New Venture Commercialization of Clean Energy Technologies

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This paper examines why new ventures founded to commercialize clean energy technologies that are cost effective and beneficial to adopters have failed to achieve widespread adoption. A new venture simulation model was developed that models the cash flow, labor force, market, competition, and product development for a prototypical clean energy technology venture. When the model is parameterized to correspond to a venture that starts with superior technology at an attractive price its behavior corresponds to the experience of many of the companies interviewed for this research. The modeled venture takes many years to achieve profitability due to long sales cycles, limits to market growth, and the time needed to gain experience producing and selling its products, and therefore has a high probability of failure. Analysis of the model results in a set of guidelines for what these ventures, investors, and policy makers should do to increase their odds of success.

1 Introduction

This paper addresses how to improve the odds of success of new ventures commercializing clean energy technologies. We are motivated by the importance of reducing the emissions of greenhouse gases (most notably CO_2) from energy production to address the serious risks of climate change. It is likely that the wide adoption and use of clean energy technologies is necessary in order to do so. Furthermore, many clean energy technologies are economically efficient as well as environmentally beneficial. Numerous advantages to end users include lower and less volatile energy costs and a more stable and reliable energy supply. However, these technologies have not been as widely adopted as may be presumed from these benefits, and new ventures formed to commercialize these technologies have failed to do so.

Clean energy technology can be defined as any technology that reduces harmful emissions resulting from the production and use of energy. Examples of clean energy technologies include renewable and/or efficient distributed generation (e.g. solar, wind, geothermal, fuel cells, cogeneration); energy efficiency technologies which enable the use of energy services at lower cost to users; intelligent energy management; biofuels; and ancillary products and services that improve the efficiency of power generation and transmission.

We focus on new ventures because only new ventures have been able to commercialize disruptive new technologies. And only disruptive technologies have the potential to restructure the current global energy regime. In every other case in which new technology created a new industry by replacing a standard commonly used technology, such as when electricity replaced gas lighting, or automobiles replaced horse-drawn vehicles, new ventures led the way. However, over the last several decades, as the importance and value of clean energy technologies have become widely accepted, new clean energy technology ventures have not been able to achieve success and wide adoption for their products and technologies. Why?

There is an extensive body of literature on how and why innovations are diffused, but less research has been done on what leads to success or failure for new technology ventures. In the most substantial work to date, Roberts (1991) found that larger investments of initial capital; the sales experience of the founders; a marketing orientation of the firm; and a strategic focus of the firm on its core technology and markets were correlated with success. Utterback, Meyer, Tuff, and Richardson (1992) found that lasting commitment and persistence were critical for technology ventures and Hilmola, Helob, and Ojalac (2003) found that reducing product development time was important. Joglekar and Levesque (2006) determined that allocations of resources to R&D and marketing should account for the anticipated productivity of those functions, and that a new venture is better off obtaining a single large investment than multiple smaller ones. However, prior to this research effort, it was not clear whether these results would be true for clean energy technology ventures, which have not been specifically studied or modeled before now.

Based on interviews with clean energy entrepreneurs and other stakeholders and on case studies of clean energy technology ventures, a new venture simulation model was developed that models the cash flow, labor force, market, competition, and product development for a prototypical clean energy technology venture. When the model is parameterized to correspond to a venture that starts with superior technology at an attractive price its behavior corresponds to the experience of many of the companies interviewed. The modeled venture takes many years to achieve profitability due to long sales cycles, limits to market growth, and the time needed to gain experience producing and selling its products, and therefore has a high probability of failure. Analysis of the model results in a set of guidelines for what these ventures, investors, and policy makers should do to increase their odds of success. The venture is better off starting with more sales and marketing personnel and expertise rather than engineers, and should develop no more product features than are necessary to sell the product. The venture should forego recurring revenue and instead receive payments up front whenever possible. A single initial equity investment in the venture is considerably more valuable than a series of investments. Government policies that raise the cost of carbon emissions; reduce barriers and increase incentives for adoption of clean energy technologies; and subsidize the development of these technologies can greatly increase the growth of these ventures and the odds of success.

1.1 Barriers to Adoption

Over the course of four and a half years, the principal author conducted over 100 interviews with clean energy entrepreneurs and a variety of stakeholders related to clean energy ventures. The stakeholders include the customers of clean energy technology, energy service providers, investors in the ventures, and participants in policy-making processes related to clean energy technologies. Interviewees were selected from both established and newly created clean energy technology ventures; from large and small customers of these products and technologies; and from a wide variety of sectors of the industry, including distributed generation, demand side management, renewable energy generation, energy efficient building technologies, and energy equipment maintenance. Many of the interviewees were recommended by prior interviewees. Most of the interviews were informal, though notes were recorded for most. Several formal interviews were also conducted that were based on a sequence of pre-determined questions; these were recorded on tape.

Numerous factors were identified that affect the adoption of clean energy technologies. These include regulatory factors such as subsidies for fossil-fuel based energy and/or clean energy technologies; real time pricing (or the lack thereof) for electricity use; utility interconnection requirements and surcharges for stranded costs or standby service; siting restrictions for distributed generation; and carbon taxes or cap and trade regulations, and regulations to promote energy efficiency. Also important are market factors such as the price of fossil fuels and of electricity, uncertainty surrounding the economic benefits of new technologies, and the impact of new technologies on markets. Institutional and behavioral factors, such as the agency problem in which decision makers do not receive the benefits of adoption, risk aversion, the learning curve for users to understand new technologies and the effects of word of mouth (or the lack thereof) regarding new technologies cannot be underestimated. Finally, the technologies themselves need to work as advertised and to improve over time.

Though a clean energy technology may be economically advantageous, many positive feedbacks support established energy technologies and the companies that provide them. Figure 1 depicts many of these loops.

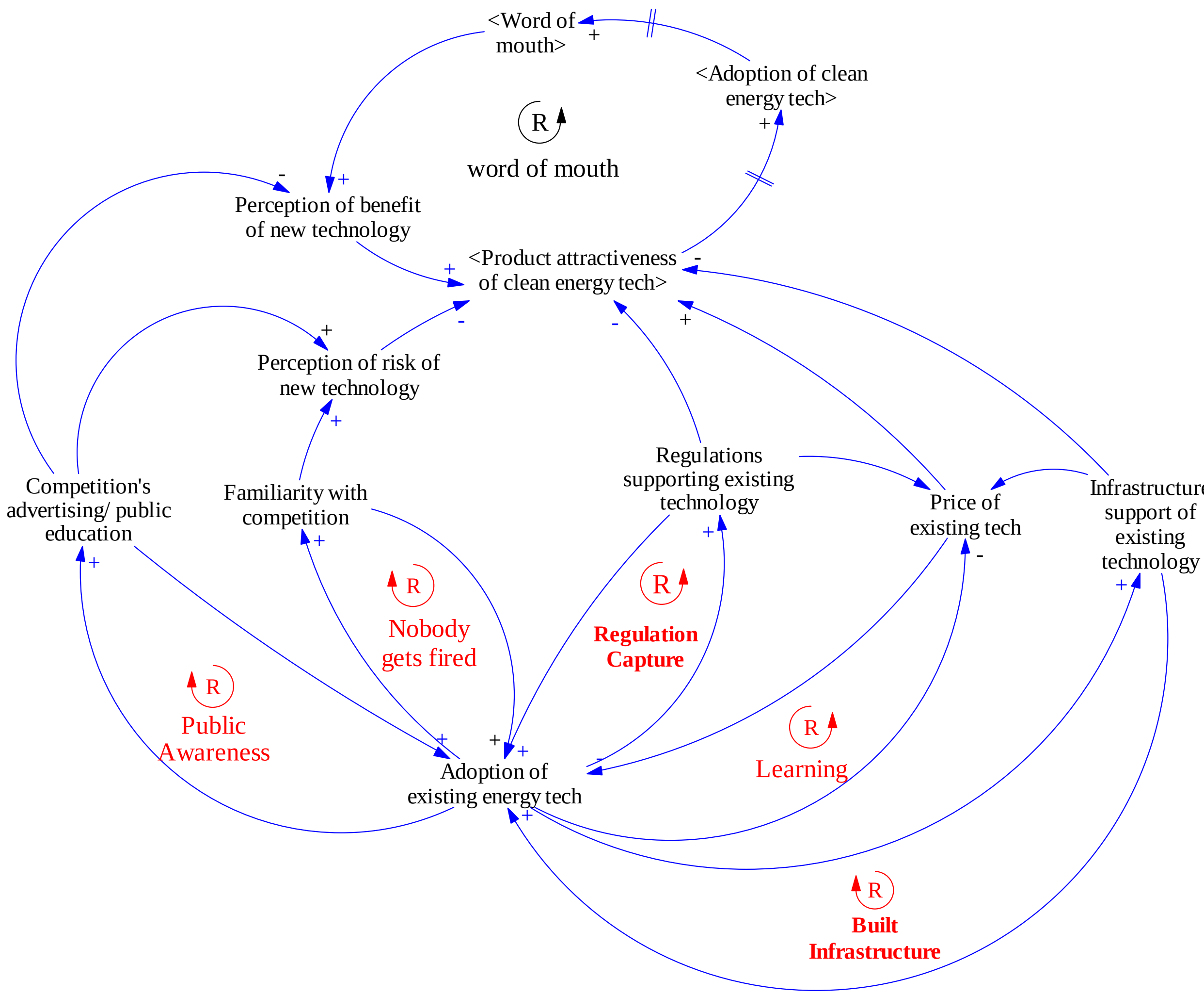

Figure 1: Loops Effecting the Adoption of Clean Energy Technology

Nobody Gets Fired: Existing energy technologies (primarily based on fossil fuel) have been widely available for many decades and therefore are very familiar to the public and to commercial enterprises that are heavy energy users. Therefore, when evaluating which energy technology to use (or to continue using) a decision maker at a firm understands that he will not be criticized (or fired) if the firm continue to use the same technologies that it has used for many years, and which all other firms use as well. Furthermore, any new energy technology will be perceived as risky (it is not tried and true like existing technologies) and the perception of risk will detract from the attractiveness of the new technology. Therefore, the “safe” decision is to continue using and purchasing the existing technology, which reinforces its familiarity and encourages further use in the future.

Public Awareness: The providers of existing energy technology have an incentive to reinforce the public’s familiarity with their technology and the perception of risk related to new technology. They also have the financial resources to mount broad advertising campaigns that tout the benefits (and familiarity) of conventional energy solutions and aggravate the perception of risks (and fears) of newer clean energy technology. The success of these campaigns bolsters the adoption of existing energy technologies, providing further resources to mount future advertising campaigns.

Regulation Capture: Large energy firms tend to make very large political contributions and exert considerable influence on policymaking and regulations that govern or are related to energy production and use. They use this influence to shape regulations that favor or lower the cost of production of their technologies (e.g. subsidies for fossil fuel exploration and development) and that increase the cost of providing alternatives (e.g. onerous interconnection and siting regulations for distributed generation technologies). These regulations result in increased profit for these firms, which they, in part, reinvest to shape future regulations.

Learning and Price: Most technologies become less costly to produce over time. Given that existing energy technologies have been produced and used for many years, firms understand them well, which reduces the expense of providing them. Negotiating the learning curve for new technologies may require a firm to invest in training and possibly new employees, thus adding to the expensive of adopting a new technology. The lower price encourages further use of the existing technologies, and inhibits the adoption of the new technologies and the cost reductions that would allow them to compete better.

Built Infrastructure: One of the reasons that existing energy technology becomes less costly to use over time is that marginal costs are lower once its supporting infrastructure is built. A massive infrastructure has been built to deliver electricity throughout the United States through the centralized grid. Though electricity users pay charges associated with the creation and maintenance of that infrastructure, its existence has lowered the cost of large-scale fossil-fuel-generated power. A developer of a large coal-powered plant does not have to worry about the cost of creating an infrastructure to deliver the power generated by that plant to end users. However, the developer of a plant meant to produce hydrogen for use in fuel cells must be very concerned about the cost of infrastructure to deliver the hydrogen to end users. That cost would severely hinder the construction of such a plant. Therefore, existing infrastructure supports the expansion of existing technologies which then justify incremental improvements to the infrastructure and further use of the existing technologies.

Insufficient Word of Mouth: The reinforcing “word of mouth” loop is often used to explain an exponential increase in the adoption of a new technology as new users contact potential users and encourage further adoption, therefore creating even more new users. However, this only works if there are enough users to spread the word. If there are many factors inhibiting the adoption of a new technology (as per above) there may not be enough new adopters to encourage others to use the new technology. A lack of peers using the new technology may further discourage any new users from adopting.

1.2 Case Studies

We studied three clean energy technology firms in depth to determine the details of their sales cycles and the particular challenges they faced (as well as the successes they had) in achieving wide adoption of their products and services. Leaders of these ventures, and others that were interviewed, found themselves facing much longer sales cycles and much more conservative prospective customers than anticipated. They found that low prices for conventional energy decreased the attractiveness of their technology and that regulations hindered the adoption of their products.

2 Model Development

We developed a simulation model to better understand the factors that most directly determine the success or failure of a new clean energy technology venture. The model was designed to help uncover strategies and policies that would increase the odds of success and of wider adoption of clean energy technologies.

The focus of the model is a firm that starts with an attractive product, but no customers and few employees. The model tracks the working capital of the firm, the development of features of the product, the growth (and contractions) of the firm's labor force, and the status of each of its prospective and current customers. Figure 2 is an overview of the model highlighting three sectors: the firm, the market and the competition. Space precludes full presentation of the model, however complete documentation is available in Miller (2007).

2.1 The Firm

The key parameter for the firm is its working capital. The firm's working capital determines how much capability it can develop, and when working capital runs out, the firm fails. The working capital is increased by investments and by revenue from selling products, and is used primarily to pay for the cost of goods sold (COGS) and to create and enhance the firm's capabilities, primarily through hiring engineering and sales and marketing personnel (the salaries of these personnel in the model include all non-production operating expenses of the new venture). The engineering personnel create and enhance the features of the firm's product. The sales and marketing personnel expend effort (e.g. direct selling, creation of marketing material, advertising, etc.) to increase the attractiveness of the firm's product to the market.

The firm's working capital is affected by two important loops. One is the "positive cash flow loop" in which working capital spent to develop products and make them attractive to the market results in sales and revenue to the firm. This process increases working capital and enables the firm to make the product more attractive and generate even more revenue. The other important loop is the "running out of money loop" in which working capital is spent to increase the firm's capabilities, and the more capabilities the firm has, the more working capital it needs to spend. The "running out of money loop" runs in a much shorter timeframe than the "positive cash flow loop", creating some of the challenges we will explore in later sections.

The cash flow sector of the model is based on aspects of the financial accounting module in Oliva, Sterman, & Giese (2003), the product development sector of the model is based on the inventory management sector described in section 18.1 and figure 19-5 of Sterman (2000), and the labor sector of the model is closely based on the labor supply chain introduced in Section 19.1 of Sterman (2000).

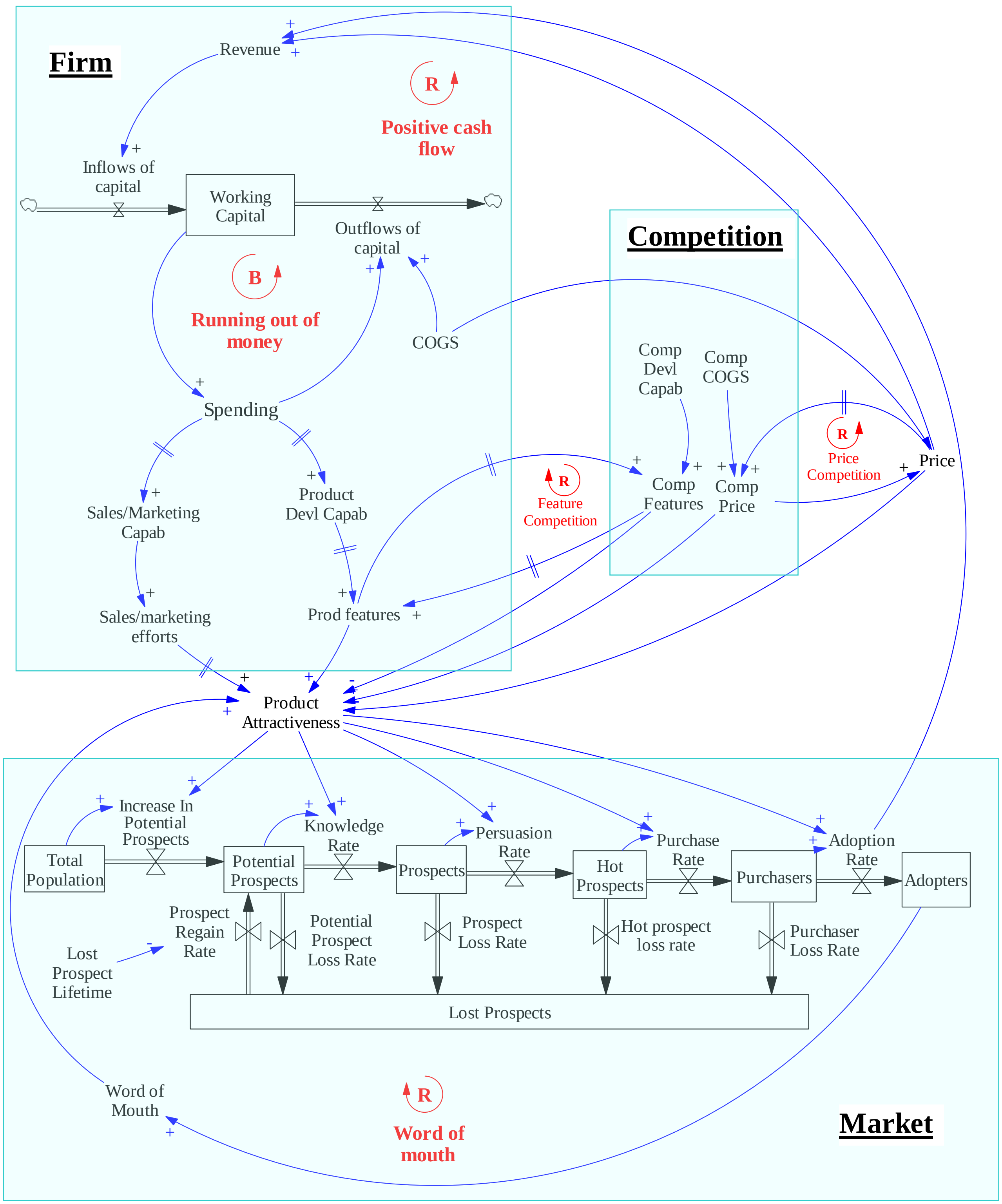

Figure 2: High Level Overview of Model

2.2 The Market

The market sector is composed of a series of stocks representing prospective customers at various stages in the sales cycle. This structure is based on an extension of the Bass model (Bass, 1969). However, rather than focusing only on the stocks of potential adopters and adopters, the model developed here disaggregates the stock of potential adopters into more specific stocks including potential prospects, prospects, hot prospects, and purchasers. "Potential prospects" are firms that are capable of adopting the current version of the product that the venture has chosen to apply sales effort to persuade them to learn more about the product. "Prospects" are firms that are capable of adopting the product and have been made aware of the product by the venture, and have not ruled out adopting it. "Hot prospects" are firms that have expressed interest in adopting the product and are either actively trialing it or evaluating it in some other fashion. "Purchasers" are firms that have purchased the product, but have not yet started using it. "Adopters" are firms that have purchased and are actively using the product. Also, there is a stock of "Lost Prospects" which are firms that were prospects, but then lost interest in adopting the product or actively made the decision not to adopt.

The model also takes into account how the stock of potential prospects is replenished from the total population (what we call "market growth"). Also, in addition to the influence of advertising and word of mouth, the new model makes it possible to more clearly calibrate the influence of factors such as price and product features that might make the product more attractive and drive the adoption cycle. The "word of mouth" loop from the Bass model is still important, but the significance of Bass's "market saturation" loop may be lessened if the size of the total population is large relative to the stock of potential prospects, and if there is a positive rate of market growth to replenish potential prospects.

The rate of the flow from stage to stage of the prospect chain is a function of the number of prospects at that stage, the average amount of time prospects remain at that stage, the amount of sales effort expended, and the productivity of that sales effort:

(1) Advancement Rate = f(Prospects / Avg Prospect Lifetime, Potential Rate from Sales Effort)

(2) Potential Rate from Sales Effort = f(Sales Effort * Productivity of Sales Effort)

(3) Productivity of Sales Effort = f(Max Productivity of Sales Effort, Sales Experience, Features/Competitor Features, Price/Competitor Price, Marketing Effort, Word of Mouth, Customer Support)

Prospects that do not advance from one stage to the next within the average lifetime for that stage become lost prospects. For details of the factors and equations that determine the rate of prospects moving from each stage to the next, see Miller (2007).

2.3 The Competition

The competition sector of this model includes ways in which the firm's competitors directly affect the firm's behavior and the "competitor" represents an aggregate of all competitors to the firm. Because the firm under consideration here is a clean energy venture, it is assumed that the competition is comprised primarily of conventional fossil-fuel-based energy firms such as a utility selling electricity generated by coal-fired plants.

The competition's working capital is presumed to be unconstrained compared to the new venture, and the competition's costs, capabilities, etc., are exogenous to the model. The endogenous parameters related to the competition are their prices and features. When the new venture develops additional features, the competition may respond, usually after a delay, by developing additional features themselves. Also, if the new venture's prices are lower, the competition may respond by lowering their prices. However the model is parameterized so that the competition has limited ability to adjust their prices, based on the assumption that the competition cannot control the price of fossil-fuel-based energy. Of course, if the competition is able to improve their prices or features, the new venture may respond in kind, creating positive loops of price and feature competition.

2.4 Novel Aspects of Model

The model is based on prior research on the dynamics of technology ventures and the adoption of new technologies, and incorporates a number of novel attributes:

Market sector for clean energy technologies: General new product diffusion models work well for goods being sold into a mass market, but do not fully represent the dynamics of adoption of high value technology products into a conservative customer base. Based on interviews and case studies of clean energy technology ventures, the "potential adopter" stock was disaggregated into potential prospects, prospects, hot prospects and purchasers, each of which could be lost before becoming an adopter. The time delays and most important factors for transition (e.g. price, features, marketing, word of mouth, customer support) were identified for each stage of adoption.

Product development sector including intellectual property: Technology ventures often depend on their ownership of and ability to develop intellectual property that is not easily appropriable by competitors. Since technology products usually contain both appropriable and nonappropriable features, a product development sector was developed that takes into account varying values and development resources needed for appropriable and nonappropriable features for both the modeled venture and for the aggregate competitor.

Runway: New ventures are often constrained by working capital in ways that larger ventures are not. New ventures usually do not have the ability to borrow money to cover expenses; a single hire or layoff could make or break the firm. The simulation model reflects these ventures' focus on their runway – the amount of time they have before they run out of capital – and bases hiring and layoff decisions on this parameter.

Effect of government policies on new clean energy ventures: Most venture simulation models consider government policies to be outside the boundaries of the model. The model developed here considered the effect various government policies related to clean energy technology would affect the modeled venture, and includes parameters that allows one to adjust the existence and effect of those policies. See below for more information about the policies included in the model and the effects they have.

3 Base Case Simulation and the Valley of Death

Table 1 presents business projections taken from the investor presentation for a clean energy technology startup (and is typical for a business plan projection of the ventures examined for this research). In each of the following scenarios, the "base case" venture is based on attributes of this and the other startups that were studied for this research.

Year	**1**	**2**	**3**	**4**	**5**
Revenues	$189	$4,126	$16,712	$32,106	$51,925
COGS	$174	$3,535	$8,457	$9,311	$10,413
Gross Margin	$15	$591	$8,255	$22,795	$41,512
Operating Exp	$2,324	$3,177	$6,496	$10,316	$14,508
EBITDA	($2,309)	($2,586)	$1,759	$12,479	$27,004
Total Installs	6	69	235	435	713
Employees	7	16	31	46	63
($ amounts in 000's)					

Table 1: Business Plan

The base case venture is planning to sell a high value product (cost of over $100,000) into a conservative market. We assume that the new venture starts out with a product that has better features at lower cost than competitors, with the bulk of its feature advantage non-appropriable (e.g. protected by patents). Furthermore, the new venture starts out with at least $3,000,000 of investment capital, based on management's projections of how much capital is needed, and how much the investment market is willing to provide this particular management team.

The venture starts with six employees, four focused on engineering and support, and two on sales and marketing. The engineering-focused employees in the firm have above average experience (having already developed the product), but the sales employees are at an experience disadvantage, given that the product has never been sold before. However, the employees learn and become more productive over time and in particular after working with customers by making sales and installing their product. There are 100,000 firms that could conceivably adopt the new product (total population), and initially 100 of them are reachable by the startup and would consider the prospect of purchasing the new product (potential prospects). The CEO of this typical firm strives to maintain at least a 25% feature advantage of their products over the competition and attempts to maintain sufficient working capital to operate by instituting a hiring freeze whenever they have less than twelve months of capital left at the current burn rate, and laying off employees as necessary to maintain at least three months of working capital.

The venture whose projections are in Table 1 secured a $4M initial investment and an additional $1.5M investment in Year 2 when the venture began running out of capital. Given these investments, and the simplifying assumption that all revenues go directly to working capital in the year they are recognized, and all working capital is retained, then Figure 3 shows a graph of the working capital based on the projections in Table 1. Note that this graph looks distinctly like a hockey stick. Indeed, if we remove delays in the sales cycle, triple the default capability of firms to adopt the technology (and therefore to become prospects), and assume that all engineers are hired with the same experience as the founding engineers (assumptions in Table 2), then the simulation model comes close to replicating the pro forma performance (See Figure 4).

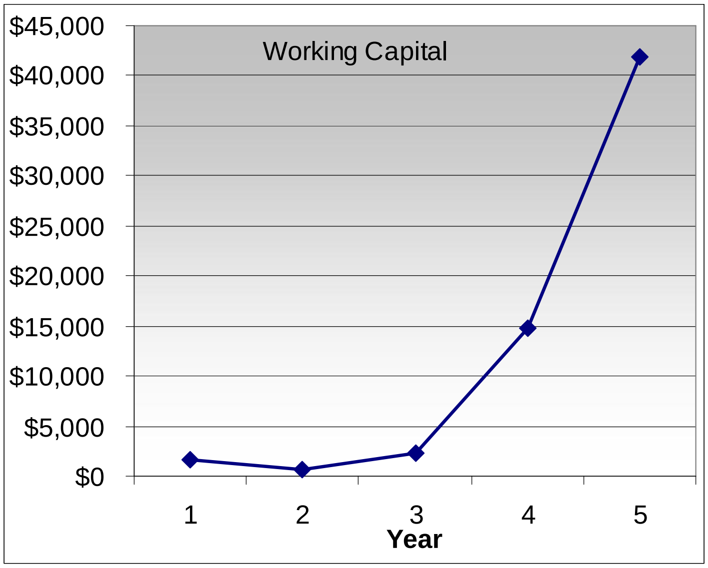

Figure 3: Projected Working Capital from Business Plan ($1,000s)

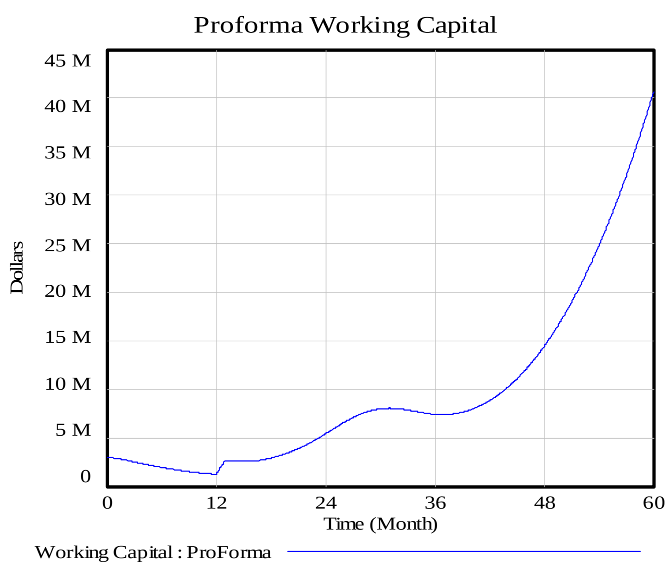

Figure 4: Working Capital from Model with Relaxed Assumptions

Avg Prospect Lifetime	0.1
Avg Hot Prospect Lifetime	0.1
Avg Purchaser Lifetime	0.1
Initial Capab of Firms to Adopt	0.15
Avg Experience of New Eng Hires	10,000

Table 2: Assumptions Necessary to Replicate Business Plan Projections

However, the experiences of the clean energy ventures interviewed for this research do not bear that expectation out, and neither does the simulation model. Figure 5 shows the simulation model results of the performance of the venture. The venture does achieve strong profitability, but only after fifteen years. In the experience of the entrepreneurs and investors interviewed for this research, most startup companies that have investors to pay back do not get nearly that many years before they need to start showing results. Hence, the new venture in this example is likely to fail.

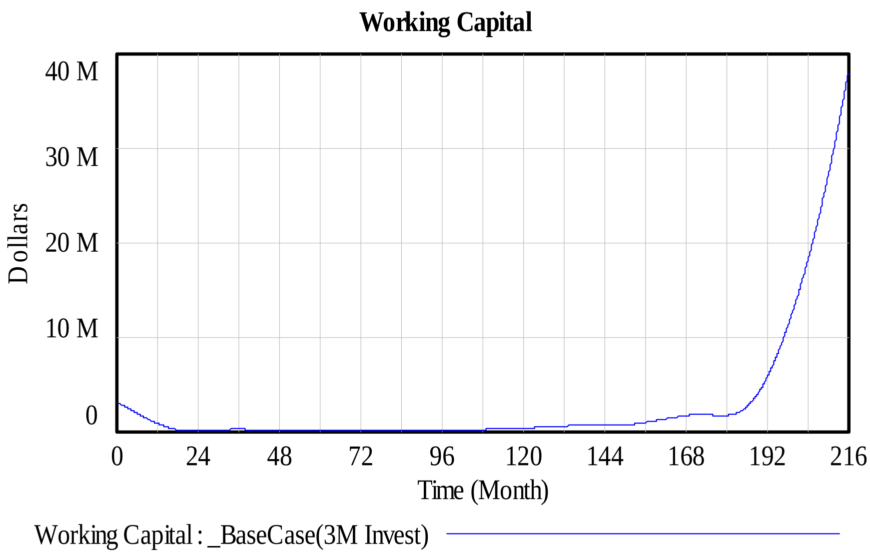

Figure 5: Performance of Venture over 18 Years

The “valley of death” refers to a period of time during which a startup company may not have sufficient capital to grow and is not able to attract new investments, and appears over a wide range of scenarios for clean energy technology companies. Figure 6 shows a sensitivity analysis of working capital over the first seven years of the firm’s existence given a uniform distribution of initial investments between $1M and $10M. Figure 7 shows a sensitivity analysis of working capital over a uniform distribution of initial production costs and initial features from 50% less to 50% greater than the default values. Note that in all cases, the valley is evident, and lasts at least four years.

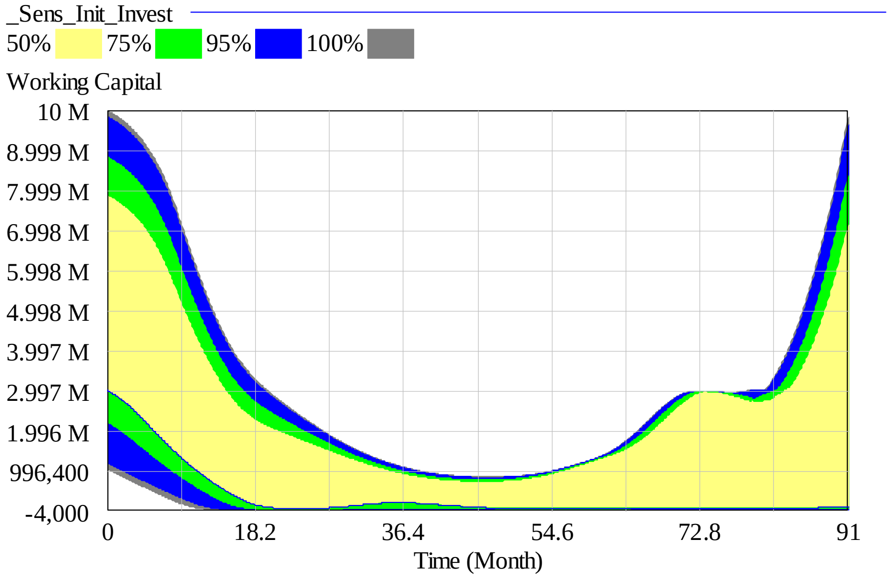

Figure 6: Sensitivity Analysis Over Range of Initial Investments

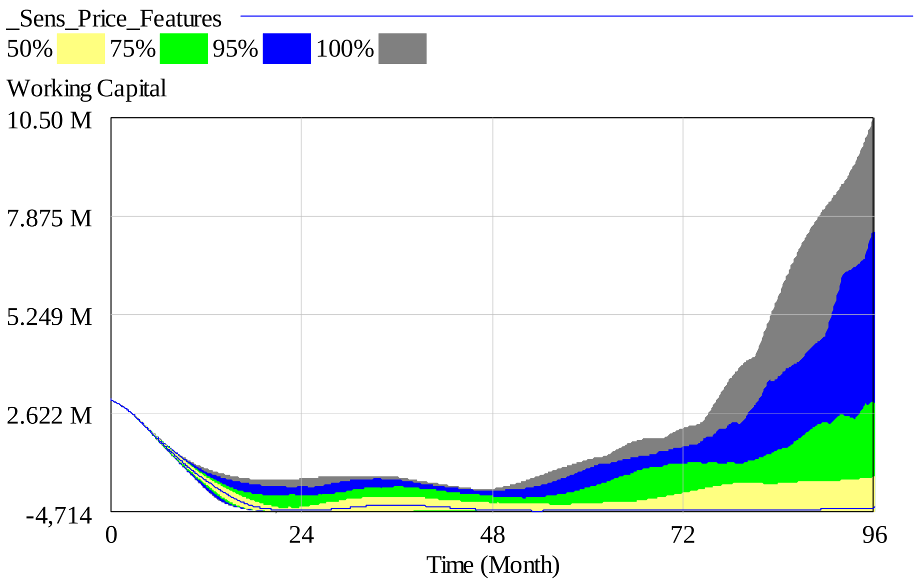

Figure 7: Sensitivity Analysis over Initial Costs and Features

4 Emerging From the Valley

What is the difference between the state of the venture and its market between the points in time when the venture starts its dip into the valley and when it leaves? Assuming no new sudden infusion of capital or breakthrough in technology during that period, what changes allow the firm to seemingly suddenly become very profitable and rapidly increase its working capital after so many years of operation?

Table 3 shows the stocks that determine whether cash flow will be negative, neutral or positive. When we set the initial values of these parameters to their month 180 values from the base case simulation, the cash flow starts off positive (see Figure 8). This demonstrates that these parameters are sufficient to generate positive cash flow in the model. Further, sensitivity testing shows that these parameters are necessary, since a significant reduction in the value of any of these parameters from its Month 180 value results in negative cash flow for at least some period of time. Table 3 summarizes what happens when any of these parameters are reduced by 50% at Time 0 of their Month 180 value. The table shows the percent reduction in working capital at one, three, and five years into the run.

Time (Month)	**12**	**36**	**60**
Accounts Receivable	37%	29%	12%
Engineers	9%	67%	33%
Avg Engineer Experience	65%	83%	45%
Avg Sales Experience	6%	2%	1%
Cumulative Purchases	12%	13%	7%
Potential Prospects	38%	64%	34%
Hot Prospects	44%	40%	21%
Purchasers	21%	14%	7%
Adopters	58%	87%	68%
Features [self,appropriable]	65%	19%	-14%
Features [self,nonappropriable]	68%	44%	76%
Features [competitor,nonappropriable]	-18%	55%	56%
FUD [self,appropriable]	49%	20%	8%
FUD [self,nonappropriable]	66%	54%	42%
FUD [competitor,nonappropriable]	-11%	32%	21%

Table 3: Percent Reduction in Working Capital from 50% Reduction in Parameter

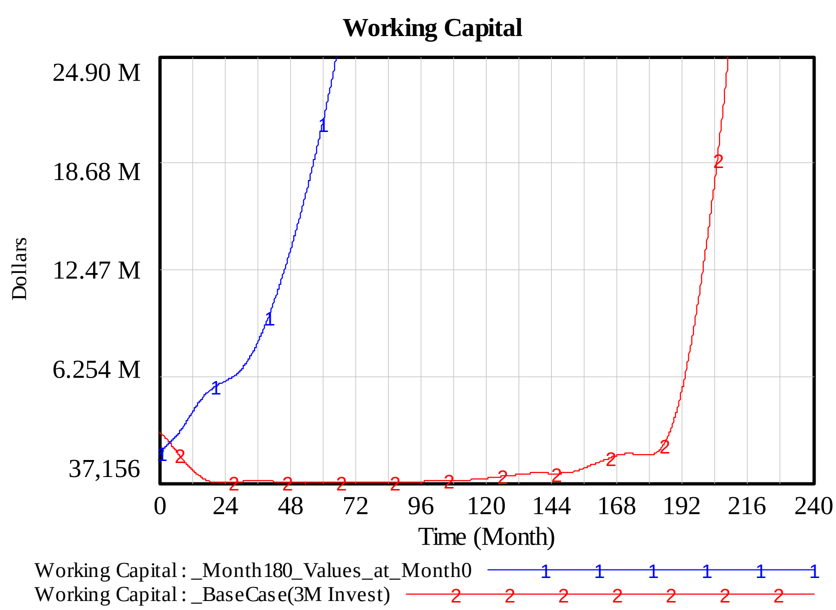

Figure 8: Performance of Firm with Month 180 Values Set at Time 0

This analysis helps to inform us what factors determine when the venture will be profitable. Working capital is critical to enable the firm to maintain its workforce and produce its products. A full sales pipeline (potential prospects, prospects, hot prospects, etc.) is necessary for the venture to close sales and generate revenue. The market for the venture's products must be growing to sustain growth of the venture and the venture's customers must be paying reasonably promptly for their purchases. The venture needs enough sales people and needs them to be experienced and effective at selling the firm's product. And the venture needs engineers who are effective at maintaining the features of the product and keeping it ahead of competition. The venture must be able to sell the product at an attractive price and still make a profit. And the product must generate positive word of mouth in the market.

Unfortunately, a venture cannot start with a full pipeline, positive accounts receivable, employees experienced in working with customers for the firm's product, or with positive word of mouth. The question then is how long it will take for a new venture to reach a sustainable positive cash flow, and what must happen for this to be achieved.

5 Public Policy Factors

Even though a clean energy technology venture may do everything right, it still may have difficulty succeeding if government policies discourage adoption. US government policies currently provide substantial subsidies to the fossil fuel industries, creating substantial barriers to the adoption of distributed generation and other clean energy technologies (California Energy Commission, 2000; Lillis, Eynon, Flynn, & Prete, 1999; National Renewable Energy Laboratory, 2000). Coupled with a conservative customer base this presents an uphill battle for any clean energy technology venture.

Many policies have been proposed to encourage the development and adoption of clean energy technologies (Barringer & Revkin, 2007; Center for Clean Air Policy, 2006; Stavins, Jaffe, & Schatzki, 2006; Stern, 2006), and these policies generally fall into three categories:

Carbon Policy: Most climate change or global warming legislation attempts to impose a cost to the emissions of CO_2 (the most common greenhouse gas). The Kyoto Protocol, legislation recently passed by the state of California, the Northeastern and Mid-Atlantic states' Regional Greenhouse Gas Initiative (RGGI), and climate change legislation before the US Senate all attempt to create CO_2 emissions trading systems that would impose costs on companies emitting CO_2. Other proposals have suggested simply placing a tax on the emission of CO_2. Any of these regulations would impose a cost on any fossil-fuel-based competition (or on not adopting the new clean energy technology). For this reason, the model represents a carbon policy as an increase in the costs of the competition. An increase in the competition's prices due to a carbon policy enables the new venture to charge a higher price and extract higher profits while retaining a price advantage, or to sell more easily at the original price.

Subsidy Policy: Another common type of policy is to subsidize the development or purchase of clean energy technologies. For example, the federal government provides grants to cover a portion of the research and development costs for some clean energy technologies. An example is the Small Business Innovation Research Program (SBIR).[1] The result of this policy is to lower

[1] See http://www.science.doe.gov/sbir/ for information on SBIR grants for energy technology development

the cost of providing the clean energy technology, enabling higher profits for the firm without raising the price to the consumer.

Increasing adoption capability: The final group of policies either remove regulatory barriers or provide regulatory incentives for the adoption of clean energy technologies. Examples of regulatory barriers that can be removed are those that impose high additional costs on companies that connect and utilize distributed generation. Regulatory incentives provide tax breaks for companies that implement energy efficiency measures, or tax credits for the development of, for example, wind farms. These policies increase the number of firms that are capable of adopting clean energy technologies and therefore increase the rate at which the number of potential prospects increases.

Figure 9 illustrates a comparison of three policies: a carbon policy, which causes competing solutions to be 20% more expensive than the base case; a subsidy policy, which reduces production costs for the new venture by 20%; and a policy that enables 5% more firms to become capable of adopting the product. Implementation of any of the policies results in significantly better performance than the base case.

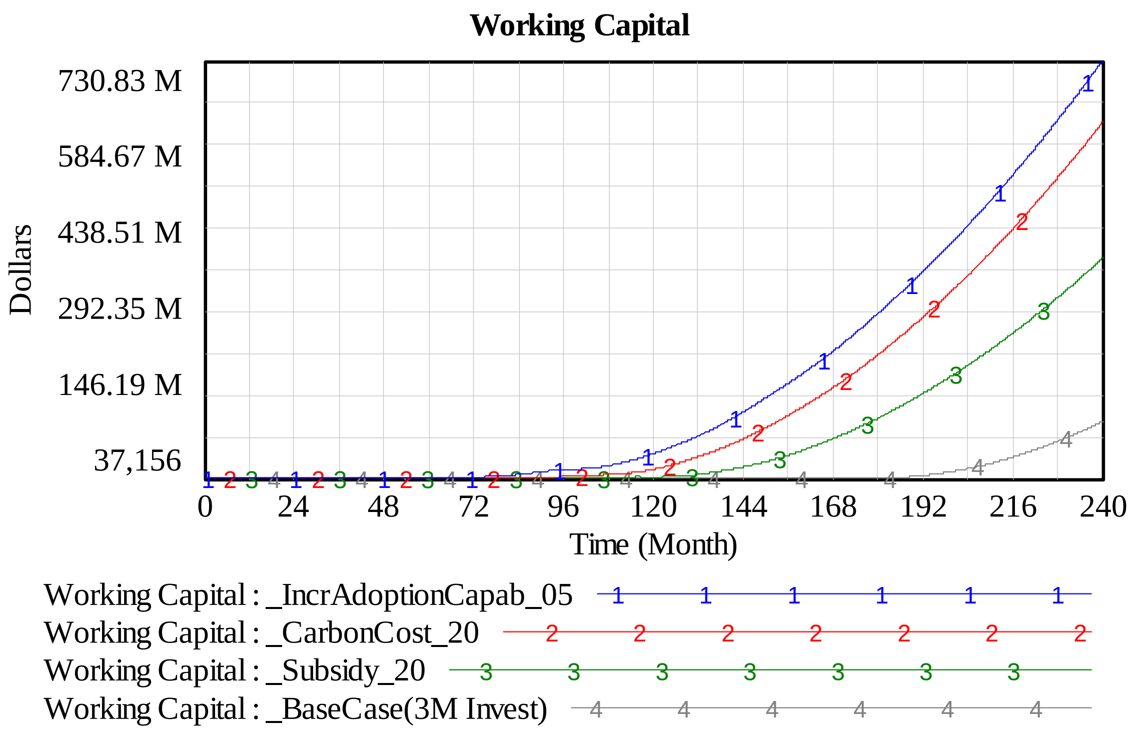

Figure 9: Effect of Policies

6 Strategies to make a clean energy technology venture successful

We know from prior research, from the sources interviewed from this research, from direct experience and from analysis of the model that the following three attributes are critical to success for any new technology venture; management, market, and sustainable competitive advantage. These factors are already well established in the literature (Eesley & Roberts, 2007; Porter, 1985; Roberts, 1991; Utterback et al., 1992), and are briefly summarized here:

Right Management Team: Experienced investors state that the first and most important attribute of any new venture are the talents, experience and attitudes of the management team. Prior startup experience and sales experience are strongly correlated with success. The importance of personal characteristics, such as persistence and flexibility in the face of adversity, and the appropriate need for and use of personal power cannot be underestimated. It is challenging for an analytical simulation model to reflect the impact of these personal characteristics, but the model reflects in several ways that greater experience leads to greater success.

Right Market: Another well established success factor for technology ventures is that the venture is addressing a market need they understand well in a way that is a good match for the size and capabilities of the venture, and that the target market has high growth potential. The simulation model captures this by taking into account the sales and marketing effectiveness of the venture, the growth potential of the market, and the nature of the sales cycle.

Sustainable Competitive Advantage: For a new technology venture to succeed, it needs to offer a technology-based product that not only meets a market need, but also is different from and better than competing alternatives at an attractive price. Further, the venture must be able to sustain these advantages over time in the face of determined and resourceful competition and establish a good reputation by word of mouth.

It is comforting that the simulation model captures well-known factors for the success of new technology ventures. But, more importantly, what new insights does the model provide us about clean energy technology ventures? The model offers some answers to important questions regarding capital investments, the right mix of employees, product development goals, selling versus leasing of the product, pricing in relation to competitors' prices, and the significance of government policy.

6.1 Capital Investments

Is it better to have a single initial investment of $3M, or three investments of $2M each, at 0, 12 and 24 months?

Investors typically prefer to stage investments over time. And, given this example, most entrepreneurs would prefer the staged investments totaling $6M over two years to the single $3M investment. Even if we assume a 20.5% discount rate based on the average long term performance of early stage venture investments (Thomson Financial/National Venture Capital Association, 2007), the staged $2M investments have a NPV of $4.18M, which is still considerably higher than a $3M initial investment. It would take a very high 45% discount rate for the two alternatives above to be equivalent on a NPV basis.

At the earliest stages of a new venture, the value of the venture is minimal, and the entrepreneur must sell the equity of the venture at a relatively low price in order to attract capital. The entrepreneur's need for capital is tempered by a desire not to "give away" too much of the company. If the venture's management believes it will be able to attract additional capital after a year or two of operation, gaining experience, and establishing a presence in the market, the venture might wait, and sell the equity at a higher price at that time. In this case, putting off additional investments is preferable.

From the investor's perspective, the initial investment is very risky. The investor may be intrigued enough by the technology and management team to "put a toe in the water" but will likely want to keep the initial investment as small as possible. Only after the venture has proven itself to at least some degree, will investors be more willing to invest additional capital.

It is therefore very common for technology ventures to receive a series of investments over time. And most entrepreneurs would rationally choose to receive three $2M investments spaced over two years rather than a single investment of $3M. However, if their firm behaved like the prototypical clean energy technology venture simulated in the model, they would be wrong.

As can be seen in Figure 10, the model shows that a venture that would succeed with a $3M initial investment would go bankrupt with three $2M investments spread over two years. The venture goes bankrupt because it never has sufficient working capital and enough of a runway to hire the engineers needed to keep the product better than the competition. More importantly, the venture will never have the sales and marketing resources and experience needed to build up a strong enough pipeline. A $3M initial investment provides enough working capital over the first 18 months to fund the product development and sales and marketing resources and develop the experience needed to build up a pipeline that will enable the venture to survive and eventually to thrive.

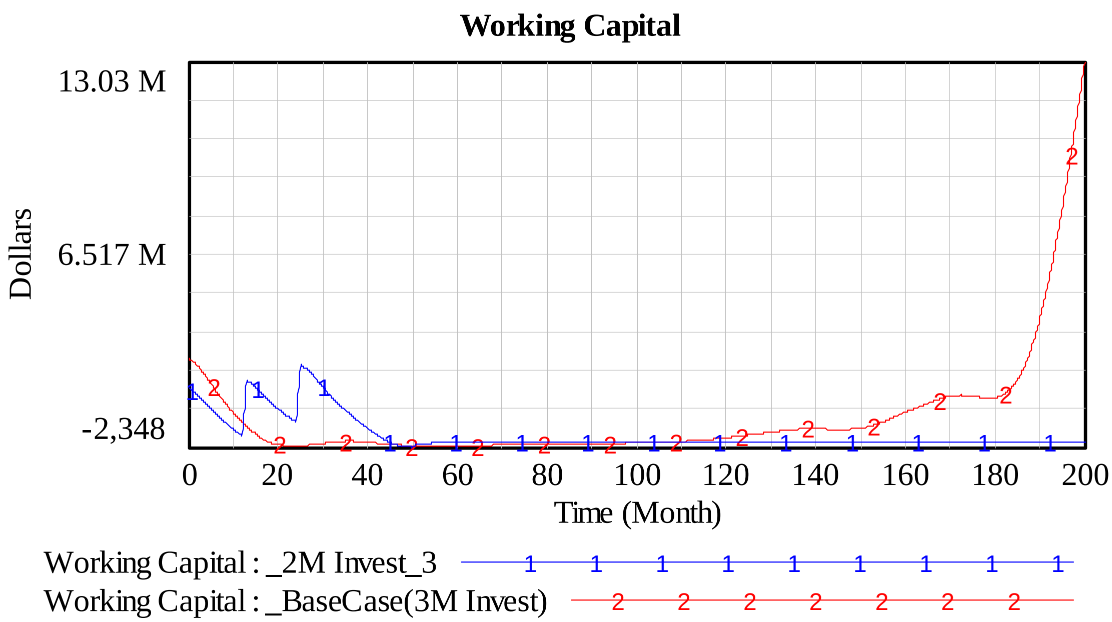

Figure 10: Comparison of $3M Investment vs. Three $2M Investments

Given that clean energy technology ventures take a long time to develop a market, and that labor and production costs must be paid over that period, clean energy technology companies may require and justify a higher initial investment than other technology companies justify. For example, software ventures usually have a product that can easily be trialed and adopted if the customer finds its features and price attractive. These ventures usually do not need years to develop a pipeline and revenue if they have a product demonstrably better than the competition. Therefore, there is less risk that a delayed investment will irreparably damage a software venture. Such a company is likely to perform better with three $2M investments rather than a single $3M investment.

In contrast, biotech companies take a very long time to develop a market. For them, factors critical to their success are based on the outcomes of product tests and the decisions of regulatory agencies that are largely beyond the control of the sales force. A larger initial investment to build up a sales force may not make the difference between success and failure, and investors are well advised to reduce their risks by staging their investments.

However, investors who follow a staged investment strategy that is rational for early stage software or biotech ventures may fail with the same strategy for clean energy technology ventures. For the energy ventures, the market takes a long time to develop and development of the market can be proportional to the early stage resources of the venture.

Given that clean energy technology ventures may require a risky larger initial investment, how do investors decide which ventures are worth the risk? Investors would be well served to consider the factors detailed in Section 4 that the model shows have the largest effect on the fortunes of a clean energy technology venture and that may be evident at the start of the venture. The more a venture can demonstrate that it has a nonappropriable technology that makes its product attractive to customers, that a large number of prospective customers already exist, and that its market will grow quickly over time given the resources to develop it, the more that company may justify a relatively large initial investment. Given the size of the energy market, a truly innovative energy company with many potential prospects has the potential to grow very large, rewarding the investment made by the early investors.

6.2 Labor force composition

What is the best balance between the engineering and sales staff?

The base case clean energy technology venture starts with four engineers and two sales persons. As is typical for technology startups, it is assumed that the engineers played a role in the development of the product which is now ready for market, and that the sales persons are new to the firm. Given that this is a technology venture, this would seem a reasonable ratio. The engineers are needed to maintain the product and develop it further, and to support the early customers. The sales people still need to learn the market before they become effective.

However, it turns out that this common ratio is suboptimal. If the venture were constrained to six employees, it would do much better with four sales people and two engineers (See Figure 11). The most important task for the company once its product is ready is to develop a market and fill the pipeline, and sales resources are needed for those tasks. Only later on, when customers begin to adopt the product and competitors begin to catch up, are additional engineers needed to shore up customer support and product development. But in the early stages, once the venture has a product that is attractive to the market it should maximize sales and marketing staff, and minimize engineering and product development staff if necessary to do so.

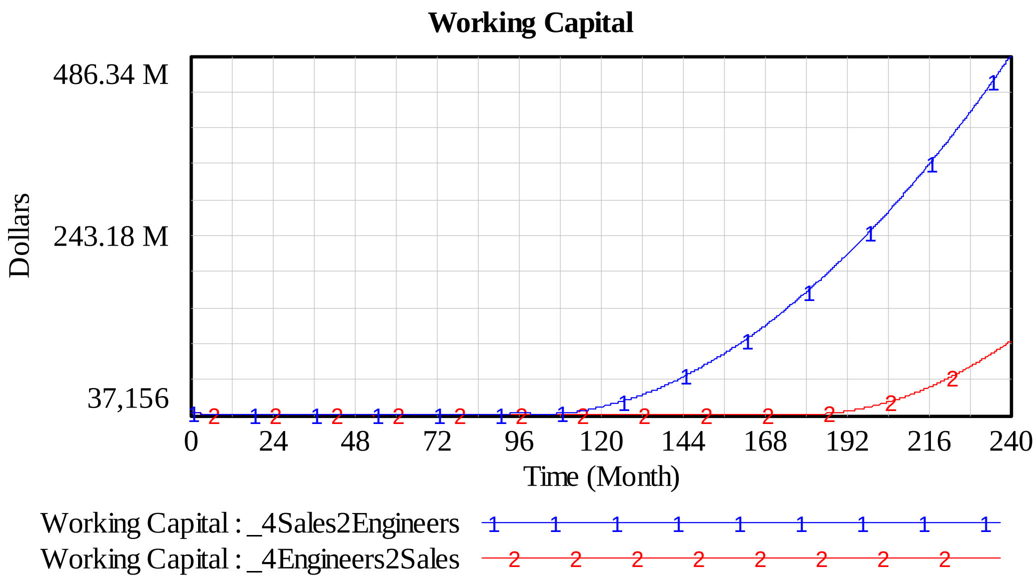

Figure 11: Sales vs. Engineering Focus

6.3 Product Development Goals

How much better than the competition should the venture strive for its products to be?

In the base case of the simulation model, the simulated venture desires its product features to be 25% more attractive than the competition. In reality, it is difficult to know exactly how much more attractive a product is than the competition, since each customer will value the features of the products differently. However, management must decide how much resources to allocate to product development. An argument can be made that the venture should devote resources so that its product is at least 50% better than the competition. After all, greater features do lead to more sales, and many technology ventures focus on maximizing the features and functionality of their products.

For the simulated venture, that approach would be wrong. In fact, that decision would bankrupt the company. Conversely, if the venture de-emphasizes product development and only strives for 10% more attractive features, the simulated venture will be much more successful (see Figure 12 for a comparison of results from striving for 10% better features, 25% better features, or 50% better features). Naturally, these results depend on the assumption that a 10% differentiation is sufficient to motivate sales for the product. Working in isolation, the product development staff cannot know how many features are needed, and the bias is often to develop too much. The new venture needs to work with current and potential customers to determine which features are important and which are not. The optimum strategy is to develop only the features that customers confirm will most differentiate the product.[2]

[2] Note that this is in reference to the improvement of an existing product that customers do or can have experience with and not the creation of a new product

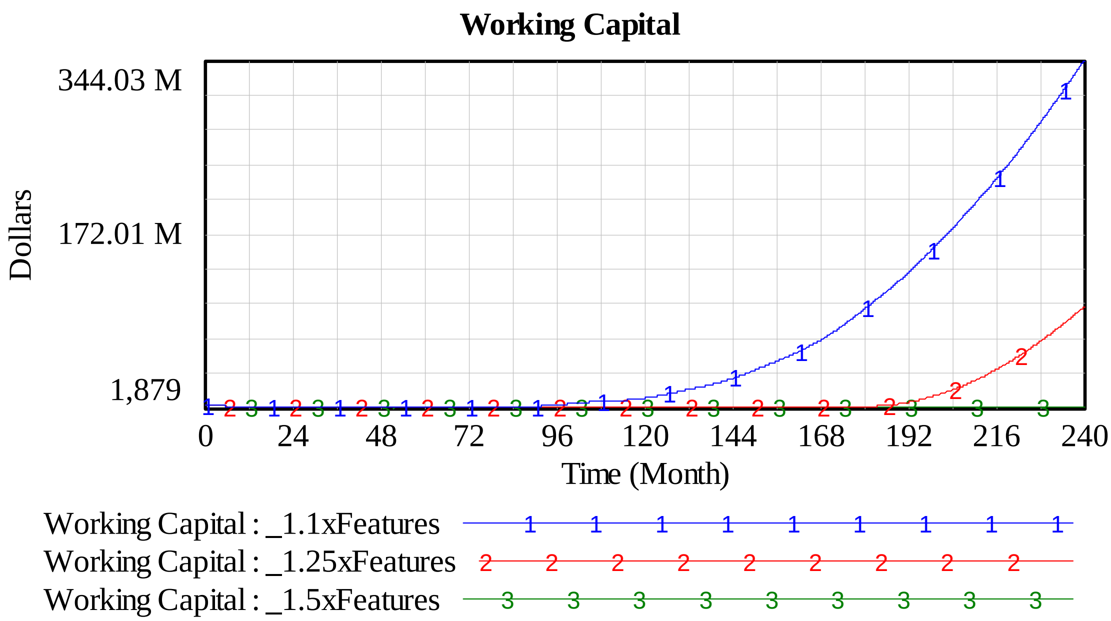

Figure 12: Comparison of Desired Features

6.4 *Selling vs. Leasing*

Should the venture prefer up front payments or recurring revenue?

The sample firm we are modeling charges the full price of their product up front, and also charges a 20% annual maintenance fee as long as the customer remains an adopter. One might wonder how the firm would fare if it adopted a leasing policy, charging little to nothing up front, but receiving significantly higher recurring revenue per customer. Assume a very high lease rate of 30% of the purchase price annually as long as the customer is using the product, in addition to the 20% maintenance charge, and compare the following two scenarios:

(4) Base Case Revenues = New Adopters * Price + Existing Adopters * Price * 20%

(5) Leasing Revenues = Existing Adopters * Price * (30% + 20%)

Assuming they could find customers to accept this, most entrepreneurs would choose the leasing model, which yields significant additional revenue per customer over time. Even with a 20% discount rate over 10 years, the leasing model yields 25% more revenue on an NPV basis. With a 10% discount rate over 20 years, the leasing model results in an NPV that is 63% higher. The payback period is only a little over three years. But in the life of a new venture, those three years are critical, and the choice of the leasing model would be wrong. Under the leasing scenario, the simulated venture would go bankrupt.

Figure 13 graphs the line between success and failure for the base case venture based on the percent of the product price paid up front and the percent paid annually as either a leasing or a maintenance charge. Note that the firm will not succeed unless it charges both. The graph also shows how much a customer that has a 10% cost of capital would be willing to pay for a lease in addition to the 20% maintenance charge. Note that the regions of customer preference and venture success only intersect at the default 100% up front price. For any reasonable cost of capital, the customer would not be willing to pay a high enough annual fee in exchange for a reduction in the up-front cost to enable the venture to succeed. This is because the implicit discount rate for the venture is extremely high. Up-front cash is much more valuable than future payments.

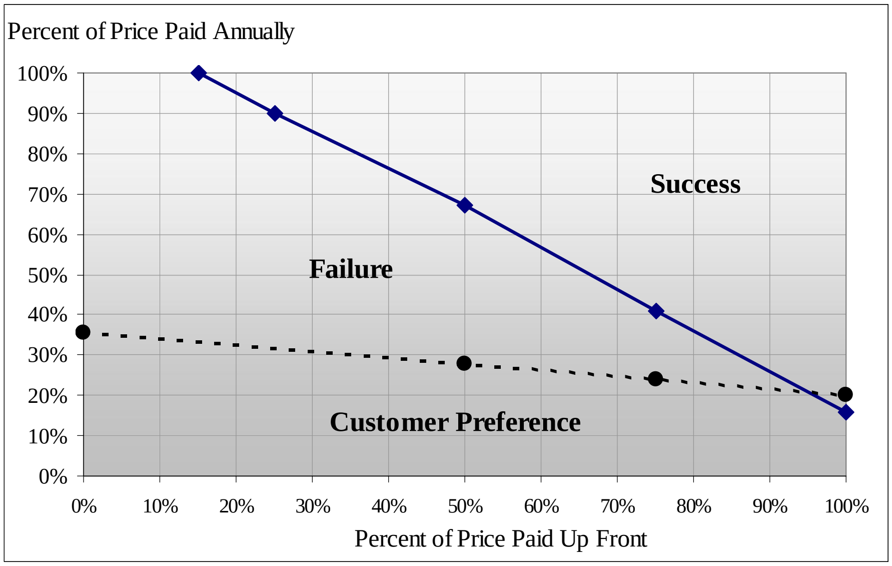

Figure 13: Up Front Payment vs. Annual Lease and Maintenance Payment

6.5 Pricing

What percent of the competition's price should the venture charge?

We assume that an advantage that the new venture has is that it can learn to produce its product at a lower cost over time, while competitors with much more mature technology have already reached the end of their learning curve. Therefore, the new venture will have lower production costs over time and can choose to sell its product at a lower price or to extract higher margins.

Given that lower prices drive additional sales, entrepreneurs often strive to charge as low a price as possible. This is often a good strategy. In the base case simulation, the venture strives to charge 25% less than the competition. The model results show that these lower prices result in higher sales over the first years of the venture's existence when we compare the base case against a simulation in which the venture is charging the same price as the competition (Figure 14).

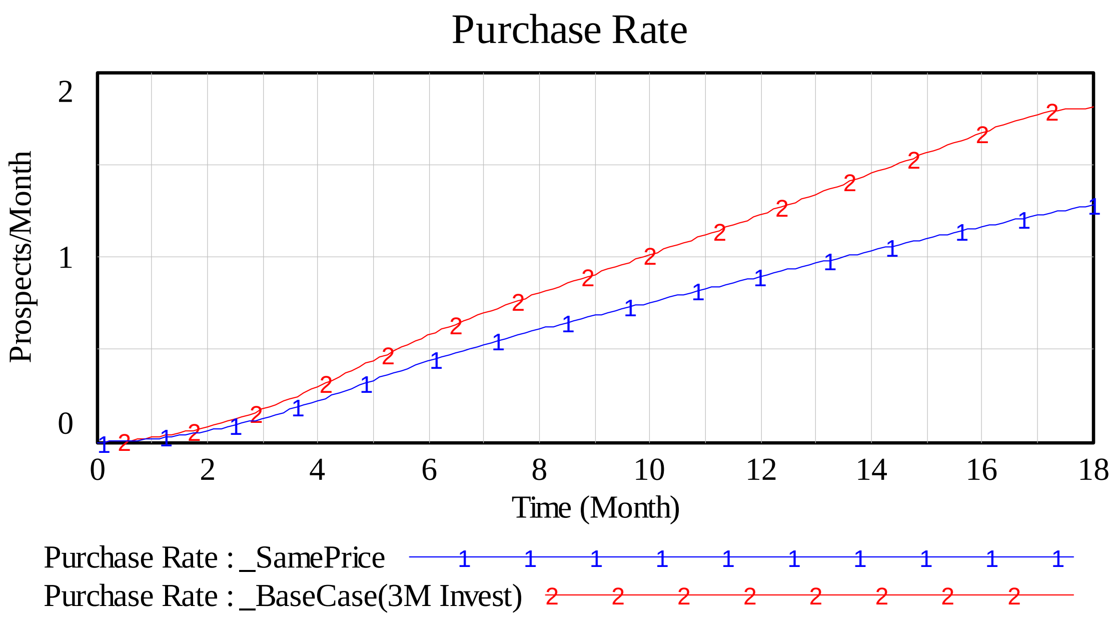

Figure 14: Comparison of purchase rate over 18 months

However, if we assume for the clean energy technology business that other factors (such as features and word of mouth) play significant roles in a purchase decision, and that relatively low quantities of the product are sold at relatively high prices and high margins, then the advantages of a lower price diminish over time. Furthermore, a new venture is likely to lose a pricing war against competitors with significantly greater resources and cash reserves if the competitors choose to respond by lowering their prices. Therefore, the simulated venture performs best when it charges the same price as competition and maximizes its margins.

Figure 15 shows a comparison over the 20 years of the simulation of purchase rate between the base case, in which the venture charges 25% less than competition when its costs allow it to do so, and the case in which the venture always charges the same price as the competition. Note that the increased purchase rate from a lower price over the first years turns out to be temporary. Counter to what might be expected, after about eight years the purchase rate in the case in which the venture charges a higher price exceeds the lower price case. Naturally, working capital will increase at a higher rate when the venture is selling more of its product at a higher price. In this simulation, the additional resources (more sales persons and engineers) gained from the higher margins outweigh the increased attractiveness from a lower price. Clean energy technology entrepreneurs need to keep in mind when pricing their products that sometimes charging a *higher* price will ultimately result in more customers.

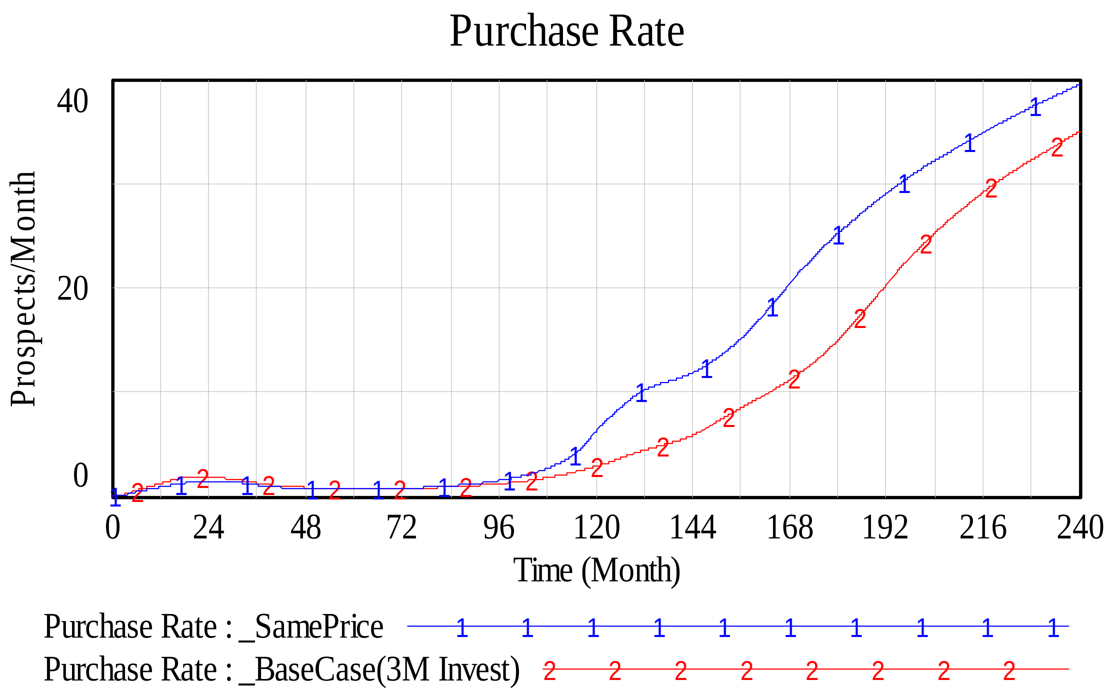

Figure 15: Charging same price as competitors vs. charging 25% less in base case

7 Effect of Government Policies

The preceding section examined the effect that various management strategies would have in improving the performance of a clean energy technology venture. This section will explore the effect of combining these management strategies with the government policies described in Section 5.

> *Can a clean energy technology venture succeed without government policies in place to support clean energy technologies?*

The answer to this question is both yes and no. If we implement the above management strategies in the simulation model in an optimal manner by reducing the desired feature ratio from 1.25 to 1.1, increasing the initial sales force from two to 16, and increasing the target price from 75% to 100%, the base case venture does significantly better. As shown in Figure 16, these strategies enable the simulated venture to leave the valley of death sooner, and result in nearly $1B of working capital by year 20, for an annual IRR on the initial $3M investment of over 33%. By most measures, that would be considered highly successful.

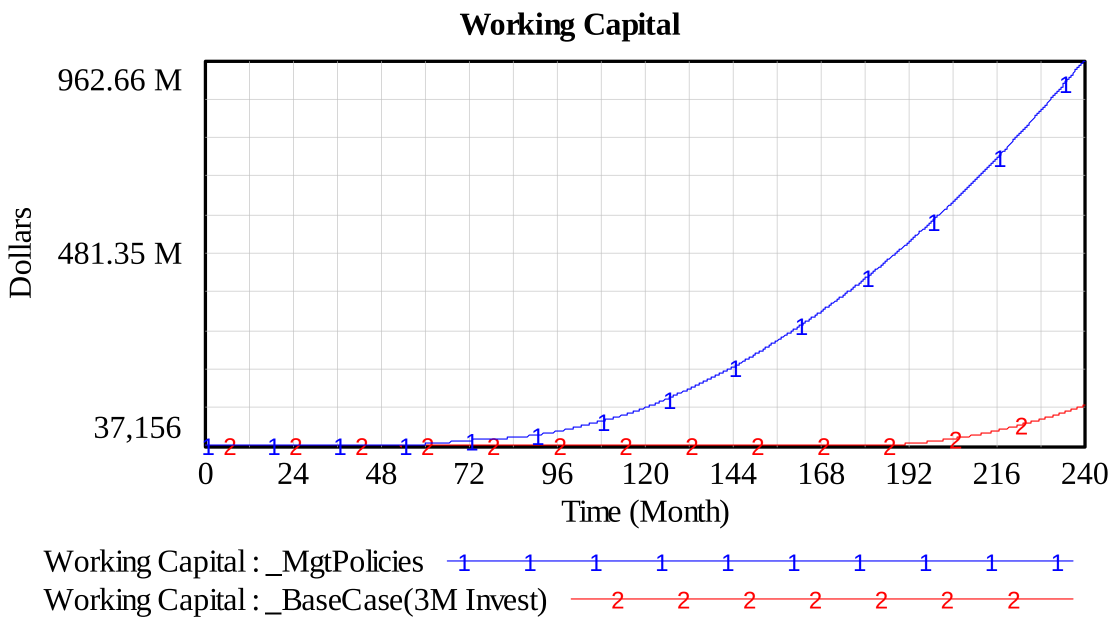

Figure 16: Results of Implementing Management Strategies

However, the venture still has a significant chance of failure during the four years before it achieves a consistently positive cash flow and begins to rise out of the valley of death. Though this firm will eventually be very successful, this is by no means obvious by year four. Investors or entrepreneurs may become disenchanted after facing several years of losses with minimal revenue, customers or working capital, and give up before realizing increasing profitability in year five.

We consider the cumulative probability of the investors or entrepreneurs giving up on the venture based on the accumulation over time of a hazard rate of failure. The hazard rate of failure is the inverse of the expected life of the venture at any point in time and is a function of the cash position of the venture, its features compared to the competition, the current number of prospects compared to the initial prospects, and the length of time the firm has been in operation:

(6) Hazard Rate of Failure = f(1 / Current Ratio, Competitor Features / Features,
Initial Total Prospects / Total Prospects, Time)

(7) Current Ratio[3] = f(-Cash Flow From Operations /
(Working Capital + AR Multiple * Accounts Receivable))

As any of the working capital, features or total prospects approach zero, the hazard rates from these terms will approach infinity (i.e. the expected lifetime of the firm will be very small). Conversely, when cash flow is positive, or the features or prospects have favorable values, the contribution of the corresponding term to the overall hazard rate will be negative (e.g. better than normal prospects will increase the expected lifetime of the venture).

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[3] If the firm is bankrupt (Working Capital < 0), the Current Ratio is set to a very small number instead of this equation, and therefore the Hazard Rate from Current Ratio will be very large, and bring the Cum Prob of Failure to >= 1 (i.e. the firm has failed)

Figure 17 presents the cumulative probability of the investors or entrepreneurs giving up on the venture in the base case or with the optimal management strategies.. Even with the management strategies in place, the venture still has a significant probability of failure.

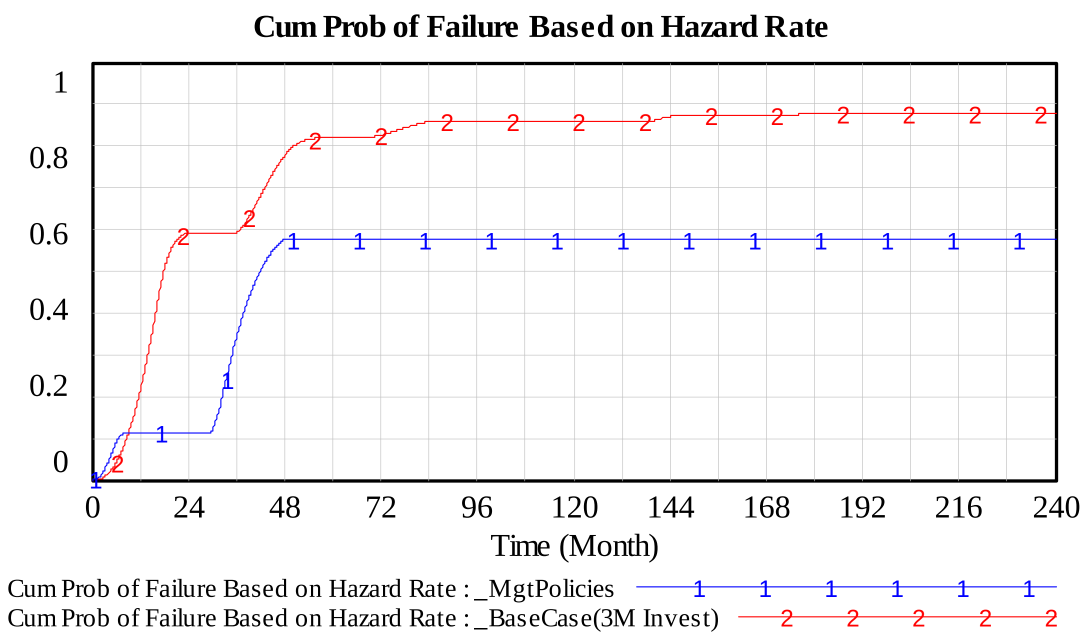

Figure 17: Cumulative Probability of Failure with Management Strategies

The implementation of the government policies described and analyzed in Section 4 can change this story. As shown in Figure 18, the venture accumulates twice the working capital and leaves the valley of death much sooner in the presence of favorable policy than it might with the management strategies alone. As can be seen in Figure 19, the presence of the government policies reduces the probability of failure substantially.

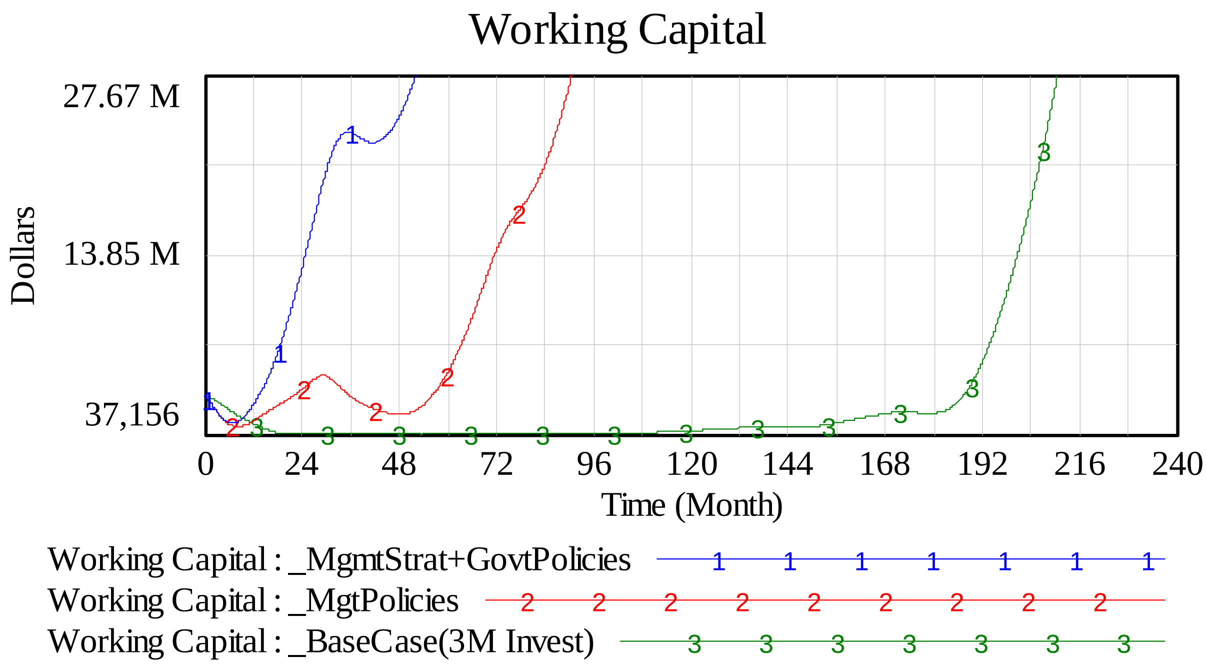

Figure 18: Results of Government Policies in addition to Management Strategies

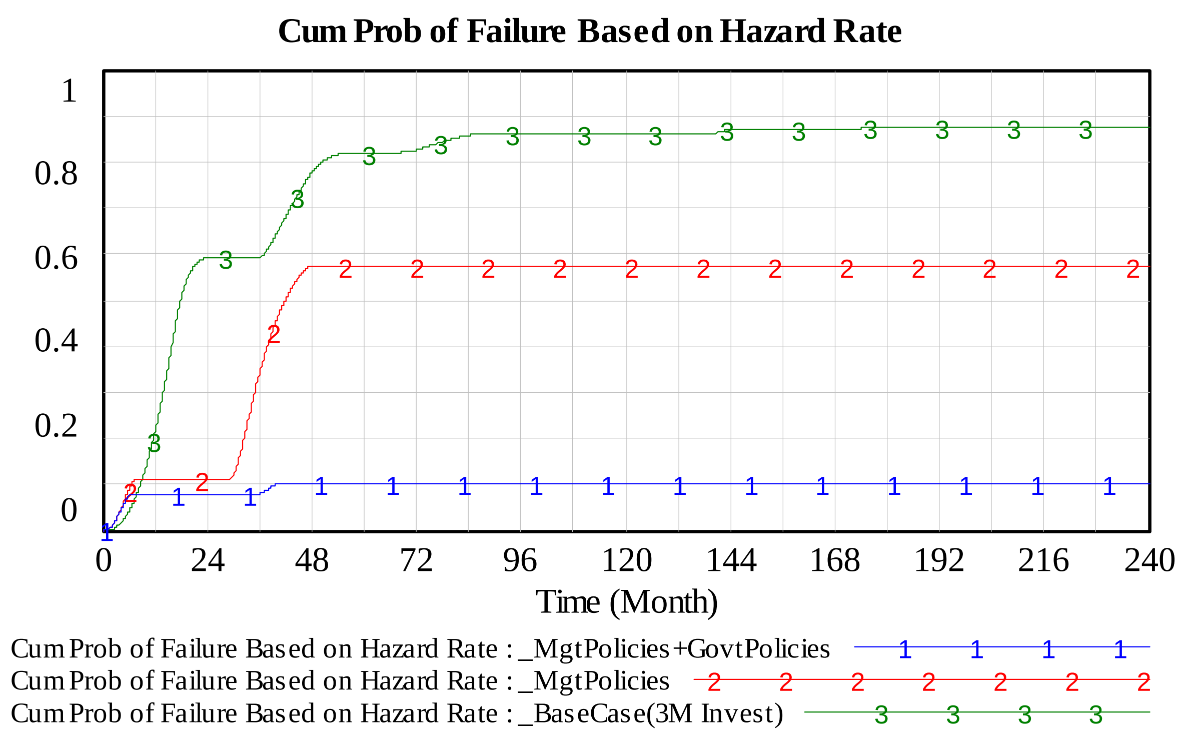

Figure 19: Probability of Failure with Govt Policies in addition to Mgmt Strategies

A clean energy venture with superior technology and the ideal management strategy *can* succeed without government policies in place to support clean energy technology. However, the long duration of the valley of death suggests a high risk of failure. Government policies reduce the barriers to success and provide the venture a much higher chance of succeeding and achieving wide adoption of clean energy technology.

Note, however, that though the combination of strategies and policies reduces the probability of failure, they by no means assure success. As noted previously the model developed here is meant to be used as a learning tool, and is not predictive. Though it is possible a real company could do better than the simulated one, many factors are not taken into account in the model that could cause a real venture to do worse, and to have a higher probability of failure. These factors include:

- Macro economic factors, such as an economy-wide recession, or a slowdown in the industry of the venture's customers
- Energy market factors, such as a decrease in the price of fossil fuels or other alternative energy technologies
- A new innovation that is more attractive than the venture's technology
- New regulations that negatively impact the venture
- Stochastic disruptions in the acquisition of new prospects or customers that significantly disrupt the firm's revenue stream
- Personnel issues within the venture that cause management and/or employees to be less effective (e.g., personality conflicts, health problems, etc.)
- Incompetence or theft on the part of management or employees
- Negative word of mouth (whether justified or not)

Clearly, the success of a new venture is never assured. However, the key lesson is that the combination of the above management strategies and government policies may significantly increase the odds of success (and the widespread adoption of the technologies) from what they would have been otherwise. Given that policies make such a significant difference, governments wishing for new clean energy technology ventures to succeed have a rationale to act. And it is in the interest of the ventures themselves to exert as much influence as possible on governments to promote the policies discussed (perhaps by forming industry lobbying groups).

8 Extensions

During the course of this research, quantitative data on over 1,000 clean energy technology-related ventures was gathered, but the level of detail and quality of the data was too sparse for much of it to be of use. Research is needed to determine the actual success and failure rates of clean energy technology ventures based on a better sample of data. It would also be instructive to gather detailed quantitative and qualitative attributes of these firms, and to establish statistical correlations between the attributes and the level of success of the firms.

Also, the simulation model developed here could be enhanced in many ways.

- Policies meant to promote the adoption of clean energy technologies may spur additional competition to the venture being modeled. Competition may expand the market, but may also make it more difficult for the venture to succeed. The model does not address this interaction.

- Competition in the model could be disaggregated (in particular between fossil-fuel-based competitors and other clean energy competitors).
- The model does not take into account factors and feedbacks that would limit exponential growth of the new venture.
- The workforce in the model could be further disaggregated (with potentially separate stocks for product development, customer support, sales, marketing, management, administrative). Overtime, burnout and other important factors that shape the effectiveness of the workforce could be modeled.
- The cash flow sector of the model could be expanded and improved to incorporate more of the factors important to the balance sheet and income statement of a new venture.
- The existence and impact of equity and debt investments could be more explicitly modeled.
- The modeling of the impact of policies could be expanded and improved to include other policies that affect the venture, and to incorporate more of the resulting effects and feedbacks from the implementation of these policies.
- The modeling of intellectual property (IP) development (non-appropriable features) could be improved to more accurately reflect the value, costs and time delays inherent to the development of IP
- The determination of desired sales effort could be improved to better reflect the hiring decisions for sales and marketing personnel of actual firms.

For every sector of this model, more detail and additional feedback loops could be added and new estimates could be made for values of the parameters (perhaps based on a more extensive data set for clean energy technology ventures). However, it must be kept in mind that the model cannot fully reflect reality. Any improvements should be made with the purpose of learning about the performance and attributes of these ventures in general and not of predicting the future for any one. Towards that end, we intend to turn the model into a management flight simulator for educational purposes.

Though the simulation model here was developed based on data collected from and about new clean energy ventures, it is quite possible that the lessons learned from analysis of the model can be applied to other kinds of new ventures. In particular, when not taking the clean energy policies into account, the model is very likely to apply to the commercialization of any new energy technology. More generally, lessons from the model with the parameters described here may apply to a new venture in any industry that faces conservative customers and long sales cycles. Finally, with a different set of parameters, the model possibly can be used to explore the commercialization and adoption of any new technology. However, it must be kept in mind that the model is not meant to be predictive of any particular real company's experience, and the lessons learned from analysis of the model will only be as valuable as the parameterization of the model enables it to be.

9 A final word

As noted in the introduction, climate change is one of the most serious challenges of our time, and the wide adoption of clean energy technologies is critical in order to address it. Considerable focus has been appropriately devoted to the development of these technologies, to improving their features, and to reducing their costs to make their wide adoption possible.

However, there must be commensurate focus on strategies and policies to enable the wide adoption of the clean energy technologies once they are ready. History shows that the wide adoption of disruptive new technologies is driven by new ventures. It is in the interest of society to promote strategies and policies that will help clean energy technology ventures successfully distribute their products and technologies.

Neither the private sector nor the public sector can address this problem alone. Private investments coupled with optimal management of clean energy technology ventures may fail and have failed without policies in place that address the impediments to the adoption of clean energy technologies. The technologies already exist to address climate change, and entrepreneurs and private investors are committing their resources to promote their adoption. However, particularly in the U.S., policies must also be put in place to help enable wide adoption. There is little time to waste.

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