worked on product roadmap."*
>
> – Cleantech Angel Investor

It is crucial to have a management team that has a clear road map on how they want to enter markets, de-risk their technology, be acquired or IPO to provide their investors an exit, network in the ecosystem, and market their technology's sustainability side-benefits. These commercially oriented management teams need to tell a story that resonates with customers and investors and focuses on market pull rather than technology push. Commercially oriented entrepreneurs must leverage all these points to increase investor confidence and venture financing (See Figure 16), and increase customer willingness to purchase and product sales.

All investors interviewed ranked management team characteristics as their top criteria for investment (See Figure 17). However, often times these capital-intensive cleantech companies are developed and managed by the technical co-founders, often graduate students, who have little business acumen. For example, one angel investor noted, "too many technology companies have technologists, but nobody that knows what the market need is. There is too much technology push." A government investor also mentioned that for "a lot of academic teams it's challenging to align incentives, so part of our program is to ensure an established team with market focused person to compliment technical people." This overwhelming technical orientation makes it difficult for companies to focus on the business development essentials that drive venture investment and customer sales. Commercially oriented management teams are therefore critical for capital-intensive cleantech success.

Figure 17: Top Criteria for Investment Among Investors Interviewed



Hynes, Ashton, and Siegert from the XL Hybrids case demonstrate this commercial orientation. They were all businessmen who had decided to develop a technology company: Hynes and Ashton were management graduates from MIT while Siegert was a supply chain expert. Their propensity to focus on market pull and scale was partly what allowed them to develop a winning electric powertrain and value chain. Their nimbleness and not being too attached to any single technology was another reason.

"Hold Fast" Mentality

Ability to attract private investment and commercialize pass the Valley of Death is dependent on persisting rather than failing and starting again.

> *"The valley of death is certainly true, there are good ideas and businesses that don't survive it, but a lot of them shouldn't survive. It's survival of the fittest."*
> –Angel Investor

A few investors touched on the fact that the Valley of Death should strike down cleantech companies. According to them and one VC investor in particular, "the valley of death is a gauntlet and trial by fire that people need to survive. If an idea is that great then it should survive and come through and resonate with investors." Commitment to the idea, the technology, and the capabilities of the management team is essential. Entrepreneurs must be ready to endure tough times and push forward.

Unlike IT entrepreneurs who can fail fast and often because their product is just software code, cleantech entrepreneurs must be persistent and tenacious because their products are physical equipment. Investment in physical assets, like solar panels and batteries, is capital-intensive, and requires reassurance that investments will not be squandered through "agile[54]" approaches to business development. Management teams must be ready to persist through the "thick and thin" as one VC stated. Commitment and tenacity are everything in capital-intensive business development, as well as resourcefulness and frugality in the early-stages. It builds investor confidence (See Figure 16).

Hynes and the XL Hybrids demonstrate a "hold fast" mentality throughout the case study. Between using their personal investment to the greatest extent possible and driving sales through low oil prices, they persisted through trials of the Valley of Death. Their smart persistence in developing the business and technology in an iterative fashion was a major factor in winning over investors for their continued growth. It is strongly distinguished from the dumb persistence and typical failure mode of entrepreneurs that are too wedded to their technologies.

[54] Agile development is a project management methodology used in the IT sector to quickly develop products. It is opposed to traditional waterfall development, which takes place over longer time periods.

Sequenced Market Entry

Ability to attract private investment and commercialize pass the Valley of Death is dependent on entering markets that actively lower capital intensity, technology risk, and time to investor exit.

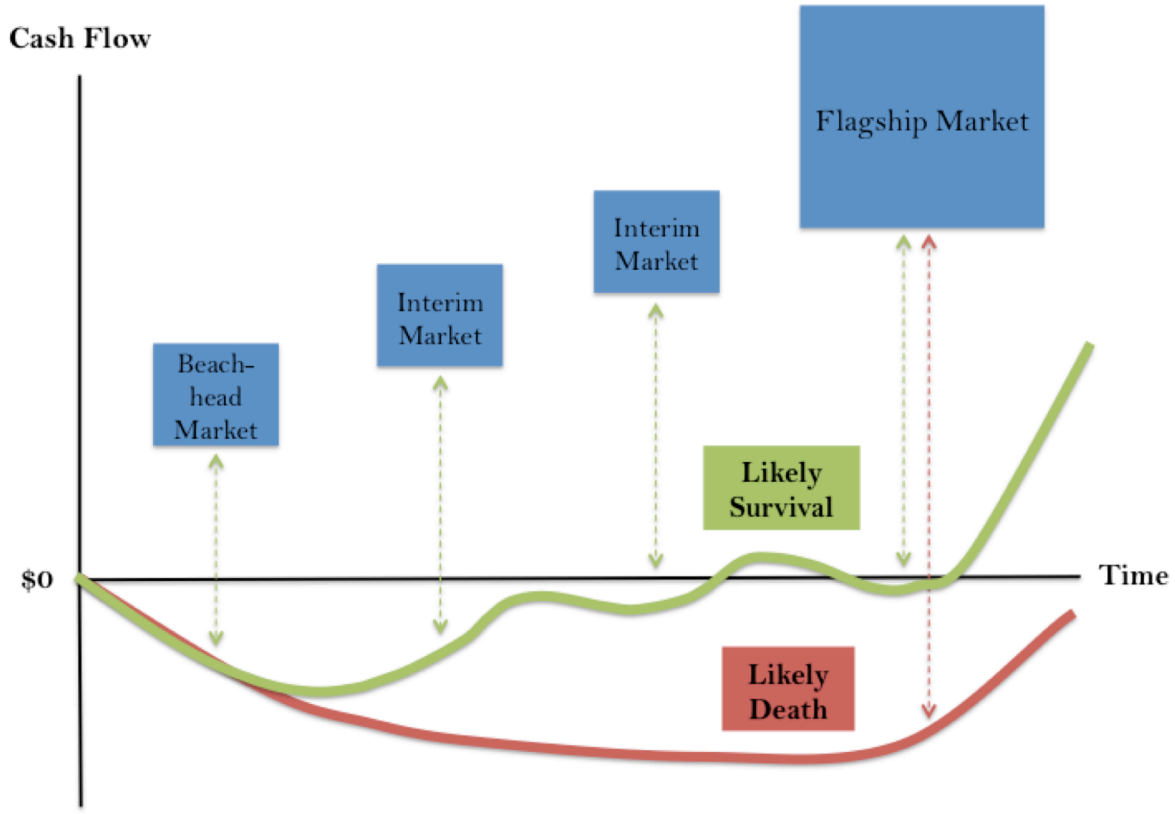
> *"You have to have some DNA around commercializing something with a near term market they could reach quicker and scale to larger reach buyers that have quicker cycles, think through the business cycle more so instead of one large long term market a lot of interim markets."*
>
> –Generalist VC

Solyndra, A123, and KiOR all had in common a market entry strategy that meant going straight for some lucrative "flagship" market. Whether in utility-scale solar, utility-scale storage, or utility-scale biofuel refineries, they were all aimed at markets that took significant time and capital to enter. Then they all went bankrupt. This was the reason why VC left cleantech: their short time horizons and limited check sizes did not match these market entry strategies. A generalist VC summed it up best in the statement:

> *"The mistake the cleantech sector made was it thought itself like biotech. You spend years developing something in storage or generation to reach a commodity market, but there is no reward like the next blockbuster pharmaceutical. Cleantech has to create real revenue markets along the way to keep going. That's hard to do because it requires a lot of thinking."*

Cleantech entrepreneurs must infuse near-term and sequential thinking into their market entry strategies, as shown in Figure 16. By starting with interim markets that can be captured quickly and then progressing to larger markets with slower rates of adoption, a new cleantech company can nimbly develop their product to the point of being able to capture their ultimate flagship market. This sequenced market entry strategy permits more sustainable cash flow and increases investor confidence since the companies are more likely to survive than to go bankrupt. Figure 18 depicts this sequence.

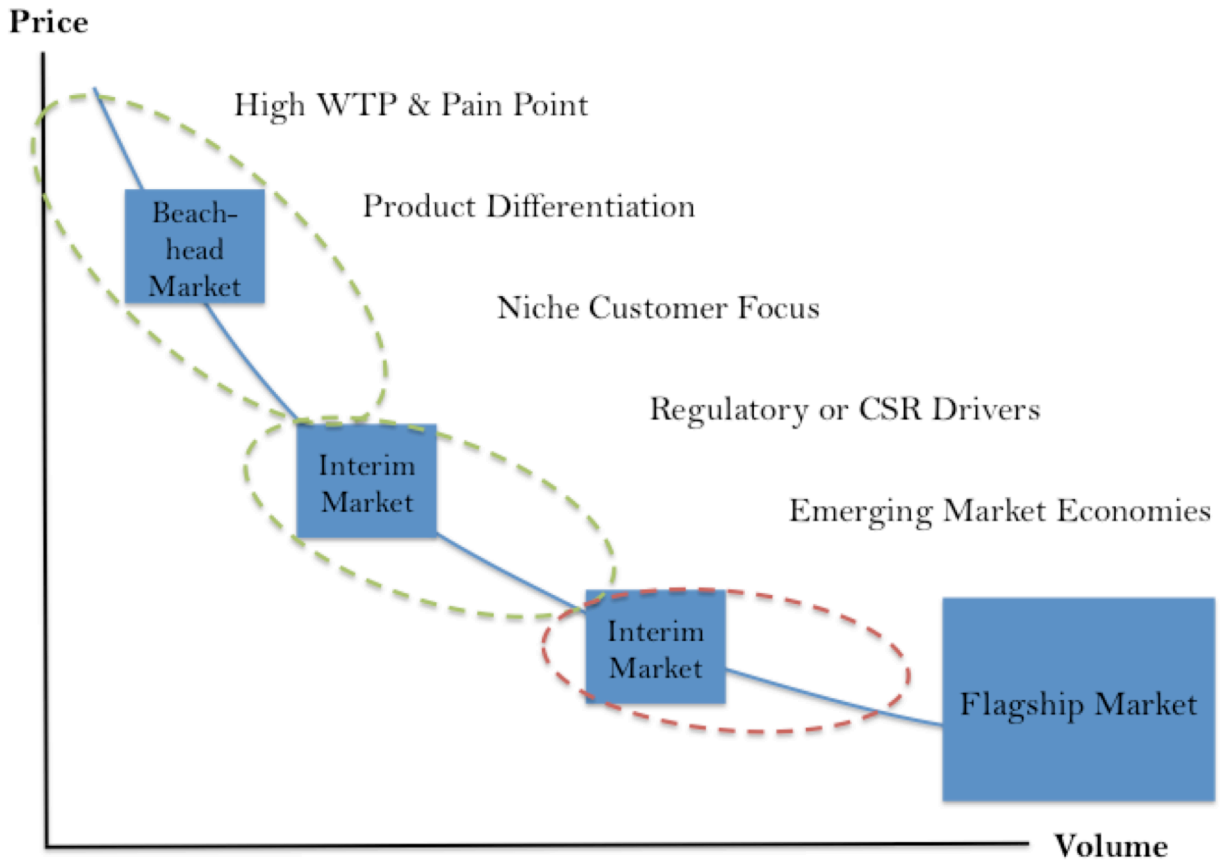
Figure 18: Capturing Interim Markets to Sustainably Progress to Flagship Markets



There are multiple strategies that cleantech companies are employing to capture the low-hanging fruits in the interim markets. Many are mentioned by (Clay 2013). In the following order, the most common strategies include: 1) focusing on individual consumers with high willingness-to-pay (WTP) and/or large pain points, 2) creating products that compete on a basis other than cost, 3) targeting niche consumer markets, 4) engaging companies that are mandated by new regulation or CSR goals to improve their technology, and 5) moving into emerging markets in the developing world or elsewhere that have little established infrastructure and fixed costs investments, and/or are adopting new technologies to with strong regulatory or cultural incentives[55]. Figure 19 depicts these sequenced market entry strategies down a price-volume curve.

[55] An emerging economy market in the developing world may also become a flagship market once it becomes developed. At the present they present a quicker opportunity for market entry than the same markets in developed economies because of their relatively smaller infrastructure base.

Figure 19: Sequenced Market Entry Strategies to Work Towards Flagship Markets



For example, Elon Musk and his master plan of selling the Roadster, Model S, Model X, and Model 3 in that sequence is a prime example of a cleantech entrepreneur employing these market entry strategies to reach the flagship U.S. middle-class automotive market. Musk leveraged the booming population of Silicon Valley tech millionaires to purchase his all-electric and high margin Roadster and Model S cars in order to finance development of his mass market Model 3. By beginning at low-volume high-value products, Musk has been able to penetrate the heavily entrenched auto industry, and build the cash pile necessary to deliver an affordable mass-market offering through the Model 3 and also build the world's largest lithium-ion "gigafactory" to deliver affordable home energy batteries.

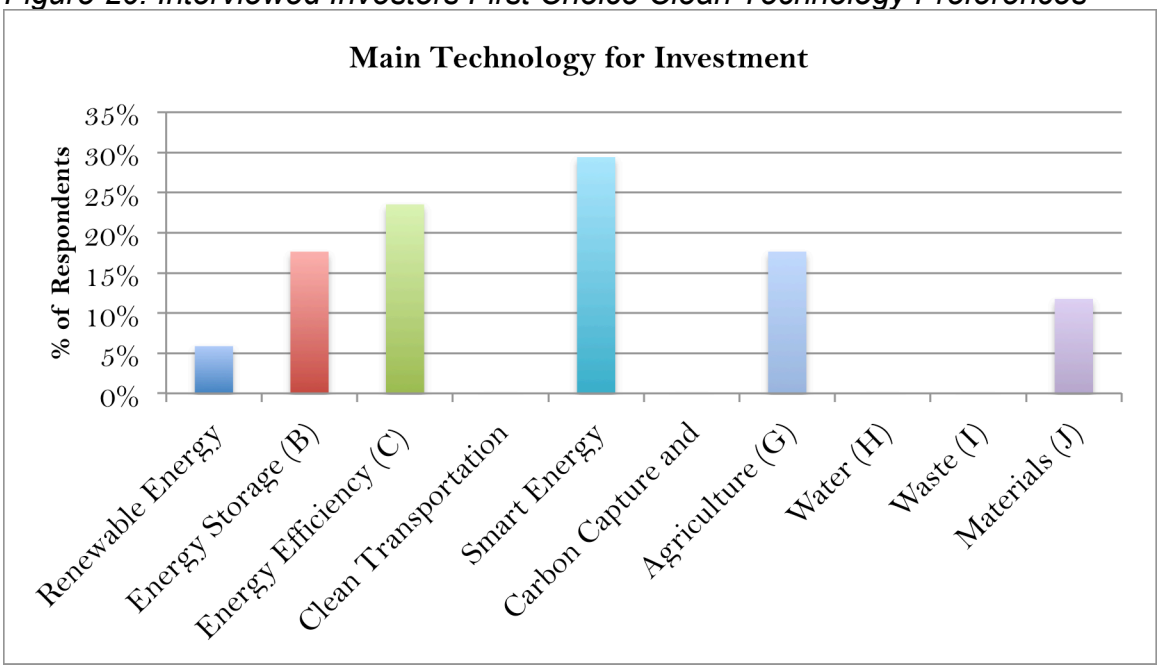
Other Sequencing Techniques:

Other important principles of sequenced market entry, outside the price-volume framework, include letting the technology incubate as long as possible within academic contexts, in order to maximize non-dilutive funding from government and corporates, and creating smaller or capital-light versions of the technology that can be sold in individual consumer markets. A generalist VC offered an example during an interview when he stated that:

"… If you're doing a battery company, maybe you create smaller batters for [Internet of Things] and don't create car batteries, but start with toys because you're closer to the individual customer. [One] company started by selling hydrogen toys, reached the energy customer first with science kits, and they did very well. That was enough to keep them going and experimenting on bigger scale."

As the example mentions, offering data and analytics capabilities to whatever hardware-based technology as an "Internet of Things" offering is a powerful motivator for VCs. In the case of XL Hybrids, Hynes and the team added data and analytics capabilities by using sensors to capture information from their electric powertrains. The IT functionality allowed the team to optimize the system design for different makes, models, and customers. They ended up patenting the functionality and it turned out to be a big selling point to their investors. Indeed, amongst all the investors respondents interviewed, IT-like "Smart Energy" technologies rated as a top investment category (See Figure 20), showing the power of integrating data and analytics into capital-intensive cleantech.

Figure 20: Interviewed Investors First Choice Clean Technology Preferences



Use of Proven Parts

Ability to attract private investment and commercialize pass the Valley of Death is dependent on using proven parts and infrastructure to the greatest extent possible in overall system designs and offerings.

> *"In the early-days of the technology valley of death, you need to figure out what you're going to do in-house versus what you're going to outsource. A startup can't do it all in-house, you would have to raise hundreds of millions, so you have to find the right partners and leverage existing infrastructure where possible, and be selective about partners, suppliers, and what you do in-house."*
>
> –Cleantech CEO

Resources are critical in the early stages of a company. As touched upon by Erzurumlu, Tanrisever, and Joglekar (2010), it is important to know what engineering must be done internally versus what can be outsourced. The novelty of the cleantech sector makes this decision hard for many early-stage entrepreneurs, since many times they are developing new technologies with little to no suppliers or manufacturers. This novelty also makes it tough for investors to provide capital, given the large risks and uncertainties surrounding unproven technologies with unproven physical and sometimes regulatory infrastructures. Capital-intensive cleantech entrepreneurs must therefore build their system with the greatest amount of proven parts as possible, and offer it through whatever existing infrastructures are best suited, in order to de-risk their technologies sufficiently for investment and customer willingness to adopt. This is shown in Figure 16.

The main benefits of using "off-the-shelf" parts and infrastructure is that it leads to greater chances of early-stage equity *and* debt financing. Outsourcing certain system parts reduces technology risk and decreases capital-intensity since it demands less custom manufacturing equipment and processes. This increases confidence in both debt and equity investors, increases scalability[56], and increases adoption the rate by customers. Design therefore becomes a critical function in enabling the use of proven parts and infrastructure, and decreasing overall technology risk. Creating good designs with this logic, early on, is essential to maximize chances of financing, growth, and survival.

In the XL Hybrids case, Hynes and the team made the decision to use "off-the-shelf" batteries from Johnson Controls and the upfitting infrastructure by Knapheide so their system was perceived as more reliable and accessible to their customers. Though the decision required extensive integration and increased overall costs in the short-term, it led to quicker and greater customer adoption later on. The company was able to come back in the future with a better designed system at even lower costs and easier installation because they had used proven parts and infrastructure to their early advantage.

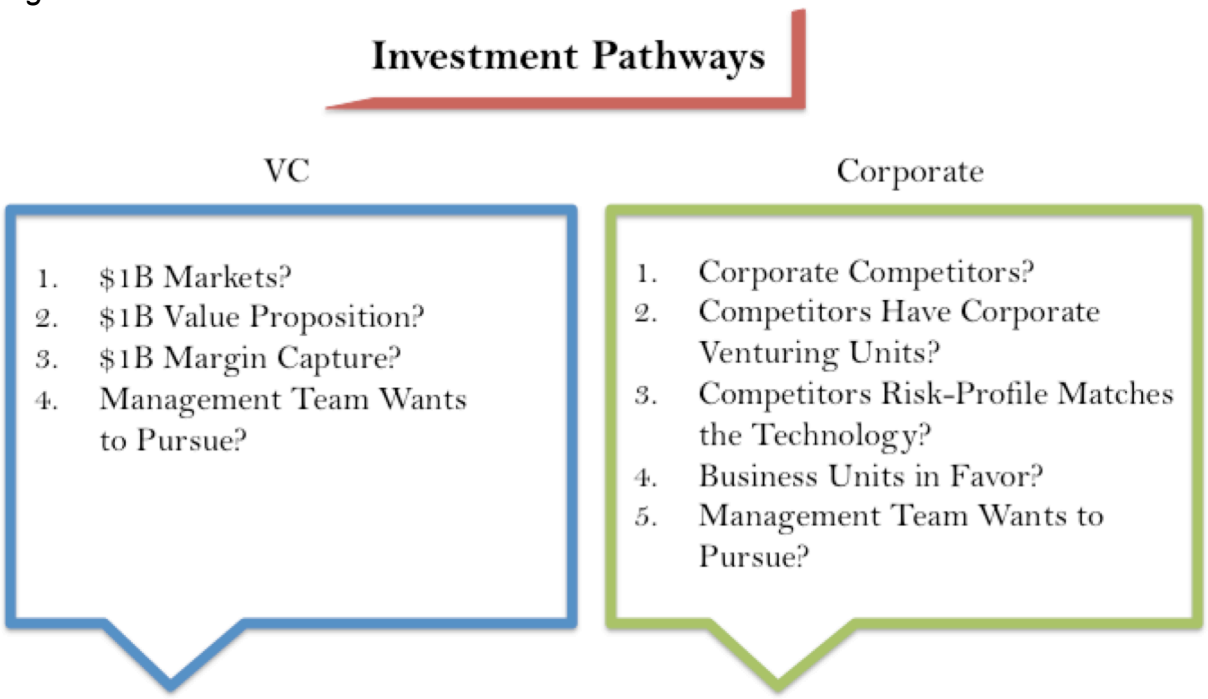
[56] Defined by the Comprehensive Initiative on Technology Evaluation as the "capability to reach consumers and impact society on a large scale, taking into account issues of supply-chain configuration, sourcing, manufacturing, distribution and after-market support."

Awareness of Investor Demands
Ability to attract private investment and commercialize pass the Valley of Death is dependent on knowing the pros and cons to different types of venture investment.

> *"Acceleration can happen if you give the entrepreneurs time to figure out what their technology is capable of first, and then you orient them to the appropriate market. That market could be one VC underwrites or maybe one they don't."*
> – Cleantech Incubator Officer

Not all cleantech companies are well suited for VC money. Sometimes VC creates structural issues that can sometimes impede corporate acquisition later; sometimes forgoing or delaying VC money can allow capital-intensive cleantech companies to engage corporates much better. It depends on the VC and their pressure on growth. In scenarios without VC funding, technologies can sometimes be given more time to develop into a product that is useful for a corporate business unit. They may then become an acquirer of the technology and/or the entire cleantech company. Each entrepreneur therefore has a different set of circumstances to consider when deciding if they want to pursue the VC or corporate investment pathways (See Figure 21). Having awareness of investor demands early on can guide a significant portion of the conversations that the entrepreneur should be pursuing (See Figure 16).

Figure 21: Heuristics for VC and Non-VC Investment



If the entrepreneur does want to pursue the VC pathway, then they will have to check that 1) the technology has the ability to get to a $1B outcome in one or several markets, 2) the technology can actually create $1B worth of value in the selected applications, and 3) the $1B in value is not split up by the supply chain and have margins captured by

multiple suppliers. If these points check out positive, then there is a good chance the technology is prime for VC backing (by a GP driven firm with the flexibility to invest).

If the entrepreneur wants to pursue the corporate pathway, then they will have to check that 1) the technology competes with some existing corporate(s) application, 2) those corporate competitors have corporate venturing units, 3) the technology matches the risk-profile of the competitors (Optimizer, Distributor, Explorer), and 4) the relevant business units would likely be in favor of the technology. If these points check out positive, then there is a good chance the technology is prime for corporate backing through investment, sales, joint partnerships, and/or acquisition.

There is also emerging non-VC and non-corporate pathways for entrepreneurs to pursue. These options include crowdfunding platforms like Propel(x), family office investment from professional groups like CREO Syndicate, and nonprofit intermediaries like Prime Coalition. If entrepreneurs want to pursue these pathways then they will have to check the specific requirements of each. The novelty of these financing sources makes their relative advantages and disadvantages less known than traditional VC and corporate investment pathways.

An example of a cleantech company that appeared to fail because of going down a wrong investment pathway was Boston based Next Step Living. The residential solar and energy efficiency provider, which had received about $52 million in venture investment[57] and grew to more than 800 employees and more than $100 million in annual revenue, was founded in March 2008 and closed in March 2016. Inc. 5000 named Next Step Living as one of the fastest-growing companies in Massachusetts and the nation[58] in multiple years, yet still the cleantech failed. Massachusetts's reluctance to raise the state's cap on solar net energy metering was cited as a major demise of the company,[59] but what was happening in Next Step Living's last few years was actually slew of service complaints[60]. Work being done too hastily came from management pressure to complete projects, which seems to have come from VC pressure to scale up quickly, and the result was a proceeding down an unsustainable investment pathway. The example shows the need for entrepreneurs to be aware of investor demands, and the latitude they need to grow human capital, management processes, and technological development at the right pace.

[57] VC investors included Braemar Energy Ventures and Vantage Point Capital Partners, as well as family office investor Black Coral Capital and the government backed Massachusetts Green Energy Fund.

[58] http://www.prweb.com/releases/2015/08/prweb12902795.htm

[59] http://www.xconomy.com/boston/2016/03/18/next-step-living-once-a-promising-energy-startup-shuts-down/

[60] http://www.bizjournals.com/boston/blog/techflash/2016/03/boston-energy-efficiency-firm-is-shutting-down.html?ana=e_bost_bn_breakingnews&u=LKPNmzsMoT6umhib0Qyw2w004cd791&t=1458312640&j=71540462

Champion Supporter
Ability to attract private investment and commercialize pass the Valley of Death is dependent on having an investor and/or customer "champion" the team and technology.

> *"Investments have been driven by a champion, or someone in the group who really likes the deal."*
> –Angel Investor

It is hard for many investors to cope with the ambiguity and inherently large risk in capital-intensive cleantech unless they have forcing functions or other motivations to make them do so. CSR objectives, government regulations and subsidies, and corporate strategic imperatives have all served as catalysts for cleantech adoption and investment. Although these have been powerful forcing functions, ultimately someone has to be advocating for a project and making use of certain incentives and justifications. Someone with the authority and/or decision-making power to stand up for a team and technology has to become its champion supporter in order for change to happen. Cleantech entrepreneurs must seek these individuals because they can hold tremendous power in influencing more investment into their companies and/or making more cleantech purchasing decisions (See Figure 16).

During a corporate innovation conference, one panel touched on the point when a panelist stated that "corporates need more super strong champions to drive innovation," and that they need "visionaries to make a bet on the future." These champions and visionaries usually arise organically from personal connections and interests, and serve as catalysts of investment in new technology companies. Buy-in from VC partners, corporate business unit managers, and individual angel investors almost guarantees a thorough consideration of an entrepreneur and the technology they present. Entrepreneurs must be networking early on and networking diligently to find these champions and bring them on their side. It is important to note that champions can also come from other groups like nonprofits and corporate sustainability teams, who may also have strong interests for a particular technology with strong sustainability benefits.

In the XL Hybrids case, former Morgan Stanley banker Peter O'Brien ended up being a champion supporter of the cleantech company, as evident of him leading XL Hybrid's Series C round. Bruce Kara, Vice President of Environment and Sustainability of Coca-Cola, also ended up being a champion supporter of XL Hybrids. He convinced Coca-Cola's commercial fleet manager to purchase 100 XL Hybrid systems, which was the startup's single largest purchase order up to that point.

Early Networking
Ability to attract private investment and commercialize pass the Valley of Death is dependent on early communication with customers, strategic partners, and investors.

> *"They say it's all about being in the right place at the right time… well you have to be there."*
> – Cleantech CEO

Across many of the interviews there was a common theme of engaging in early interaction with potential customers, partners, and investors. Developing relationships early on can dramatically speed up the purchasing, partnering, and investing cycles of capital suppliers. As mentioned in the XL Hybrids case “it gets the clock ticking” on purchase and/or investment decisions. Figure 16 shows that networking before an entrepreneur needs investment and while they are pre-revenue can lead to gaining a champion supporter and expedite important investor/customer decisions.

Investors that are engaged early are more likely to make quicker decisions with people they have already met and have known for a long time. One angel investor interviewed said he “needs to know management team for at least six months before he can decide to make an investment,” which is a sentiment most likely implicitly or explicitly shared with most other investors. It is best for entrepreneurs to begin networking with investors far before they need to fundraise, and do so while they are predominantly in an information gathering rather than solution selling mindset.

Customers and strategic partners that are engaged early are more likely to make purchase and/or investment decisions by the time the entrepreneur needs them. Both have very long sales and decision cycles. One cleantech incubator officer put it best when she said, “as an entrepreneur, you need to talk to big companies as early as possible, get on their radar, figure out how they make decisions and know their timelines, even when you’re not selling.” Early communication is essential to gather the feedback necessary to steer product development to customer specifications and/or strategic partner requirements, and accelerate time until market ready.

In the case study, Hynes and the XL Hybrids team did early networking with various corporate fleet managers to commence long sales cycles. Once they had definitively decided that the class 2-6 van market was ideal for their electric powertrains, they proactively engaged a multitude of corporate companies. Their early networking with Coca-Cola and FedEx among others allowed them to speed final purchasing decisions and enhance their revenue forecasts during investor fundraising.

Smart Networking

Ability to attract private investment and commercialize pass the Valley of Death is dependent on having a strong personal brand and an open-minded approach to networking.

> *“Entrepreneurship is a team sport: it takes a lot of people. The entrepreneur needs to be part of the network and play in the ecosystem. They need to be nice people. If somebody writes to them they should write back and say thank you. If they are looking to hire somebody, they have to know whom to call. If they are raising money, they will want someone who knows them beforehand since that means a lot. If they want an introduction to a customer, they will want to know someone beforehand. If they want the right lawyer or accountant, they have to*

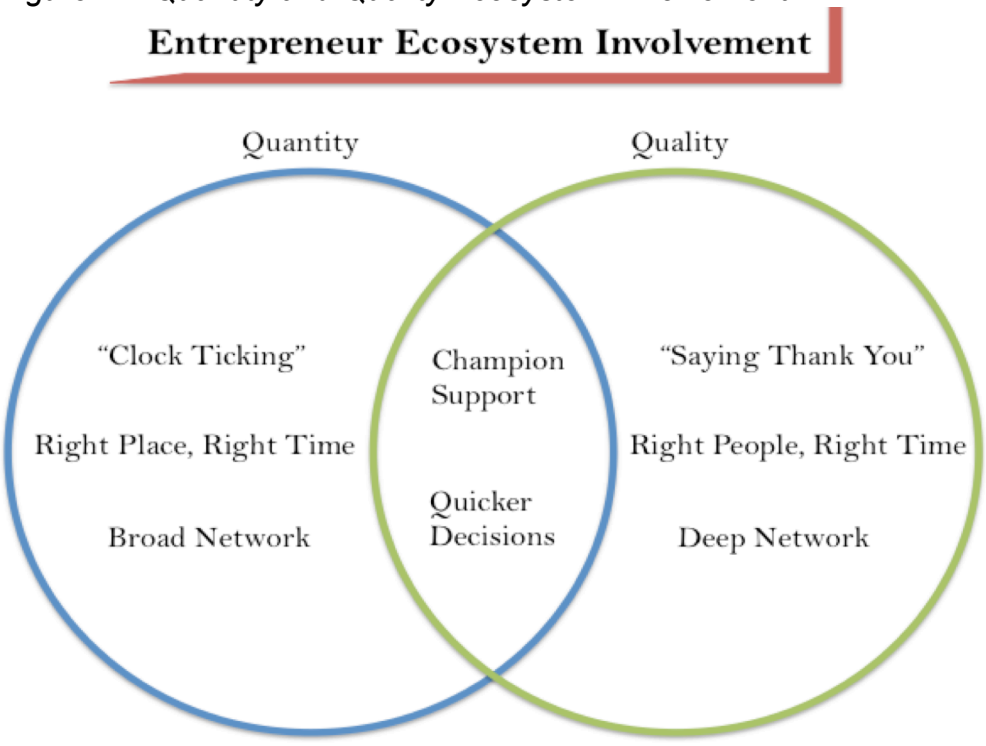
know the ecosystem and engage early. Getting to know people through events, competitions, mentor networks and incubators is important."

–Angel Investor

Just as for investors, ecosystem involvement is key for entrepreneurs. Getting to know customers, partners, and investors early on is only one piece of the puzzle, but besides the "quantity" of interactions, the "quality" of interactions is equally important. Gathering info from every contact in an open-minded manner leads to more trust and likelihood of support; transparency throughout the process reduces principle-agent problems that can heavily dilute an entrepreneur's stake in the venture. Figure 16 shows how this smart networking plays a principle factor in gaining champion supporters.

Creating strong personal connections gives rise to champion supporters who as mentioned previously, can vouch for the company in the face of investment and strategic partnership groups. A strong personal brand, through open-mindedness and a certain level of transparency, makes it much easier for these champions to advocate on behalf of the entrepreneur and the technology. Though champion supporters are difficult to find and require broad networking, once found they can be decisive. Therefore high-quality interactions are just as important as high quantity interactions for entrepreneurs. It is essential to attract the right people who will support the capital-intensive enterprise, and speed up important investment and/or sales decisions (See Figure 22). One angel investor summarized this best when he stated that, "if everyone in the ecosystem knew each other's name, we could all fly faster. Whether a strategic partner, customer contact, or supplier, we could all fly faster."

Figure 22: Quantity and Quality Ecosystem Involvement



Although not explicitly seen in the case study, Hynes employed smart networking in order to successfully develop XL Hybrids: one VC investor interviewed had evaluated XL Hybrids for investment and although did not invest for macroeconomic reasons, mentioned that XL Hybrids team were "great" and "one of their strongest points." Another VC investor interviewed that did ultimately invest in XL Hybrids said that Hynes and another cleantech entrepreneur were "super smart individuals who also happened to be very passionate about what they were doing." Smart networking and a strong personal brand definitely played a role in propelling Hynes and XL Hybrids forward.

Sustainability Side-Benefits

Ability to attract private investment and commercialize pass the Valley of Death is enhanced by tracking sustainability metrics and presenting them as a side-benefit.

> *"Talking sustainability to corporates is the best way to go since they are all looking for sustainability impact to report. We bring it up with corporates and immediately get directed to their sustainability teams and business units that want to see our solution and address its technical risk."*
>
> –Cleantech CEO

Corporates and individual consumers are beginning to value sustainability more. Entrepreneurs must leverage this in their discussions with potential customers. To do so they must be tracking whatever sustainability metrics are most relevant in their technology use case, operations, and supply chain. Sustainability impact must be used as a side-benefit, however, as using sustainability as a focal point in conversations and presentations can lead to a sensation of "green washing." Too much focus on sustainability, like technology push, is a turn off for customers and investors. Entrepreneurs that use sustainability to their advantage therefore keep it as a side-benefit to their core value proposition. This can make a substantial difference in increasing customer willingness to adopt (See Figure 16).

Certain "impact investors" also require sustainability metrics and a sustainability story to invest in certain companies. These can be angels, family offices, nonprofits, and government investors that have an explicit mandate for environmental and/or social impact and may be willing to forgo market rate returns for certain kinds of impact[61]. Part of their evaluation will be based on potential for sustainability impact, so entrepreneurs that have thought of these metrics beforehand can also use them in the fundraising discussions.

Hynes in the XL Hybrids case used sustainability side-benefits to win purchase orders from the likes of Coca-Cola and to win support from government funded MassCEC and Massachusetts Green Energy Fund. Both the corporates and the government had

[61] Impact investors are called "concessionary" investors because of their willingness to forgo returns for impact. "Non-concessionary" investors are those that seek market rate returns no matter the investment. This does not exclude them from making cleantech investments, however.

criteria for potential GHG emission mitigation in their evaluations. Hynes catered to these criteria well in his pitch after first covering potential for fuel and cost savings.

Policy Independence
Ability to attract private investment and commercialize pass the Valley of Death is enhanced by not relying on policy support.

> *"We built our business from the beginning to not rely on incentives or subsidies, which is a big difference from our competitors who almost all are heavily subsidized by the government."*
> –Cleantech CEO

Sticking to business fundamentals and designing business plans to not rely on policy support is critical to attract private capital. Unanimously, almost all investors interviewed mentioned that reliance on policy is undesirable and raises concerns. Entrepreneurs can correct this mishap from the moment they incorporate their company. By doing so and increase investor confidence and dramatically increase their chances of seeking investment (See Figure 16).

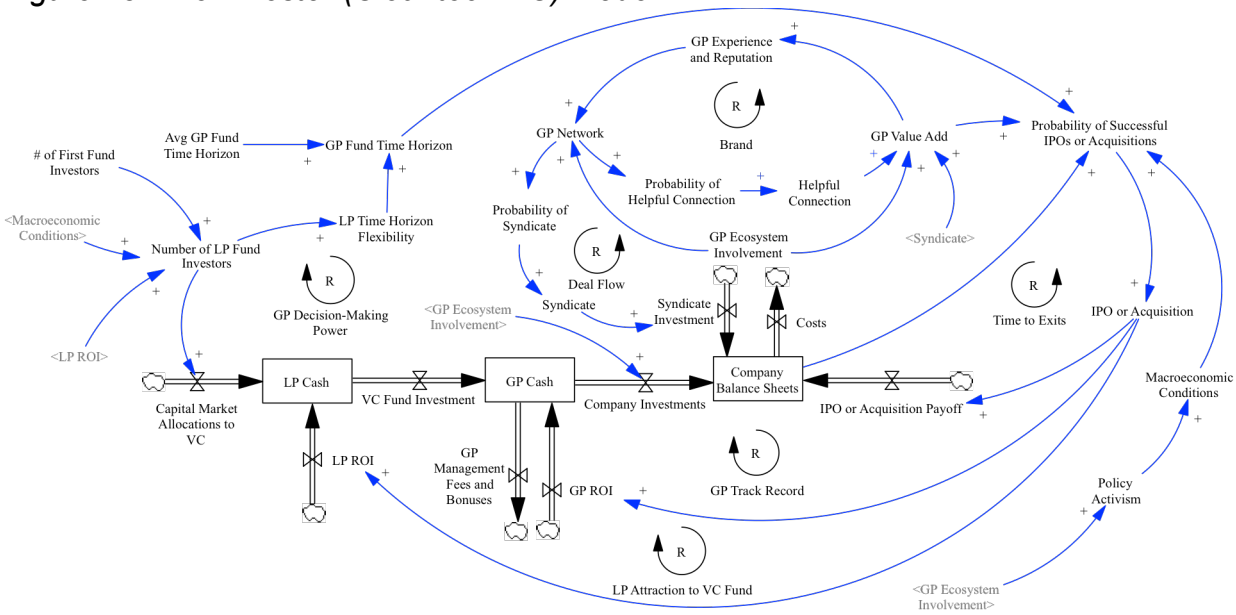
There are many incentives at the state and federal that are aimed at helping cleantech companies, both in cleantech and in other sectors[62]. Entrepreneurs must be aware of these incentives and proactively try to qualify for them. However, they must still center their value proposition and unit economics based on unsubsidized scenario assumptions. They need to demonstrate that their companies can survive beyond ephemeral political cycles and are worthy of long-term financing.

Hynes in the XL Hybrids case was selective with the incentives he and the team decided to pursue. They took advantage of a tax credit opportunity to expand into Illinois and the DOE's new credit allotments for hybrid electric vehicles in the updated Energy Policy Act, but they were adamant about maintaining the consistent $8,000 price point, which they had based on unsubsidized regulatory environments and a significant value proposition at around $70 a barrel of oil. The team's unit economics changed dramatically when oil prices dropped in late 2014, but they still maintained their price point to uphold investor confidence and customer willingness to pay.

[62] These take the form of tax incentives for early-stage companies and subsidies for certain technologies. They are not to be confused with technology performance standards, like vehicle emission standards or renewable portfolio standards that are long-term legal mandates.

Investors

Figure 23: The Investor (Cleantech VC) Model



Early Track Record

Ability to invest in long-term and capital-intensive technologies requires a build up of investments from the start.

> *"Time horizons matter a lot. [A prominent cleantech VC] was saying that given her track record, her LPs are willing to be more patient and give some wiggle room that may require bigger longer bet. Results matter and she has a track record to point to, and concrete examples for why they took longer and how they were able to work with them."*
>
> – Government Investor

As a new VC fund begins to invest and prove its worth, it will likely have a few LP investors and require a liquidation event within 10 years time. In this first time fund, the GP will have limited discretion to invest outside of its primary areas for investment and less than 10 year time horizons. They must prove that it can return roughly ten times on its investments in order to raise another fund[63]. Only after the GP exits its first fund and raises a subsequent fund can it can begin to gain the ability to invest for longer time horizons and invest in "riskier" cleantech companies. This is the GP's track record and ability to attract LP investors. Both are shown as loops at the bottom of Figure 23.

Building a track record is difficult at the start of a new VC fund as it is any new endeavor. The GP will have a small fund size, limited deal flow, and low-quality

[63] VC funds are usually labeled as I, II, III, and so forth as the firm continues to produce large returns on investments for its LP.

investment prospects. Regardless, the GP has to make at least one investment in a hardware-based company to build its track record. The GP has to leverage its entire network to facilitate joint partnerships, provide technical expertise, expand supply chain reach, and introduce potential first customers to help that company scale up. This increases the probability of the investment reaching a successful exit, which makes it possible to explain to LP investors why some investments may take longer. Then LP investors in subsequent funds become more flexible with their time horizons and technology selection because they understand that it is necessary for successful investments.

Vinod Khosla, a Silicon Valley VC renowned for his capital-intensive investments in biofuel technologies, started his investing career at Kleiner Perkins. He focused on IT investments until 2004 when he decided to leave, believing that "investing his own money would give him the freedom to pursue 'high-risk, high-return science projects' in the newly developing clean technology industry (Lassiter, Sahlman, and Wagonfeld 2012)." He founded Khosla Ventures and began making Series A investments in many types of cleantech ventures. His success in working closely with entrepreneurs led many of his investments to require follow-on funding. From there on Khosla Ventures became a prominent VC in cleantech. Even though its reputation suffered from failed investments in biofuel companies, the firm had a track record to back further investments in capital-intensive companies.

Strong Brand

Ability to invest in long-term and capital-intensive technologies is enhanced by contributing to the greater cleantech ecosystem.

> *"If you get involved as a value-add player in successful companies and you build your brand, the brand and your networks will drive the volume of your deals. Your brand, notoriety, and networking will create a large network of folks…you will hopefully come to know some of the high powered and highly successful people in the field."*
>
> *–Cleantech VC*

The GP builds its VC brand by investing solid companies and being involved in the cleantech ecosystem. The top loop labeled as Brand in Figure 23 shows how successful exits lead to greater reputation, broader networks, and greater value-add to portfolio companies. However, value-add is not exclusive to portfolio companies: value-add also applies to contributions made to the greater cleantech ecosystem. This ecosystem involvement is a critical element in building a strong brand.

What is ecosystem involvement? It is writing white papers and blog posts, attending and speaking at conferences, and getting on the boards of nonprofits and research centers. These activities outside the realm of investing serve as contributions to the greater cleantech ecosystem and as signals of a strong brand. They help build networks and investment syndicates. It is an important enabling function for funds to invest in capital-intensive cleantech.

Rob Day, a Boston area family office investor, was able to co-found the $30 billion Cleantech Syndicate partly because of his significant amount of ecosystem contributions. The partner of Black Coral Capital writes about cleantech financing and development in all sorts of media outlets—including Greentech Media, Tech Crunch, and Xconomy—and has been involved in some capacity with the Cleantech Open competition, the New England Clean Energy Council policy group, and the Renewable Energy Business Network, which he co-founded. All these activities have given him and his fund a strong brand, and the ability to invest "patient, flexible capital not hindered by the fund structure limitations typical of private equity and venture capital[64]" into capital-intensive cleantech like energy storage.

Decision-Making Power

Ability to invest in long-term and capital-intensive technologies depends on the number of LP investors in a VC and the demand for them to join.

> *"We came up with the first idea and focus, and then went out and tried find LPs who were of the same mind and interest as us… certainly if you have a lot of LPs, [sustainable investing] is driven by the GP."*
>
> – Cleantech VC

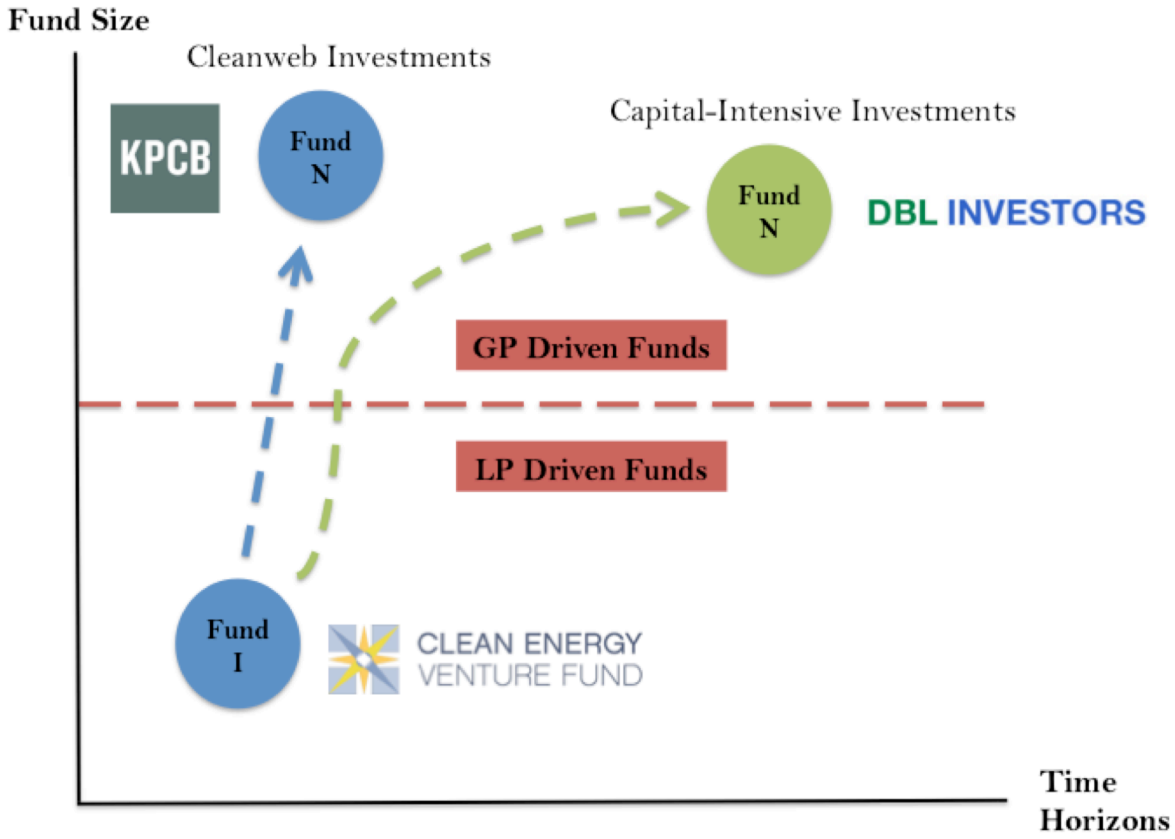
Decision-making power is an essential factor for early-stage investing in hardware-based cleantech. The more power that lays in the hands of sustainability-driven VC professionals, the greater the amount of financing that can be channeled to capital-intensive cleantech. Decision-making power is gained by having a large number of investors in the LP and having a successful track record. In this GP driven model, the GP has greater flexibility to invest for longer time horizons and in capital-intensive companies since the LP decision-making power is diffused amongst many investors and over multiple fund cycles. This decision-making power is shown as a loop on the left side of Figure 23.

On the flipside, when the GP has few investors in its LP and is still a nascent fund, the LP end up having more power over GP time horizons and areas of investment. Their numbers and influence is concentrated. In this case, the GP often revert to typical VC fund 10 year time cycles and relatively capital-light investments[65]. This is the LP driven model. Figure 24 graphically depicts both the GP- and LP-driven models.

[64] http://www.cleantech-syndicate.com/images/Cleantech_Syndicate_Investment_Placemat.pdf

[65] The typical VC fund length is 10 years. Investments are usually carried out the first three years, followed by an average holding period of five years, and an exit window of two years.

Figure 24: Decision-Making Power and GP versus LP Driven Models



Note: KPCB is Kleiner Perkins Caufield & Byers. Clean Energy Venture Fund is a new VC firm in Boston.

Nancy Pfund, a Silicon Valley VC investor, built her VC's decision-making power with several extraordinary investments and bringing on a large pool of LP investors. Her VC, DBL Investors, was an early investor in Tesla Motors and Solar City, and the successes catapulted her GP to a prominent position of decision-making power. Many investors wanted to join her LP, and by the time she raised her third fund in 2011, DBL Investors II, she had a total of 108 LP investors signed up, according to SEC filings[66]. She and her GP had proved that capital-intensive cleantech can be profitable, and in doing so were able to command investment flexibility to continue investing over long time periods in the space.

[66] https://www.altassets.net/private-equity-news/by-news-type/deal-news/dbl-investors-doubles-fund-ii-hitting-356m-target-for-third-vc-fund.html

High-Quality Network
Ability to invest in long-term and capital-intensive technologies is dependent on having good contacts to stimulate deal flow.

> *"There was a lot of deal flow coming out of MIT through faculty interest and competitions, and we were right by MIT so we had close contacts. The nature of early-stage venture is filtering the people as much as the idea… we trusted a lot of the professors spinning out companies and their networks so human network was very strong."*
>
> – Generalist VC

Strong ties and involvement with academia, corporates, nonprofits, government, and ancillary groups are all important. It gives rise to greater syndicates and deal flow, as shown in Figure 23. These ties are primarily created by ecosystem involvement and from longstanding mutual experiences.

For example, spinout companies coming from repeat entrepreneurial professors[67] were highly rated by the investors interviewed. Their close ties with the professors lead to significant trust and willingness to invest in the spinout teams and technologies. Many VCs work directly with top institutions like MIT, Stanford, and Berkeley to have access to new cutting-edge ventures.

Robert Metcalfe, inventor of the Ethernet and a former partner at Polaris Venture Partners, used his close ties with MIT to almost single handedly create the clean energy ("Enertech") practice at the Boston based VC firm. During his 10 years at Polaris, he invested in over a dozen clean energy companies, many of which came out of MIT labs. In an interview he recounts:

> *"The first filter that VCs are generally forced to use is 'do I know these people?' Or 'are they referred to me by people who I know?' I don't even read proposals from people I never heard of… I hang around MIT because those MIT professors are way over the threshold of acceptable. But even there you find that some professors are more prolific than others in terms of commercializing technology…[68]"*

Metcalfe's status as a MIT life trustee, and stints as director and board advisor with the MIT Energy Initiative, gave him significant deal flow when investing in energy, IT, and biotech. It played an important part in enabling him to make investments in cutting-edge and capital-intensive cleantech companies like MIT spinout 1366 Technologies, which was also backed by ARPA-E.

[67] Professors that co-found multiple companies as continuations of their line of research.
[68] http://ubiquity.acm.org/article.cfm?id=1979463

Strategic Syndication
Ability to invest in long-term and capital-intensive cleantech depends on syndicating with corporates and other investors.

> *"Syndication is generally a good thing. It allows you to spread the risk. You can bring in other skillsets. It's usually too risky to go all alone in one venture."*
> – Corporate Investor

> *"You need to have a good syndicate. Don't rely on one name. Spread the wealth. Spread the net widely."*
> – Cleantech VC

Syndication with multiple different investors is essential for cleantech investing. Whether as a generalist VC, cleantech VC, corporate investor, family office investor, angel investor, or government investor, syndication with other investor types plays multiple important functions in financing early-stage cleantech. They broadly fall into three categories: 1) value-add (V), 2) risk-sharing (R), and 3) venture / technology exploration (E). Figure 25 summarizes the main contributions each different investor adds to a syndicate, which is shown as another source of investment in Figure 23. Tables 1 and 2 provide a comprehensive overview of the relative gains each investor obtains by syndicating with another type of investor. Each of the three categories is explained next.

Figure 25: Syndicate Contributions by Investor

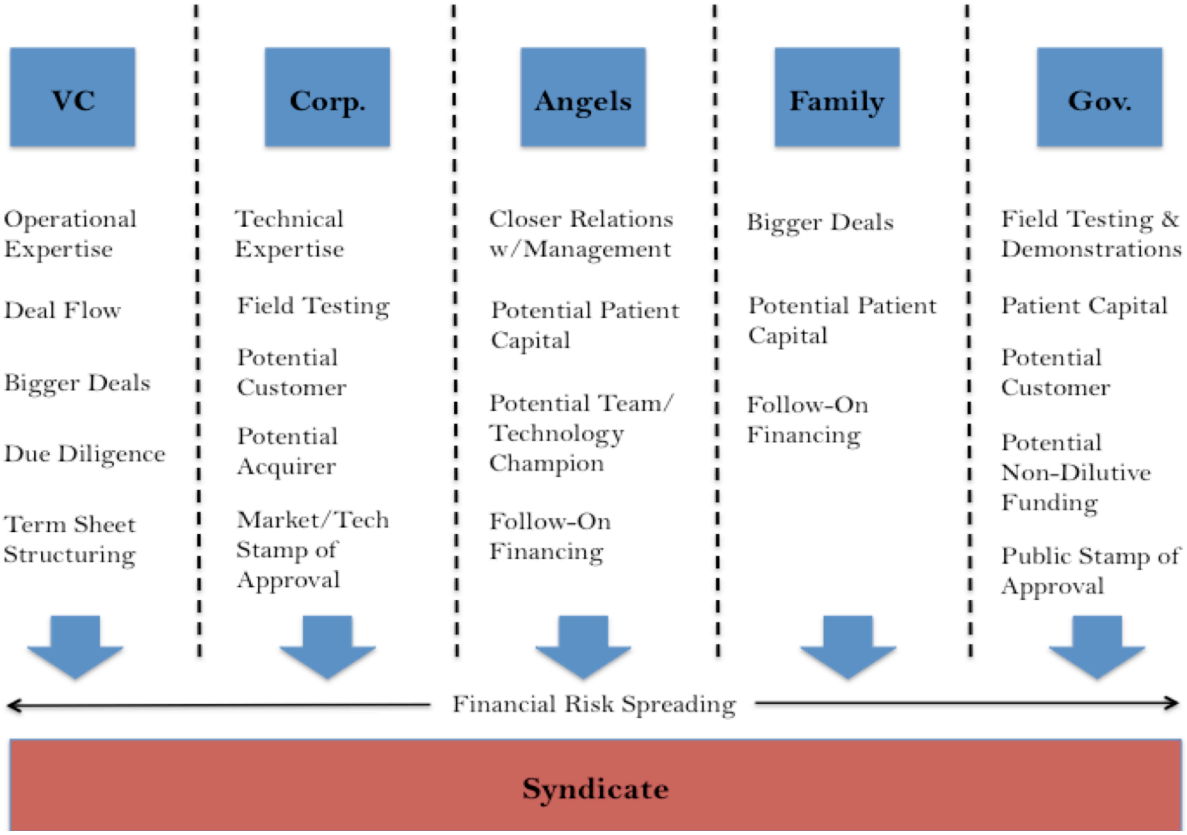


Table 1: Syndication Benefits Amongst Different Investors – VC, Corporates

Investor	Corporate	VC
VC	Greater operational expertise and management frameworks **(V)** Bigger deal sizes and potential for follow-on investment **(V)** Help w/leading rounds and structuring term sheets **(V)** Access to greater deal flow and new technologies **(E)** Flexibility in investments (LP or direct)	Greater operational expertise **(V)** Larger networks **(V)** Bigger deal sizes and potential for follow-on investment **(V)** Less financial downside and potential harm on reputation w/LPs **(R)** Potential early-stage debt financing **(V/R)** Access to greater deal flow **(E)**
Corp.	Alternative market and technology applications **(E)** Potential customer and/or acquirer **(V)** Resources for testing and demonstrations **(V)** New non-competitive partnerships **(E)**	Greater technical expertise **(V)** Resources for testing and demonstrations **(V)** Potential customer and/or acquirer **(V)** Market and technology stamp of approval **(R)** Potential patient capital **(R)**
Angels	Closer relational connections w/management teams **(V)** Potential patient capital **(R)**	Follow-on financing for portfolio companies at fund end-of-life **(V)** Closer relational connections w/management teams **(V)** Potential patient capital **(R)**
Family	Bigger deal sizes and potential for follow-on investment **(V)** Potential patient capital **(R)**	Follow-on financing for portfolio companies at fund end-of-life **(V)** Potential patient capital **(R)**
Gov.	Potential first investor and customer **(V)** Resources or potential pooling of resources for demonstrations **(V/R)** Patient capital **(R)** Access to greater deal flow and advanced gov backed technologies **(E)** Better public reputation **(V)**	Potential first investor and customer **(V)** Resources for demonstrations **(V)** Public stamp of approval **(R)** Patient capital **(R)** Potential non-dilutive funding **(C)** Access to greater deal flow **(E)**

Note: Each cell represents the relative benefits gained to the investor at the beginning of the row when syndicated with each investor in the columns.

Table 2: Syndication Benefits Amongst Different Investors – Gov., Families, Angels

Investor	Gov.	Family	Angels
VC	Greater operational expertise and management frameworks **(V)** Bigger deal sizes and potential for follow-on investment **(V)** Help w/leading rounds and structuring term sheets **(V)**	Access to greater deal flow **(E)** Larger networks **(V)** Less resources needed for diligence **(V)** Greater operational expertise **(V)** Bigger follow-on investment **(V)**	Access to greater deal flow **(E)** Larger networks **(V)** Less resources needed for diligence **(V)** Greater operational expertise **(V)** Bigger follow-on investment **(V)**
Corp.	Greater technical expertise **(V)** Potential for pooling of resources for demonstrations **(V/R)** Potential customer and/or acquirer **(V)** Potential patient capital **(R)**	Greater technical expertise **(V)** Resources for testing and demonstrations **(V)** Potential customer and/or acquirer **(V)** Potential exit opportunity **(V)** Market and technology stamp of approval **(R)**	Greater technical expertise **(V)** Resources for testing and demonstrations **(V)** Potential customer and/or acquirer **(V)** Market and technology stamp of approval **(R)**
Angels	Potential champion for the company/technology **(V)**	Potential champion for the company/technology **(V)**	Access to greater deal flow **(E)** Larger networks **(V)** Less resources needed for diligence **(V)** Potential champion for the company/technology **(V)**
Family	Potential for follow-on investment **(V)**	Access to greater deal flow **(E)** Larger networks **(V)** Less resources needed for diligence **(V)**	Bigger deal sizes and potential for follow-on investment **(V)**
Gov.	Potential for follow-on investment and non-dilutive funding **(V)** Resources for demonstrations **(V)** Access to more geographically advantageous markets **(V/E)**	Potential first investor and customer **(V)** Resources for demonstrations **(V)** Public stamp of approval **(R)** Access to greater deal flow **(E)** Potential non-dilutive funding **(C)**	Potential first investor and customer **(V)** Resources for demonstrations **(V)** Public stamp of approval **(R)** Access to greater deal flow **(E)** Potential non-dilutive funding **(C)**

Note: Each cell represents the relative benefits gained to the investor at the beginning of the row when syndicated with each investor in the columns.

In terms of value-add, it has been shown that syndication amongst VCs leads to complementary skillsets, pooling of resources and diligence, and higher returns on investments (Brander, Amit, and Antweiler 2002). However, syndication between VCs and other investor types produces new value-adds. For example, VCs can leverage corporates as both potential customers and acquirers of cleantech companies, and corporates can leverage the operational skillsets and term structuring capabilities of VCs to advance their corporate venture capital (CVC) units. VCs can also bring on angels and family offices to continue to finance their portfolio when their funds reach end-of-life, and angels and family offices can in turn tap into the greater deal flow and deep diligence of the VCs to save resources.

For example, VantagePoint Capital Partners, a Silicon Valley VC that specializes in leveraging strategic partners[69], brought on Unilever to help its investment in algae-based chemical and fuels producer Solazyme. Unilever's research and development agreement with the cleantech in 2009, equity investment in 2010, and final incorporation of the startup's algal-based soaps in their products (instead of palm oil) was a significant source of value-add in the syndicate with VantagePoint. Today, Solazyme is listed as a public company on the NASDAQ (SZYM).

In terms of risk-sharing, it is known that VCs use syndication to reduce risky investment exposure and information asymmetries with entrepreneurs (Lockett and Wright 2001). However, like syndication for new value-adds, syndication between VCs and other investor types also produces new risk-sharing advantages. Gaining corporate involvement substantially de-risks and increases confidence across all other private investors, as they often provide valuable demonstration resources and technology vetting. In return, gaining VC and other private investors lessens the financial burden on corporates seeking to make many investments. Government investment also has the potential to de-risk technologies with dedicated demonstration resources, and in return is also rewarded by having deep-pocketed private investors to continue to finance technologies with great public promise.

Returning to the example of VantagePoint Capital Partners and their investment syndicate in Solazyme, another strategic partner they brought onboard was energy conglomerate Chevron. In this case, Chevron Technology Ventures provided equity investment and non-dilutive research funding to the cleantech startup. The partnership gave Solazyme vital funding that reduced the financial burden on the VCs like VantagePoint, and also increased their market credibility since one of their primary products was biofuels. The investments and market accreditation from Chevron served as an important risk-reduction element in supporting Solazyme's attainment of follow-on investment, which reached nearly $120 million before they went public in May 2011.

In terms of venture/technology exploration, syndication with corporate investors is one way VCs can finance some of their funds. Bringing on corporates as LP investors can make up a significant source of financing when it is time to fundraise. It is a way for VCs to gain more value-add and risk-sharing opportunities. For forward-thinking corporates

[69] A list of VantagePoint Capital's strategic partners is available at: http://vpcp.com/about/

who are exploring new radical technologies, investing in a VC LP is a simply way to gain a window into early-stage innovation. Syndication with VCs provides them and other investors valuable deal flow and due diligence they would otherwise have to spend extra resources to acquire. The same holds for syndication with government investors who may also invest in VCs and their portfolio companies. They can also serve as a source of financing for VC funds and co-investments, and in return support new clean technologies that may reduce ratepayer's rates or enhance public infrastructure.

For example, Boston based sustainability-oriented VC Flagship Ventures formed strategic partnerships with AstraZeneca, Nestle Health Science, and Bayer CropScience when they raised their fifth fund in May 2015. The three corporates all invested in the $537 million Flagship Ventures Fund V, and signed partnership agreements stating that they would collaborate with companies resulting form the fund through direct investments, licensing, joint ventures and/or acquisitions[70]. In return, they would gain access to Flagship's VentureLabs venture creation unit, their track record of successful VC investments, and a window into companies seeking to transform agricultural production and food security (as well as therapeutic platforms).

Although syndication is essential to increase investments in cleantech, it is also worth noting that it can have potential downsides. For example, it was mentioned by a corporate investor that angels can cause trouble for investors in future rounds if write down valuations occur, because the angels are reluctant to accept the fact. A family office investor also expressed that sometimes they have issues with other investors, and are not comfortable investing with certain groups. I also heard from corporates that family offices can be low value-add players unless they have high quality professional staff. These realities inhibit the formation of certain syndicates and realizations of certain benefits. They make selection of syndicate partners an essential process.

Choosing the Right Strategic Partners:

Corporate investors have different investing and decision-making structures that VCs need to take into account. The ability for a corporate to invest in capital-intensive cleantech companies is constrained by its long-term strategy and its individual business unit needs. If a particular business unit needs a particular technology, then its ability to invest in new companies will depend on 1) the corporate's relative "corporate venturing" capabilities, 2) risk-tolerance for new disruptive technologies, and 3) strength of connection between the corporate venturing teams and the corporate sustainability teams. VCs seeking syndication must look for all three of these factors when choosing strategic partners.

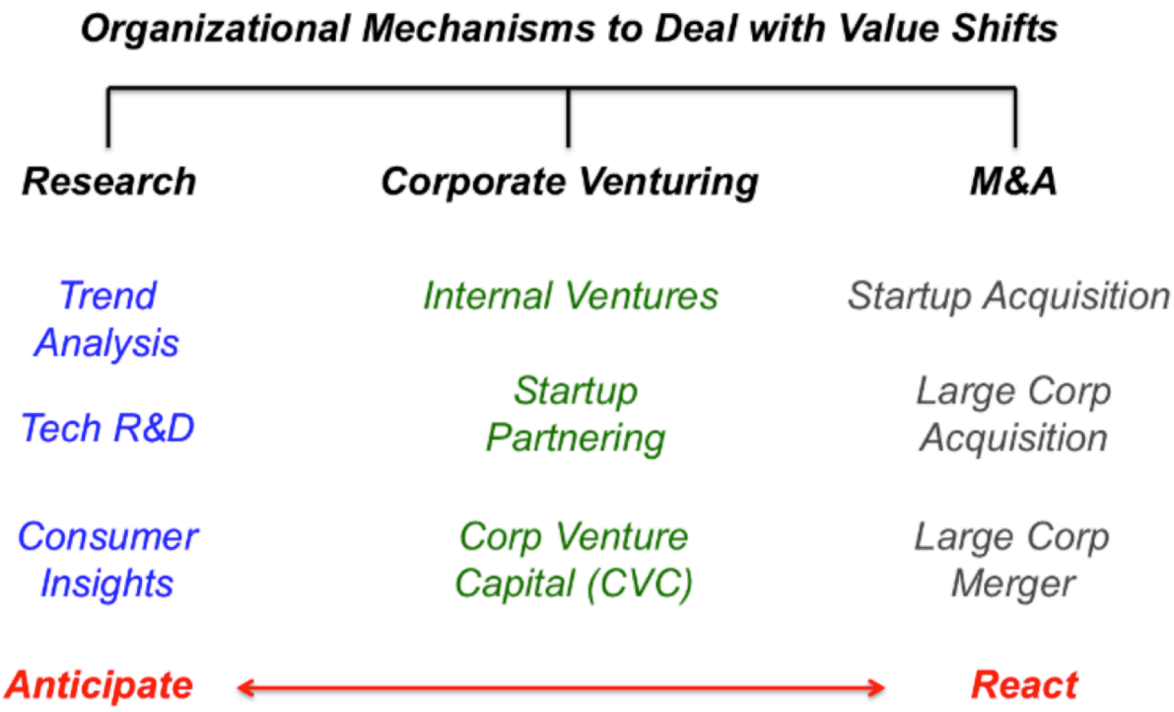
First, VCs must seek strategic partners actively engaging in corporate venturing initiatives. Corporate venturing is a new realm blurring the lines between internal innovation and external company acquisition (See Figure 26). In this middle ground, corporates are beginning to strike a balance between anticipating future demand with

[70] http://www.flagshipventures.com/about/news/flagship-ventures-forms-strategic-innovation-partnerships-astrazeneca-nestlé-health-scien

long-term internal R&D, and reacting to near-term market fluctuations by acquiring early- and later-stage companies. They are:

1. Spinout their own early-stage companies based off internal innovation teams
2. Partner with early- and later-stage companies in joint ventures (JV) or development agreements (JDA)
3. Take equity investments in early- and later-stage companies

Figure 26: Corporate Innovation Strategies: Anticipation Versus Reaction



Source: (dos Santos 2016)

Corporates are using these mechanisms to stay nimble in the wake of large "value shifts" (dos Santos 2016) that are changing industry dynamics. The more forward-thinking corporates fund capital-intensive cleantech with their CVC units and sign JVs and JDAs with cleantech companies. They do this in order to scout and develop next generation technologies that will give them a competitive and sustaining advantage in the future.

Energy conglomerate Shell exemplifies a large company doing corporate venturing. Their multiple corporate venturing initiatives include: Shell Gamechanger, a formal startup accelerator; Shell Techworks, an internal innovation program that brings together entrepreneurs and technology startups from outside the energy industry; and Shell Technology Ventures, Shell's corporate venture capital unit. Although the initiatives do have some focus on oil and gas technologies, many of them also focus on

radical and capital-intensive clean energy technologies. VCs frequently work with Shell to engage in the products of their multiple corporate venturing initiatives.

However, having a corporate venturing unit is not a sufficient condition for corporates to fund risky and capital-intensive cleantech companies. Therefore secondly, VCs must also seek strategic partners that are risk-tolerant and risk-seeking "explorers" (See Table 3). Explorers are characterized by corporate's having top-level engagement in corporate venturing initiatives, and a bold vision in seeking cutting-edge and disruptive technologies. Incremental innovation sought by the "optimizers" will not lead to productive syndicates that can advance capital-intensive cleantech. They are often just beginning their corporate venturing initiatives. Explorers are the ones VCs must engage because they have dedicated CVC teams and budgets, and make multiple investments per year on accelerated timelines (Kaji and Peltz-Zatulove 2015). They are the more forward-thinking corporates that are more likely to fund and support capital-intensive cleantech companies.

Table 3: Corporate Risk Tolerances – Optimizer, Distributor, and Explorer

Impact / Risk

1. "Optimizer"	2. "Distributor"	3. "Explorer"
Incremental solutions	New product development	Blue sky vision
Specific use case	Broad use case	Broad use case
Internal facing	External facing	Expansion/evolution
Very budget conscious	Budget conscious	Often a set 'pot' to spend
Short time frames	Moderate time frames	Not time constrained
Need driven by operations/ engineering	Need driven by end customer	Need driven by strategy/C-suite
Funded by Business Unit Head	Funded by CTO/COO	Funded by CEO/CIO
Do not want to be first mover	First mover may provide advantage/edge	Willing to be first mover
May prefer proven vendor	May prefer proven vendor	Want innovative thinking

Source: (Goel 2015)

Energy conglomerates make for an ideal comparison of companies spanning the risk tolerance continuum since they are incumbents of fossil fuel resources in the midst of a burgeoning clean energy sector. For example, Schlumberger, Shell, and Total would be good examples of an optimizer, distributor, and explorer respectively. Using the criteria listed in Table 3, it would be evident that Schlumberger is an optimizer because it has

predominantly more incremental investments in oil and gas companies[71]. Shell would be classified as a distributor because it has several external facing corporate venturing programs and invested a quarter of its second fund in "future energy" technology like clean energy[72]. Total would be the best example of an explorer amongst energy conglomerates given its long track record of investing in capital-intensive cleantech, like its investments in desalination membrane manufacturer NanoH2O, bioplastic manufacturer Gevo, solar panel manufacturer SunPower, and energy storage company Ambri to name a few[73]. VCs would have greater traction with risk-tolerant companies like Total when forming strategic syndicates for capital-intensive cleantech investments.

Thirdly and finally, corporate social responsibility (CSR) or sustainability teams also have a role in pushing corporates to pursue capital-intensive cleantech companies. One corporate investor interviewed mentioned that sustainability is playing a bigger role in their corporation, and if the corporate sustainability team is very interested in a company or product, the CVC team will look at it. Granted, the opportunity must have a profit-making motive and a strong market pull since sustainability will never be the primary investment factor, but it can still be a differentiating factor in the minds of CVC professionals. Therefore VCs should seek corporates that have significant liaison and communication between their corporate venturing units and sustainability teams. It can lead to greater syndicates in capital-intensive cleantech companies.

Venture Debt Financing

Ability to invest in long-term and capital-intensive technologies is enhanced by using early-stage debt financing.

> *"Something that is truly capital-intensive will have to raise an equal amount of equity, and if it's off-the-shelf technology then they could get standard equipment finance and project-based finance."*
>
> – Cleantech Venture Debt Investor

In the world of VC and early-stage company investing, equity investment is assumed to be the only source of financing for companies. This is because they are deemed too risky for bank loans and too early for project based financing. However, with the advent of more investors seeking lower risk profiles and increased liquidity, new debt financing models are appearing. In particular, early-stage debt financing emerging to replace highly dilutive early-stage equity finance in order to fulfill early commercial sales of ready technologies. These new VCs are coming in at the seed stage with debt financing for companies that have off-the-shelf technology components and enough collateral to secure a loan. They should be sought after from regular equity VCs for various reasons.

[71] https://www.cbinsights.com/blog/oil-gas-corporates-investing-startups/

[72] http://www.greentechmedia.com/articles/read/Shells-VC-Fund-Looks-to-Green-the-Fossil-Fuel-Business

[73] http://www.cleantechinvestor.com/portal/cleantech-funds/funds-t/3227-total-ventures/11467-big-oil-and-cleantech-corporate-venture-fund-profile-total.html

Early-stage debt VCs are replacing equity on a 1:1 ratio, and giving entrepreneurs runway to let their company valuations go up at less dilution. As long as the companies can quickly prove their technology and generate a backlog of sales, they will be prime for early-stage debt financing. Although these debt financing VCs skew towards service-based models, using them for capital-intensive cleantech can accelerate sales, deployment, and the companies' ability to later on obtain project-based financing. Acquisitions become more attractive for regular VC investors because they end up retaining greater stakes in the company at the time of exit (See Figure 23). Prominent cleantech investor Rob Day put it best in a Greentech Media article[74]:

> *"…The startup's capitalization tables will look a lot more reasonable to acquirers. Entrepreneurs will face less dilution and smaller preference stacks, and investors will get better returns as well. If the deployment capital is available and separate from VC capital, the VC math starts to make a lot more sense."*

Another serial cleantech entrepreneur and investor who was interviewed reiterated the importance of debt financing and patient equity financing when he summed up the Valley of Death situation:

> *"Probably the biggest reasons for failure was too many companies jumping into the same space and same product without a either a very patient and large source of equity that understood it had to be patient, or not having access to project based financing to finance their growth and their capital needs with debt as opposed to equity."*

Thinking in terms of debt rather than equity is counter-intuitive for most early-stage investors, but for capital-intensive cleantech it is an essential piece of the puzzle. The XL Hybrids case illustrates the importance of venture debt financing in fulfilling its over 100-unit order from Coca-Cola and FedEx. Fulfilling those capital needs with equity rather than debt would have been extremely costly for Hynes and the team. It would have also made any future acquisition math less attractive for the early equity investors.

Policy Activism

Ability to invest in long-term and capital-intensive technologies is enhanced by actively seeking to influence policy and regulation.

> *"If you don't like policy you shouldn't be in this field. We constantly talk about the need for visibility and predictability of policy... Influencing policy is what distinguishes us from regular VCs. It is one of the biggest value-adds we have for our companies."*
>
> *– Cleantech VC*

[74] http://www.greentechmedia.com/articles/read/VC-Investor-Lessons-From-the-Past-12-Years-The-Limitations-of-the-Venture

Almost every investor interviewed mentioned that reliance on supporting innovation policy (i.e. subsidies and tax breaks for certain technologies at the state and federal levels) decreased their confidence and willingness to invest in capital-intensive cleantech companies. Policy undermines investor confidence because it is highly volatile and unstable. That is why the most progressive VCs are actively pushing for policies that will help their portfolio companies. They are using groups like Environmental Entrepreneurs and the National Venture Capital Association as mouthpieces for their companies, and undertaking lobbying efforts on their own. The effort is a major way to change the macroeconomic conditions in favor of portfolio companies to scale and eventually IPO or be acquired (See Figure 23).

In mid-2015, for example, 15 prominent VCs backed the continued implementation of net energy metering[75] (NEM) in California, in light of it being up for reevaluation and utilities proposing an end to the policy[76]. According to the group of VCs in their formal letter to Governor Jerry Brown, the utilities were seeking to "replace it with radically different programs and rate designs that would destroy the economics for solar customers." They had vested interests in supporting their companies engaged in residential solar innovations. In January 2016, they heard the news they wanted: a 124-page report detailed a 3-2 vote that decided to keep NEM implementation[77]. They had actively won the policy stability that cleantech VCs and other private investors need to make continued investments in capital-intensive cleantech, like rooftop solar.

Policymakers

Public Cleantech Centers

Ability to maximize private investment in long-term and capital-intensive technologies is enhanced by investing in regional centers aimed at connecting and supporting local cleantech ecosystems.

> *"If you can create homes, bases, and communities for these companies, then more of them will emerge earlier in the pipeline."*
>
> –Cleantech Incubator

Public cleantech centers are state and/or federally funded government or nonprofit entities that connect investors, entrepreneurs, universities, government agencies, suppliers, and manufacturers in their city and region. They can take the form of a company incubator, demonstration facility, or investor and grant maker. Their role is to provide valuable resources for all the stakeholders involved and be the connective tissue for their regional cleantech ecosystem. Interviewees attested to the value they have in addressing the failure modes that still exist even when investors and

[75] NEM is a system that allows customers to sell energy back to the grid at the full retail value of electricity. Their excess energy often comes from rooftop solar PV panels.
[76] http://www.dblpartners.vc/2015/08/dear-gov-brown-energy-and-cleantech-vcs-talk-nem-policy-in-calif/
[77] http://www.greentechmedia.com/articles/read/Californias-Net-Metering-2.0-Decision-Rooftop-Solar-to-Keep-Retail-Payme

entrepreneurs follow all the best practices. The number of resources each center offers varies by region, but they primarily include:

- Demonstration support
- Access to equipment and office space
- Equity and debt investments
- Non-dilutive grants and funding
- Marketing and exposure
- Mentorship
- Networks
- Recruitment assistance

The success of public cleantech centers in promoting early-stage cleantech investment and innovation is most evident with the U.S. Clean Tech Leadership Index by Clean Edge[78]. Since innovation information became available in 2013, the metro areas that have rotated as top five leaders in the category "Cleantech Investment, Innovation, and Workforce" were: San Jose, San Francisco, Boston, Detroit, Austin, and Sacramento[79]. Interestingly, one thing these cities all hold in common are public cleantech centers dedicated to helping early-stage cleantech companies.

Of course, these cities hold in common other important factors such as strong universities, a history of innovation in a particular industry, and the largest shares of global VC investment (See Figure 27). They also have strong innovation uplift coming from IT and healthcare focused accelerators (Fehder and Hochberg 2014). However, there is still some merit to each city being a leader in cleantech innovation because of the public funds they deployed in public cleantech centers. Unlike other industries like IT, cleantech has strong regulatory influences, so public cleantech centers hold some meaningful influence in specifically enabling the rise of cleantech innovation. Table 4 summarizes the main characteristics of each city's public cleantech center, and Figure 28 highlights similarities and differences between Boston and Austin's public cleantech centers for comparison purposes.

[78] Clean Edge is a research firm that tracks the U.S. cleantech economic state of play. The U.S. Clean Tech Leadership Index was launched in 2012. The annual index ranks all 50 states according to cleantech leadership across the categories of technology, policy, and capital. The index also ranks the 50 largest U.S. metro areas according to green buildings, advanced transportation, clean electricity and carbon management, and cleantech investment and innovation.

[79] San Jose, San Francisco, and Boston have remained ranked as first, second, and third respectively since 2013. Sacramento ranked in the top five in 2013 but was later replaced by Detroit. However, Sacramento does have a public cleantech center in the California Smart Grid Center.

Figure 27: Top 15 Global Metros by Venture Capital Investment in 2016

Rank	Metro	Venture Capital Investment*	Share of Global Venture Capital Investment
1	San Francisco	$6,471	15.4%
2	San Jose	$4,175	9.9%
3	Boston	$3,144	7.5%
4	New York	$2,106	5.0%
5	Los Angeles	$1,450	3.4%
6	San Diego	$1,410	3.3%
7	London	$842	2.0%
8	Washington, D.C.	$835	2.0%
9	Beijing	$758	1.8%
10	Seattle	$727	1.7%
11	Chicago	$688	1.6%
12	Toronto	$628	1.5%
13	Austin	$626	1.5%
14	Shanghai	$510	1.2%
15	Mumbai	$497	1.2%

Source: (R. Florida and King 2016)

Table 4: Top Five Cleantech Innovation Cities and their Public Cleantech Centers

	Center Name	Year Founded	Structure	Form	Public Funding
San Jose	ProspectSV	2013	Nonprofit	Incubator, Demo Facility	City of San Jose, CA taxpayers
San Francisco	Cyclotron Road	2014	Public-Private Nonprofit	Incubator	DOE
Boston	MassCEC	2008	Quasi-Gov. Agency	Investor, Demo Facility	MA Ratepayers
Detroit	NextEnergy	2002	Nonprofit	Incubator, Demo Facility	MI Taxpayers, DOE
Austin	Austin Clean Energy Incubator	2001	Nonprofit	Incubator	City of Austin, DOE, Austin ratepayers

Note: Ratepayers are individuals who purchase electricity and gas from local utilities. They are a subset of taxpayers.

Figure 28: Massachusetts Clean Energy Center Versus Austin Clean Energy Incubator

These public cleantech centers have had tremendous success in advancing early-stage cleantech in their regions. For example, since beginning its investments program in 2009, Boston based and statewide program Massachusetts Clean Energy Center (MassCEC) has invested in $10.4 million in 18 companies; they have created approximately 345 jobs and attracted $395 million in follow on private investment[80]. Additionally, MassCEC has funded private incubators like Greentown Labs, whose member companies have employed over 400 people and collectively raised more than $118 million[81]. As another example, In Austin between 2010 and 2014, the Clean Energy Incubator graduated 24 companies, which subsequently raised $200 million in private investment and created 500 jobs[82]. It has played a central role in creating Austin's over $2.5 billion cleantech economy[83].

Though MassCEC and the Austin Clean Energy Incubator have different models, their roles in bridging the technological Valley of Death between publicly funded research and privately funded commercial enterprise has been invaluable. They are case

[80] Massachusetts Clean Energy Industry Report, 2015. BW Research and Massachusetts Clean Energy Center.
[81] http://greentownlabs.org/greentown-labs-launches-11-million-expansion-project/
[82] Austin City Council Agenda on Fiscal Year 2015-2016 Operating Budget. http://www.austintexas.gov/edims/document.cfm?id=239242
[83] Economic Impact of the Cleantech Sector in the Austin-Round Rock-San Marcos MSA, 2015. CleanTX, CivicAnalytics, Austin Technology Incubator.

examples of why public cleantech centers play critical roles in advancing cleantech ecosystems.

Policymakers should take heed of the impact public cleantech centers have in supporting early-stage and capital-intensive cleantech, as other highly ranked cleantech cities such as New York, Los Angeles, Denver, Chicago, and Sacramento also have public cleantech centers with strong track records[84]. Public cleantech centers should be on the agenda of any city and/or state policymaker's agenda if they want to support their local early-stage cleantech enterprises. They should also consider each metro's specific strengths when implementing public cleantech centers, whether it be in a particular industry or history of technology innovation.

Stable and Predictable Policy

Ability to spur private investment in long-term and capital-intensive technologies is dependent on creating stable and predictable market pull and technology push policies.

> *"What's critical often times is not so much the subsidies but their certainty. If you're trying to grow a company that takes 10 years and subsidies are only for 2 years it's detrimental. Certainty is all important and still is."*
>
> –Serial Cleantech Entrepreneur and Investor

Though many cleantech policies are attractive to private investors, private investors are still reluctant to invest in companies that utilize them given their volatility and uncertainty. Almost every investor interviewed expressed that they would rather have no policy support at all than have ephemeral support. Incentives implant additional risk within companies and many grow to rely on them. If policymakers want to stimulate private investment in early-stage cleantech, they need to make sure incentives are stable, predictable, and ratcheted down according improved performance.

Additionally, several individuals interviewed favored macroeconomic policies such as removing fossil fuel subsides and placing a tax on carbon emissions. Though these policies take considerably more political capital to instate, and according to MIT economist Robert Pindyck are "a poor tool of innovation policy because it [the tax] is not designed to be one (Cass 2015)," they still hold potential in accelerating early-stage cleantech investment because they would still increase investor confidence.

These policies are already beginning to unfold in several countries. For example, a group of eight countries known as the "Friends of Fossil Fuel Subsidy Reform" are encouraging governments to prioritize the phase out fossil fuel subsidies, and beginning

[84] New York has the Clean Tech Center in Syracuse, which is an incubator and demonstration facility, Los Angeles has a Cleantech Incubator, Denver has demonstration support through the National Renewable Energy Laboratory, Chicago has an investor and incubator through the Clean Energy Trust, and Sacramento has the California Smart Grid Center.

to do so themselves[85]. Plus, places like Costa Rica, Canada, and Finland have been able to enstate and maintain carbon taxes either on national or regional levels[86].

Macroeconomic policies such as removal of fossil fuel subsidies and placing a tax on carbon hold great promise to accelerate cleantech innovation and deployment to levels required by the 2-degree scenario. However, they still require stability and predictability, as the repeal of the carbon tax in Australia easily demonstrates after being instated for only two years[87]. Policymakers must develop protocols for stable and predictable policy in the cleantech sector that go beyond their office terms. It is essential to attract private investment into the sector.

[85] As of the end of 2015, the "Communique" has been signed by Costa Rica, Denmark, Ethiopia, Finland, New Zealand, Norway, Sweden and Switzerland. They all point to the fact that fossil fuel subsidies are harmful to the environment and economic development.

[86] Costa Rica set a 3.5% tax on the market value of fossil fuels in 19997, and uses the revenue to support their "Payment for Environmental Services Program." In 2012, British Columbia, Canada imposed an escalating and revenue-neutral carbon tax, starting at $30 Canadian dollars per metric tonne of CO_2, which they return to citizens in tax returns. Finland has been experimenting with a carbon tax since 1990 and now charges transportation, electricity generation, and heat production 35 euros per metric tonne of CO_2 (2013).

[87] Australia's carbon tax was instated in July 2012 by former Prime Minister Julia Gillard and then repealed in July 2014 by the Australian senate.

On Creating Cleantech Confluences

Ultimately, when entrepreneurs, investors, and policymakers follow the best practices mentioned throughout this work, a unique set of conditions arise to advance early-stage cleantech companies. Mutually reinforcing connections form between each actor and enhance the best practices they are following. Together, they create a scenario where more cleantech companies are qualified, de-risked, and able to receive the financing they need to scale up. This win-win-win scenario and overall economic advancement of the sector is what is called here as a "Cleantech Confluence."

This Cleantech Confluence is characterized by:

1. The number of best practices and partnerships implemented amongst entrepreneurs, investors, and policymakers in a city or region.
2. The amount of private investment entering companies with hardware- and equipment-based clean technologies in a city or region.
3. The combined economic scale of those companies in the specific city or region.

The strength of the Cleantech Confluence is governed by the individual contributions of each actor—the Confluence is only as strong as its weakest link. The fewer best practices any one actor follows, the weaker the prospects of the triad.

Entrepreneurs have the motivation and expertise to form and manage the companies so without their involvement there is no sector in the first place; investors hold the critical financing needed for the companies so without their involvement there is no sector growth; and policymakers manage the necessary regulatory and physical infrastructure needed for the companies to thrive so without their support the sector's potential scale is limited.

Each group of actors must work together in order to provide the other with the benefits they seek. Figure 29 depicts the necessary best practices needed from each actor to form the Cleantech Confluence. Tables 5, 6, and 7 show which actor's best practices co-benefit the other actor's best practices. They show how and why the Confluence requires action from all three actors in order to take place.

Figure 29: Best Practices of the Cleantech Confluence

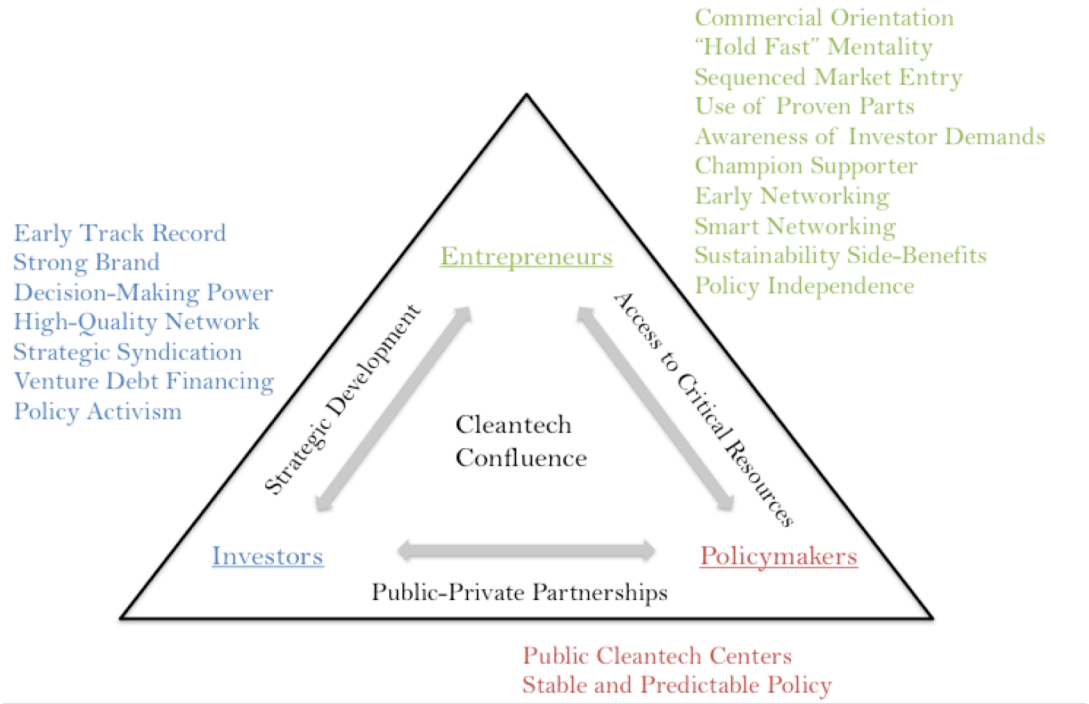


Table 5: The Cleantech Confluence Co-Benefits – Entrepreneurs, Investors

	Early Track Record	Strong Brand	Decision-Making Power	High-Quality Network	Strategic Syndication	Venture Debt	Policy Activism
Commercial Orientation	+				+	+	
"Hold Fast" Mentality	+				+	+	
Sequenced Market Entry	+				+	+	
Proven Parts					+	+	
Aware of Investor Demands					+		
Champion Supporter	+			+	+		+
Early Networking	+	+		+	+		
Smart Networking		+		+	+		
Sustainability Side-Benefits					+		+
Policy Independent	+						+

Table 6: The Cleantech Confluence Co-Benefits – Entrepreneurs, Policymakers

	Public Cleantech Center	Stable and Predictable Policy
Commercial Orientation	+	+
"Hold Fast" Mentality		+
Sequenced Market Entry		
Proven Parts		
Aware of Investor Demands		
Champion Supporter	+	+
Early Networking		+
Smart Networking		+
Sustainability Side-Benefits	+	+
Policy Independent	+	+

Table 7: The Cleantech Confluence Co-Benefits – Investors, Policymakers

	Public Cleantech Center	Stable and Predictable Policy
Early Track Record	+	+
Strong Brand		
Decision-Making Power		
High-Quality Network	+	
Strategic Syndication	+	+
Venture Debt		
Policy Activism	+	+

As shown in Figure 29 and Table 5, Entrepreneurs must also work with investors and vice-versa to develop sustainable businesses. Each must be recognizant of past failures and how their market entry and technological development strategies should be redevised to work down the price-volume curve. The two groups must work together to ensure funding milestones and are met throughout the life of a company. Their collaboration lays the foundation for sustainable business models and practices to take hold of the sector.

As shown in Figure 29 and Table 6, entrepreneurs and policymakers must work together to provide each with the critical resources and technologies the other needs and demands. Policymakers looking after the public interest desire more cleantech companies to scale up for economic, security, and environmental reasons, while on the other hand, entrepreneurs want access to public cleantech centers and favorable policy to de-risk and lower the capital-intensity of their technologies. When the two groups collaborate and understand each other's needs then they form the right conditions to attract private investment into the sector.

Lastly and as shown in Figure 29 and Table 7, investors and policymakers must work together to form public-private partnerships and syndicates to provide capital for early-stage cleantech companies. Whether by creating public-private pools of capital for demonstrations or co-investing in promising technologies, collaboration between the two groups enhances enabling conditions for cleantech companies to attain the financing they need to scale up.

The case of XL Hybrids shows how the Cleantech Confluence requires action across all primary actors—investors, entrepreneurs, and policymakers—in order to scale up technologies that have a positive impact on GHG mitigation. The sum total of the best practices and partnerships mentioned are what give rise to the Cleantech Confluence in the New England region. The more of these actions exercised, the greater the strength of the Confluence. XL Hybrids is only one example of a hardware-based cleantech company that is scaling up in the New England Cleantech Confluence.

Chapter 5: Conclusion

Summary

The findings of this exploratory thesis point to a reformation of the cleantech sector by what is called as Cleantech Confluences. Referring back to the central thesis questions:

How can entrepreneurs attract private investment and scale up pass the Valley of Death?

1. Commercial Orientation: Have commercially oriented management teams that can understand and implement best practices for business development
2. "Hold Fast" Mentality: Strive to persist rather than to fail and repeat in order to build investor confidence
3. Sequenced Market Entry: Enter non-flagship markets that are quicker to capture and grant time for learning and technology risk reduction
4. Use of Proven Parts: Leverage existing technology components and infrastructure to de-risk overall system delivery and design
5. Awareness of Investor Demands: Understand the pros and cons of different types of investors in order to scale up sustainably
6. Champion Supporter: Win over an investor or corporate officer that can make the case for their groups to support and invest
7. Early Networking: Communicate with customers, investors, and strategic partners early on to expedite decision-making processes
8. Smart Networking: Approach all stakeholders in the ecosystem with a strong personal brand and transparency to gain champion supporters
9. Sustainability Side-Benefits: Track sustainability metrics and market them as a side-benefit to please certain investors and strategic partners
10. Policy Independence: Do not have business models that rely heavily on policy support in order to build investor confidence

How can venture capitalists build the ability and confidence to invest in the cleantech sector again?

1. Early Track Record: Invest in capital-intensive cleantech early on to build an investment track record that can refine and support future investments
2. Strong Brand: Contribute to the greater cleantech ecosystem by writing reports and speaking at conferences to build reputation
3. Decision-Making Power: Bring on a large number of regular and impact investors in your LP to gain greater investment flexibility with longer time horizons
4. High-Quality Network: Stay in close contact with academia, government, NGOs, and other private investors to have access to high-quality deal flow
5. Strategic Syndication: Invest in capital-intensive cleantech with corporates and other investors to bring on new value propositions and reduce financial risk
6. Venture Debt Financing: Leverage early-stage debt investors to incentivize entrepreneurs and maintain greater company ownership upon exit

7. Policy Activism: Actively seek to influence policy favorable to portfolio companies to improve the firm brand and value-add proposition

How can policymakers address the failure modes that may still exist if investors and entrepreneurs follow best practices?

1. Public Cleantech Centers: Create regional centers that support and connect all stakeholders of the cleantech ecosystem with critical resources
2. Stable and Predictable Policy: Implement stable and predictable market-pull and technology-push policies to build investor confidence and entrepreneur tact

The extent to which these and other best practices not identified in this thesis can be exercised by each primary actor—entrepreneurs, investors, and policymakers—the greater the strength of the Cleantech Confluence. Importantly, Cleantech Confluences are local to the cities and regions that are governed under the same regulations and geographic conditions. Multiple Cleantech Confluences can therefore develop across the world and give rise to different dominating technologies. Just as no single technology can dominate the entire cleantech sector, neither can any single Confluence dominate the world. It is essential for multiple Confluences to form across a range of cultures, governments, and geographies to have maximum impact.

The Confluence Champion

The best practices and partnerships in this work hint at a new actor in the cleantech ecosystem known as the “Confluence Champion.” These are people in the private or public spheres that might seek to refine and disseminate the best practices of scaling up capital-intensive cleantech to the rest of their local ecosystem. Building a database and record of what worked and did not work in scaling up certain technologies can be invaluable for all stakeholders involved.

Disrupting large and slow industries like energy and water requires the energy of rare forward-thinking champions. The Confluence Champion will play a pivotal role in supporting the ventures seeking to disrupt the status quo with valuable learning lessons from the past. The champion must be deeply involved in the ecosystem and know all the stakeholders involved. They must be a major convener and connector of the system, for only then can they find “innovators” that are willing to adopt the best practices.

The underlying need for collaboration and knowing other stakeholders cannot be understated. Trust must be developed with other stakeholders in order to gain their support and discover other potential champions. This is not a trivial feat; it requires significant empathy, and it is the only way that many of the mutually beneficial best practices proposed in this work can be realized.

Research Limitations

This work is an exploratory study of Cleantech Confluences. It draws from a limited number of stakeholder perspectives given the time and availability constraints of the subjects at hand. As such, the work should be considered a preliminary rendering of Cleantech Confluences rather than a complete picture of it. Each best practice is a subject on its own and can be validated with more study.

Ideally, entrepreneurs and investors across all geographies and involved in all types of cleantech companies would have been interviewed. However, given the challenges of arranging interviews, this work relied heavily on the insights from professionals in New England, Texas, and California, and who work mostly with non-nuclear cleantech companies.

All system dynamics models included throughout the work are limited in scope to the primary variables discovered during the research. They can be expanded significantly more to include other microeconomic, macroeconomic, and psychological/behavioral variables. The models are used to depict the primary findings uncovered throughout the literature review, interviews, and field observations.

The original risk-return interview questions only applied to the first seven interviews. Afterwards, similar answers began to emerge so the interview questionnaire was expanded. The following interviews had different sets of questions depending on the interviewee. The overarching goal remained triangulating findings between entrepreneurs, investors, and policymakers (government agencies) to discover how each was actively trying to bridge the Valley of Death.

Actual policymakers were not interviewed in this study. Only government agencies and nonprofits were consulted. This is because policymakers are even more difficult to consult than the busy private sector professionals. The answers of public sector professionals were therefore extrapolated to represent the public interest in the study.

Future Research

This study focuses primarily on early-stage companies in the energy and water domains. Future research could be carried out on late-stage companies in the same domains and also on early- and late-stage companies in other domains, like agriculture and waste. This study also focuses on the United States. Other studies with the same design could focus on Europe and emerging economies like China and India.

Additionally, deeper analysis could be on the application of the best practices within certain technology areas, like solar and energy storage for example. This study focuses on high-level and overarching best practices that are predominantly applicable across multiple types of technologies, but there are nuances for each cleantech subsector. Future work could refine and modify the best practices according to specific technology domains.

This study also focuses primarily on entrepreneurs and venture capitalists involved in cleantech. Future research could also take the perspective of corporate venturing units. Whether through investment, JDA, acquisition, or some other means, the value-add of corporate involvement in cleantech is significant. A similar research study could look into optimal corporate venturing initiatives and structure to advance capital-intensive cleantech, and inform future involvement in the sector. Corporates hold great promise for advancing capital-intensive cleantech so measuring their impact would be beneficial.

Similarly, this study could also take the angle of incubators and accelerators involved in cleantech. Future research could look at whether nonprofit, public-private, or for-profit incubator models work best and under what conditions. It could also look at the (increased) probability participating companies have in attaining follow on funding, and eventually reaching IPO or acquisition. What mix of space, equipment, personnel, and location make a cleantech incubator more successful? Several lines of research could look into the impact of incubators and accelerator programs.

Comparative case studies on cleantech companies that failed versus others that reached IPO or acquisition would be an additional research direction to explore further. Covering a broad spectrum of technologies, geographies, regulatory environments, management teams, and investors would support the findings of this work with more contextual examples. These case studies would control for technology or market application and timing of incorporation. They could highlight strategies and macroeconomic variables that had positive or negative impacts on capital-intensive cleantech development.

Quantitative simulation of the system dynamics models is a final area to pursue further. The models in this analysis are setup to be quantified with initial parameters and rates of change. Simulations would help show the extent to which different best practices have an impact on spurring capital-intensive cleantech investment and development. The simulations could replicate case studies and be extrapolated to explore other technological and organizational developments in cleantech.

Bibliography

Accord, Copenhagen. 2009. “Copenhagen Accord.” FCCC/CP/2009/11/Add. 1. http://webdav.uct.ac.za/depts/erc/Research/Otherdocs/COP%20decisions%20BUR,%20ICA,%20dom%20MRV,%20registry%20-2.pdf.

Andrew, Brian. 2008. “Market Failure, Government Failure and Externalities in Climate Change Mitigation: The Case for a Carbon Tax.” *Public Administration and Development* 28 (5): 393–401. doi:10.1002/pad.517.

Bernstein, Shai, Xavier Giroud, and Richard R. Townsend. 2015. “The Impact of Venture Capital Monitoring.” *The Journal of Finance*, October, n/a – n/a. doi:10.1111/jofi.12370.

Bonvillian, William B., and Richard Van Atta. 2011. “ARPA-E and DARPA: Applying the DARPA Model to Energy Innovation.” *The Journal of Technology Transfer* 36 (5): 469–513. doi:10.1007/s10961-011-9223-x.

Bosetti, Valentina, Carlo Carraro, Romain Duval, Alessandra Sgobbi, and Massimo Tavoni. 2009. “The Role of R&D and Technology Diffusion in Climate Change Mitigation: New Perspectives Using the Witch Model.” SSRN Scholarly Paper ID 1397076. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=1397076.

Bossink, Bart A. G. 2014. “Demonstration Projects for Diffusion of Clean Technological Innovation: A Review.” *Clean Technologies and Environmental Policy* 17 (6): 1409–27. doi:10.1007/s10098-014-0879-4.

Brander, James A., Raphael Amit, and Werner Antweiler. 2002. “Venture-Capital Syndication: Improved Venture Selection vs. The Value-Added Hypothesis.” *Journal of Economics & Management Strategy* 11 (3): 423–52. doi:10.1111/j.1430-9134.2002.00423.x.

Bruton, Garry, Susanna Khavul, Donald Siegel, and Mike Wright. 2015. “New Financial Alternatives in Seeding Entrepreneurship: Microfinance, Crowdfunding, and Peer-to-Peer Innovations.” *Entrepreneurship Theory and Practice* 39 (1): 9–26. doi:10.1111/etap.12143.

Bürer, Mary Jean, and Rolf Wüstenhagen. 2009. “Which Renewable Energy Policy Is a Venture Capitalist’s Best Friend? Empirical Evidence from a Survey of International Cleantech Investors.” *Energy Policy* 37 (12): 4997–5006. doi:10.1016/j.enpol.2009.06.071.

Bygrave, William D., Julian Lange, Ed Marram, David Brown, and Joel Marquis. 2014. “No Financial Cleanup: A Study of Venture Capital Returns on Cleantech IPOs.” SSRN Scholarly Paper ID 2412959. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=2412959.

Cass, Oren. 2015. “The Carbon-Tax Shell Game.” *MIT Energy Initiative*. July 29. http://mitei.mit.edu/news/carbon-tax-shell-game.

Chapple, Karen, Cynthia Kroll, T. William Lester, and Sergio Montero. 2011. “Innovation in the Green Economy: An Extension of the Regional Innovation System Model?” *Economic Development Quarterly* 25 (1): 5–25. doi:10.1177/0891242410386219.

Chiang, Adrian. 2014. “How Entrepreneurs Can Crowdfund Renewable Energy Projects.” *J. Bus. Entrepreneurship & L.* 8: 659.

Clay, Tiffany. 2013. “New Venture: A New Model for Clean Energy Innovation.” *Journal of Applied Corporate Finance* 25 (3): 56–61. doi:10.1111/jacf.12029.
Coyle, Geoff. 2000. “Qualitative and Quantitative Modelling in System Dynamics: Some Research Questions.” *System Dynamics Review* 16 (3): 225.
Criscuolo, Chiara, and Carlo Menon. 2015. “Environmental Policies and Risk Finance in the Green Sector: Cross-Country Evidence.” *Energy Policy* 83: 38–56.
dos Santos, Ricardo. 2016. “The Brave New World of Corporate Venturing. Part I: The Traditional Models.” *LinkedIn Pulse*. January 2. https://www.linkedin.com/pulse/brave-new-world-corporate-venturing-part-i-models-ricardo-dos-santos.
Eilperin, Juliet. 2012. “Why the Clean Tech Boom Went Bust.” *WIRED*. January 20. http://www.wired.com/2012/01/ff_solyndra/.
Eisenhardt, Kathleen M. 1989. “Building Theories from Case Study Research.” *Academy of Management Review* 14 (4): 532–50. doi:10.5465/AMR.1989.4308385.
Eisenhardt, Kathleen M., and Melissa E. Graebner. 2007. “Theory Building from Cases: Opportunities and Challenges.” *Academy of Management Journal* 50 (1): 25.
Erzurumlu, Sinan, Fehmi Tanrisever, and Nitin Joglekar. 2010. “Operational Hedging Strategies to Overcome Financial Constraints During Clean Technology Start-Up and Growth.” SSRN Scholarly Paper ID 1625787. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=1625787.
Fehder, Daniel C., and Yael V. Hochberg. 2014. “Accelerators and the Regional Supply of Venture Capital Investment.” SSRN Scholarly Paper ID 2518668. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=2518668.
Florida, Richard L., and Martin Kenney. 1988. “Venture Capital-Financed Innovation and Technological Change in the USA.” *Research Policy* 17 (3): 119–37. doi:10.1016/0048-7333(88)90038-8.
Fontes, Margarida, Cristina Sousa, and Silvana Pimenta. 2012. “The Commercialisation of Emerging Energy Technologies : The Strategic Alliances of High-Technology Entrepreneurial Firms,” May. http://repositorio.lneg.pt/handle/10400.9/1573.
Forrester, Jay W. 1994. “System Dynamics, Systems Thinking, and Soft OR.” *System Dynamics Review* 10 (2-3): 245–56. doi:10.1002/sdr.4260100211.
———. 2007. “System Dynamics—the next Fifty Years.” *System Dynamics Review* 23 (2-3): 359–70. doi:10.1002/sdr.381.
Freed, Josh, and Mae Stevens. 2011. “Nothing Ventured: The Crisis in Clean Tech Investment.” *Report, Third Way, November*. http://content.thirdway.org/publications/456/Third_Way_Report_-_Nothing_Ventured_The_Crisis_in_Clean_Tech_Investment.pdf.
Fullmer, Sarah Elizabeth. 2014. “The Combined Incubator-Prototyping Space. A New Tool for Supporting Cleantech Entrepreneurship.” https://www.duo.uio.no/handle/10852/41460.
Gallagher, Kelly Sims, Laura Diaz Anadon, Ruud Kempener, and Charlie Wilson. 2011. “Trends in Investments in Global Energy Research, Development, and Demonstration.” *Wiley Interdisciplinary Reviews: Climate Change* 2 (3): 373–96. doi:10.1002/wcc.112.

Ghosh, Shikhar, and Ramana Nanda. 2010. “Venture Capital Investment in the Clean Energy Sector.” *Harvard Business School Entrepreneurial Management Working Paper*, no. 11-020. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1669445.
Goldberg, Marshall. 2001. “U.S. Federal Energy Subsidies : Not All Technologies Are Created Equals.” *Advances in Solar Energy* 14: 361–84.
Gompers, Paul, and Josh Lerner. 2001. “The Venture Capital Revolution.” *The Journal of Economic Perspectives* 15 (2): 145–68.
Grubb, Michael. 2004. “Technology Innovation and Climate Change Policy: An Overview of Issues and Options.” *Keio Economic Studies* 41 (2): 103.
Hall, John, and Charles W. Hofer. 1993. “Venture Capitalists’ Decision Criteria in New Venture Evaluation.” *Journal of Business Venturing* 8 (1): 25–42. doi:10.1016/0883-9026(93)90009-T.
Harborne, Paul, and Chris Hendry. 2009. “Pathways to Commercial Wind Power in the US, Europe and Japan: The Role of Demonstration Projects and Field Trials in the Innovation Process.” *Energy Policy*, New Zealand Energy Strategy, 37 (9): 3580–95. doi:10.1016/j.enpol.2009.04.027.
Hargadon, Andrew B., and Martin Kenney. 2012. “Misguided Policy? Following Venture Capital into Clean Technology.” *California Management Review* 54 (2): 118.
Harrison, Glenn W, John A List, and Charles Towe. 2007. “Naturally Occurring Preferences and Exogenous Laboratory Experiments: A Case Study of Risk Aversion.” *Econometrica* 75 (2): 433–58. doi:10.1111/j.1468-0262.2006.00753.x.
Hazels, Beth, and Craig M. Sasse. 2008. “Forced Ranking: A Review.” *SAM Advanced Management Journal* 73 (2): 35.
Hendry, Chris, Paul Harborne, and James Brown. 2010. “So What Do Innovating Companies Really Get from Publicly Funded Demonstration Projects and Trials? Innovation Lessons from Solar Photovoltaics and Wind.” *Energy Policy* 38 (8): 4507–19. doi:10.1016/j.enpol.2010.04.005.
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. doi:10.1162/itgg.2006.1.2.3.
Horwitch, Mel, and Bala Mulloth. 2010. “The Interlinking of Entrepreneurs, Grassroots Movements, Public Policy and Hubs of Innovation: The Rise of Cleantech in New York City.” *The Journal of High Technology Management Research*, Exploring Technological Innovation, 21 (1): 23–30. doi:10.1016/j.hitech.2010.02.004.
IEA. 2012. *Energy Technology Perspectives 2012: Pathways to a Clean Energy System*. Paris: IEA.
Jacobson, Mark Z. 2008. “On the Causal Link between Carbon Dioxide and Air Pollution Mortality.” *Geophysical Research Letters* 35 (3): L03809. doi:10.1029/2007GL031101.
Jenkins, Jesse, Mark Muro, Ted Nordhaus, Michael Shellenberger, Letha Tawney, and Alex Trembath. 2012. “Beyond Boom and Bust: Putting Clean Tech On A Path To Subsisidy Indepnedence,” April. http://thebreakthrough.org/archive/beyond_boom_and_bust_report_ov.

Kahneman, Daniel, and Amos Tversky. 1979. “Prospect Theory: An Analysis of Decision under Risk.” *Econometrica: Journal of the Econometric Society*, 263–91.

Kaji, Samir, and Jessica Peltz-Zatulove. 2015. “Inside the Minds of Corporate Venture Capitalists.” *CB Insights - Blog*. December 10. https://www.cbinsights.com/blog/inside-corporate-vc-minds/.

Kearney, Sarah, Alicia Seiger, and Peter Berliner. 2014. “Impact Investing in the Energy Sector.” http://www.law.stanford.edu/sites/default/files/publication/753322/doc/slspublic/Impact_Investing_in_Energy.pdf.

Knight, Eric R. W. 2010. “The Economic Geography of Clean Tech Venture Capital.” SSRN Scholarly Paper ID 1588806. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=1588806.

Laden, Francine, Joel Schwartz, Frank E. Speizer, and Douglas W. Dockery. 2006. “Reduction in Fine Particulate Air Pollution and Mortality.” *American Journal of Respiratory and Critical Care Medicine* 173 (6): 667–72. doi:10.1164/rccm.200503-443OC.

Lassiter, Joseph, William Sahlman, and Alison Wagonfeld. 2012. “Khosla Ventures: Biofuels Strategy.” Harvard Business School.

Lerner, Josh. 1996. “The Government as Venture Capitalist: The Long-Run Effects of the SBIR Program.” Working Paper 5753. National Bureau of Economic Research. http://www.nber.org/papers/w5753.

Lockett, Andy, and Mike Wright. 2001. “The Syndication of Venture Capital Investments.” *Omega* 29 (5): 375–90. doi:10.1016/S0305-0483(01)00024-X.

Luna-Reyes, Luis Felipe, and Deborah Lines Andersen. 2003. “Collecting and Analyzing Qualitative Data for System Dynamics: Methods and Models.” *System Dynamics Review* 19 (4): 271–96. doi:10.1002/sdr.280.

Marangoni, Giacomo, and Massimo Tavoni. 2014. “The Clean Energy R&d Strategy for 2°c.” *Climate Change Economics* 05 (01): 1440003. doi:10.1142/S201000781440003X.

Marcus, Alfred, Joel Malen, and Shmuel Ellis. 2013. “The Promise and Pitfalls of Venture Capital as an Asset Class for Clean Energy Investment Research Questions for Organization and Natural Environment Scholars.” *Organization & Environment* 26 (1): 31–60. doi:10.1177/1086026612474956.

McCauley, Stephen M., and Jennie C. Stephens. 2012. “Green Energy Clusters and Socio-Technical Transitions: Analysis of a Sustainable Energy Cluster for Regional Economic Development in Central Massachusetts, USA.” *Sustainability Science* 7 (2): 213–25. doi:10.1007/s11625-012-0164-6.

Migendt, Michael, Florian A. Täube, Brett Anitra Gilbert, Von Flotow, and Paschen. 2014. “Emergence of Cleantech as an Investment Category - Public Discourse and Venture Capital Investment.” SSRN Scholarly Paper ID 2388656. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=2388656.

Mitchell, Ronald B. 2012. “Technology Is Not Enough Climate Change, Population, Affluence, and Consumption.” *The Journal of Environment & Development* 21 (1): 24–27. doi:10.1177/1070496511435670.

Monk, Ashby H. B., Sarah Wood Kearney, Alicia Seiger, and Elliott Donnelley. 2015. "Energizing The US Resource Innovation Ecosystem: The Case for an Aligned Intermediary to Accelerate GHG Emissions Reduction." SSRN Scholarly Paper ID 2617816. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=2617816.

Moxnes, E. 2009. "Diffusion of System Dynamics." In *Presidential Address 2009 System Dynamics Conference*.

Murphy, Lawrence Martin, and Peter L. Edwards. 2003. *Bridging the Valley of Death: Transitioning from Public to Private Sector Financing*. National Renewable Energy Laboratory Golden, CO. http://www.globalwateradvisors.com/wp-content/uploads/NREL-Bridging_the_Valley_of_Death1.pdf.

Newell, Richard G. 2009. "Literature Review of Recent Trends and Future Prospects for Innovation in Climate Change Mitigation," November. http://www.oecd-ilibrary.org/environment/literature-review-of-recent-trends-and-future-prospects-for-innovation-in-climate-change-mitigation_218688342302.

Ottinger, Richard, and John Bowie. 2014. "Innovative Financing for Renewable Energy." In *IUCN Academy of Environmental Law Colloquium*. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2497175.

Pacala, S., and R. Socolow. 2004. "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies." *Science* 305 (5686): 968–72. doi:10.1126/science.1100103.

Pachauri, R. K., M. R. Allen, V. R. Barros, J. Broome, W. Cramer, R. Christ, J. A. Church, et al. 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by R. K. Pachauri and L. Meyer. Geneva, Switzerland: IPCC. http://epic.awi.de/37530/.

Pacyna, Elisabeth G., Jozef M. Pacyna, Frits Steenhuisen, and Simon Wilson. 2006. "Global Anthropogenic Mercury Emission Inventory for 2000." *Atmospheric Environment* 40 (22): 4048–63. doi:10.1016/j.atmosenv.2006.03.041.

Petkova, Antoaneta P., Anu Wadhwa, Xin Yao, and Sanjay Jain. 2014. "Reputation and Decision Making Under Ambiguity: A Study of U.S. Venture Capital Firms' Investments in the Emerging Clean Energy Sector." *Academy of Management Journal* 57 (2): 422–48. doi:10.5465/amj.2011.0651.

Polzin, Friedemann, Paschen von Flotow, Laurens Klerkx, and others. 2015. "Accelerating the Cleantech Revolution: Exploring the Financial MobilisationFunctions of Institutional Innovation Intermediaries." *SPRU-Science and Technology Policy Research, University of Sussex*, 1–38.

Porter, Michael, and Mark Kramer. 2015. "Creating Shared Value." Accessed June 22. https://hbr.org/2011/01/the-big-idea-creating-shared-value.

Rai, Varun, Erik Funkhouser, Trevor Udwin, and David Livingston. 2015. "Venture Capital in Clean Energy Innovation Finance: Insights from the U.S. Market during 2005-2014." SSRN Scholarly Paper ID 2676216. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=2676216.

Rijsberman, F. R, R. J Swart, and Stockholm Environment Institute. 1990. *Targets and Indicators of Climatic Change*. Stockholm: Stockholm Environment Institute.

Rogers, Everett M. 2010. *Diffusion of Innovations*. Simon and Schuster. https://books.google.com/books?hl=en&lr=&id=v1ii4QsB7jIC&oi=fnd&pg=PR15&dq=diffusion+of+innovation+rogers&ots=DKYoqNSt4W&sig=g06FTb3vA7F5V_CvnJFg2uv3GRQ.

Rosenzweig, Cynthia, David Karoly, Marta Vicarelli, Peter Neofotis, Qigang Wu, Gino Casassa, Annette Menzel, et al. 2008. "Attributing Physical and Biological Impacts to Anthropogenic Climate Change." *Nature* 453 (7193): 353–57. doi:10.1038/nature06937.

Salerno, M., A. Lambkin, and T. Minola. 2009. "Key Success Factors in Supporting Clean Tech Start-Ups: A General Framework and an Italian Experience." http://www.ct-si.org/publications/proceedings/pdf/2009/10329.pdf.

Samet, Jonathan M., Francesca Dominici, Frank C. Curriero, Ivan Coursac, and Scott L. Zeger. 2000. "Fine Particulate Air Pollution and Mortality in 20 U.S. Cities, 1987–1994." *New England Journal of Medicine* 343 (24): 1742–49. doi:10.1056/NEJM200012143432401.

Shub, Gary, Brent Beardsley, Hélène Donnadieu, Nick Gardiner, Craig Hapelt, Benoît Macé, Neil Pardasani, Katie Tamarelli, Tjun Tang, and Yasuhiro Yamai. 2016. "Global Asset Management 2015: Sparking Growth with Go-to-Market Excellence." *Www.bcgperspectives.com*. Accessed February 7. https://www.bcgperspectives.com/content/articles/financial-institutions-global-asset-management-2015-sparking-growth-through-go-to-market-strategy/.

Silla, Daniel. 2011. "Venture Capital and Clean Technology Investment and Innovation." SSRN Scholarly Paper ID 2346636. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=2346636.

Simon, Herbert A. 1955. "A Behavioral Model of Rational Choice." *The Quarterly Journal of Economics*, 99–118.

Solomon, Susan. 2007. *Climate Change 2007-the Physical Science Basis: Working Group I Contribution to the Fourth Assessment Report of the IPCC*. Vol. 4. Cambridge University Press. https://books.google.com/books?hl=en&lr=&id=8-m8nXB8GB4C&oi=fnd&pg=PA339&dq=IPCC+Fourth+Assessment+Report+&ots=hzjqA9vjHV&sig=GUQ6bOJgJnGg4ozL_EpONYG3aq4.

Stern, Nicholas. 2007. *The Economics of Climate Change: The Stern Review*. cambridge University press. https://books.google.com/books?hl=en&lr=&id=U-VmIrGGZgAC&oi=fnd&pg=PA1&dq=climate+change+market+failure&ots=9dp13wenj7&sig=gMBN63ycGKdNFNpOYuvkjAcmLtA.

Strauss, Anselm, Juliet Corbin, and others. 1990. *Basics of Qualitative Research*. Vol. 15. Newbury Park, CA: Sage. http://www.li.suu.edu/library/circulation/Stein/Comm%206020ksStraussCorbinBasicsQualitativeFall07.pdf.

Strebulaev, Llya, and Will Gornall. 2015. "How Much Does Venture Capital Drive the U.S. Economy?" *Stanford Graduate School of Business*. October 21. https://www.gsb.stanford.edu/insights/how-much-does-venture-capital-drive-us-economy.

Taneja, Hemant. 2016. "Unscaling Energy." *TechCrunch*. February 13. http://social.techcrunch.com/2016/02/13/unscaling-energy/.

Taylor Wessing. 2010. “Bridging the Funding Gap: The Financing Challenge for European Cleantech and Renewable Energy.” http://docplayer.net/12208523-Bridging-the-funding-gap-the-financing-challenge-for-european-cleantech-and-renewable-energy.html.

Tierney, Sean. 2011. “Venture Capital and Cleantech Symbiosis.” *Industrial Geographer* 8 (2): 63–85.

U.S. Environmental Protection Agency. 2015. “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013.” Reports & Assessments,. April 15. http://www3.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

Victor, David G. 2009. “The Politics of Fossil-Fuel Subsidies.” SSRN Scholarly Paper ID 1520984. Rochester, NY: Social Science Research Network. http://papers.ssrn.com/abstract=1520984.

Wilson, Karen E. 2015. “Policy Lessons from Financing Innovative Firms.” http://www.oecd-ilibrary.org/science-and-technology/policy-lessons-from-financing-innovative-firms_5js03z8zrh9p-en.

Wüstenhagen, Rolf, and Emanuela Menichetti. 2012. “Strategic Choices for Renewable Energy Investment: Conceptual Framework and Opportunities for Further Research.” *Energy Policy*, Strategic Choices for Renewable Energy Investment, 40 (January): 1–10. doi:10.1016/j.enpol.2011.06.050.

Wustenhagen, Rolf, and Tarja Teppo. 2006. “Do Venture Capitalists Really Invest in Good Industries? Risk-Return Perceptions and Path Dependence in the Emerging European Energy VC Market.” *International Journal of Technology Management* 34 (1-2): 63–87.

Appendix A: Semi-Structured Interview Questions

How long have you been venture investing?
How many investments have you made?
What stage of investments do you focus on?
Is your GP sustainability-oriented?
Is your LP sustainability-oriented?

- Describe your investment process
    - In your investment process, do you do due diligence on a few companies simultaneously and then ultimately pick to invest in 1 or 2 from a select group of qualified investments?
    - How do you choose between the final remaining qualified investments? Do you weight certain factors more than others?
    - What do you do with the qualified investments that you turn away? Do you refer them to others? Would you be willing to refer them to others?

- Describe a clean technology company where you have invested capital
    - What is the story of this investment?
    - What was your rationale for investing?
    - What were the greatest risks in this investment?
    - Did certain regulations or public policies affect your investment decision at all?
    - Did sustainability considerations affect your investment decision at all?
    - Was the team's management sustainability-oriented?

- Describe a clean technology company that you considered, but chose not to invest capital
    - What is the story of this investment?
    - What were the greatest risks in this investment?
    - What were your other rationales for not investing?
    - Did certain regulations or public policies affect your investment decision at all?
    - Did sustainability considerations affect your investment decision at all?
    - Was the team's management sustainability-oriented?

- Describe a clean technology company where you have invested capital, and where its sustainability aspect mattered or had relatively greater importance in the investment decision
    - What is the story of this investment?
    - What was your rationale for investing?
    - Why did sustainability considerations affect your investment decisions or matter relatively more?
    - What were the greatest risks in this investment?

    - Did certain regulations or public policies affect your investment decision at all?
    - Was the team's management sustainability-oriented?

- Describe a clean technology company that you considered and where its sustainability aspect mattered or had relatively greater importance, but after diligence you chose not to invest capital
    - What is the story of this investment?
    - What was your rationale for not investing?
    - What were the greatest risks in this investment?
    - Why did sustainability considerations affect your investment decisions or matter relatively more?
    - Did certain regulations or public policies affect your investment decision at all?
    - Was the team's management sustainability-oriented?

How can more companies become qualified investments and bridge the valley of death?

Appendix B: Forced Ranking Questions

1. Rank main objectives for cleantech venture investment:
    a. Financial Gains
    b. Sustainability Impact (Environmental/Social/Economic)
    c. Strategic Motives

2. Rank main determinants for venture investment:
    a. Team
    b. Product
    c. Market
    d. Deal (terms, price, equity)
    e. Personal Connection
    f. Investment Expertise (in the technology)
    g. Location
    h. Syndicates
    i. Regulatory environment
    j. IPO environment

3. Rank most likely to least likely cleantech venture investments:
    a. Renewable energy generation
    b. Energy storage
    c. Energy efficiency
    d. Clean transportation
    e. Smart energy management
    f. Carbon capture and sequestration
    g. Agriculture
    h. Water
    i. Waste
    j. Materials

Appendix C: Sample Research Memo

Research Memo
Interview – [Angel Investor]
November 17th, 2015

What I think I know:

Private investor in energy startups, with focus on lighting. Chairman of 2 LED/solar lighting companies and founder of a private investment group.

I need to understand:

Private: When and why did you start getting interested in sustainability issues? Do you invest in clean technology startup companies (or help manage them)? Describe your rationale for investing in a few of these companies (or helping manage them)? How do you think about the potential or environmental impact when evaluating an investment opportunity (or managing a company)? Describe some investments in clean technology that you almost made, but did not for whatever reasons? Does regulation effect your investment preferences? What have been the critical elements enabling your investments to grow and succeed?

Public: How can more private investment be catalyzed into the clean technology sector? How can more private investment flow specifically into early-stage clean technology companies? What government regulations can help spur more private investment in clean technology? Do strategic corporates have a role in catalyzing more private investment? What difference can individual investors and business angels make in helping these early-stage companies jump the "Valley of Death?" At what stages do capital-intensive new clean technology companies require the most managerial, financial, and regulatory support? Can private investors help de-risk these companies in certain ways?

New information:

- Overlapping interests between energy security and environmental sustainability
- Turned around a solar lighting company by merging it with a public Canadian company and engineering a takeover with a new management team.
- Seeks VC 10x returns over 5 years, looking primarily at management, markets, and "unusualness" or proprietary nature of company. Not impact investor.
- Found a niche for him to invest in VC portfolio companies that needed more funding but couldn't receive it from the VC's for institutional reasons.
- His unique role was to bring quick money, knowledge, networks, and a large informal investment group of other private investors if more capital was needed.
- Starts with assumption that certain technologies (e.g. solar panels) are beneficial and that more efficient solar panels could produce more electricity and have big environmental impact.

- Have to evaluate impact look over a product, project, or company lifetime.
- Likes smart grids and microgrids because of distributed renewable energy AND potential to reduce backbone electrical wiring materials and cost
- Likes investing/working in solar lighting because it is one of the few technologies that doesn't need a green bank or tax credit, payback is immediate
- Believes a tax on carbon is key. Regulation is not helpful, little other initiatives not as helpful. Let the markets work under corrected externalities
- How to spur private investment: have the true cost of social/environmental issues incorporated into business schools and business practice.
- Inculcate impact investing into the psyche of our brightest minds
- Use the same tools to evaluate cleantech investments as they would biotech

My theory:

- A price on carbon would activate downstream clean technology markets and enable increased innovation and private investment in early-stage clean technology companies.
- Private investors can fill the funding gap that VC's leave when their fund expires, allowing for continued investment in early-stage cleantech companies.
- Social/Environmental issues need to be thought as inherent to business rather than as ancillary to it. The true cost of business activities is not reflected, but business can take the lead on this despite government intervention.
- Environmental impact assessment is not necessary for investment by private investment. Total estimates or feelings of impact are sufficient enough.
- Energy and national security a forgotten issue in sustainability circles: it can help the argument for more private investment in clean technology.

Notes:

2 different periods: 1st started investing in solar lighting company 25-27 years ago because he thought it was magic that you could create light without grid power. Environmental, sailor his whole life, problems of climate change were not as well known or urgent at the time. Good smart thing to do. Over the last decade as climate change has become more obvious threat, his investing has shifted dramatically to sustainable investments that mitigate CO2.

Always starts with the realization that when you switch the light switch you expect the light switch to go on: always find a balance between winding down fossil fuels and winding up alternative energy. More of a centrist then a total activist. National security issues that sometimes play in different directions. Good example is the struggle of figuring out keystone pipeline where on the one hand from environmental perspective you want to keep stranded assets on the ground but on other hand minimize import of foreign oil from people that want to kill us. Overlapping interest between energy security and environmental. Looks for anything related to solar or wind, no biotech, toned down

investments and try to adhere to growing set of constraints around not buying fossil fuel assets although according to certain sustainability indexes that doesn't include transportation companies. Hasn't divested from transportation, but has stopped investing in oil and gas company.

1.5 full time portfolio manager. He just spends whatever time on investments. They'll explore almost anything that seems to make sense. 2 early-stage investments. Both companies that have been around for 10 years but pre-revenue. Both have just started revenue, one in battery tech, and other solar panels.

Because of remarkable turnaround he participated in his canadian company where he merged his solar lighting business that he owned privately for 25 years into a public company in Canada that he engineered a takeover and put in a new management team, where he took one business that lost money for 17 years public company and 25 years of company lost, private company, and hoped by putting them together they would float. Because of new management team the company has had incredible turnaround of financial returns. Big part of why he was introduced to a cleantech fund in Silicon Valley. For whatever reason when he was introduced that fund was closing and there were no more slots available so that would've been a cleantech venture fund and the principle of the firm a couple weeks later called him up and said he had an investment that the fund has made and if Michael wanted to co-invest in the solar panel business (pre-revenue). When they underwriting something pre-revenue they want a 10x return over 5 years. Starts with management perspective and does underwriting to concur or not. Underwriting: have vc returns of 10x over 5 years. Management, markets, and "unusual or proprietary" nature of company.

The battery company was the second investment of that same vc fund. Was asked to co-invest again. In the vc space, he's found that as a single investor its very hard to get a proper underwriting given the resources so they tend to piggyback with institutional investors when there's some role they might play that's unique. Sometimes what happens is that there's a round in an investment that has not matured well enough (7-years or down round) and have original vc's want to support by have limitations that they can't invest anymore, then he'll step in. When vc's invest but have institutional limits and have to fill up a round but don't want competitors, they want to bring in a private party that can step into the plate quickly and add value. Unique role: work quickly, in the space with knowledge and networks, lead an informal investment group to raise more capital quickly if needed that's not competitive. VCs always reserve money for follow on but at some point they go through or the time has expired and even though they've put money they can't put anymore because of fund closing, so that's where private investment steps in.

In terms of solar panels, underwriting their features against Chinese companies and competitors. Started with assumption that solar panels were good things and that more efficient solar panels could produce more electricity at higher efficiency then they didn't have to do any deep dive on relative environmental merits. "Yea but did you do environmental impact statement on the factory" those are legitimate concerns but he

starts believing in the case that anytime you manufacture once and it replaces something that's burning fossil fuels at every use, that 20-yr life from solar panel it would be almost impossible not to be a net gain from an environmental perspective. In case of the battery company, they had to educate themselves on the technology and the uses because they are the holy grail of alternative energy: core of smart grid and intermittent power users. At the first order for base load, reducing marginal demand, but for microgrids and off grids they become critical. Also important uses for industrial scale batteries. It happens that because he's in the solar lighting business, the primary value of solar lighting is not simply that its solar but that its wireless, which means that in most instances they are saving money in solar lighting and avoiding the cost of the wiring, cost of the energy is secondary from upfront costs of avoiding wiring. Solar lighting is literally one of the very few alternative energy that doesn't need a green bank or tax credit or any kind of government help because the payback is literally on day one. Having understood the difference between not just saving CO2 but also saving materials from wiring, there's a lot of similar ways to think about microgrids that have less electrical backbone distribution to reduce environmental impact.

From a government policy point of view, there are different ways to impact: huge difference between taxing and regulating. Right now the only tools the government have in terms of climate change that are fundamental start with clean air act but actually subsidies for oil company, so different ways to address national security. Anything that reduces CO2 or methane would be excellent. Much better to price than to regulate. Releases entrepreneurial alternatives rather than stifle innovation. The most fundamental role of tax policy or regulatory policy is to understand the social cost of one activity or another. and stimulate it or not. It is in his belief that fundamental role of government is to acknowledge threat of climate change and do what's necessary to reduce GHG emission and do it most efficiently and do it in a way that least burdens the citizens, unquestionable that an appropriate revenue neutral carbon tax would be most bipartisan way to do that. Any other government regulation has a range.

Business schools and business practice has to understand the broader context of what's going on. Always a social impact of any business investment. Always destroy or help communities. There's a million ways to do it. Snobbish notion that single purpose in life is to maximize shareholder value and be blind to other externalities is Darwinian. He's an devout capitalist that wants to make money but not harm society and the environment. Most important thing is to inculcate impact investing into the psyche of our brightest minds so people are never blind to the impact of environmental.

They're using the same tools for their cleantech investments that would use on a biotech investment. Look at the traditional venture criteria. Much more productive thing is not to give specific things but price on carbon would put everything in place. When the market properly values the cost of carbon in society. Big issues.